Identifying Levers to unlock Clean Industry

Background Report

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
2DS	2°C Scenario
AC	Alternating current
AIS	Automatic Identification System
AMA	Arbeitsgemeinschaft Messwerteaufnehmer
AMT	Advanced Manufacturing Technologies
ATC	Air Traffic Control
ATM	Air Traffic Management
ATP	Automatic Train Protection
B2C	Business-to-Client
BAT	Best Available Technology
BERD	Business Enterprise Research and Development Expenditures
BEV	Battery-electric vehicles
BPIE	Buildings Performance Institute Europe
BSRIA	Building Services Research and Information Association
CAES	Compressed air energy storage
CAGR	Compound Annual Growth Rate
CAGR	Compound annual growth rate
CAPEX	Capital Expenditure
CCS	Carbon capture and storage
CCU	Carbon capture and utilization
CEPA	Classification of environmental protection activities
CHP	Combined heat and power units
CI	Clean Industries
CLEG	Combined List of Environmental Goods
CO2	Carbon Dioxide
COHERENO	Collaboration for housing NZEB renovation
CreMA	Classification of resource management activities
CSP	Concentrated Solar Power
D&D	Demonstration & deployment
DBFM	Design, built, finance and maintain
DC	District Cooling
DC	Direct current (in smart grids chapter 9)
DER	Distributed energy resources
DH	District Heating
DHC	District Heating and Cooling
DMS	Demand management systems
DR	Demand response
DSM	Demand side management
DSO	Distribution/distributed system operator
ECO	Energy Company Obligation
ECSIP	European Consortium for Sustainable Industrial Policy
EED	Energy Efficiency Directive
EEI	Electrical and Electronic Engineering industries
EGEC	European Geothermal Energy Council
EGSS	European Environmental Goods and Services Survey
EHI	Association of the European Heating Industry
EHPA	European Heat Pumps Association
EJ	Exajoule

EMS	Energy management systems
EN	European Standard
EnPC	Energy Performance Contracting
ENTSO-E	European Network of Transmission System Operators for Electricity
Env-Tech	Environment-related technologies
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
EPEC	European Policy Evaluation Consortium
EPO	European Patent Office
EPS	Expanded Polystyrene
ERA	European Railway Agency
ERTMS	European Railway Traffic Management System
ESCO	Energy saving companies
ESTIF	European Solar Thermal Industry Federation
EU	European Union
EuroACE	The European Alliance of Companies for Energy Efficiency in Buildings
EV	Electric Vehicle
EWEA	European Wind Energy Association
FACTS	Flexible AC transmission systems
FCEV	Fuel-cell-electric vehicles
FiP	Feed-in Premiums
FiT	Feed-in Tariffs
FTA	Free Trade Agreement
G2V	Grid-to-vehicle
GDP	Gross Domestic Product
geoDH	Geothermal District Heating
GFP	Gas Filled Panels
GHG	Greenhouse gases
GIS	Geographic information systems
GPS	Global Positioning System
GW	Gigawatt
GWEC	Global Wind Energy Council
HEV	Hybrid electric vehicles
HS	Harmonized Commodity Description and Coding System
HVAC	Heating, Ventilation, Air-Conditioning, and Cooling
HVDC	High voltage direct current
IBM	Independent Blade Manufactures
ICE	Internal combustion engine
ICT	Information and Communications Technology
ICTSD	International Centre for Trade and Sustainable Development
IEA	International Energy Agency
IFC	International Finance Corporation (World Bank Group)
IGG	The Institute of Geosciences and Earth Resources
IP	Internet Protocol
IPA	Industrial Process Automation
IPC	International Patent Classification
IPR	Intellectual Property Rights
ISM	Independent Specialized Manufactures
ITS	Intelligent Transportation Systems
JRC	Joint Research Centre
KET	Key Enabling Technology

KfW	Kreditanstalt für Wiederausbau (German bank)
kWh	Kilowatt-hour
LCEGS	Low Carbon and Environmental Goods and Services
LCOE	Levelised Cost of Energy
LRIT	Long-Range Identification and Tracking
MDI	Methylene Diphenyl Diisocyanate
MEMS	Micro-Electromechanical Systems
MNCs	Multinational Corporations
MON	Measuring and Monitoring
MS	Member States
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
NACE	National Classification of Economic Activities
NAFTA	North American Free Trade Agreement
NEA	National Energy Agency
NEMS	Nano-Eletromechanical Systems
NER	New Entrants' Reserve
NZEBs	Nearly Zero Energy Buildings
O&M	Operations and Maintenance
OECD	Organization of Economic Co-operation and Development
OEM	Original Equipment Manufacturers
OMS	Outage management systems
OPEX	Operating Expenditures
ORE	Offshore Renewable Energy
PATSTAT	Worldwide Patent Statistical Database
PCT	Patent Cooperation Treaty
PHES	Pumped-heat electricity storage
PHEV	Plug-in hybrid electric vehicles
PHS	Pumped Hydroelectric Storage
PJ	Petajoule
PU/PIR	High-performance polyurethane rigid foam
PV	Photo Voltaic
R&D	Research and Development
R&D	Research and development
RCA	Revealed Comparative Trade Advantages
RDD&D	Research, Development, Demonstration and Deployment
RED	Renewable Energy Directive
RES	Renewable Energy Sources
RIS	River Information Services
RoW	Rest of the World
RXA	Relative Export Advantage
SCADA	Supervisory control and data acquisition
SCMES	Superconducting magnetic energy storage
SESAR	Single European Sky ATM Research
SIMs	Super Insulation Materials
SMEs	Small and Medium Enterprises
SPF	Polyurethane Spray Foam
STEM	Science, Technology, Engineering and Mathematics
STRIA	EU's Strategic Transport Research and Innovation Agenda initiative
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TB	Trade Balance

TNO	Research organisation in the Netherlands
ToR	Terms of Reference
TSO	Transmission system operator
TWh	Terra watt-hour
USD	US Dollar
V2G	Vehicle-to-grid
VC	Value chain
VIPs	Vacuum Insulation Panels
XPS	Extrude Polystyrene

1/ Introduction

The study "Identifying Levers to Unlock Clean Industry" aims to feed the new Energy Union Integrated Strategy on Research, Innovation and Competitiveness. To reach the overriding goal of creating growth and jobs, the competitiveness of the EU28's manufacturing industry has to be improved. This is in part possible via a stronger diversification of traditional industries in the production of clean solutions (partly due to their own high energy demand), thereby increasing growth and export potential. Moreover, these clean solutions can spread in other industries and thus have efficiency gains and competitive advantages for the users of these technologies.

The aim of this study is to gain insights in existing and potential markets for Clean Industries both at European and world level. Notably, the definition of "Clean Industries" within the context of this study refers to specific sectors or segments within the economy that supply clean solutions. This is different from the "green economy", where the focus is mainly on sustainable development all industries and sectors (OECD 2011, 2014). Clean Industries are the main drivers of the greening economy and therefore can provide long-lasting innovation and export potential, which is why these industries are the focus of this study.

Markets for Clean Industries could be defined at the level of sectors and subsectors (for both goods and services), thus they should comprise technology providers, clean processes, clean technologies, clean products and related services. Clean Industries are not depicted in existing industry statistics (like NACE or ISIC). Hence, in order to judge competitiveness and innovation potential of Clean Industries, delimitation of the market segments and a methodology to depict them have to be tackled in the first place.

The study comprises the results of three tasks of which the first is presented in Part 1. The first task comprised defining the scope of the Clean Industry and providing a methodology to identify priority sectors within the Clean Industry. Those priority sectors have been examined in more detail as part of task 2 and task 3 with regard to their competitive relative strengths, weaknesses, opportunities and threats. Where possible an assessment of the export potential has been included. Particular attention has been paid to the identification of barriers which prevent these Clean Industries reaching their full potential, and to the corresponding policy levers to overcome the barriers.

Following the research logic of the study, this background report presents in PART 1 the results of the analysis to obtain a workable definition and taxonomy of Clean Industries. Subsequently the methodology for selecting Clean Industries that are the most promising ones in terms of policy prioritization is presented. Part 1 concludes with the resulting selection of 12 priority sectors, including the results of a sensitivity analysis and robustness check.

In PART 2 of this report the competitiveness, barriers and levers of the 12 selected sub-sectors and activities are presented in more detail according to their position in the ranking which has been presented in PART 1. These chapters can be read as self-standing pieces. The annexes have been grouped at the end of the report.

PART 1 Definition and the selection of priority sectors

1.1 Definition of the scope of Clean Industry

1.1.1 Definition of Clean industry

The goal of Task 1.1 is to obtain a conceptual basis for a concise description of EU and global markets for Clean Industries (CI), meaning in particular shares of Clean Industry regarding, e. g., sales and exports, employment, and value added. Over the last years numerous studies tried to describe, define, measure, and quantify the green or clean economy, or only single segments such as the clean-tech industry. The denominations used encompass a variety of headings such as Environmental, Eco, Renewables, Sustainable, Clean Tech, Low Carbon or No Carbon (see BIS, 2013). Economic figures for different countries or regions have been published, regardless of their comparability. Thereby, the terms "green" and "clean" are often mistakenly used interchangeably. The focus of the green economy is on the "greening" of all industries and sectors (OECD 2011, 2014) and associated with growth expectation in specialised green jobs.[1] On the other hand, the Clean Economy or Clean Industry concept refers to specific sectors or segments within the economy that are directly responsible for supplying technologies, products, and services that have measurable environmental benefits in terms of their abilities to reduce GHG emissions and to improve both energy and resource efficiency.[2] In the definition used in this study Clean Industries exclude simple users of technologies and rather focuses on the core sectors supplying the means for a transformation to a greener economy (supply-oriented approach).

A slightly different definition compared to the above mentioned CI approach demanding environmental *benefits* comes from Eurostat and has also been adopted by the OECD. There, technologies and products "must have an environmental protection or resource management *purpose* (…) as their prime objective" (Eurostat, 2009, p. 32). The focus on the environmental purpose leads to a more narrow definition since technologies not directly aiming to reduce environmental harm are excluded (e.g. process technologies that improve material efficiency but mainly target on cost reduction and productivity gains). Also in our approach, electric vehicles (EV) are part of CI due to their environmental benefits in terms of GHG reductions, whereas the whole mobility sector is excluded in the Eurostat definition because it does not have a primary environmental protection purpose.

The term "environmental goods and services" is further politically used in the course of WTO tariff negotiations. Tariff cuts for a particular set of 54 environmental goods have been agreed upon, for example, by the leaders of the 21 Asia-Pacific Economic Cooperation (APEC) economies meeting in Vladivostok, Russia in 2012 or in the DOHA negotiations (Sugathan 2013) and are also the starting point for the current negotiations on an Environmental Goods Agreement (EGA) between the EU and 16 other WTO members. Other suggestions consider

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1 See e.g. ECO Canada (2010), Ecorys (2012) or the different publications launched in the context of the ILO Green Jobs Initiative (http://www.ilo.org/global/topics/green-jobs/lang--en/index.htm)

2 See e.g. Globe Advisors (2012) and the discussion of several definitions in Gittell and Carter (2011).

much more products as being environmentally related without following the Eurostat/OECD definition (c.f. chapter 2.4).

The opening of environmental goods or CI markets to international competition has brought many economic benefits in the form of increased efficiency, economies of scale, and easier access to the best available technologies. Trade liberalization alone may, however, not be enough as demand for clean solutions remains essentially determined by environmental regulations (Sauvage 2014).

Importantly, denominations like "clean" and "environmental" mostly denote nominal differences. That is, references made to Clean Industries and lists of environmental goods and services basically target the same. In the context of the Integrated Strategy for Research, Innovation and Competitiveness, the focus is on industries that contribute to the reduction of carbon emissions.

1.1.2 *Empirical Approach*

As outlined in the proposal, a funnel approach is taken to define CI. Consideration and synthesis of existing taxonomies provides a comprehensive list of sectors and the activities related to CI. These activities shall be statistically translated into data concepts for corresponding products, technologies and services and subsequently into measurements and estimates which will be used for the selection of the 12 priority sectors and the subsequent analyses.

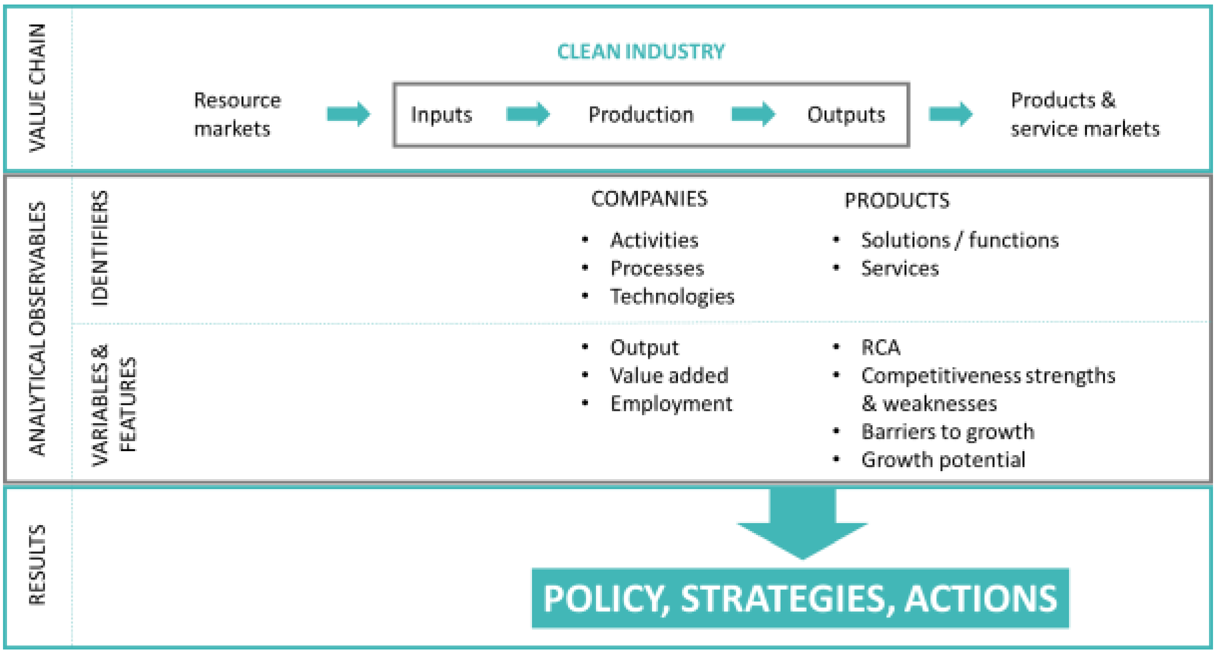
CI is part of other sectors which also produce conventional products and services. It is therefore not possible to identify CI in commonly used statistical industry classifications (like NACE or ISIC), which would represent the top-down strategy of identification. Taking the whole industry (e.g. electrical engineering, the automobile industry) would cause a large overestimation of the economic relevance of CI and would not provide much informational value of international comparisons.

Since 2011 Eurostat collects output, value added, employment and export data on environmental goods and services (EGS) in EU member states and the EFTA. Thereby, the scope of the EGS Statistic (EGSS) is defined according to the classification of environmental protection activities (CEPA) and the classification of resource management activities (CReMA) (European Commission 2009, 2015). From 2017 onwards reporting of data for EGSS will be mandatory firstly for 2014 and 2015. Up to now, data are collected on a voluntary basis and the quality of the available data is not appropriate for the purpose of this study.

From data point of view there are two ways to analyse CI, namely the product approach and the company approach. While the former analyzes comparable product data based on common statistical conventions, the latter analyzes the main actors and how they perform, mainly using Orbis company level data, and how their interrelation is (upstream, downstream the value chain). Analyses from the product approach are also used to support the selection process of priority fields and to evaluate SWOT and export potential. Note that since an integrated dataset of companies and their corresponding products does not exist at the company level, we are only able to link both information sources at the at the (sub-)sectoral CI level. In other words although we will be using two different approaches for assessing the CI's sectors, the results at the level of the sectors will be comparable and meaningful.

The value chain provides the link between both approaches and furthermore helps to understand how growth and employment can be created from the CI. As outlined in Figure 1, the product approach identifies outputs via CI-related components and intermediates contributing to clean solutions while the company approach indirectly identifies processes and technologies embedded in companies. While the latter provides information on output, value added as well as employment and thereby allow for an assessment of the competitiveness, the former enables to analyze revealed comparative trade advantages (RCA) in the EU and extra-EU market.

Figure 1: Methodologies in context: from the CI value chain to analysis and results



Trade plays a vital role in the diffusion of clean technologies respective environmental goods and services. Advances in technology and transportation have reduced the costs of trade, making previously disparate goods and services globally available (ITC 2014). Given growing global awareness of the importance of environmental sustainability, according to ÌCT (2014) citing Environmental Business International (EBI 2014, 2012) the demand for clean technologies has been increasing rapidly; the global market for environmental goods and services was estimated to have reached US$ 1.047 trillion in 2013 and is expected to rise to US$ 1.9 trillion by 2020. Removal of possible barriers to growth is therefore an important target.

Downstream the value chain of the Clean Industry are other industries which benefit from the clean industry's output, which ultimately may lead to improved competitiveness for the latter ones and consequently growth and job creation.

1.1.3 Taxonomy of Clean Industry

1.1.3.1 An overview of existing relevant taxonomies

In addition to the overall scope of the Clean Industry (CI) (section 1.1.1), there exist several taxonomies segmenting CI in different categories and sectors. They all show basic similarities in the main categories although the wording is partly differing. Table 1 summarizes corresponding categories from four exemplarily taxonomies showing the similarity in approach while at the same time using different denominations.

Table 1: Examples and correspondence of existing taxonomies of CI under different definitions

Clean Industry (Globe Advisors 2012; Brookings 2011, PEW 2007)	EGS classification (European Communities 2009, 2015)	Cleantech sector (Kachan 2012)	Environmental technology and resource efficiency (BMU/ RB 2014)
Clean energy (generation, transmission and storage)	Management of energy resources A: renewable energies	Clean Energy / Energy storage	Environmentally friendly power generation, storage and distribution
Energy efficiency	Management of energy resources B: heat/ energy saving and management C: minimization of the non-energetic usage of fossil fuels	Efficiency	Energy efficiency
Environmental friendly production processes	Resource Management Activities > Management of energy resources (B: heat/ energy saving and management, C: minimization of the non-energetic usage of fossil fuels) > Management of water > Other natural resource	Clean Industry	> Material efficient processes (Material efficiency) > Energy-efficient production processes (Energy efficiency)

	management activities		
Clean transportation	n.a.	Transportation	Sustainable mobility
Conservation and pollution mitigation	> Protection of ambient air and climate > Noise and vibration abatement > Protection against radiation > Other environmental protection activities	Air & Environment	Protection of environmental goods (Material efficiency)
Knowledge & Support services	Research and development activities of environmental protection and resource management	included in the respective main category	included in the respective main category

Comment: NIW compilation.

The inquiries show that "*Clean Energy (generation, transmission, and storage)*" and different aspects of "*energy efficiency*" are main categories included in each definition of clean industries. Clean Energy and energy efficiency are, for example, referred to in Brookings (2011), Kachan (2012), BMU/RB (2014), Globe Advisors (2011) and in the EGS classification (European Communities 2009, 2015). Other categories found are "*Environmental friendly production (processes)*", "*Agriculture & natural resources conservation*", "*Clean transportation*", and "*Conservation and pollution mitigation*" (aiming at waste and recycling, water & wastewater). As outlined in the ToR, this last category shall be excluded in this study since the focus shall be laid on technologies and products contributing to a decrease in GHG emissions.[3] In some taxonomies "Clean Transportation" presents a main category on its own while in others it is a part of "Energy Efficiency" as, for example, in Brookings (2011). Furthermore, "*Knowledge & Support Services*" are considered in all the examined taxonomies. Partly, they form a separate main category (see i.e. Brookings 2011), and partly they are included in other CI domains (see i.e. Kachan 2012).

3 Recycling, which is an important aspect of resource efficiency, was excluded from the outset as indicated by the contractee.

Another, slightly different, delimitation comes from BIS (2013) under the heading of "Low Carbon and Environmental Goods and Services" (LCEGS) encompassing the three categories *"Environmental"*, *"Renewable Energy"* and *"Low Carbon"*, the last category embracing a variety of sectors reducing CO2 emissions. Developing a taxonomy to estimate the relevance of the clean economy in the UK, the delimitation was narrowed down recently (BIS, 2015), now targeting low carbon sectors and omitting environmental sectors. The new delimitation comprises six categories: *"Low Carbon Electricity"; "Low Carbon Heat"; "Waste Processing, Energy from Waste and Biomass"; "Energy-Efficiency Products"; "Low Carbon Services"* and *"Other Low Carbon"*.

The example of BIS (2013) and (2015) for two different taxonomies of the clean economy helps to illustrate how differing delimitations lead to remarkably distinct estimations of the overall volume of the clean economy. While BIS (2013) for the broader definition estimate a volume of 152.8 bn € (128.1 bn £) for 2011/2012 (measured as sales of UK companies belonging to LCEGS), BIS (2015) for the narrower definition estimate a volume of 83.4 bn € (70.8 bn £) in 2013. If they, however, include the supply chain, their estimate grows to 143.3 bn € (121.7 bn £), which is rather similar to the values of BIS (2013) for 2011/12. At the global level, estimates of the clean economy's value of course drift apart to a larger extent. BMU/RB (2014) estimate the clean economy to encompass 2,536 bn € in 2013. The estimate of BIS (2013) for 2011/12 is 4,055 bn € (3,400 bn £). ICT (2014) citing Environmental Business International (2012) provides a figure of 6,220 bn € (8,660 bn US-$) for 2011. The estimate of EBI (2012) is thus more than 2.5 times larger than that of BMU/RB, pointing to the dependency of these figures on the definition of the clean economy as well as on the assumptions of the models used for estimation.

1.1.3.2 A workable taxonomy for the EU Clean Industry

Coming back to the compilation of an own taxonomy, in a first step, we considered and synthesized the existing taxonomies to gain a comprehensive definition of CI that is suitably segmented to select priority sectors. For this purpose we primarily use Kachan (2012), Globe Advisors (2011), BMU/RB (2014), Brookings (2011), BMBF (2013), MKULNV NRW (2015) and European Communities (2009, 2015). Categories and sectors occurring in all or most taxonomies are hereby weighted more strongly than those occurring only in few or one taxonomy. For the choice to include particular sectors or leave them out, further reference is made to the overall definition of CI. That is, emphasis is put on the provision of core technologies, products and services that are responsible for producing measurable environmental benefits. During further inquiry in the course of the sector selection, the taxonomy was adapted. Segments were shifted into other categories, some segments were deleted due to missing information and some other segments were combined since further research indicated that differences are small and the underlying technology is more or less the same. This first approach has led to the following taxonomy as depicted in Table 2.

The proposed taxonomy comprises five main categories, namely Clean Energy (production, storage and distribution), Energy-Efficient Buildings & Appliances, Clean Mobility, Clean Production and Environmental Protection. We decided to state Clean Mobility as a main category on its own albeit this is not the case in all existing taxonomies. One reason for this choice is the regulatory framework within the EU. In September 2009, the European Union and the G8 countries agreed that CO_2 emissions must be cut by 80% by 2050. Considering the high contribution of road transport to CO_2 emissions, this may not be feasible considering improvements to the traditional internal combustion engine (ICE) or alternative fuels only. It rather demands a basic technological change from conventional vehicles with ICE to electric vehicles (EVs). This comprises particular challenges for the automobile industry as one of the baselines of the manufacturing industries in the EU28, providing high value added and millions of jobs, because it's contemporary global success is mainly attributed to ICE technology. Here, it is necessary to use the existing knowledge and innovation potential as a starting point for the development of competitive vehicles with alternative combustion technologies to manage the demanded transition from ICE to EVs. The importance of the automobile industry is further highlighted by the EU's Strategic Transport Research and Innovation Agenda (STRIA) initiative.

Each of the five main categories is further subdivided into segments as displayed in the first column of Table 2. In considering Clean Mobility as a main category on its own, there may be some overlap to segments of other categories derived from taxonomies where Clean Mobility is part of categories like Energy Efficiency. The second column refers to further sub-segments. In order to make the various categories less abstractive, as well as to provide a more refined taxonomy, the third column describes examples of products and technologies which correspond to the categories in the first and second column. This allows for a more refined specification of potential subsectors that can be selected for further analysis using the product and company approach, as has been introduced in the proposal and is further outlined in part 1.1.2.

Some segments and the respective sub-segments are highlighted in grey. These are either not in the focus of the study (as, for example, waste treatment and management as well as their respective technologies, but also traffic infrastructure as agreed in the kick-off meeting) or hardly identifiable. This refers in particular to most of the more energy-efficient products and appliances like energy efficient white goods or consumer goods. It is not possible to differentiate these so-called adapted goods from conventional goods of the same kind with respect to production or trade data (see also below in section 1.1.4 "Product Approach").

(Sub-)segments highlighted in violet are not possible to be analysed by the product approach. This is partly due to the fact that they mainly describe process technology that cannot be attributed to particular aligned products. The implementation and future growth of others, like smart grids and super grids, rather rely on management or ICT competencies than on specific components or products and / or they are - like CCS or CCU - more or less in the phase of research and development and are not displayed in products. Those segments motivate further investigations delivered by the company approach.

Table 2: Taxonomy of Clean Industry

Segments	Sub-segments	Examples of technologies/products
Clean Energy (production, storage and distribution)		
Renewable Energies	Wind (onshore, offshore)	e.g. turbines, components, towers
	Solar (thermal, photovoltaic, concentrating solar power (CSP))	e.g. PV module technologies, inverters, mirrors
	Biomass	e.g. combustion equipment
	Geothermal	e.g. heat pumps
	Hydropower (e.g. run-of-river and other small-scale hydro)	e.g. turbines, components
	Wave/ocean power	e.g. turbines, components
Storage technologies	Mechanical storage	e.g. pumped Hydroelectric Storage (PHS), compressed air energy storage (CAES)
	Electrochemical storage	accumulators, capacitors
	Thermal storage	e.g. pumped-heat electricity storage (PHES)
	Hydrogen storage	
Ecofriendly energy conversion	Combined Gas and steam power plants	
	Combined heat and power units (CHP)	
	Waste heat recovery[1]	
	Carbon capture and storage (CCS), carbon capture and utilization (CCU)	
	Fuel cells	stationary use
Efficient networks	Smart grids (to improve flexibility of existing regional networks), Super grids (across regions and national borders to access generation and demand diversity; requires new subsea and land routes)	transmission (e.g. superconductors, high-voltage control devices), demand response, management (e.g. monitoring and metering*, networking equipment, data analysis system)
	District heating and cooling	
Energy-Efficient Buildings& Appliances		

Thermal insulation		e.g. wall insulation, improved glazing of windows, floor insulation, loft insulation
Building automation		e.g. monitoring sensors and controllers*, software, data analysis and communication
Efficient heating and cooling		e.g. heat pumps
Nearly Zero Energy Buildings (NZEBs)		
Energy-efficient appliances	Efficient lighting	e.g. LED
	Energy-efficient white goods	
	Energy-efficient consumer electronics	
	Energy-efficient data centers (Green IT)	
Clean Mobility		
Electric vehicles	Battery-electric vehicles (BEV)	
	plug-in hybrid electric vehicles (PHEV)	
	Fuel-cell-electric vehicles (FCEV)	
Batteries	energy storage systems used in EVs	lead-acid batteries, nickel-metal hybrid batteries, lithium-ion batteries, ultra-capacitors
Renewable fuels	conventional biofuels	e.g. ethanol, biodiesel, biogas
	advanced renewable fuels	e.g. hydrogen and synthetic methane
Energy efficiency gains in vehicles powered by internal combustion engine (ICE)	technologies to reduce vehicle loads by lightweight materials,	
	aerodynamics improvements	
	energy-saving tires	
Rail/tram		
Other transportation vehicles	Electric bikes	
	electric motorcycles	
Traffic control		e.g. lighting and signals

systems		
Infrastructure	Sustainable mobility concepts	e.g. car sharing
	Alternative filling station	
	Public mass transit	
	Traffic management services	
Energy and/or Material-Efficient Production (Processes)/Clean Production		
Energy- and/or material-efficient production technologies	Advanced manufacturing technologies[2]	e.g. digital printing, laser-cutting techniques
Cross-application technologies	Organic electronics	e.g. organic solar cells, organic LED display
	Industrial biotechnology & renewable resources	e.g. bioplastics, enzymes to reduce the amount of harsh chemicals used the textile or pulp and paper industries
Measuring and monitoring	Automation, software systems, sensors and other measurement, process efficiency	
Environmental Protection		
Air pollution control	Air handling equipment	e.g. condensers, vacuum pumps
	Catalytic converters, chemical recovery systems	e.g. limestone flux, magnesium hydroxide or peroxide
	Separators, precipitators	e.g. machinery for liquefying air/other gases
Water purification		
Noise and vibration abatement		
Protection and remediation of soil		
Waste treatment and management		
Sustainable forestry,		

agriculture and aquaculture	

Source: IDEA/NIW compilation.

Notes:

[1] The term "waste heat recovery" refers to technologies that allow to gain energy from waste heat.
[2] Following the definition used in the EU Key Enabling Technologies (KETs) Observatory. https://ec.europa.eu/growth/tools-databases/ketsobservatory /

A very important category is that of **Clean Energy** regarding all related aspects of the value chain such as production, storage and distribution. It is segmented into Renewable Energies, Storage Technologies, Ecofriendly Energy Conversion and Efficient Networks. *Renewable Energies* are further differentiated according to the energy source: wind, solar, biomass, geothermal, hydropower, and wave or ocean power. When approaching renewable energies, there may be different kinds of technologies for each energy source. Solar energy, for example, comprises solar thermal energy, which can produce thermal as well as electricity energy. Photovoltaic, by contrast, produces electricity only. Concentrated solar power (CSP) generates electricity via a heat engine drawing on concentrated light or solar thermal energy. Additionally to renewable energies, nuclear is also recognized as a low carbon solution. However, this technology will not be considered further in this study, as it is already well analyzed in other works.

Rising amounts of energy produced from renewable resources require increasingly sophisticated *Storage Technologies* since most renewable energy sources have fluctuating energy generation, especially regarding solar and wind energy. The segment of storage technologies is further differentiated into mechanical storage, electrochemical storage, thermal storage and hydrogen storage. Mechanical storage technologies refer, for example, to pumped hydroelectric storage (PHS), where water is elevated by the use of off-peak electricity and released through turbines in times of high demand. Compressed air energy storage (CAES) applies a similar method. Electrochemical storage draws on accumulators and capacitors to store electrical energy. These also include batteries for buildings intended to store energy drawn from solar photovoltaic in rooftop systems or other small-scale use. Thermal storage saves thermal energy, for example, via pumped-heat electricity storage using very different technologies. Finally, hydrogen storage refers to processes converting electricity (mostly from renewable energy sources) into hydrogen which can then be stored, distributed or used. Power-to-Gas is a one example that converts renewable electricity to hydrogen or methane and stores it in the gas infrastructure for later use. Importantly, hydrogen and methane from renewable electricity can also be used in mobility, industrial, heat supply and electricity generation application. This makes Power-to-Gas a multi-system solution which supports the integration of renewable energy into the energy system.[4]

[4] Source: Deutsche Energie Agentur (dena), http://www.powertogas.info/english/roadmap-power-to-gas/.

The segment of *Ecofriendly Energy Conversion* comprises technologies that produce or use energy in a more environmentally friendly way compared to conventional technologies. This applies to combined gas and steam power plants, combined heat and power units (CHP), waste heat recovery, carbon capture and storage (CCS) as well as carbon capture and usage (CCU) and fuel cells. Combined gas and steam power plants use the exhaust of gas turbines (fueled with fossil resources) to drive a steam turbine and thereby increase the energy generated from fossil resources. CHP units also make more efficient use of fuels using the waste heat of electricity generation for heating. A similar technology is waste heat recovery.

The idea of carbon capture is to capture waste carbon dioxide of large power plants to reduce emissions. These emissions can then either be stored (CCS) or used (CCU), nonetheless both technologies are still in development and besides some pilot projects not already commercially used.[5] While carbon storage faces possible problems of leakage or suitable geological sites (see, e.g., Pires et al, 2011), carbon usage via chemical conversion, mineral carbonation (to be used as construction materials) and biofuels from algae (e.g. from photobioreactors) are other possibilities how carbon dioxides can be prevented from entering the atmosphere (Styring and Jansen, 2011).

Fuel cells can be part of storage systems but can, however, not store energy themselves. They also provide an alternative to electric and hybrid powertrains possibly implemented in cars, ships or airplanes. Up to now however, its commercialization is even lower than that of other alternative powertrains.

The final segment of Clean Energy is *Efficient Networks* and comprises smart and super grids as well as district heating. The first two represent concepts to optimize the agreement between energy generation (from renewable), storage, transmission and demand. Here, the application of smart measurement and monitoring technologies, ICT and management competencies plays a major role. While smart grids improve the flexibility of existing regional networks, super grids cross regions and national borders. In the EU, the European Network of Transmission System Operators for Electricity (ENTSO-E) coordinates harmonization of network codes, investments and R&D since 2009 to build a comprehensive transmission system, hence an EU-wide super grid. District heating and cooling is also part of efficient networks supporting the adjustment of energy distribution to a more decentralised system. District heating (and cooling) plants can provide higher efficiencies and better pollution control than localized boilers.

The second category, **Energy-Efficient Buildings**, has five segments: thermal insulation, building automation, heating and cooling systems, Nearly Zero Energy Buildings (NZEBs) and energy-efficient appliances. *Thermal Insulation* as well as *NZEBs* ensure that less energy is used or set free and the potential for lowering emissions by insulation is estimated to be very high. It is estimated that from 2007 on until 2020 global carbon dioxide emissions from buildings can be lowered by 29% (Levine et al., 2007) in a cost effective manner by implementing adequate measures such as efficient insulation, heating and cooling or energy management systems resulting in

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[5] The EU-SCO2T-Project (htp://www.scotproject.org/) demonstrates the transformation of CO2 as feedstock in the manufacturing of construction products.

lower energy demand. The IEA further estimates that global annual investment in buildings energy efficiency is more than USD 80 billion (OECD/IEA, 2015). *Building Automation* mostly refers to measuring and monitoring equipment that reduces energy demand. *Heating and Cooling Systems* is another approach to comprehensively handle energy needs in buildings more efficiently. Here, heat pumps are a largely used product. Finally, *Energy-Efficient Appliances* refer to efficient lighting, such as by LED, which become more and more prevalent. Furthermore, energy-efficient consumer electronics and energy-efficient white goods contribute to lower GHG emissions related to buildings. Besides, energy-efficient data centers ("green IT") are also part of energy-efficient appliances. The complete segment, nevertheless, refers to adapted goods and can therefore not be displayed via the product approach using common statistics. Consideration of eco-labels or energy classes cannot overcome this problem because they are not internationally comparable and change over time. Thus, the potential of these goods can at most be captured by the company approach.

The third category refers to **Clean Mobility**. In general, mobility does – as already indicated above – not have an environmental purpose but since transportation is responsible for a large part of GHG emissions, new low-carbon technologies within the transportation industry can be relevant for the clean economy. Although transport mainly refers to road transport, air, marine and rail transport are also included. In 2012, 71.9% of GHG emissions from transport pertained to road, 12.8% to air, 13.9% to maritime and 0.6% to rail (EU transport in figures, 2014). This distribution highlights that technologies aiming to avoid GHG emissions should mainly target road transport. *Electric vehicles* as one of the segments within Clean Mobility encompass battery-electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV) and fuel-cell-electric vehicles (FCEV). Whereas the number of hybrid vehicles (HEV) has been rising in the last years exceeding the threshold of 2 Mio cars in 2014 and expected to pass 5 Mio by 2020 (OECD, 2015), BEV as "truly" electric vehicles without ICE are just about to be commercialized in a less relevant number. Norway and the Netherlands are the global forerunners in BEV as a no carbon substitute for conventional passenger cars and local buses. In 2013, 6.2% of total car sales in Norway were BEVs, in the Netherlands, the respective figure was 4% (Amsterdam Round Table Foundation and McKinsey, 2014).

The still low market penetration of EVs is especially due to the development in *Batteries* (storage capacity and price of the battery pack), which is one of the crucial aspects of the adoption and distribution of electric mobility. The most promising technologies within the electrochemical storage of energy in batteries or accumulators regarding electric mobility are lead-acid batteries, nickel-metal hybrid batteries, lithium-ion batteries (including lithium-polymer batteries) and ultra-capacitors. They are, however, in different stages of development and commercialization (Frieske, Kloetzke and Mauser, 2013). Another aspect of clean mobility apart from electric vehicles are *Renewable Fuels*. These comprise either conventional biofuels like ethanol or biodiesel or advanced renewable fuels gathered from wastes and residues instead of food crops. Also hydrogen or synthetic methane that is obtained by power to gas from renewable energies is part of advanced renewable fuels.

The segment of technologies to realize *Efficiency Gains* in vehicles powered by Internal Combustion Engines (ICE) contains all kind of technologies, which reduce vehicle loads by lightweight materials, improve the aerodynamics or other ways to realize efficiency gains regarding energy needs such as energy-saving tires. These segments refer to maritime and air transport in addition to road transport. Improvements in aerodynamics are particularly important for the reduction of GHG emissions of trucks that are generally less appropriate for electric powertrain than passenger vehicles.[6] Rail and Tram (driven by electricity) also provide cleaner possibilities of transportation and are therefore listed. Other *Transportation Vehicles*, such as electric bikes or motorcycles, complete the picture but are not as relevant regarding their size. Furthermore *Traffic Control Systems*, providing, for example, lighting and signals, are considered. The more efficient (in terms of energy-saving) management of traffic is potentially valid albeit harder to depict. Finally, aspects with respect to the general *Infrastructure* are part of Clean Mobility, but not regarded here.

The main category of **Clean Production** is segmented into three parts. *Energy- and/or Material-Efficient Production Technologies* refer to advanced manufacturing technologies, which are also defined as a part of Key Enabling Technologies (KETs).[7] An example for material-efficient production technologies is laser-cutting, which reduces scrap during the manufacturing process. Important *Cross-Application Technologies* in the field of Clean Production are organic electronics and industrial biotechnology. Today, organic electronics comprise organic solar cells or organic LED displays, but it is still unclear what the potential of this technology is. Organic-based electronic devices are more eco-friendly than silicon-based devices due to the replacement of fossil resources but also due to a more resource-efficient production process (CS3, 2012). Industrial biotechnology is another cross-application technology, whose implementation already reduces emissions because natural organisms or enzymes replace chemicals such as in the textile industry or reduce energy demand as in the food industry. *Measuring and Monitoring* is an elementary segment of Clean Production since it enables energy and material efficiency in various ways as well as the application of new technologies.

The last category contributing to the clean economy is **Environmental Protection**. It can further be segmented according to the medium that the environmental benefits are directed at. Air is the only medium in the focus of this study, and the segment of *Air Pollution Control* comprises air handling equipment, catalytic converters, chemical recovery systems, separators and precipitators as well as incinerators and scrubbers. Although air pollution refers to all kinds of greenhouse gas emissions, most technologies also refer to CO_2 emissions, which is the particular focus in this study. Other segments of Environmental Protection are *Water Purification, Noise and Vibration Abatement, Protection and Remediation of Soil, Waste Treatment and Management* and *Sustainable Forestry, Agriculture and Aquaculture*.

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[6] However, also in the truck segment innovative alternatives powertrains are under development. In February 2016 Scania as one of the world's leading manufacturers of trucks for heavy transport appliances will start testing electric trucks on the electric roads using a conductive technology which involves electrical transmission through overhead lines. The demonstration facility for conductive technology is part of the Swedish Electric Roads Project which will demonstrate and evaluate electric roads as a possible method for reducing the use of fossil energy in the transport system. http://www.scania.com/media/pressreleases/N15020EN.aspx.

[7] https://ec.europa.eu/growth/tools-databases/ketsobservatory/home

1.1.4 Product Approach

The product-based approach aims to provide strongly reliable empirical evidence for international trade performance in CI based on common statistical nomenclatures. These products take up a key position in the development of low carbon technological progress and thus are of special interest for economic policy purposes. In order to derive conclusions on the contribution of CI to economic goals such as employment and economic growth, however, a complementary approach based on firm-data, industry statistics and investments bypasses the respective limitations of the product-based approach.

For the comparative trade analysis, we align existing lists of environmental products corresponding to the identified sub-segments of clean industries. Starting from the disaggregated product level allows a more precise demarcation of CI and enables to analyze internationally comparable data. We investigate which categories and (sub-)sectors are represented by goods that can be found in common production or trade statistics. This approach represents a bottom-up strategy. For this purpose, existing lists of environmental goods are consolidated, "cleaned" according to the taxonomy introduced above and products are finally assigned to the (sub-)sectors of this taxonomy. This procedure allows investigating trade competitiveness indicators for the identified sectors, which represents also one pillar to select priority sectors for further analysis. The consolidated list of environmental goods and services used as a starting point builds on two basic lists and several supplementary lists referring to specific (sub-)sectors of the CI.

The first basic list is the CLEG (Combined list of environmental goods), that itself is an up-to-date combination of several approved available lists (APEC 54, Friends 153, revised PEGS)[8], see Sauvage (2014), that originate from tariff negotiations.

The second basic list is the NIW list of potential environmental protection goods (Gehrke, Schasse 2015). This compilation of goods that are (capable of being) used for environmental and climate protection purposes is based on the combination of two complementary methodical approaches. On the one hand, potential environmental protection goods have been empirically identified using the reports of companies that have explicitly declared

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8 'APEC 54' refers to a list of 54 HS codes that was released at the 2012 Vladivostok summit (APEC 2012). The subscribing 21 Asia-Pacific economies agreed to reduce the tariff rates for these environmental product categories to 5% or less by the end of 2015. 'Friends 153' comprising diverse sectors with a total of 153 HS codes has been submitted in the context of the Doha negotiations (WTO 2009). It was the result of compiling products from individual submissions by the countries in the Friends' Group, namely Canada, the EU, Japan, Korea, New Zealand, Norway, Switzerland, Taiwan, and the United States (Sugathan 2013).
The 'PEGS list' was initially prepared by the OECD for the 2010 G20 summit in Toronto. It comprises more than 150 products but focuses mainly on goods of relevance to combating climate change. The revised version excludes HS lines for general cars and other road vehicles included in the original PEGS list and only considers HS codes for vehiceles using fuels other than gasoline or diesel fuel (Sauvage 2014).

themselves as suppliers of environmental protection goods and participate in the German EGSS (European Environmental Goods and Services Survey) on the firm level (empirical approach). On the other hand, based on their content description, the identified goods were assessed for their environmental or climate protective purpose following the criteria for defining environmental purpose goods applied in the EGSS (European Communities 2009, 2015) (theoretical-methodical approach). Subsequently, the list of potential environmental protection goods was compared with other national and international lists and conclusively validated at an expert workshop.[9]

The sector-specific lists used apply to particular climate-mitigating technologies and associated goods. Three of them, Kejun (2010) for the transport sector, Lako (2008) for the renewable energy supply sector, and Goswami, Dasgupta and Nanda (2009) for the building sector were commissioned by the International Centre for Trade and Sustainable Development (ICTSD). Furthermore, OECD (2015) for electric vehicles and batteries and Moinudding, Bhattacharya (2013) for renewable energy equipment were employed. All these sector-specific lists are considered to fine-tune depiction of the sectors in the combined CLEG and NIW list and are further used to provide more details on sectors to differentiate sub-sectors.

Subsequently, products referring to categories of the CI not aimed at in this study are removed from the consolidated list. For example, products associated with wastewater treatment are not considered since they do not meet the focus on climate-mitigating technologies and goods. Finally, the products in the consolidated and narrow list will be assigned to (sub-)sectors of the CI taxonomy as far as possible.

Special cases are so-called adapted goods. According to the EGSS Handbook (European Commission, 2009, p.37) those are "technically less pollutant or more resource efficient than equivalent normal goods which furnish similar utility". In most cases common statistics do not distinguish adapted and conventional goods or their composition underlies continuous changes, respectively. Hence, it is not feasible to analyse these goods in a consistent and comprehensive quantitative product-based approach.

Examples of this kind are products representing "clean" electrical appliances (e.g. particularly energy-efficient refrigerators, washing machines, consumer electronics, Green IT) and parts of clean mobility (technologies to achieve efficiency gains in conventional cars). Also electric cars, which are in the focus of the EU clean transportation strategy, are not completely unambiguously distinguishable from conventional cars. According to the definition of the International Energy Agency (IEA), electric vehicles are defined as battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and fuel-cell electric vehicles (FCVs).[10] Whereas BEVs have no

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9 Ecotec (2002), Steenblik (2005a,b, 2006), EAU (2011), WTO (2005), Committee on Trade and Environmental Special Session (2007), World Bank (2007), Wind (2009), Ernst & Young (2009), Bilsen et al. (2009).

10 Hybrid electric vehicles (HEVs) which are powered by internal-combustion engines but can run for part of the time on electric power generated by generative braking, are not included in the definition of EVs.

combustion engine and only one or more on-board electrical batteries which provide energy to an electric motor, PHEVs are part battery electric and part conventional car in that they have a large capacity battery and a small on-board combustion engine and draw part of their energy from the electric grid (OECD 2015). Sales and registration statistics generally apply to BEVs and PHEVs, because the number of FCEVs is still very low due to a limited number of models on the market, limited infrastructure, and higher costs compared to a BEV or PHEV (OECD/IEA 2013).

In production and trade statistics, PHEVs are part of those HS lines for general cars and other road vehicles. Thus, it is not possible to separate them from conventional cars. Including total car production would be totally misleading, because in most countries, the shares of PHEVs over total vehicle production and trade are still very small. Only BEVs can be identified statistically, because there are separate production and HS codes[11] for vehicles using fuels other than gasoline or diesel fuel. A similar problem occurs with fuels produced from re-growing natural resources in trade statistics. Only with the transfer to the trade classification HS 2012 a separate product category for bio-fuels was introduced. Thus it is possible to analyze this category in foreign trade from 2012 onward, but not for long time series.

With respect to the sub-segment "technologies to achieve efficiency gains in vehicles powered by ICE", that cannot be unambiguously identified via products, we approximately analyze the comparative advantage of the EU-28 for all vehicles (road vehicles, airplanes, ships and boats[12]) as well as for all tires compared to other countries. However, those calculations only serve to indicate the potential for the reduction of GHG emissions by the consistent development and use of innovative materials and technologies (e.g. lightweight materials, aerodynamics improvement, efficiency gains in combustion engines, energy-saving tires) in those large industries. Nevertheless, conventional vehicles and tires are basically not part of CI.

Further statistical limitations will be solved by the collection of additional information from other data sources and their consideration within the broader company and stakeholder based approach. In the case of EVs, e.g. sales and registration statistics and market studies have to be used to get information about growth and market development of total EVs. Moreover, market and trade figures for EVs will be compared with respective figures for total motor vehicles to allow better estimations of recent growth rates on the one hand and to illustrate the growth potential of EVs in realizing the long-term transition to electric drive systems on the other hand.

However, some analytical and methodological aspects have to be considered. While international trade statistics for products are widely available, this is not the case for services. A wide range of services contributes to the development and promotion of energy-efficient and low-carbon technologies (see Steenblick and Grosso, 2011), e.g. R&D, engineering, design and construction services, laboratory analysis, consulting and financial services,

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[11] Harmonized Commodity Description and Coding System, also known as the Harmonized System (HS)

[12] Only the railway industry is excluded because it is analyzed separately.

installation and maintenance services, energy distribution services, data transmission services or education services. Only services in pollution control, waste disposal, and water treatment can be empirically identified via Balance of Payments Statistics (EBOPS No. 282), others are not depicted in existing statistics. On the one hand, this is unfortunate because services continue to grow in importance, especially in preventive environmental protection. On the other hand, services are mostly of a complementary character in projecting, financing, marketing and operation, and therefore of minor importance for policy instruments mainly concerned with technology promotion.[13] Yet, the implementation and future growth potential of some potential priority fields rather rely on management or ICT competencies than on specific components or products as, for example, smart energy networks. They will be further investigated by the company-based approach.

Moreover, "multiple purpose" or "dual use" problems[14] aggravate an unambiguous allocation of CI products. Besides their climate protection or low carbon character, many products fulfil other functions as well (e.g. pumps or pipes, and especially measuring and control devices) so that it remains unclear whether a client uses the goods for climate protection or other purposes.

1.2 Methodology for selecting sectors for priority actions

Task 1.2 focuses on an adequate and effective selection of sectors within the scope of the Clean Industry definition defined in Task 1.1. The selection essentially depends on the selection criteria and subsequently on the evidence. The following sections will therefore first elaborate the selection criteria, and subsequently describe the method how these selection criteria will be applied in order to obtain 12 relevant sectors or activities.

1.2.1 Selection criteria

Building further on the general approach for developing an appropriate selection methodology we use the following set of selection criteria:

- Clean potential, in terms of low carbon, energy and resource efficiency potential, as a proxy of policy priorities
- Absolute growth potential, reflecting the economic relevance in terms of value added per job and number of jobs, and growth potential
- Technology leadership, reflecting EU technology and innovation leadership, technology advantage
- Comparative advantage.

13 Example: wind farm projects and operators.

14 See for instance OECD (2007), Steenblik (2005c), Stilwell (2008) or Sugathan (2009).

In the following paragraphs we shortly explain the meaning of each of the indicated criteria.

The clean potential criterion has been proposed in the kick-off meeting, with the aim of posing a more specific policy relevant topic. Since there is no uniform data on the low carbon, energy or resource efficiency potential available that could support a quantitative comparison, a qualitative assessment is required to list the sectors. In this qualitative assessment, information regarding carbon emission, energy and resource efficiency targets, both from public and private reports, current carbon emission and energy and resource efficiency levels have been taken into account.

The absolute growth potential covers essentially the significance of the (sub-)sector in current and future value added creation. Rather than separating economic relevance and growth potential we combined them since both current size and expected growth are intertwined and from a leverage point of view it is the combination of the two criteria that matters rather than each separately. Before elaborating this further it is useful to depict shortly each of the two sub-criteria:

- Economic relevance points to the economic importance of the (sub-)sector as it stands today. Given the political goal of the Commission to boost economic growth and jobs, it is important to focus on those (sub-) sectors and industries that are already of significance for the EU economy. Evidently policy actions applied on a larger sector will have, ceteris paribus, a bigger leverage effect on the EU economy than the same actions on a smaller sector or industry.
- Yet not only does the current economic situation play an important role for the selection. The future one does as well. The economic growth potential refers to the expected market development in the relatively near future.

Both economic relevance (size) and growth potential are relevant selection criteria. Yet due to the fact that sector size and growth tend to have a negative relation over time, both criterions may point to different sectors. A large and mature sector, displays little growth potential, yet from economic relevance point of view is worth selecting, and vice versa. In order to avoid this type of problem we propose to combine both criteria into one single criterion, labelled as the absolute growth potential. In principle this could be measured in quantitative terms such as total value added for the subsector, number of jobs and value added per job, as well as growth percentage over a specific time period, yet it turned out that this quantitative information is rarely available in a systematic comparable manner.

Given the nature of the data, the absolute growth potential is therefore measured as the average score on a 1 to 5 Likert scale of two sub-scores: the current size and the expected growth. The sub-scores are also measured in a qualitative manner in a 1 to 5 Likert scale. The information comes from a meta-analysis of relevant reports and studies. Where possible quantitative information has been used to obtain a systematic scoring, e.g. benchmarks for defining different size classes and growth percentages. However this was done taking relevant context information into consideration.

The untapped potential for EU technology and innovation leadership refers to the technological possibilities in the longer term for EU companies. It is an important criterion, yet not easily quantifiable. Therefore we assess the

EU's relative technology leadership position based on a meta-analysis of relevant literature for the respective subsectors, as indicated below.

The revealed comparative advantage measured in terms of trade indicators provides more insight in the current relative strengths of EU Clean Industry goods in the global market and helps to identify the sectors that perform already relatively well in this respect. Furthermore, by making an intertemporal comparison promising sectors can be identified, under the hypothesis that the near future can be modelled by simple extrapolation. While this criterion draws on official trade statistics, it is well applicable for those potential sectors which also rely upon statistical classifications. In the case of potential sectors which are not represented statistically this does not imply the exclusion from the final definition but rather treating the comparative advantage just as a subordinate criterion.

1.2.2 Selection method

Each of the (sub-)sectors and activities of the Clean Industry, which have been defined in Task 1.1, has been assessed against each of the selection criteria. The following parts of this section illustrate the methodology which in essence results in an appropriateness score for each (sub-) sector or activity. The 12 (sub-) sectors or activities with the highest scores will be selected for further and more detailed analyses in Tasks 2 and Tasks 3.

Table 3 provides an illustration of the methodology. Each score represents a harmonized score of an underlying measure which indicates the degree to which the selection criterion is fulfilled. The scores are all presented on a 5-point Likert scale. The harmonization allows compiling an overall score which in this table is calculated as the average score over all the selection criteria for a particular (sub-)sector, which implies that each of the criteria has an equal weight. This has been used as the baseline selection.

Table 3: Ranking of EU Clean Industry (sub-)sectors by selection criterion

	Selection criteria				
	Low carbon & resource efficiency potential	Economic relevance and growth potential (absolute growth potential)	Technology leadership	Comparative advantage	Overall score
Scale	1 - 5	1 - 5	1 - 5	1 - 5	1 - 5
Clean Industry (sub-)sector					
sub-sector 1	4	5	1	3	3,25
sub-sector 2	2	2	3	2	2,25
…					…
…					…
…					…
sub-sector n	5	3	4	4	4,00

Each of the criteria will be shortly described in the following paragraphs.

Low carbon, energy and resource efficiency potential: is a qualitative measure rated in a 5-point Likert scale:

1. Very low potential
2. Low potential
3. Medium potential
4. High potential
5. Very high potential

Several information sources are used in order to make the rating:

- Current emissions and resource efficiency. Eurostat data will be used were possible.
- Targets from the European Commission regarding low carbon and resource efficiency potential. This information will be composed by desk research and literature review of relevant EU documentation. Missing information will be requested from the Commission.
- Industry reports regarding low carbon and resource efficiency potential
- Other reports regarding low carbon and resource efficiency potential

Since there is no uniform data or information about the low carbon and resource efficiency potential of sectors, the (quantitative) information needs to be interpreted qualitatively. Besides lacking uniform data, targets posed by public organisations or intermediaries often vary from the targets industries pose themselves, advocating more realistic targets. The assessment was done using desk research and literature review. Also cross-industry checks have been done comparing various sectors with each other in order to obtain a consistent assessment across sectors.

Economic relevance: has been measured in terms of EU market size. Market size has mostly been assessed using indicators of turnover and jobs. Indications of value added are rare. The following scale has been used:

1. Very small size
2. Small size
3. Medium size
4. Big size
5. Very big size

Growth potential: has been assessed in terms of expected annual growth in turnover or jobs in the coming 5 years for each of the (sub-)sectors. The information for the expected annual growth rates comes mainly from existing market reports. The following scale has been used to assess growth potential:

1. Very low expected growth
2. Low expected growth
3. Medium expected growth
4. High expected growth
5. Very high expected growth

Technology leadership: has been assessed using a 5-point Likert scale with the following scores:

1. Clear lag of the EU in key technologies for the sector
2. Relative small lag position of the EU
3. EU at par with other main players in the world
4. Relatively small leading position of the EU
5. Clear lead of the EU in key technologies for the sector

The information is mainly qualitative in nature, based on a literature reviews.

Comparative advantage: is based on the product-based trade analysis, in particular on export specialization, significance for total manufacturing exports, and export dynamics.

- To assess the comparative advantage of single segments of CI, trade data is evaluated. The most important information used is Revealed Export Advantage (RXA). It compares the export share of a certain CI product group c on all manufacturing exports in a given country i with the global export shares of these product groups on the global exports in manufacturing goods. Thus, a positive RXA value indicates that the country realises comparably higher export market shares in this specific product group than it does in total manufacturing goods. RXA is provided as an average for the EU28 for the years 2012 to 2014 (t):

$$\mathrm{RXA}_{ic} = \ln[(\frac{X_{ict}}{X_{ct}})/(\frac{X_{it}}{X_t})] * 100$$

- Additionally, information on the relevance of the sector with regard to trade as well as the export growth within the segment is used to further substantiate the assessment of comparative advantage. Relevance of trade, denoted as significance (SG), is measured as the export share of CI products c related to the respective sector in reference to total manufacturing for the EU28 in 2014 (t):

$$\mathrm{SG(E)_c} = \mathrm{E_c} / \mathrm{E} * 100$$

- Export growth is calculated as compound average annual growth rate (CAGR) of the respective CI product group c for the years 2007 to 2014:

$$\mathrm{CAGR(E)}_{c(2014,2007)} = \mathrm{EXP}(\ln(\mathrm{E}_{c2014} / \mathrm{E}_{c2007})/7)*100\text{-}100.$$

As a first step towards a score for the comparative advantage indicator, scores are defined separately for each figure – RXA, significance, export growth. Therefore, quintiles of the distribution of each figure are calculated. Here, calculation only refers to sectors and not superior categories so as to prevent double counting. The quintiles are used to build five distinct intervals. Values within the intervals are then assigned the scores ranging from 1 to 5, whereby 5 indicates very good performance of the indicator and 1 very bad performance.

Finally, the three single sores are combined into an overall score for the comparative advantage indicator. For this purpose, the RXA receives weight 0.5 and significance as well as export growth receive weight 0.25. Sensitivity checks were made to test the robustness of the final score. Using RXA only or applying equal weighting of all three figures does not seriously change the overall score. Moreover, the comparative advantage score is only one indicator used for the final scoring of the sectors.

1.2.3 Sensitivity analysis

In order to test the sensitivity of the baseline selection with respect to different weights that one may attach to each of the criteria a sensitivity analyses has been done. In essence the weights represent different perceptions and/or priorities with respect to the selection of priority sectors to boost the EU Clean Industry. In comparison with the baseline result, three alternative views have initially been tested:

1) A stronger focus on the Clean Potential, which is related to the EU policy objectives on GHG emission reduction, energy efficiency and resource efficiency,
2) A stronger focus on the economic side,
3) A stronger focus on technology leadership.

Given that for a few sectors no relevant data for calculating the comparative advantage were available, we have also tested the sensitivity of the results using only the Clean Potential, technology leadership and absolute growth potential, each with an equal weight. Section 1.3.2 provides more detail on the weights used and the results.

1.2.4 Robustness

It is important that the selection results are robust. Especially since the selection is based on a wide set of literature and reports, of which the methodology, nature of the information (quantitative, qualitative), and sector definition may vary. Robustness in this study would mean that if the selection would be replicated, one would arrive to the same results. This replicability could be influenced by several factors in this study:

- The availability and selection of relevant data and information
- Differences in assessing, selecting and interpreting data
- Differences in assigning scores based on the available information.

In order to mitigate these factors that might negatively influence the replicability and therefore robustness of the study, a systematic and iterative selection process has been designed which contains:

1) The systematic reporting of the relevant information in a reporting and scoring template, and
2) The use of an internal Delphi method for assigning scores by various internal experts based on the information gathered.

The reporting and scoring template has been designed so that data and information is systematically stored. This allows the internal experts to review, modify and complement the gathered data and information.

The internal Delphi method consisted of three rounds: first, after all data and information had been gathered, the experts within NIW and IDEA Consult each conducted an individual scoring based on the gathered evidence. Second, within each institute the assigned scores were compared and discussed in order to come to a common score by institute. Third, the scores of NIW and IDEA Consult were compared and discussed in order to come to a final ranking across institutes. In this way, given the information obtained, the final score can be considered as a relatively robust result in which the effects of subjective interpretation of the available evidence and implicit scoring schemes have been reduced to the minimum possible within the scope and time of Task 1.2.

1.3 Selection of sectors /areas

Following the methodology that has been described in previous sections, this part of the report presents the results of the selection methodology. In first instance the results for the selection based on equal weights for each of the selection criteria are presented; this are the so-called baseline results. Subsequently the results for the sensitivity analysis will be shown.

1.3.1 Selection on the basis of equal weights for the selection criteria

Table 4 shows the resulting 12 priority subsectors. The selection in the right column, is based on a subset of sectors that all have data on comparative advantage, hence on all the four selection criteria. Subsectors that are coloured in grey in the left column have not been scored on the comparative advantage criterion due to a lack of data. In the right column these sectors therefore have been replaced by the subsequent priority sectors for which data on comparative advantage were available (coloured in blue).

Table 4: Baseline results: 12 priority subsectors

	All subsectors	**Only subsectors with data on comparative advantage**
1	Wind	Wind
2	Technologies to realize efficiency gains in ICE powered vehicles	Technologies to realize efficiency gains in ICE powered vehicles
3	District heating and cooling	NZEBs
4	NZEBs	AMT
5	AMT	Heating and cooling systems
6	Heating and cooling systems	Measuring and monitoring
7	Measuring and monitoring	Rail/tram
8	Thermal storage	Hydropower
9	Smart grids and super grids	Solar
10	Rail/tram	Biomass
11	Hydropower	Thermal insulation
12	Mechanical storage	Traffic control systems

Detailed information on the scores per criterion and the final score per subsector can be found in Table 5 and Table 6.

Table 5: Ranking of all subsectors with equal weights (baseline results)

	Selection criteria [1 - 5]				
	Clean potential	Absolute growth potential	Technology Leadership	Comparative Advantage	Overall score
1 Wind	5	5	5	4,75	4,94
2 Efficiency tech. ICE vehicles	3	4,5	5	4	4,13
3 District heating	4	4	4		4,00
4 NZEBs	5	3	5	3	4,00
5 AMT	3	4	5	4	4,00
6 Heating and cooling systems	4	3,5	4	3,75	3,81
7 Measuring and monitoring	3	4	4	4	3,75
8 Thermal storage	4	3	4		3,67
9 Smart grids and super grids	4	4	3		3,67
10 Rail/tram	3	3,5	4	4	3,63
11 Hydropower	4	2,5	3	4,5	3,50
12 Mechanical storage	3	2,5	5		3,50
13 Solar	4	3,5	3	3,25	3,44
14 Biomass	4	3	3	3,75	3,44
15 Thermal insulation	5	2,5	3	3,25	3,44
16 Traffic control systems	3	3	4	3,75	3,44
18 Waste heat recovery	3	3	4		3,33
19 Building automation	3	3	4		3,33
20 Biofuels	3	3	4		3,33
21 Organic electronics	2	4	4		3,33
22 Industrial Biotechnology and Renewabl	3	3	4		3,33
17 Combined heat and power units	3	3	4	3	3,25
23 Separators, precipitators	1	3,5	5	3,5	3,25
28 Gas and steam power plants	1	3,5	4	4,5	3,25
24 Lead-acid batteries	3	2,5	4	3,25	3,19
25 Plug-in hybrid electric vehicles	4	2,5	3		3,17
26 Advanced renewable fuels	3	2,5	4		3,17
27 Hydrogen storage	2	2	5		3,00
29 Battery-electric vehicles	5	2,5	2	2,5	3,00
30 Aerodynamics improvement to realize e	1	2	5	4	3,00
31 Air handling equipment	1	3	5	3	3,00
32 Catalytic converters, chemical recovery	1	2,5	5	3,5	3,00
33 Energy-saving tires	2	2,5	5	2	2,88
34 Geothermal	3	2,5	3	2,75	2,81
35 Fuel-cell-electric vehicles	5	2	1		2,67
36 Nickel-metal hybride batteries	3	1	4		2,67
37 Wave/Ocean power	1	3	5	1	2,50
38 Ultracapacitors	3	3	2	1,25	2,31
39 Electrochemical storage	2	2,5	2	2,5	2,25
40 CCS & CCU	3	1	2		2,00
41 Electric bikes	1	3	2	2	2,00
42 Lithium-ion batteries	3	1,5	1		1,83
43 Electric motorcycles	1	1	3	2	1,75
44 Fuel cells	2	2,5	1	1	1,63

Table 6: Ranking of subsectors with available data on comparative advantage (baseline results)

		Selection criteria [1 - 5]				
		Clean potential	Absolute growth potential	Technology Leadership	Comparative Advantage	Overall score
1	Wind	5	5	5	4,75	4,94
2	Efficiency tech. ICE vehicles	3	4,5	5	4	4,13
3	NZEBs	5	3	5	3	4,00
4	AMT	3	4	5	4	4,00
5	Heating and cooling systems	4	3,5	4	3,75	3,81
6	Measuring and monitoring	3	4	4	4	3,75
7	Rail/tram	3	3,5	4	4	3,63
8	Hydropower	4	2,5	3	4,5	3,50
9	Solar	4	3,5	3	3,25	3,44
10	Biomass	4	3	3	3,75	3,44
11	Thermal insulation	5	2,5	3	3,25	3,44
12	Traffic control systems	3	3	4	3,75	3,44
13	Combined heat and power units	3	3	4	3	3,25
14	Separators, precipitators	1	3,5	5	3,5	3,25
15	Gas and steam power plants	1	3,5	4	4,5	3,25
16	Lead-acid batteries	3	2,5	4	3,25	3,19
17	Battery-electric vehicles	5	2,5	2	2,5	3,00
18	Aerodynamics improvement to realize e	1	2	5	4	3,00
19	Air handling equipment	1	3	5	3	3,00
20	Catalytic converters, chemical recovery	1	2,5	5	3,5	3,00
21	Energy-saving tires	2	2,5	5	2	2,88
22	Geothermal	3	2,5	3	2,75	2,81
23	Wave/Ocean power	1	3	5	1	2,50
24	Ultracapacitors	3	3	2	1,25	2,31
25	Electrochemical storage	2	2,5	2	2,5	2,25
26	Electric bikes	1	3	2	2	2,00
27	Electric motorcycles	1	1	3	2	1,75
28	Fuel cells	2	2,5	1	1	1,63

1.3.2 Sensitivity analysis

A sensitivity analysis has been conducted in order to analyse the influence of assigning different weights to the criteria on the outcome of the 12 selected priority sectors. Four different weight distributions have been tested and compared with the baseline result with equal weights.

1. In the first weight distribution, the scores of the criterion Clean Potential have been given a weight of 50%, with the remaining 50% equally divided between the other three criteria. This scenario thus simulates that a greater importance is assigned to the Clean Potential score.
2. In the second weight distribution, the scores of the criteria Absolute Growth Potential and Comparative Advantage have each been given one-third of the total weight, with the remaining third divided equally between the other two criteria. This scenario thus simulates that a greater importance is assigned to the economic side for selecting sectors that provide leverage for the EU Clean Industry, and consists of the absolute growth potential in combination with the comparative advantage.
3. In the third weight distribution, the scores of the criterion Technology Leadership have been given a weight of 50%, with the remaining 50% divided equally between the other three criteria. This scenario thus simulates that a greater importance is assigned to the Technology Leadership score.
4. The fourth weight distribution comprises equal weights of one third for the Clean potential, Absolute growth potential and technology leadership, while the weight for Comparative advantage has been set at zero. This was done to test the robustness of the base selection with respect to the presence of comparative advantage scores.

The results of this analysis are displayed in Table 7. The table displays the top 12 selected priority sectors according to the given weights on the different criteria. The first column of Table 7 shows the 12 priority sectors for the baseline results where all criteria have an equal weight. The other columns show the results of alternative weighting schemes as indicated above. At the bottom of the table changes in comparison with the baseline results are shown. Sectors that have been included in a particular simulation setting are indicated in cyan, and the sectors that have been excluded are coloured in red.

The sensitivity analysis shows that the selection is relatively robust, with minor changes when different weights are assigned to the different criteria. The largest differences occur when a greater weight is placed to the technology leadership criterion.

Table 7: Sensitivity analysis with four scenarios

		Clean potential	Economic potential	Technological leadership	No comparative advantage
Weights	**CP**	1/2	1/6	1/6	1/3
	AGP	1/6	1/3	1/6	1/3
	TL	1/6	1/6	1/2	1/3
	CA	1/6	1/3	1/6	0

	Base scenario	**Clean potential**	**Economic potential**	**Technological leadership**	**No comparative advantage**
1	Wind	Wind	Wind	Wind	Wind
2	Efficiency tech. ICE vehicles	NZEBs	Efficiency tech. ICE vehicles	Efficiency tech. ICE vehicles	NZEBs
3	NZEBs	Thermal insulation	AMT	NZEBs	Efficiency tech. ICE vehicles
4	AMT	Heating and cooling systems	Measuring and monitoring	AMT	AMT
5	Heating and cooling systems	Efficiency tech. ICE vehicles	Heating and cooling systems	Heating and cooling systems	Heating and cooling systems
6	Measuring and monitoring	Hydropower	NZEBs	Measuring and monitoring	Measuring and monitoring
7	Rail/tram	AMT	Rail/tram	Separators, precipitators	Rail/tram
8	Hydropower	Battery-electric vehicles	Hydropower	Rail/tram	Solar
9	Solar	Solar	Gas and steam power plants	Air handling equipment	Thermal insulation
10	Biomass	Biomass	Solar	Aerodynamics improvement	Traffic control systems
11	Thermal insulation	Measuring and monitoring	Biomass	Catalytic converters, chemica	Combined heat and power ur
12	Traffic control systems	Rail/tram	Traffic control systems	Traffic control systems	Biomass
	+ Sectors included	Battery-electric vehicles	Gas and steam power plants	Separators, precipitators Air handling equipment Aerodynamics improvement Catalytic converters, chemica	Combined heat and power ur
	- Sectors excluded	Traffic control systems	Thermal insulation	Hydropower Solar Biomass Thermal insulation	Hydropower

1.3.3 Final selection

Given the results of the sensitivity analysis and the results for the baseline scenario in Table 4, a final selection was made in cooperation with the Commission, taking on board policy priorities as well as a few sector specific considerations. The first 10 sectors of the baseline scenario were retained, reflecting the idea that lack of data should not be an argument to exclude the sector from taking into consideration for further policy focus. Since the market potential for hydropower is mainly situated outside the EU, while in stark contrast with this, the internal market potential is rather limited, it was decided not to select hydropower. Mechanical storage has the property that it contains at the same time rather mature technologies and certain segments with projects that are mainly in pilot phase. Due to this duality, it was decided to leave this sector out as well. The next candidates to be included would then be solar, biomass, thermal insulation and traffic control systems. The value added for including solar was perceived as relatively limited giving the sheer amount of information that is available on the sector in the EU already. Biomass would be a good candidate, however was not included considering the uncertainty about the precise environmental benefits of certain bioenergy applications (e.g. first generation biofuels). Therefore the two remaining sectors thermal insulation and traffic control systems completed the list of 12 selected sectors. Table 8 provides an overview of the various subsectors in the final selection. The following paragraphs show for each of the selected sectors, the main arguments and motivation for inclusion.

Table 8: Final selection of priority sectors

N°	Subsector
1	Wind
2	Technologies to realize efficiency gains in ICE powered vehicles
3	District heating and cooling
4	NZEBs
5	AMT
6	Heating and cooling systems
7	Measuring and monitoring
8	Thermal storage
9	Smart grids and super grids
10	Rail/tram
11	Thermal insulation
12	Traffic control systems

[1] The **wind energy** sector is the dominating sector within the EU's renewable energy production. Employment in the EU is forecasted to grow by 5.4% from 320,000 (2013) to more than 462,000 in 2020. Not only the EU, but also other world regions have set ambitious targets to increase their wind capacity (onshore and offshore) in the coming years, helping to avoid a high amount of CO2 emissions. In this context, the global demand for wind turbines will increase significantly. The European wind industry profits from long experience, technological leadership (indicated by a comparably high patent share), holding a strong market position (share of global sales or installed capacity) and a high comparative export advantage. Since the technology is quite mature, innovations mainly target cost efficiency and productivity gains.

[2] The sector **efficiency gains in vehicles powered by internal combustion engines (ICE)** encompasses several technologies which allow vehicles to consume less energy, by reducing weight, improving aerodynamics and other techniques. These technologies can have a major impact considering the high environmental impact of the transportation sector. Moreover, they constitute an important growth market. For example, the overall lightweight market in automotive is expected to increase from EUR 70 in 2010 to 300 billion in 2030, reflecting an annual growth rate of 8 percent (McKinsey, 2012). Importantly, the EU automotive industry is world leading in adopting these technologies, making the sector particularly interesting from an EU perspective.

[3] While district heating (DH) already has a significant share in the European heat market (12-15%, 2013 capacity of DH being 264,195 MWth), district cooling (DC) is an emergent field but with a large potential to reduce GHG emissions (-75% CO2 compared to conventional electrical chillers). **District heating and cooling (DHC)** provides an important means to integrate the potential of low carbon energy such as from cogeneration, waste heat or from renewables. Moreover, the centrally provided infrastructure of DHC is more efficient compared to, for example, individually installed heat pumps, especially in terms of grid requirements. These synergies as well as the technological leadership of the EU with some countries having long-term experience with large DHC systems justify an in-depth study of this sector regarding its economic condition and outlook.

[4] In its `Roadmap for moving to a competitive low carbon economy in 2050' GHG emissions in the residential and service sector are targeted to be reduced by 79% by 2050 compared to 1990 levels. This target can to a large part only be achieved via intensified regulation. Since the EU has a comparative advantage with respect to energy efficiency in buildings the internal market will be stimulated via regulations while exports are expected to grow due to the technological leadership in many of the related products.

The Energy Performance of Buildings Directive is one of the important policy instruments for implementation and requires all new buildings in the EU to be **nearly zero energy buildings (NZEBs)** from 2021 on (from 2019 on for public buildings). At the same time, the EU has gained technology leadership in NZEBs due to its pioneering role in this field. While investments today are still small (6.1 bn. EUR worldwide in 2013), the regulations together with the technological advantage lead to a high growth outlook for NZEBs making them one of the priority sectors to be further analysed.

[5] The **advanced manufacturing technologies (AMT)** sector is key to transforming industries towards higher productivity as well as lower environmental impact. Its market size was assessed over 500 billion euros in 2013 (source: KETs Observatory), making its economic relevance for the EU indisputable. Moreover, this market is growing considerably (a CAGR of 5,5% between 2002-2013), especially in fast developing high tech segments such as laser processing, additive manufacturing and robotics. Europe is leading in terms of share of patents (technological leadership) as well as share in total export and depicts a high and increasing trade surplus compared to East Asia and North America, highlighting the importance of this industry for the EU.

[6] Within residential and service buildings the largest amount of energy is demanded for heating and cooling. The high energy-savings potential as well as relatively short payback-periods induce growth in this sector which is estimated to benefit from 70 to 140 Mio EUR of yearly investments during the next decades if GHG emissions reduction targets shall be reached. The EU has a comparative advantage in **efficient heating and cooling technologies** and is a technological leader with respect to advances in, e.g., heat pumps or solar heating and cooling.

[7] **Measuring and monitoring (MOM)** including instruments, software and services is an elementary segment of CI. The corresponding technologies and services are a necessary prerequisite for renewable energy production, storage or distribution (smart grids), as well as for innovative solutions to improve energy efficiency in buildings, production or mobility. In 2013, the European instruments industry alone made a turnover of 70.5 bn € and employed 386,000 people.15 Thereby, it holds a strong technological position (with a patent share of nearly 50%) and an above-average comparative export advantage. The European market accounts for one third of the global market and is suggested to reach CAGR of around 5-7% until 2020.

[15] Data come from Eurostat, Structural Business Statistics, and refer to NACE group 26.51: Manufacture of instruments and appliances for measuring, testing and navigation.

[8] **Thermal energy storage (TES)** allows for mismatches in generation and consumption of energy to be resolved, and is hence a key element for both waste heat valorisation as well as renewable energy development. According to the IEA the global market for TES amounted 1.1 bn. EUR in 2013, having witnessed a sharp increase over the past 10 years, with Europe representing the largest market. Europe has a good starting position in technological competition in this area due to several leading companies in among others phase change materials (PCM) and core research institutes.

[9] The development of **smart and super grids** is pivotal for the deployment of EU's energy policy. Smart grids are one of the six priority areas of the Commission's 2012 Industrial Policy Communication. Smart grids are not only useful for better matching supply and demand through smart metering systems, yet they are also key to better integrate renewable energy. In terms of Clean Potential one of the major benefits of smart grids are energy savings. The estimated benefits from installing smart meters vary across Member States. For instance the potential energy savings range from 0% in the Czech Republic to 7% in Austria[16]. It is expected that within the EU € 56 bn. will be invested in smart grids between 2010 and 2020. At a global scale a CAGR of 18.2% between 2013 and 2019 is estimated. Technology leadership is rather at par with other leading economies.

[10] The selection of **rail and tram** as a priority sector is mainly the result from the EU's relative strong technology leadership in this sector. The EU rail supply industry has been the source of major innovations such as automatic obstacle detection systems, improved braking systems, hybrid and diesel electric technologies, satellite-based positioning. This is also evidenced by its relatively strong export position in the sector's products. The EU host a number of world players such as Alstom and Siemens. EU rail suppliers cover 46% of the global accessible rail supply markets. The EU rail sector employs approximately 1.8 million people including production of material, services, operators and infrastructure management. The EU internal market is the world's largest market segment in rail and tram. The Clean Potential essentially depends on the share of renewable energy sources in the sector's energy supply. In the hypothesis that electricity would be entirely produced by renewable resources, CO_2 emissions could be reduced up to 45%.

[11] Since most of the buildings stock in the EU is old, reductions in GHG emissions from buildings cannot be achieved from higher efficiency of new buildings only but renovation and retrofitting of older buildings is required as well. Deep renovation focusing especially on **thermal insulation** can thereby lead to similar efficiency levels as new buildings. With more than 11bn EUR revenues in 2014, the market is large and although it can be considered mature, the regulatory incentives will stimulate sales and investments. Technology leadership and a comparative advantage in thermal insulation allow to profit from exports in other regions since building codes elsewhere increasingly set higher demands with respect to energy efficiency.

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16 European Commission (2014) p 63.

[12] Given Europe's relatively dense traffic with substantial risks of congestion for road, rail and aviation, **traffic control systems** play an important part for realising the EU's Clean Potential. Vreeswijk et al (2010) estimate that 22% of all wasted fuel is due to inefficient deceleration and lack of anticipation. Congestion counts for another 15%. The global market for Intelligent Transportation Systems (ITS) was estimated at € 12 bn. in 2013. The global market for advanced transportation management systems is expected to grow by 12% between 2014 and 2020. For the air traffic control equipment market a CAGR is expected of 4.79% between 2015 and 2020. The market for intelligent traffic control systems is dominated by the US which generated in 2012 more than 42% of the total global turnover in ITS. Yet this does not mean that the EU's is lagging in terms of technology. Given the relatively close relation to the measuring and monitoring sector we assess that the EU has a small leading position in traffic control systems.

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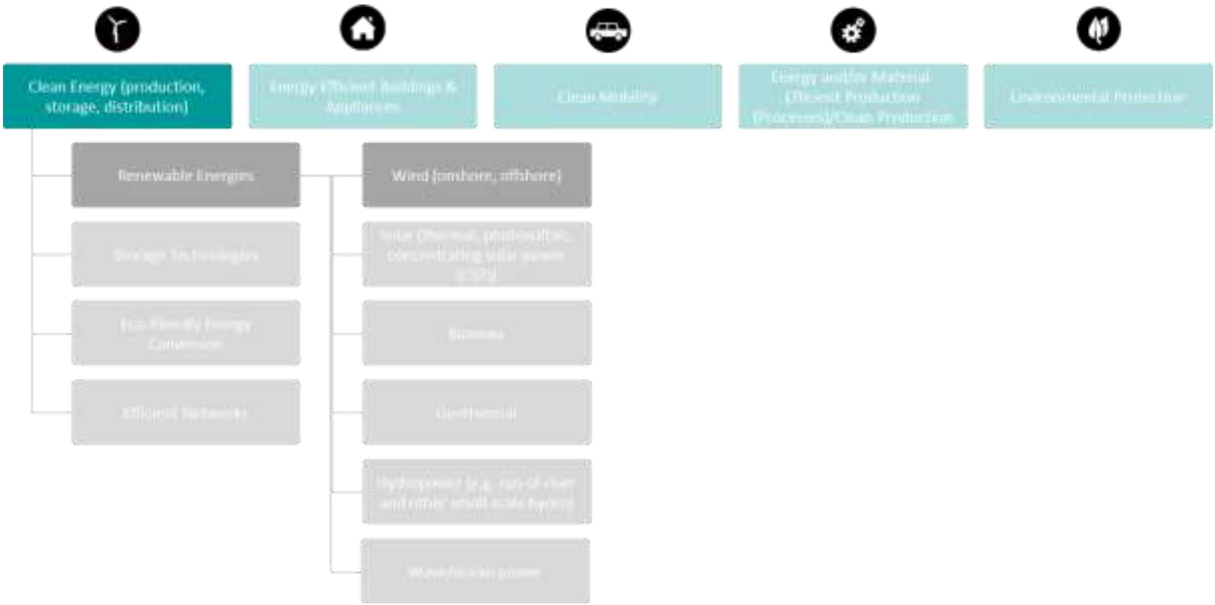
PART 2 Competitiveness, barriers and levers of the 12 priority sectors

1/ Wind energy

Figure 2: Presentation of the selected priority sector within the Clean Industry taxonomy



1.1 Description and value chain

For the past four decades, wind power is the leading source of renewable energy and has also been one of the world's fastest growing energy sources due to its reliability and cost-effectiveness. In 2014 Wind Energy covered 8 % of the European electricity demand and will provide at least 13% of the electricity demand by 2020 (Lacal Arántegui, 2016). This would be a significant contribution to the 20-20-20 targets of the European energy and climate policy and highlights the importance of wind power within renewable energies.

Wind turbines transform kinetic energy into mechanical energy which can then be converted by generators into electricity. Often single wind turbines are grouped together into a wind power plant in order to achieve economies of scale. At the end of 2015 the EU had a cumulative capacity of 141.7 GW installed of which 11 GW was attributed to offshore Wind Energy compared to a global cumulative capacity of 432.6 GW (Eurobserv'Er 2016). Currently sixteen Member States have more than 1 GW wind power capacity connected to the grid. Germany remains the largest market for Wind Energy, accounting for 31.7% of the EU's wind capacity (onshore and offshore). Yet Spain (16.2%), Great Britain (9.8%) and France (7.3%) hold significant wind capacity market shares as well. A detailed overview over installed Wind Energy capacities in the EU can be found in Annex 2/ Table 27. Contrary, offshore wind power capacities are only installed in ten member states – 76% of the capacity is installed in Great Britain and Germany (see Annex 2/ Figure 84) – as on the one hand sites are presently limited to the North Sea, the Baltic Sea and the Irish Sea and on the other hand offshore capital costs are relatively high.

Since 2010 total installed wind capacity in the EU has grown at a compound annual growth rate of 11% whereas the European offshore capacity has grown at a CAGR of 30% over the last five years[17]. During the record year 2015 the EU newly connected an estimated 12.5 GW to the grid of which Germany accounted for half of the installed capacity. These reflect the grid connection of a large amount of offshore capacity on the one hand, but also a rush to complete new projects before Germany will switch to a tendering scheme in 2017 (REN 21 2016). Besides Germany, also Poland (1.2 GW)[18], France (1 GW) and Great Britain (0.87 GW) added significant capacities in 2015 (Eurobserv'Er 2016).

Overall the European wind industry (onshore and offshore) occupied 319,600 direct and indirect employees in 2013[19], an increase by 5.6% compared to the year before. Germany accounted for 43% of these jobs (REN21 2015), followed by the United Kingdom, Italy and Denmark (Irena 2015). Approximately 56% of total jobs are directly derived from the Wind Energy supply chain (EWEA Green growth 2012). The offshore wind industry represented 58,000 jobs in 2013 (Irena 2014) that grew by 29% to 75,000 jobs in 2014.

Core technologies required by the wind industry are forgings and castings, turbine blades and wings, bearings, gearboxes and drive trains, generators, power take-off assemblies, cables, foundations, energy storage systems and software/control systems. The capital expenditures (CAPEX) for an onshore project are dominated by the turbine with more than 60%, applying to 18% to the tower[20], 14% to blades, 24% to the electrical (generator, power converter, controls), 20% to mechanical (gearbox, shafts, bearing) groups and 24% to different other components. In the offshore sector the turbine costs make up 30-40% of CAPEX, because foundations and cables (array cables and submarine export cables) are decisive cost factors (Lacal Arántegui, Serrano Gonzàlez 2015, Lacal Arántegui 2016). Generally those technologies are mature and the sector has already adopted common standards (EC 2014a). However incremental as well as radical technology improvements are developed by manufacturers and research centers, especially in the offshore sector that aim at decreasing the levelized cost of energy (LCOE) and to reduce downtime of the turbines. Examples are floating structures still being in the R&D stage, or the use of downwind wind turbines instead of the upwind configuration used on land-based turbines, tested in some demonstration projects (Koh / Ng 2016).

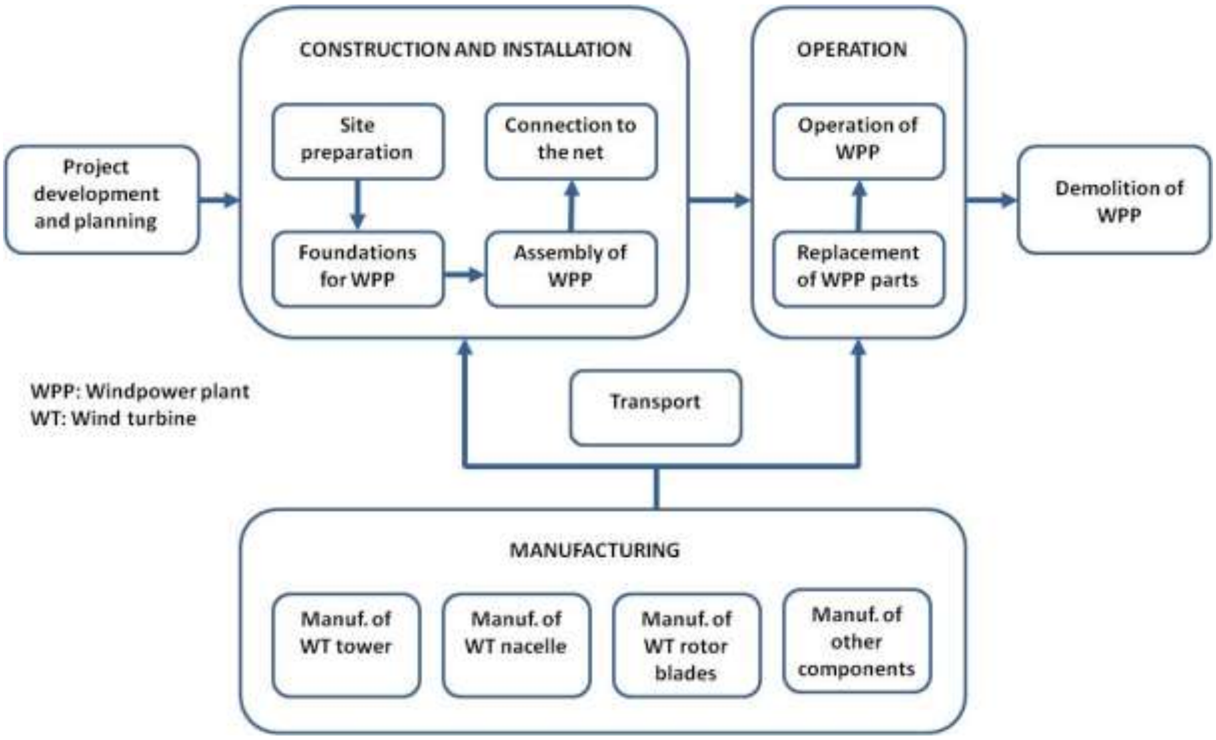
17 NIW calculation with data from EWEA and Eurobserver.

18 The large additions in Poland (nearly three times the 2014 level) were also – similar to Germany - driven by foreseeable changes in the national support mechanism (GWEC 2015, REN21 2016).

19 Most current data available.

20 Tower costs have decreased significantly since 2008, mainly caused by the reduction in raw materials (steel) prices.

Figure 3: The Wind Energy supply chain (onshore and offshore)



Source: EC 2014 p.217

Europe has a strong manufacturing base with four companies among the top ten turbine manufacturers (onshore and offshore) that accumulate a global market share (with respect to newly installed capacity) of around 43.5 % in 2014 (Lacal Arántegui 2016). Vestas (DK) and Siemens (DE) are the largest wind turbine manufacturers with global market shares of 12.3% and 9.9% respectively, followed by German Enercon (7.8%) and Spanish Gamesa (4.7%) (Figure 85 in Annex 2/). Other manufacturers among the global top fifteen include Nordex (DE) and Senvion (DE). At the moment, there is a high demand for wind turbines which is creating a seller's market but since raw material prices are decreasing and components are readily available, price hikes are prevented (Lacal Arántegui 2016). Along the onshore value chain some prominent companies specialized in installation, operation and maintenance (O&M) and project development are RES, WKIN AG, Energie Kontor, Enel Green Power, RWE, Scottish Power, and Vattenfall (EC 2014a/ Eurobserv'Er 2016).

Often turbine manufacturers outsource a significant share of their production and only produce core technologies in-house like electricity generators, power converters and control systems. Among the components that are often outsourced to independent specialized manufactures (ISM) are towers, blades, gearboxes, shafts and bearings.

As a result of the crisis of the wind energy sector 2010-2012, particularly the production of blades has been recently more outsourced.21 Nowadays independent blade manufacturers (IBM) account for 50% of the world market compared to 30% in 2006 (Karcanias et al 2015). The largest ISM and IBM in the world is LM Wind Power (DK) and also the market for gearboxes, shafts and bearings is dominated by European companies including Winergy (DE), ZF (DE), Bosch Rexroth (DE) and Moventas (FI) (Lacal Arántegui 2016).

In the offshore wind industry Siemens is the main player with a global market share of 80%, followed by MHI Vestas, a joint subsidiary formed by Vestas and the Japanese manufacturer Mitsubishi in 2013 (Eurobserv'Er 2016). Adwen, BARD, Senvion and WinWind are also involved in the production of wind turbines for the offshore industry. Offshore wind parks in Europe are largely developed and operated by Dong Energy, E.ON, RWE Innogy and EDP Renovaveis which often offer installation services as well (EC 2014a/ Eurobserv'Er 2016). European manufacturers are also leading the foundations market with Bladt (DK), EEW SPC (DE) and SiF Group/Smulders (NL) and the absence of low-cost competition indicates the technological complexity of the product. However, more competition in this sector would be beneficial (Lacal Arántegui 2016).

Generally, European manufacturing companies are more vertically integrated than foreign competitors and branch out to natural subsectors like O&M and wind farm development in order to diversify their risk in case a sector suffers from an economic crisis (Lacal Arántegui 2016).

The interests of the wind industry are represented by the European Wind Energy Association (EWEA) that aims at promoting Wind Energy in Europe and worldwide. However, many smaller associations are active on a national level like the Spanish Renewable Energy Association and others.

1.1 Assessment of the global environment

1.1.1 Main competitors outside the EU

The top ten wind turbine manufacturers (onshore and offshore) accumulate nearly 70% of the global market (with respect to newly installed capacity) in 2014. European and Chinese manufacturers obtain 43.5% and 34% of the market segment respectively while US manufacturer GE Wind holds around 9% and the Indian Suzlon Group 5.8% of global market shares (Lacal Arántegui 2016; see also Figure 85 in Annex 2/).

The two wind power market segments differ in their competitive situations. In the onshore segment, competition is fragmented because of the high number of major players, yet no manufacturer dominates the world market. Most turbine manufacturers are supported by a strong and growing domestic demand which creates sufficient preconditions to enter foreign markets (Eurobserv'Er 2016). Examples from this are GE Wind of the USA,

[21] Advantages are cost savings and easier compliance to local content.

Enercon, Senvion and Nordex in Germany, Suzlon in India and Goldwind, United Power, Mingyang and Envision in China. Especially the Chinese manufacturers, profit from a strong domestic growth in total installed capacity since 2008 and a greater protectionism that excludes international competitors from the Chinese market. Chinese manufacturers have the largest tower manufacturing capacities (41%) and also play an important role in the global blade manufacturing market (44%) and among independent electricity generator manufacturers. Both towers and blades are components which are often outsourced or only partly made in-house by turbine manufacturers since they are not a core technology. Although only a small part of their production is exported at the moment, recently there are signs that Chinese turbine manufacturers are starting to expand more strongly into foreign markets (e.g. in Australia, Chile, Panama, Ethiopia) (Lacal Arántegui 2016). One interviewed expert indicated that, if at some point the Chinese market slows down or reverses, the overcapacity of Chinese manufacturers will push these to offer their products at a discount to foreign markets, with significant consequences for the European wind industry (increasing cost pressure, profit loss etc.).

Contrast to the onshore market, the offshore wind power market is much more limited than the onshore segment and so far has not been subject to international expansion (Eurobserv'Er 2016). For the time being it is dominated by only a small number of European companies as wind park sites are currently limited to the North Sea, the Baltic Sea and off the British Isles. As already mentioned above, the German wind turbine manufacturer Siemens Wind Power is the number one supplier in the offshore market with a current market share of 80%, followed by MHI Vestas. Interestingly, South Korea is quite active in the offshore supply chain and recently built some of the most advanced turbine installation vessels (Lacal Arántegui 2016).

1.1.2 Relative competitive strengths

European manufacturers have substantial first mover advantages and a vast experience in the Wind Energy market. While most Chinese manufacturing companies were founded in the twenty-first century, Vestas already entered the market in 1979 and just one year later Siemens and Enercon installed first wind turbines followed by Nordex in 1985. Moreover, public and private expenditure on R&D in the EU is high with over 75% concentrated in Germany, Spain, UK and Denmark (EC 2014a). The Wind Energy industry has invested more than 5% of its total turnover into research and development projects over the past years which is over twice as much than the EU average. Out of all the Wind Energy sub-sectors, wind turbine manufacturers committed with around 10% the most to R&D (EWEA 2012 Green Growth). Likewise public R&D expenditures are very high compared to the global average (EC 2014a), supporting Wind Energy research for example with the NER300 programme and further national funding programmes.

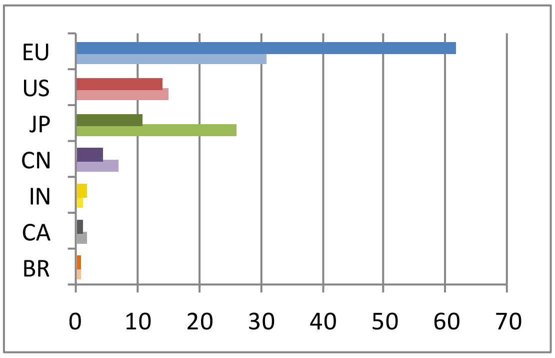
Consequently, European companies achieved a technology leadership position. This becomes evident when looking into the share of Wind Energy patents covering onshore and offshore.22 The EU clearly stays ahead of the patent race and reveals a 61.2% share on patents in wind power related products, almost 50 percentage points above the share of the United States which hold the second highest patent share, followed by Japan with a patent share of 10.4% (Figure 4). China, Canada, and particularly India and Brazil, only play a minor role in the global patent race. Compared to selected third countries, the EU's patent share of wind related products is significantly higher than its total patent share indicating its competitive advantage in this field and the immense innovation potential of the Wind Energy industry that results out of the high public and corporate R&D expenditures.

Particularly Germany, Denmark, Spain, Great Britain, Italy and France depict a specialization in wind innovations as their share of patents in wind technology is significantly higher than their total patent share which can also be explained by the fact that some advanced research, test and demonstration centres are located in these member states.

Increasingly European governments and the European Commission foster R&D specifically in the offshore segment in order to reduce the LCOE and make offshore wind competitive which has led to the establishment of several state-of-the-art offshore wind research facilities like the ORE Catapult in the UK. This provides the EU with a strong competitive advantage in the offshore wind industry.

[22] The OECD Environment Directorate, in collaboration with the Directorate for Science, Technology and Innovation, has developed patent-based innovation indicators that are suitable for tracking developments in environment-related technologies. The patent statistics are constructed using data extracted from the Worldwide Patent Statistical Database (PATSTAT) of the European Patent Office (EPO). Patent data based on family size "two and greater" were used to count only the higher-value inventions that have been applied for protection in the home market and at least one foreign market. The relevant patent documents are identified using search strategies for environment-related technologies (Env-Tech: http://www.oecd.org/env/consumption-innovation/env-tech-search-strategies.pdf) which were developed specifically for this purpose. The data are available under http://stats.oecd.org/. The European Patent Office is also working with this definition, e.g. in the context of analysing the EU's patent performance in "Green Building" (http://www.epo.org/news-issues/technology/sustainable-technologies/green-construction.html).

Figure 4: Share of patents in wind technology (onshore and offshore) compared to all patents 2010 to 2012



The upper bar shows the patent share in thermal insulation, the lower bar the total patent share (with respect to all technologies).
Source: OECD.stat; Theme Environment; Dataset: Patents - Technology Development - NIW calculation

Based on literature (EC 2014, and Lacal Arántegui 2016) and interviews it became clear, that the EU has high competitive strengths in the manufacturing of wind turbines, turbine components and structures, wind farm development, offshore wind foundations as well as cable manufacture and installation. As Windpower monthly stated in December 2015, Northern Europe remains the hotbed for wind power's pioneering technology. An overview over the top innovations in 2015 gives Figure 86 in Annex 2/.

1.1.3 International trade performance

Box 1: International trade performance

This section investigates the EU-28's trade performance in the respective CI products with regard to the development in six competitive countries in America (USA, Canada, Brazil) and Asia (Japan, China incl. Hong Kong, India). Six trade indicators are analysed to observe how the EU-28 and its Member States (MS) succeed in commercializing internationally competitive CI products. Those are significance (i.e. how important the specific CI products are in a country's total manufacturing exports), export market share (i.e. how important a country is for total global exports in the relevant CI), medium-term dynamics (i.e. how exports have changed within the pre-crisis years 2007/08 and 2013/14), trade balance (TB, comparing the absolute volumes of exports and imports), and two specialization indicators, namely export specialization (RXA, i.e. whether a country's global export share in a certain CI is higher/lower than its export share in total manufacturing products) and trade specialization (RCA, considering a country's relative export/import ratio of a certain CI compared to its total export/import ratio). Four of these indicators (export market share, significance, RXA and TB) are illustrated in the following chapter, the other two (medium-term dynamics, RCA) in the Annex 3/.

It is important to note that the analysis comparing the external trade performance of the EU-28 in a regional perspective only considers extra-EU trade flows. Otherwise, analysis that compares single Member States with non EU countries has to consider extra- and intra-trade. Hence, the calculated export market shares and export specialization figures (RXA) differ according to the respective perspective. Figures on the country level can be found in Annex 3/.

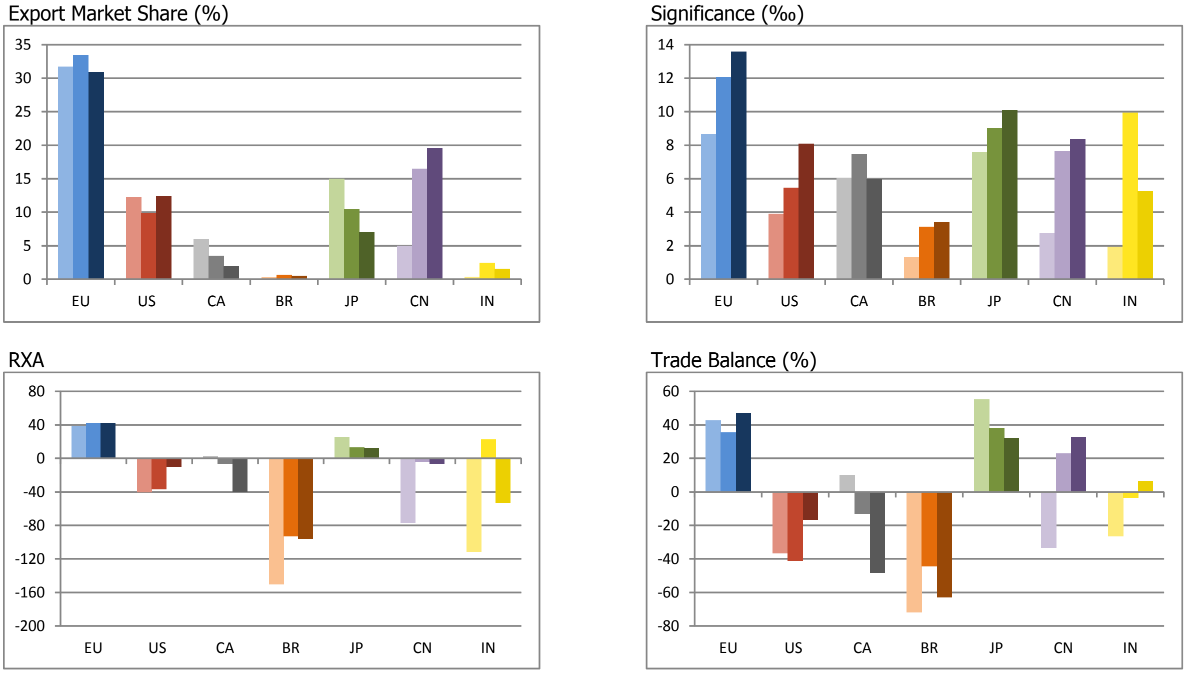
High comparative advantage for the EU-28 in international trade of Wind technologies/products

Trade analysis for Wind (onshore and offshore) shows a clear comparative advantage of the EU-28, realizing high export specialization (RXA) and trade specialization figures. Furthermore, the EU-28 has the by far highest export market share (about 30% of global exports in 2014) and the significance of Wind product exports in total exports applies to nearly 1.5% and has significantly increased over time (2002: less than 0.9%, see Figure 5). The strong export position of the EU in Wind related products is underlined by the positive trade balance that has increased by 12 percentage points between 2008 and 2014 and the positive medium-term dynamics (6.5% p.a., see Figure 88 in Annex 3/). However, the trade specialization (RCA) has declined over the last decade, indicating that the import competition of Wind producers from non EU countries has increased higher-than-average, although the still positive RCA value proves that the EU's export/import ratio with respect to these products is still significantly higher than referred to total manufacturing goods (Figure 88 in Annex 3/).

China succeeded in gaining significant export market shares, 2014 holding the second highest share (20%) behind the EU and prior to the USA (12%) that has also improved its export performance in Wind related products over time (Figure 5). Japan holds an export market share of 7%. Canada (2%), India (1.5%), and particularly Brazil (0.5%) only play a very minor role in the production and export of Wind technology and have no specialization advantages in this field.

Along with a strong export growth (China: 12% p.a., USA: 10% p.a., Figure 88 in Annex 3/), China meanwhile reveals a positive TB, though 2002 its TB has still been negative, and an almost balanced export specialization (RXA) in wind products, while the USA still depicts a negative trade balance (see Figure 5. Contrary to the EU-28, China and the USA, Japan and Canada did not succeed in participating to the same extent in the growing global demand for Wind technology. This is particularly true for Japan: decreasing export market shares, long-term declining specialization figures and trade balances and comparably low export dynamics indicate that the country significantly lost ground especially on the fast growing Asian market that is more and more dominated by Chinese Wind firms.

Figure 5: Trade indicators for the EU and selected other countries 2002, 2008 and 2014: Wind related products (onshore and offshore)



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Besides Denmark, Germany, Spain, Finland some smaller Southern and Eastern MS depict particular strengths

The EU-28's good performance is mainly driven by Germany and Denmark, whereby Germany (2014: 17%) has the world's highest export share followed by China and the US. Within the EU-28, Germany's total export market share[23] is far above of the shares of Denmark (4.5%), Italy (4%), Spain and France (about 3% each) (see Figure 89 in the Annex 3/). Within the group of the larger exporters, particularly Denmark, but also Germany, Spain and Finland depict comparative advantages (measured by RXA and RCA values, Figure 89 and Figure 91). Moreover, some smaller Southern and Eastern MS (Portugal, Czech Republic, Hungary, Poland, Slovakia, Romania) reveal significant export market shares (>0.5%) and comparative advantages (RXA, RCA). By contrast, other larger and/or highly developed MS (France, Great Britain, the Netherlands, Belgium, Sweden, and Austria) have a quite weak position. Yet, the vast majority of MS are net exporters of Wind products (positive TB). Only Great Britain, Sweden, Ireland, and Cyprus depict an import surplus in 2014 (Figure 90). With regard to the significance of

[23] Regarding EU-Extra-trade and EU-Intra-trade.

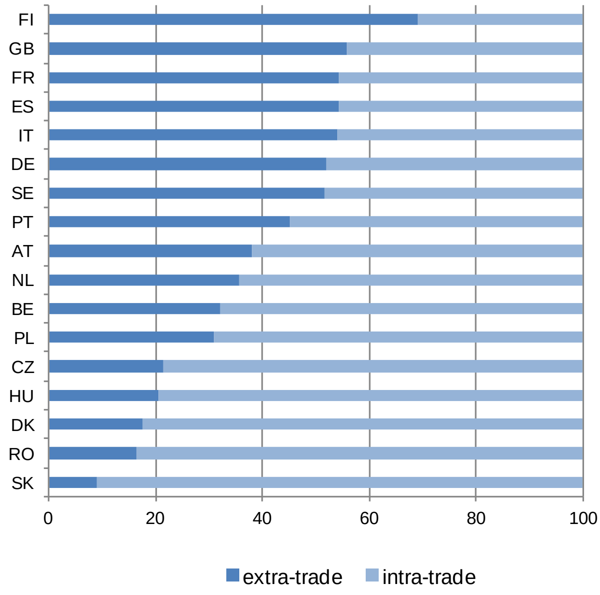
Wind exports, Denmark shows the by far highest value (6%). In Germany, Finland, Spain and most of the Eastern EU countries Wind exports account for 1.0% to 2.0% of all exports. In the other MS, the structural weight of Wind related products is comparably low (Figure 90 in Annex 3/).

Seven MS realize high medium-term export growth of more than 10% p.a. (see Figure 91 in Annex 3/). Starting from a very low level, especially Bulgaria and Romania succeeded in expanding their Wind exports impressively. But also Denmark, Spain and Portugal reveal export growth rates higher than 10%.

On average, 57% of total EU exports are designed to the internal market, but the importance of external markets is growing over time

Figure 6 reveals the high importance of the EU's internal market for wind product with respect to MS with a global export market share of at least 0.5%. Yet, the importance of the external market has significantly grown over time: while 2014 on average 57% of the EU's Wind exports refer to intra-trade and 43% to extra-trade, in 2008 about 61% of total exports were designated to the internal market and only 39% to non EU countries.

Figure 6: Share of EU-Extra-trade and EU-Intra-trade (in %) in country exports: Wind related products (onshore and offshore)



Including EU countries with an export market share in Wind products higher than 0.5% in 2014.
Source: UN COMTRADE-Database. – NIW calculation.

Besides, the country perspective for 2014 shows some quite different results. For example the high German export market share in Wind products is equally attributed to EU extra- and intra-trade, thus showing a relatively above average orientation to non EU markets. The same is true for the other larger EU countries (France, Italy, Spain, Great Britain, and Sweden). For Finland the share of EU-extra trade is even larger (nearly 70%). Contrary to this, the other MS with an export market share of at least 0.5% export most of their Wind products into other EU-28 countries. This applies particularly to the Eastern European countries, but also to Denmark, for which the share of EU-intra trade amounts to more than 80%, indicating the intense division of labor and economic integration within the EU in Wind technology production.

1.1.4 Market outlook

One of the main drivers for the future development of the wind energy market is the increase of renewable energies in all world regions. According to estimations by the GWEC global wind turbine capacity could reach 666.1 GW by 2019. In the Asian region 282 GW could be installed by that time mostly led by China's strong growth which will continue in the next years. Europe could have 204 GW installed (onshore and offshore), followed by North America with a possible capacity of 122.1 GW in the medium-term. However, new markets are also emerging elsewhere in Asia, particularly in the Philippines, Pakistan, Taiwan and Thailand, as well as in Latin America, namely in Brazil, Chile and Uruguay.

Looking at the long-term development of Wind Energy, the EWEA has projected that Wind Energy capacity (onshore and offshore) in the EU could reach between 320 GW and 392 GW under different scenarios by 2030. In a central scenario approximately 192 GW wind turbine capacity could be installed by 2020 that could grow to 392 GW by 2030 including 66 GW offshore. In this scenario Wind Energy will meet 22.7% of the European electricity demand. The high scenario is calculated based on the European target for 2030 which requires that at least 27% of the EU energy consumption will be met by renewable energies. Hence, wind turbine capacity would reach around 215 GW in 2020 and 392 GW in 2030 of which 98 GW would be contributed by offshore wind. On this account Wind Energy would produce 28.2% of the European electricity demand. The high scenario is rather similar to JRC's projection, forecasting 210 GW installed in Europe by 2020 (thereby 27 GW offshore) and 350 GW by 2030 (110 GW offshore). Globally, 680 GW (40 GW offshore) are estimated by 2020 and 1400 GW by 2030 (200 GW offshore) (Lacal Arántegui and Serrano-González 2015). Along with the extension of wind turbine capacity, employment in the Wind Energy sector in Europe will grow to approximately 334,000 to 366,000 in 2030 according to the EWEA scenarios. Yet, the European Wind Energy Technology Platform (2014) and Irena (2014) expect skill shortages in the Wind Energy sector which could impede further growth of wind capacity (see chapter 1.3).

In order to achieve cost reductions and to improve grid compatibility, acoustic emissions, visual appearance and suitability for site conditions, increasing R&D investments and technology development is expedited (IEA 2013 Roadmap Windenergy). Therefore turbine design continues to evolve with a trend towards ever larger turbines up to 10 MW for offshore (EC 2014a), larger blades and rotors, lower wind speed turbines (class 3 turbines) for onshore, higher towers for lowland sites (e.g. in Central Europe), downwind offshore turbines (Koh / Ng 2016) and new materials[24]. Also electricity generators need to be further developed in order to work with more demanding grid codes (Lacal Arántegui 2016). Offshore wind parks move farther away from shore into deeper waters. This has an impact on foundations manufacture and the characteristics needed from installation vessels (Lacal Arántegui 2016). Moreover, the interest in floating turbines will further increase. In general, growing R&D investments in offshore wind technologies will reduce LCOE and make this segment more competitive (EWEA 2016).

Increasingly, retrofitting (mostly onshore) will be on the top of the agenda especially in Germany, Denmark and to a lesser extent Spain and Great Britain, where there are prospective markets for repowering turbines that are older than 15 years. Since these already existing windfarms have better wind conditions than sites that are currently available, lower cost of energy and higher profits are expected and make repowering very attractive. Besides, the capacity of these windfarms can be massively increased while turbines are also becoming more reliable and maintenance costs are reduced. In central and northern Europe and possibly in Japan, offshore deployment will probably dominate beyond 2030. In the rest of the world onshore will continue dominating to 2050 (Lacal Arántegui 2016). Yet, the recent development of the offshore wind market in Asia can result in lower costs in the segment of submarine cables that has been determined by a cartel of European manufacturers for a long time (EC 2014b).

Moreover, offshore wind parks moving farther away from shore into deeper waters which has increased the interest in floating turbines. Currently, wind turbines are on average installed 43km away from shore in an average water depth of 27m (EWEA 2016).

Major European operators suffer from overcapacity for which reason they are likely to lower the development of renewable energy (EC 2014a, GWEC 2016). Consequently local manufacturers will increasingly enter international markets that are often tied to local content requirements (e.g. China, Brazil, Egypt, Marocco) (REN 21 2016). Therefore Eurobserv'Er anticipates a slow down for the European Wind Energy market with a realistic Wind Energy capacity at around 190 GW in 2020.

As the first months of 2015 have already depicted, Chinese turbine manufacturers are beginning to expand into markets abroad which will significantly increase competition. Hence, it can be foreseen that European manufacturers might need to accept profit losses in order to keep market shares (Lacal Arántegui 2016). Challenges are mounting particularly for companies that only manufacture turbines (e.g. Enercon, Nordex, Vestas) and are not part of large conglomerates of manufacturers, developers, data and service providers (REN 21 2016).

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[24] An example: since the cost of carbon fibre is lowering slowly, it will eventually enable higher penetration rates in blade manufacturing, that is actually dominated by glass fibre (Lacal Arántegui 2016).

To achieve technological synergies, market diversification and to meet rising competition in a mature market, industry consolidation that could also be observed during the last years is likely to continue in the next years, both in the offshore and in the onshore segment. It started with the merger of Vestas and Mitsubishi in 2013 that created the joint subsidiary MHI Vestas Offshore Wind Energy, Areva and Gamesa created Adwen in 2014 (Eurobserv'Er 2016). Oftener, large strategic partners, like Areva and Gamesa in 2014, are entering joint ventures but also acquisitions take place. In January 2016 Gamesa and Siemens started discussions about joining their forces. Siemens is interested in becoming a joint stakeholder of Adwen (Eurobserv'Er 2016). In April 2016, the acquirement of ACCIONA Windpower by Nordex was announced, together forming the fifth largest wind turbine manufacturer worldwide. Nordex has a strong market position in Europe, while ACCIONA Windpower is well-positioned in the Americas and emerging markets with manufacturing facilities in the US, Brazil and Spain, and a new factory under construction in India. ACCIONA Windpower's products are primarily aimed at large-scale wind farms that require efficient and sturdy machines for unconstrained terrains, while Nordex's products are well-suited to complex projects in populated areas subject to technical restrictions.[25]

1.2 Assessment of the competitiveness aspects

1.2.1 Export potential

Box 2: Export potential

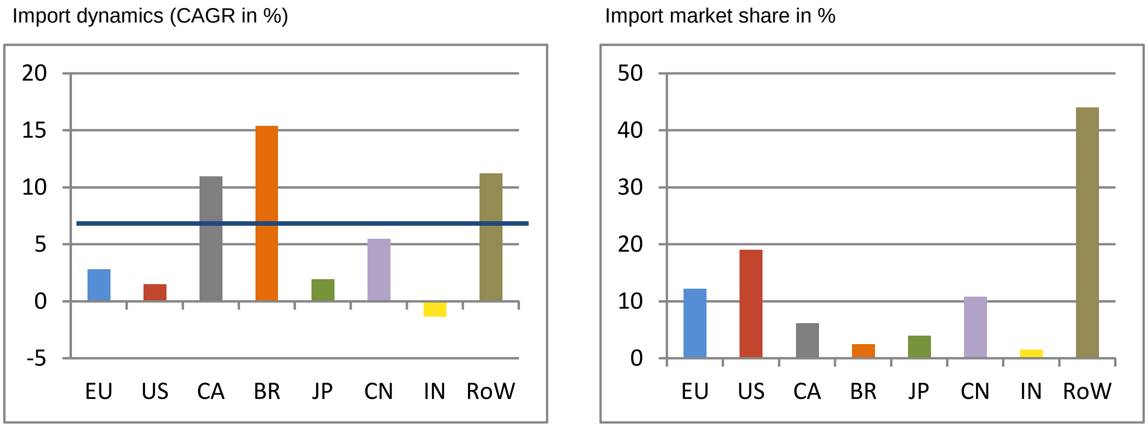
Export potentials emerge primarily in those goods and activities, in which the EU-28 already holds comparative advantages (measured in export specialization or trade specialization). In these goods and activities, trade volumes can be used as an initial indicator for market and growth potential. Hence, growing import rates of third countries may serve as a proxy for an increase in demand for CI goods in a specific country or world region that may subsequently translate into a growing export market for the EU and its Member States. At the same time, existing export advantages (indicated by RXA values) of the EU and its Member States in certain products may indicate promising preconditions for further growth and export potential.

Figure 7 reveals the global import market shares of the EU (excluding intra-trade) in comparison to other selected countries and the rest of the world (RoW) in Wind Energy products (onshore and offshore), indicating that the US has been the largest single importer (20%) in 2014 followed by the EU (12%) and China (11%). Compared to its structural weight in total manufacturing imports, also Canada revealed a considerably high demand for wind products (6%), whereas Japan (4%), Brazil (3%) and India (1.5%) are still falling behind. However, Brazil

25 http://www.acciona.com/news/acciona-windpower-nordex-join-forces-create-major-player-wind-industry

(15.5% p.a.) and Canada (11%) yield the highest import dynamics since 2007/08, indicating growing demand for Wind Energy production in these countries. Otherwise, also lower growth rates connected with a high absolute import volume, as can be seen in China (5.5%) and the US (1.5%), can create considerable export potential. The same is true for the EU (3%), from whose perspective external imports could be substituted by internal production. As Table 27 in Annex 1/ depicts, the EU constitutes high export market shares and export specialization values (RXA) for Wind Energy products in each of the five selected foreign countries. Thus, they basically all promise further export potential for the EU wind turbine manufacturers as well as related service suppliers in case of growing import demand for Wind Energy production, although Japan and India are actually falling behind in this field.

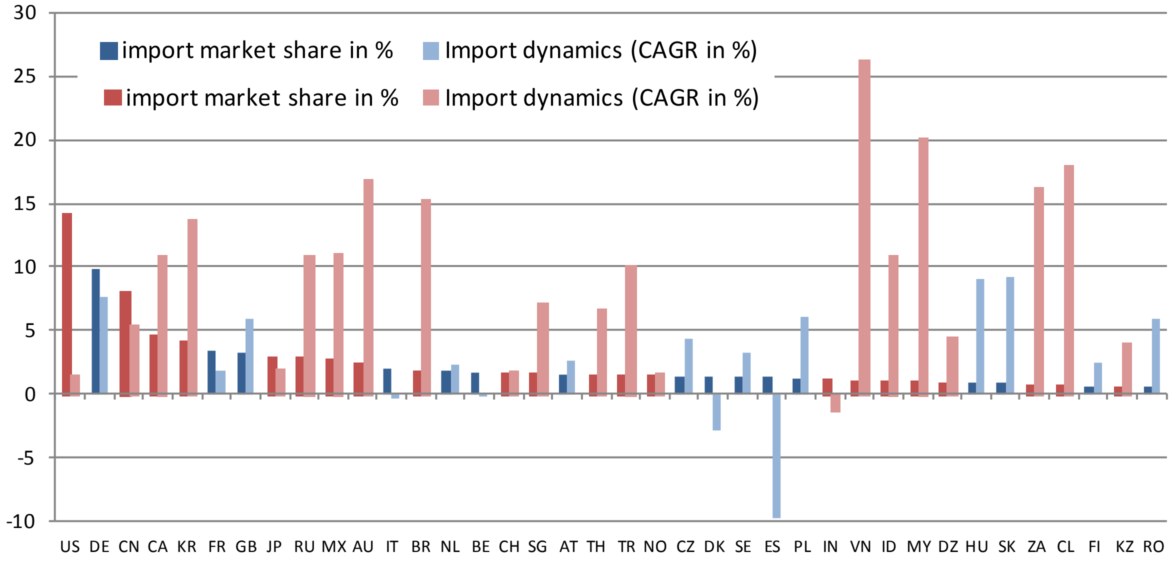
Figure 7: Import market share 2014 and import dynamics 2007/08 to 2013/14 in the EU-28 and selected non-EU countries: Wind Energy (onshore and offshore)



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

On the other hand, Figure 7 reveals that almost 45% of the import demand for Wind Energy products in 2014 applies to other than the selected countries (RoW). Furthermore, the import dynamics of RoW achieved 12% p.a., thus being significantly higher than the global average (7%). Hence, Figure 8 illustrates import market shares and import dynamics for all countries with a global import market share higher than 0.5% in 2014. This points out that besides the US, China, Canada, Brazil and some larger EU MS (Germany, Great Britain), also other European (e.g. Russia, Turkey) and overseas countries (e.g. South Korea, Mexico, Australia, Vietnam, Malaysia), constitute considerable import market shares and/or remarkable growth rates, hence creating additional sales respective export potential for the EU Wind industry.

Figure 8: Import market share 2014 and import dynamics 2007/08 to 2013/14 in Wind Energy (onshore and offshore) on the country level



Global imports including EU-intra-trade. - Regarding countries with a global import share higher than 0.5%. – EU MS: blue coloured; non EU countries: red coloured.
Source: UN COMTRADE-Database. – NIW calculation.

1.2.2 SWOT

Below the strengths, weaknesses, opportunities and threats (SWOT) for the European wind industry that could be identified by literature, own data analysis and based on expert interviews, are specified in bullet points.

Table 9: SWOT for the wind energy sector (onshore and offshore)

Strengths	Weaknesses
▸ Innovation potential of European manufacturers: technological leadership in the Wind Energy sector, onshore and offshore (offshore nearly exclusively) ▸ Compared to selected third countries, the EU's patent share of wind related products (onshore and offshore) is significantly higher than its total patent share indicating the immense innovation potential of the Wind Energy industry that results out of the high public and	▸ Due to insufficient grid extension and storage facilities, European manufacturers suffer from overcapacity ▸ Insufficient grid infrastructure ▸ Reduction in government support in some MS ▸ EC R&I funding is much welcomed for R&D. However, one of the interviewees indicated that for innovations that need a fast time-to-market, Horizon 2020 is less suitable because its procedures (programme definition, call

corporate R&D expenditures ▶ Particularly Germany, Denmark, Spain, Great Britain, Italy and France depict a specialization in wind innovations as their share of patents in wind technology (onshore and offshore) is significantly higher than their total patent share which can also be explained by the fact that some leading research, test and demonstration centres are located in these MS ▶ Strong, developed supply chain with competitive strengths in the manufacturing of wind turbines, turbine components and structures, wind farm development, offshore wind foundations, cable manufacture and installation ▶ Vestas, Siemens and Gamesa are present in multiple markets which makes them more resilient to a crisis in their respective home markets ▶ Having a strong local market enables manufacturers to better compete abroad, underlined by high export strength (onshore and offshore) of European companies and high export potential (positive export specialization) on foreign markets: offering job creation and added value at home. ▶ Within the group of the larger exporters, particularly Denmark, but also Germany, Spain and Finland depict comparative advantages (RXA and RCA). Moreover, some smaller Southern and Eastern MS (Portugal, Czech Republic, Hungary, Poland, Slovakia, Romania) reveal significant export market shares (>0.5%) and comparative advantages.	definition, assessments and evaluations by non-biased external experts, etc.) lengthen the project life cycle to 4 to 7 years.
Opportunities ▶ Globally growing efforts to increase power	Threats ▶ Increasingly production is taking place in China

generation from renewable energies create further export potential for European suppliers of wind turbines, equipment and service providers ▸ Technology and innovation are main drivers of the future market development in Wind Energy production (turbines and components like generators) to achieve cost reduction, efficiency gains and to improve grid compatibility, acoustic emissions, visual appearance and suitability for site conditions: the EU can profit from its technological leadership in this field ▸ The importance of the external market has significantly grown over time: while 2014 on average 57% of the EU's Wind exports (onshore and offshore) refer to intra-trade and 43% to extra-trade, in 2008 about 61% of total exports were designated to the internal market and only 39% to non EU countries ▸ Increasingly, retrofitting will be on the top of the agenda in many European countries and push the demand for innovative plants in the upcoming years (mainly onshore). ▸ Emerging markets in Africa (Marocco, South Africa), Asia (Pakistan, Iran) and Latin America (Brazil, Uruguay, Chile, Peru) ▸ Export potential analysis shows that also other European (e.g. Russia, Turkey) and overseas countries (e.g. South Korea, Mexico, Australia, Vietnam, Malaysia), constitute considerable import market shares and/or remarkable growth rates, hence creating additional sales	and Chinese companies are entering respective markets, although the large majority of Chinese production covers the high local growth rates. One interviewee argued that if the Chinese market slows down or reverses, Chinese manufacturers will offer their products at dumping prices to foreign markets, with significant consequences for the European onshore wind industry. ▸ Since Chinese manufactures are increasingly trying to enter markets abroad, this will significantly increase competition. Thus it can be foreseen, that EU manufacturers will not be able to maintain their high market share in global turbine installations (43.5% in 2014 globally, 78% just regarding markets outside China). ▸ Chinese financial institutions are starting to fund projects abroad that require Chinese equipment to be used (Pakistan. Green Silk Road Initiative) (Lacal Arántegui 2016); American export banks also subsidise wind farms in South-America, build with EU equipment, however (partly) made in the US ▸ One interviewed expert indicated that EU programmes subsidise R&I learning that might be eventually transferred to competitors abroad. Thus, there are some examples of European subsidies of Chinese players competing on the European market (e.g. from the EcoSwing project[26]). ▸ According to one of the interviewees there is a

[26] http://ecoswing.eu/project

respective export potential for the EU Wind industry (onshore and offshore). ▸ Because of better technologies, new market also arise in low-wind areas (e.g. Central-Europe) ▸ Stronger EU market integration: cross-border exchanges of RE allow higher shares of wind energy in the power system (IRENA 2015b) ▸ Increased use of CHP generation coupled with heat storage, heat pumps and electric vehicles can be scheduled to accommodate the variability in wind (or solar) power generation (IRENA 2015b)	lack of a strong and foreseeable long-run internal market due to changing national support. This issue can hamper the future development of the Wind Energy sector (onshore and offshore) in Europe. ▸ Although the still positive RCA value proves that the EU's export/import ratio with respect to wind products (onshore and offshore) is still significantly higher than referred to total manufacturing goods, the trade specialization (RCA) has declined over the last decade, indicating that the import competition of wind producers from non EU countries has increased higher-than-average.

In summary the EU holds an outstanding position in the Wind Energy industry (products and services, onshore and offshore), underlined by its high technological and trade competitiveness, creating good preconditions for participating on the globally increasing demand for wind technology. Until now, the large production capacities in China mainly serve the growing home market demand. However, as the amount of wind output and its share of total generation have increased, so have grid-related challenges in several MS. This influences national development targets (e.g. in Germany) and support mechanisms and may hamper the future development of the onshore and offshore Wind Energy sector in Europe. Furthermore, supported by financial institutions, Chinese manufacturers are increasingly trying to enter foreign markets.

1.3 Analysis of barriers

Regulatory uncertainty and the lack of a stable legal framework as well as insufficient grid extension are the main barriers to the development of further Wind Energy industry (onshore and offshore) as it increases investor risk and impedes long-term planning. Furthermore, the maturity of existing storage technologies does not fit the growing production of wind energy.

Administrative barriers, including building permits, compliance with spatial planning, grid connection permits, delays in processing and analysing critical aspects of projects, the number of parties involved and land ownership are other issues in many Member States (EC 2014a, IEA 2013), because they make the wind farm development process long (and thus expensive) posing a high risk in the project development phase. In its Global Status report 2014, the GWEC mentions that long planning and permitting procedures are particularly problematic in France, Italy and Germany where they can take between 3 to 5 years. In addition, environmental regulations regarding radar, rare species and turbine distance from housing can create issues in particularly in Germany. In fact, it often takes more time to permit and build transmission lines than wind power plants (IEA 2013). Interviews with key experts indicated that this greatly reduces the amount of projects that reach the final investment decision milestone. If the effort (and cost) that it takes to develop a project is reduced (e.g. by harmonizing environmental requirements for offshore across Europe), more projects would enter the pipeline and eventually are realized. This is an obstacle for innovation projects in the wind industry that often require long-term research projects and hinders the growth of the internal market.

Even though new targets for 2030 have been announced in 2014 there aren't any binding national targets in place at present and governments in several MS modify regulations on renewable energies frequently creating unstable markets. According to interviews and supported by literature, some countries lack long term vision, which is partly caused by a lack of knowledge about the effective and final capacity of Wind Energy in the home country. Local interests in favour of fossil fuels over the renewable energy industry are important barriers, too. In Poland especially, the new government decided recently that the RES Act, which had been approved by the previous parliament, would not come into force on the 1st January 2016 but further changes will need to be made.

In general, government support mechanisms for wind energy in the EU are shifting towards market-based schemes such as Feed-in Premiums (FiP) instead of Feed-in Tariffs (FiT).[27] Furthermore, an increasing number of MS use auctions to achieve high cost efficiency due to price competition as well as volume and budget control. Those schemes are being introduced in Poland (2016) and Germany (2017), while already been used for some years in Denmark, Italy, the Netherlands, Latvia, Lithuania, Portugal and Great Britain (GWEC 2016). In this case only selected wind energy generators benefit from the governmental support tariff or premium and the level of support is based on the prices indicated during the auction process. Thus, the investment risk for bidders is less predictable than before (FS-UNEP 2015, IRENA 2015b, Eurobserv'Er 2016). This could result in less investment in wind energy projects and may particularly slow down future development of community and citizen ownership models (REN 21 2016).

The rapid growth of Wind Energy capacity, characterized by a high variability of supply, puts pressure on grid companies. As a result grid connection for wind farms is still insufficient in many MS and a better integration of wind power in the electricity system is needed. Further grid expansion is specifically needed to connect offshore wind parks to the grid; however, it will be more challenging in deeper waters. Supplementary, additional transmission lines to neighbouring countries are necessary inter alia in Denmark and Sweden to reduce the load on already congested transmission corridors and to support further integration into the European grid, according to the GWEC. Resulting from insufficient grid interconnectivity, operators in some MS continue to suffer from overcapacity problems that have a negative impact on the profitability of their production facilities (Eurobserv'Er 2016). If wind forecasting becomes more accurate, the magnitude of aberration will reduce and wind power will become more competitive. Smart grids may also improve load management and prevent system failures. In the

[27] For the differences between single tariff-based mechanisms see Ferroukhi / Hawila (2012).

medium term, the variability issue may be resolved if utility-scale storage technologies become commercially competitive and widely deployed (IEA 2013).

Technological leadership and innovation determine the high competitiveness of the European wind industry. EC R&I funding could successfully support necessary long-term research projects. However, existing programmes such as Horizon 2020 that should support the following time-to-market process are not suitable for wind energy innovations, because their procedures lengthen the project cycle life to 4 to 7 years instead of enabling a fast time-to-market process. Another obstacle is the lack of support for some demonstration projects, not allowing companies to bridge the valley of death.

According to a requested expert, access to capital and finance in Europe in general is not a concern at the moment, at least for large, well-managed projects, but economic conditions are crucial in countries like Bulgaria or Romania. Yet, in the offshore wind sector, project developers and manufacturers are faced with high capital costs that present a major obstacle to the market entry. With the enduring reductions in government support for Wind Energy financing offshore wind will continue to be a challenge although new investments are attracted by Great Britain and Germany. In addition, the limited market competition and the importance of reputation in the offshore industry create barriers to the entry in the supply chain (EC 2014a) and may – besides changing location sites and commodity prices - also be responsible for the increase in CAPEX (Voormolen, Junginger, van Sark 2016).

Furthermore, an increasing shortage in skilled labour is expected by the European wind energy sector, whereby already in 2013, the majority of questioned stakeholders stated that it is difficult to find suitably trained staff.28 Following a study conducted by the European Wind Energy Platform (2013), there is currently a shortage of 7,000 qualified personnel each year, that could increase to 15,000 by 2030 (Figure 87 in Annex 2/). Particularly occupations for project developers; service technicians; data analysts and electrical, computer, mechanical and construction engineers will be hard to fill (Irena 2014). Especially the employment in operations and maintenance is expected to rise driven by the growth in cumulative wind capacity in Europe (Figure 87 in Annex 2/).

Lastly, the increasing number of onshore wind turbines may evoke public rejection towards further onshore capacity extension including repowering and a "not in my backyard" attitude (EC 2014a). An interviewed expert carried out that this makes governments increase the distance requirements of Wind Energy (e.g. to houses), which limits the availability of suitable locations.

1.4 Suggested Actions

Above all, support mechanisms should aim to reduce project risks and stimulate deployment, while encouraging the technology to reduce costs. Continued and collaborated work is needed to resolve issues arising from a

[28] European Wind Energy Platform 2014.

coordinated onshore / offshore grid approach (IEA 2013). After defining targets for 2030, the EWEA (2014) demands that Member States need to grant their commitment regarding renewable energy deployment and set up predictable long-term market and regulatory frameworks with respect to individual national circumstances and wind power potential. In order to assist Member States in the delivery of their targets, a governance system for the 2030 climate and energy package should be established.

Furthermore, an optimization of energy market policy is necessary to pave the way for an energy union. The stronger implementation of EU energy market integration can help to resolve variability issues: cross-border exchanges of renewable energy allow higher shares of wind energy in the power system (IRENA 2015). Therefore, financial support for the European Projects of Common Interest is necessary to ensure that Member States reach their interconnectivity targets. The interconnection of the Iberian Peninsula and the Baltic States with the rest of the EU needs to be improved to avoid bottlenecks in the future and the European grid needs physical strengthening (EWEA Policy Issues). In addition, transmission system and grid operators should strengthen regional cooperation and predictable grid connection regimes are necessary to help with the allocation of responsibilities and cost recovery mechanisms (EC 2014a).

In order to create a level playing field for all energy technologies and to drive investment, taxes and subsidies should take the total life-cycle costs of energy sources into account and apply appropriate carbon pricing (EWEA 2014).

Moreover, administration should be streamlined and procedures simplified and shortened to achieve greater clarity and faster project consenting. In order to improve administration procedures and social acceptance of wind power projects the EU funded WISE project29 has implemented an interactive platform (one-stop-shop) for information-sharing which allows groups and individuals to have a say in the siting and expansion of wind projects and aims to foster public support for onshore wind power in order to at least halve the average permitting time for a wind farm. The project has a strong focus on alternative financing, such as community and cooperative funding of wind farms as a method to broaden local engagement (EC 2014a). The information gathered can provide guidance on removing administrative hurdles and consenting procedures. Further, a better coordination among different authorities will be needed not only with regard to onshore wind projects but in particular with regard to cross-border offshore projects. Offshore projects also require that marine spatial planning is assessed in consideration of energy generation, wildlife conservation and maritime transport routes (EWEA 2014).

With respect to technology and innovation, the EU should maintain its current R&D funding to guarantee that the LCOE are further reduced in order to make Wind Energy, onshore and offshore, competitive against traditional forms of energy and to sustain its competitive advantage in the long-term (EWEA 2014). For high technology

[29] http://wisepower-project.eu/

readiness levels, R&D support should be strengthened in expediting time-to market of innovations and in maintaining demonstration projects (interview and IEA 2013).

Since a shortage in skilled labor is expected measures need to be taken to ensure the availability of qualified personnel. Thus, a greater transfer of knowledge between the industry and academic institutions should be promoted and further multidisciplinary postgraduate training programs offered which include project development and technical skills particularly in the O&M area. According to a study conducted by the European Wind Energy Technology Platform (2013), a qualification in STEM subjects is a prerequisite for many jobs in the wind industry hence STEM skills of employees should be improved through targeted courses. Furthermore, the cross-sector mobility should be encouraged, as a lot of competencies required e.g. in the growing offshore wind in coastal regions can take advantages of skills and man-power available from the oil and gas industry. Furthermore, specific vocational training programs aimed at the needs in those EU member states and regions, which are in the early phases of development of wind energy, are necessary and can be done most effectively through partnerships with the existing knowledge centers in other regions (EC / JRC 2014). In general, the standardization of vocational education and training across the EU to common quality standards can help to secure the supply of qualified personnel and is also seen as being beneficial in order to increase workforce flexibility within the EU.

To meet public rejection of new wind projects, it is important to increase public acceptance by raising awareness of the benefits of wind power (emissions reductions, security of supply, economic growth, jobs) and of the accompanying need for additional transmission.

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2/ Technologies to realise efficiency gains in vehicle powertrains

Figure 9: Presentation of the selected priority sectors within the Clean Industry taxonomy

2.1 Description and value chain

The sector technologies to realise efficiency gains in vehicle powertrains can be widely interpreted and it is therefore important to propose clear boundaries. We aim to limit our scope to a manageable range for the purpose of the analysis. Vehicle powertrains could be described as the mechanism that transmits the drive from the engine of a vehicle to its axle, where vehicles could be defined as things used for transporting people or goods. In this definition, the sector would entail all different modes of transportation, including the ground transport (rail and road), waterborne transport, and air transport vehicles. In order to focus our analysis in this report, we will limit the analysis to road transport, and more specifically to cars and light commercial vehicles (thus excluding non-road vehicles, trucks, busses, trailers etc.). Setting these boundaries allows to perform a more thorough sector specific analysis and to identify more sector specific strengths, weaknesses, barriers and policy suggestions. Within the scope of cars and light commercial vehicles, we will not consider electric or semi-electric vehicles. Electro-mobility is explicitly left out of the analysis due to the fact that plug-in hybrid electric vehicles and battery electric vehicles sectors have not been selected as one of the 12 priority sectors. The influence of electro-mobility on the sector will be taken into account however in the course of this chapter.

In summary, the sector "technologies to realise efficiency gains in vehicle powertrains" encompasses several technologies which allow vehicle powertrains, (as defined above), to consume less energy and reduce emissions. The term "fuel efficiency" is used in the context of transportation as the energy efficiency of a particular vehicle, given as a ratio of distance travelled per unit of fuel consumed. Further in this report we will therefore refer to fuel efficient cars instead of technologies to realise efficiency gains in vehicle powertrains. Fuel efficiency can be increased in several ways: by optimising internal combustion engines, reducing weight, reducing friction, or improving aerodynamics. As indicated before, energy savings and emission reductions from increasing electrification of powertrains are not taken into account.

The remaining potential improvements regarding the efficiency of the internal combustion engine and transmission system can still have a significant impact on reducing emissions and realising efficiency gains in the 2020-2025 timeframe. Examples of technologies that contribute to more efficient combustion are variable valve systems, gasoline direct injection, cylinder deactivation, and homogeneous-charge compression ignition, turbocharging, smart cooling systems, reduced engine friction, and more efficient transmissions. One of the most cost-effective ways of achieving reductions of 5-10 percent in CO2 emissions is using start-stop technology using advanced lead-based batteries. Other technologies with a high potential on the short term include engine downsizing coupled with boost and direct injection for petrol engines. On the medium term additional improvements can be expected regarding the application of these technologies in combination with other technologies like variable valve actuation and eventually the use of multi-port injection technologies and low temperature combustion technologies using "auto-ignition", like homogenous charge compression ignition (Cambridge Econometrics, Ricardo-AEA, 2013; Sperling & Lutsey, 2009). An overview of key internal combustion engine (ICE) optimisation technologies and their CO2 reduction potential is displayed in Figure 92 in Annex 4/. An overview of various GHG and efficiency technologies including their efficiency benefits and costs, published by the International Council on Clean Transportation is displayed in Table 28 in Annex 4/.

Further efficiency gains can be achieved through reducing weight, aerodynamic drag and rolling resistance, regardless of the powertrain type used in the vehicle. Weight reductions, possibly the area with the greatest potential in terms of efficiency gains, can be achieved through minimising vehicle weight in the design process and the application of lightweight materials. A common rule of thumb is that a 10 percent reduction in weight can reduce fuel consumption by 5 to 7 percent. Several studies have revealed that achieving overall vehicle weight reductions of up to 20 percent is possible by 2020 at minimal or even zero net costs while maintaining performance parity relative to current vehicles, while more significant weight reductions (in the range of 40-50 percent) may be possible in the longer term (Cambridge Econometrics, Ricardo-AEA, 2013; Sperling & Lutsey, 2009).

Between 1990 and 2011, carbon dioxide emissions from road transport had increased by 21%, and the sector was responsible for 23% of all CO2 emissions in the EU. Cars and light commercial vehicles are responsible for around 15% of total EU CO2 emissions. In response to this problem, the EU implemented legislation setting mandatory emission reduction targets, with a short-term target for average new car emissions to be below 130 grams carbon dioxide per kilometre (g CO2/km) by 2015, and a long term target of 95 gCO2/km by 2021. Furthermore, binding annual specific emissions targets are calculated for each manufacturer based on the average mass of its fleet both for passenger cars and vans (European Commission, 2016; European Environment

Agency, 2013). As stated before, the technologies to realise efficiency gains in cars and light commercial vehicles derive from the automotive industry as incremental improvements. According to European Automobile Manufacturers' Association (ACEA, 2014), the European automotive industry supports 13 million jobs in Europe directly and indirectly, is responsible for €32 billion in annual R&D investment, and contributes €95.7 billion in net exports to the EU economy. A general depiction of the value chain of the automotive industry is displayed in Figure 10. Raw materials include different alloys such as steel and aluminium that are being used for the engine and the chassis and polymers such as polyurethane being used for the interior. Tier 2 suppliers manufacture sub-components. These Tier 2 suppliers are often well-integrated in the supply chains of major Tier 1 suppliers and operate under thin margins. Tier 1 suppliers produce major components for the Original Equipment Manufacturers (OEMs). In turn, Tier 1 suppliers are often well-integrated in the supply chains of OEMs, usually dedicated to specifically supply to a major OEM. OEMs assemble those major components in order to produce the final product, being a car or an airplane. Few and specialised players operate in this part of the value chain, making it the most critical link in the entire value chain. Furthermore, these players implement and drive innovation across the entire value chain. The final part of the value chain is represented by the dealers, dedicated points of sale for each OEM. The dealers represent the OEM to the final costumer and provide after sales support (AEA, 2012). All actors in the value chain of the automotive industry can have a role in increasing the fuel efficiency of cars and light commercial vehicles. Raw material suppliers can deliver from lightweight material innovations, suppliers and OEMs can develop internal combustion engine optimisation technologies or improve aerodynamics, and dealers can influence demand for fuel efficient cars.

Figure 10: General value chain transportation industries (adopted from (Noealt, 2016))

The main innovations to improve the fuel efficiency in vehicle power trains are being driven by the major Tier 1 suppliers and the OEMs of the automotive industry. Suppliers and OEMs work closely together, particularly in Europe. Innovations are usually initiated by suppliers, after which OEMs provide joint funding for further development of such technologies. In recent years, strong consolidation in the automotive supply sector due to economic pressures has led to a shift of power towards several big suppliers. Some of these suppliers are now bigger than some OEMs and even have more advanced R&D capabilities. Suppliers are typically responsible for around 75% of the vehicle engineering and around 50% of all R&D spending. This upward shift in the supply chain may even further advance due to the increasing electrification of vehicles, with core technologies such as batteries (AEA, 2012; Wiesenthal, Condeço-Melhorado, & Leduc, 2015). Figure 93 and Figure 94 in Annex 4/ display the top 50 European and top 100 global Tier 1 suppliers. Leading European players are Robert Bosch GmbH, Continental AG, Faurecia, and ZF Friedrichshafen AG. Figure 95

Figure 95displays the world's leading car manufacturers (OEMs) in 2014. Leading European car manufacturers are Volkswagen AG, Fiat SpA, Daimler AG, and BMW. Evidently there are differences in energy efficiency of the cars produced by the different players in the automotive industry. Generally speaking, European car manufacturers are strong in developing fuel-efficient and high performance internal combustion engines, particularly in the area of diesel engines. Asian car manufacturers however are stronger in developing hybrid and fully electric vehicles (AEA, 2012). Published in an annual report by the European Environment Agency (EEA) (European Environment Agency, 2015) tracking progress towards CO2 emission targets for new passenger cars and vans, the new car fleet emitted in 2014 on average 123.4 g CO2/km, significantly below the 2015 target of 130 g CO2/km and a reduction of 2.6% compared with 2013. Provisional data for the year 2015 (European Environment Agency, 2016) showed that new cars sold in 2015 emitted on average 119.6 g CO2/km, more than 10 g CO2/km below the 2015 target. The 2014 report also showed that almost all manufacturers achieved their individual emissions targets set for 2014. Renault, Automobiles Peugeot, Automobiles Citroen and Toyota Motor Europe continue to produce most of the lowest-emitting cars. Of the individual car manufacturers, Renault had the lowest average CO2 emissions (108 g CO2/km) for new passenger vehicles registered in 2014. Renault also had the highest percentage of vehicles with emissions below 95 g CO2/km (34%). Nissan has made the greatest improvement between 2013 and 2014. The average emissions from their passenger vehicles have decreased by almost 16 g CO2/km. This good performance relates to an increased number of electric vehicles in the share of new cars sold, as well as sales of smaller vehicles and the improved performance of conventional vehicles (European Environment Agency, 2015). Table 10 shows the average CO2 emissions, average mass, and number of registrations of the car's fleet for manufacturers registering more than 100 000 vehicles a year. It should be noted that there is a relation between the average mass of the vehicle and the average CO2 emissions (also illustrated in Figure 96 in the Annex 4/).

Table 10: Average CO2 emissions, average mass, and number of registrations of the car's fleet for manufacturers registering more than 100 000 vehicles a year

Manufacturer	Registrations 2014 (a)	Average mass (kg) 2014	Average CO_2 (g CO_2/km)				
			2014	2013	2012	2011	2010
Renault SAS	871 328	1 250	108	110	121	129	134
Automobiles Peugeot	766 531	1 270	110	115	121	128	131
Automobiles Citroen	594 263	1 268	111	116	123	126	131
Toyota Motor Europe NV SA	538 723	1 310	113	116	122	126	129
Hyundai Assan Otomotiv Sanayi VE (b)	120 988	1 070	113	112			
Nissan International SA	469 215	1 351	115	131	137	142	147
Fiat Group Automobiles SPA	666 763	1 143	116	116	117	118	125
Seat SA	316 546	1 242	117	119	127	125	131
Skoda Auto AS	546 145	1 276	121	125	132	135	139
Ford-Werke GmbH	939 565	1 316	121	122	129	132	137
Magyar Suzuki Corporation Ltd	108 700	1 147	123	126	128	128	137
Volkswagen AG	1 549 656	1 384	124	127	133	135	140
Kia Motors Corporation	216 352	1 293	125	128	129	137	143
Automobile Dacia SA	372 685	1 206	125	127	137	143	145
Volvo Car Corporation	234 160	1 676	126	131	142	151	157
Mazda Motor Corporation	159 721	1 407	128	134	142	147	149
Adam Opel AG	860 970	1 405	130	132	133	134	140
Bayerische Motoren Werke AG	791 579	1 579	131	134	138	144	146
Audi AG	683 782	1 558	131	133	138	145	152
Daimler AG	685 986	1 579	131	137	143	153	160
Honda of the UK Manufacturing Ltd	111 222	1 437	134	145	156	161	162
Hyundai Motor Manufacturing Czech SRO (b)	200 750	1 440	140	138			
Kia Motors Slovakia SRO (c)	130 606	1 449	141	140			
Jaguar Land Rover Limited (d)	140 264	2 044	178	182			

Source: (European Environment Agency, 2015)

In the next section of this chapter, an assessment will be made of the EU global environment. The particular strengths of the key regions in the automotive industry will be highlighted, including the relative comparative strengths of the EU industry. Particularly important in this sector is the market outlook since the automotive industry is subject to major changes, which will significantly impact the power positions in the industry. This market outlook analysis, in combination with the assessment of the global environment will provide important insights into the barriers limiting the EU industry, and possible levers for unlocking the EU industry.

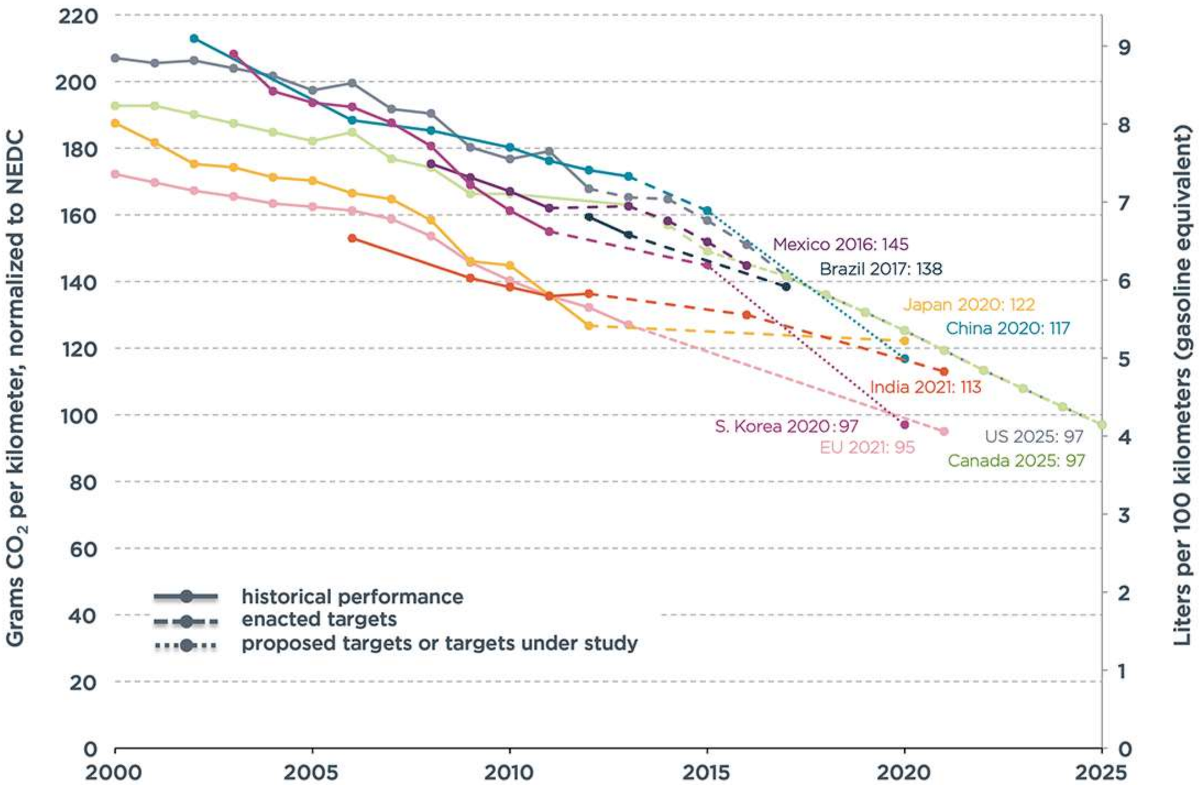
2.2 Assessment of the global environment

2.2.1 Main competitors outside the EU

With respect to the automotive industry, the main competitors outside of the EU are Japan, the US, China, and South Korea. Japan is the third largest car manufacturer in the world and has technological leadership in the field of hybrid vehicles and a dominant position in the field of battery and cell manufacturing for electric vehicles. The leading Japanese company is Toyota. The US, the third largest vehicle manufacturer in the world after Europe, differs in a couple of aspects to Europe. American cars are usually more fuel consuming and consist of a very small share of diesel cars. Furthermore, the relation between Tier 1 suppliers and OEMs is less intense than in Europe. Leading American manufacturers are General Motors and Ford. China has the ambition to become the world leader in electro-mobility. Despite being the largest car manufacturer in the world, China is having difficulties in levelling the technological standards of European car manufacturers. South Korea, the fifth largest car manufacturer in the world, is particularly strong in the field of lithium-ion battery technology and manufacturer. South Korea's leading manufacturer is Hyundai. Other countries showing significant growth in the automotive industry are India, Mexico and Brazil (AEA, 2012). As stated in interviews, Europe remains the dominant region in the field of technology in the automotive industry.

Differences between the key regions can be found with respect to the fuel efficiency of the vehicles. The International Council on Clean Transportation produces annually a report on worldwide passenger vehicle fuel efficiency standards, with the aim of comparing the relative stringency of regulations as accurately and fairly as possible (International Council on Clean Transportation, 2014). *Figure 11* presents an overview of historical fleet CO2 emissions performance and current or proposed passenger vehicle standards. The figure shows that Europe maintains one of the most stringent regions with respect to passenger vehicle fuel economy and CO2 emission standards around the world. The regions that come close to matching the current European standards are Japan and India.

Figure 11: Historical fleet CO2 emissions performance and current or proposed passenger vehicle standards



Source: (International Council on Clean Transportation, 2014)

2.2.2 *Relative competitive strengths*

In the automotive industry, Europe is leading in the premium brand segments and this is where most of the technological innovations are initiated, including fuel efficiency innovations. The reason that innovation mostly derives from the premium segments is that the uptake and willingness to pay for new technologies from their customers is higher. Europe has particular competitive strengths in the design and development of fuel efficient and high performance internal combustion engines for all market segments. Particularly in diesel technologies Europe is absolutely world leading. Furthermore, European car manufacturers are well known for their ability to design and small vehicles and European suppliers are considered to be strong in the area of electronics. Finally, Europe has the strongest base of Tier 1 suppliers (AEA, 2012). In the interviews it was added that Europe has a relatively high depth in terms of expertise across the value chain and across a broad range of technologies (e.g. from eco-innovation technologies to ICT). This high depth and excellent value chain coverage is not present in all world regions, and particularly the supply business is well established in Europe.

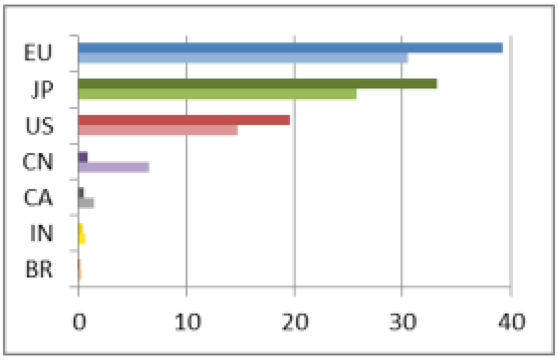
Something that also can be considered as a strength is the reputation of the European automotive industry. Despite the expensive conditions, every manufacturer is present in Europe, even though the operation is not profitable. Expertise in this area identifies two reasons. The first is reputation: if you want to be a global brand, you should be in Europe, otherwise you are considered to be "just a local brand abroad". The second reason is that Europe is the place where the latest trends and new technologies appear. An example of a company that is in Europe despite not being profitable is Ford. Ford operates in the difficult low-cost mass market. By closely following the latest technological developments in the premium segments, Ford is always the first player to implement technologies from the premium market to the mass market. Another example is Hyundai, which would like to make room for hydrogen powered vehicles in 20 years, but in order to do so, they need to be respected as a global brand and show customers that they can deliver.

The technological leadership of the EU in the automotive sector is reflected in an analysis regarding transnational patent applications[30]. Figure 12 shows that the EU has the highest patent share (39.3%) in the combined fields of

[30] The OECD Environment Directorate, in collaboration with the Directorate for Science, Technology and Innovation, has developed patent-based innovation indicators that are suitable for tracking developments in environment-related technologies. The patent statistics are constructed using data extracted from the Worldwide Patent Statistical Database (PATSTAT) of the European Patent Office (EPO). Patent data based on family size "two and greater" were used to count only the higher-value inventions that have been applied for protection in the home market and at least one foreign market. The relevant patent documents are identified using search strategies for environment-related technologies (Env-Tech: http://www.oecd.org/env/consumption-innovation/env-tech-search-strategies.pdf) which were developed specifically for this purpose. The data are available under http://stats.oecd.org/. The European Patent Office is also working with this definition, e.g. in the context of analysing the EU's patent performance in "Green Building" (http://www.epo.org/news-issues/technology/sustainable-technologies/green-construction.html).

conventional vehicles (based on internal combustion engine) and fuel efficiency-improving vehicle design. The strong position of Japan is notable with a patent share of 33.2% (compared to Germany's 22.9%, by far the largest patent holder within the EU), and also the US has a fairly high share of 19.6%. EU's relative comparative strength in this area is illustrated when the patent share is compared with its overall patent share of 30.5%. This is also the case however for Japan and to a lesser extent for the US, whereas China's weak position in the area is striking when compared to China's overall patent share. Within the EU, Germany holds by far the largest patent share of 22.9%, whereas the remaining share is divided between countries such as France (5.2%), UK (2.8%), Sweden (2.4%), Italy (2.0%) and Austria (1.4%).

Figure 12: Patent share in the fields of conventional vehicles (based on internal combustion engine) and fuel efficiency-improving vehicle design (common to all road vehicles) compared to total patent share 2010 to 2012



The upper bar shows the patent share (%) in the fields of conventional vehicles (based on internal combustion engine) and fuel efficiency-improving vehicle design (common to all road vehicles), the lower bar the total patent share (with respect to all technologies).

Source: OECD.stat; Theme Environment; Dataset: Patents - Technology Development - NIW calculation

2.2.3 International trade performance

Box 3: International trade performance

This section investigates the EU-28's trade performance in the respective Clean Industry products with regard to the development in six competitive countries in America (USA, Canada, Brazil) and Asia (Japan, China incl. Hong Kong, India). Six trade indicators are analysed to observe how the EU-28 and its Member States (MS) succeed in commercializing internationally competitive Clean Industry products. Those are significance (i.e. how important the specific Clean Industry products are in a country's total manufacturing exports), export market share (i.e. how important a country is for total global exports in the relevant Clean Industry), medium-term dynamics (i.e. how exports have changed within the pre-crisis years 2007/08 and 2013/14), trade balance (TB, comparing the absolute volumes of exports and imports), and two specialisation indicators, namely export specialisation (RXA, i.e. whether a country's global export share in a certain Clean Industry is higher/lower than its export share in total manufacturing products) and trade specialisation (RCA, considering a country's relative export/import ratio of a certain Clean Industry compared to its total export/import ratio). Four of these indicators (export market share, significance, RXA and TB) are illustrated in the following chapter, the other two (medium-term dynamics, RCA) in the Appendix.

It is important to note that the analysis comparing the external trade performance of the EU-28 in a regional perspective only considers extra-EU trade flows. Otherwise, analysis that compares single Member States with non EU countries has to consider extra- and intra-trade. Hence, the calculated export market shares and export specialisation figures (RXA) differ according to the respective perspective. Figures on the country level can be found in the Appendix.

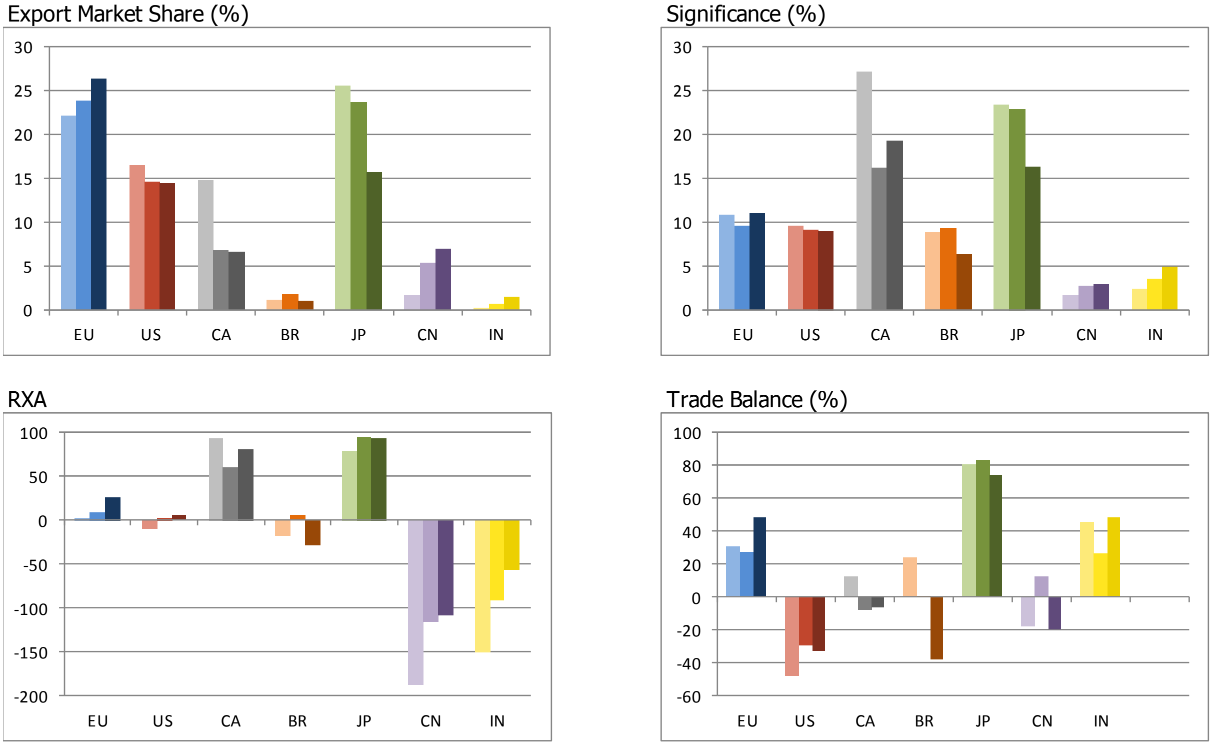
Strong and growing comparative advantage of the EU-28 in vehicles trade as a good precondition to implement new technologies to reduce vehicles loads

Trade analysis shows a clear comparative advantage of the EU-28 in vehicle powertrain manufacturing, realizing high export specialisation (RXA) and trade specialisation figures (RCA) that have further improved since 2008 (see Figure 13 and Figure 97 in Annex 5/). Furthermore, the EU-28 shows the highest export market share of about 26% of global exports in 2014 compared to 22% in 2008. The significance of vehicle exports in total exports applies to 11% in 2014, more than 2008 (10%), but identical to 2002. The strong export position of the EU in vehicle construction is underlined by the positive trade balance (2014: 48%) that has strongly increased since 2008 (27%) and the positive medium-term dynamics (8.9% p.a., see Figure 97 in Annex 5/). Further innovations in technologies to reduce vehicle loads can help to secure and strengthen this outstanding export position.

Japan (16%) and the US (14%) hold the second and third highest export market shares in vehicle powertrain manufacturing. Contrary to the EU, both have lost ground on international markets over time, indicated by weak export dynamics, falling export market shares, and deteriorations in trade balance and trade specialisation (RCA). Yet, vehicles are still a relative strength within the Japanese trade portfolio (RXA, RCA), because the losses in other manufacturing goods were even higher (Figure 13, Figure 97 in Annex 5/). The same applies to Canada, whose export market share has halved between 2002 (15%) and 2008 (7%), keeping constant since then.

China succeeded to raise its export share in vehicles manufacturing to 7% in 2014. However, it is still rather low compared to other manufacturing goods (RXA) and the export/import ratio has even worsened since 2008 (TB, RCA), indicating that the Chinese imports of vehicles have grown even faster than its exports (19% p.a.). India (2%) and Brazil (1%) still only play a very minor role in the production and export of vehicles, although India, from a very low level, realized high medium-term export dynamics (22% p.a.) and an increasingly positive trade balance and comparative advantage (RCA) in this field.

Figure 13: Trade indicators for the EU and selected other countries 2002, 2008 and 2014 and export dynamics 2007/08 to 2013/14: Vehicles



EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Younger MS profit from the division of labour with traditional vehicles manufacturing EU countries

Vehicle powertrain manufacturing is on the one hand highly concentrated on the leading markets, and on the other hand characterized by a distinctive geographic division of labour within economic areas like the EU or North America (NAFTA). With respect to country comparison, e.g. considering EU-Extra-trade and EU-Intra-trade, Germany is the by far largest exporter of road vehicles, with an export market share of 19.2% (2014). Within the EU MS, Great Britain (4.0%), Spain (3.9%), France (3.4%), Belgium (3.3%), Italy (2.8%) and the Czech Republic (2.5%) attain export shares of at least 2%. Within this group of larger EU exporters, particularly the Czech Republic, Germany, and Spain depict unambiguous comparative advantages (indicated by positive RXA and RCA figures, see Figure 98 and Figure 100).

Moreover, also other Eastern MS (Hungary, Poland, Slovakia, Romania) profit from the growing division of labour within the EU and reveal significant export market shares (>0.5%) and comparative advantages in vehicles trade. The favourable export performance of most of the Eastern European countries is also proved by high medium-term growth rates (Figure 100). By contrast, other larger and/or highly developed MS (Italy, the Netherlands, Austria, and Denmark) show a quite weak export position and are net importers (1egative TB, *Figure 99*). In

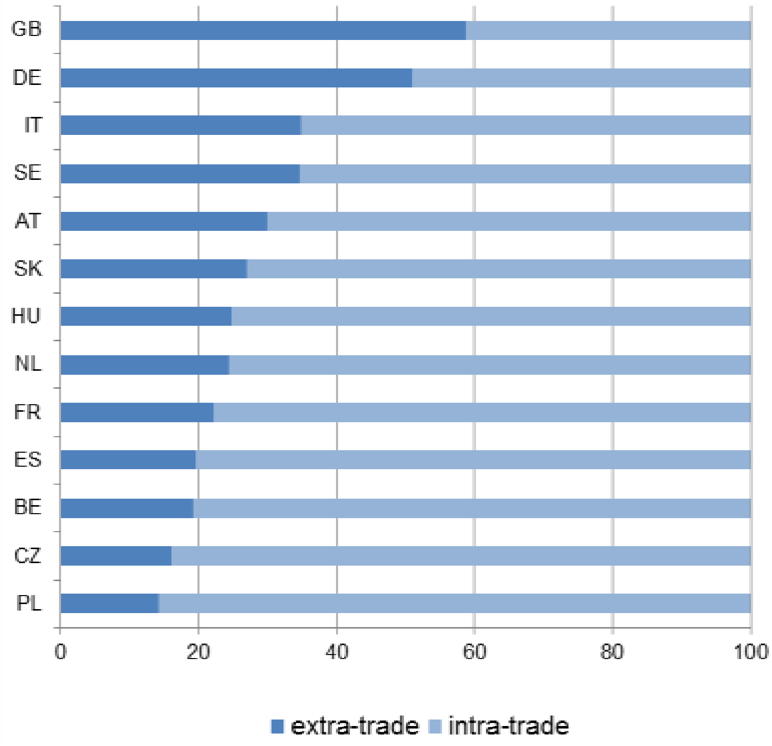
Slovakia, Spain, Germany, and the Czech Republic, vehicles exports account for 2.5% to 1.5% of all manufacturing exports. In the other MS, the structural weight of those products is comparably low (*Figure 99*).

60% of EU vehicle exports are designated to the internal market

In 2014, on average 71% of the EU's vehicles exports refer to intra-trade and only 29% to extra-trade, indicating the high importance of the internal market for vehicle manufacturers located in the EU-28. However, the importance of the external market has significantly increased over time, because in 2008 the share of intra-trade still amounted to 32%.

Figure 14 reveals that the country perspective with respect to extra- and intra-trade shows some differing results. Thus, in 2014 British (59%) and German exports (51%) are more oriented towards non EU countries, whereas other diagrammed MS export most of their products into other EU-28 countries. This applies particularly to Spain and the larger Eastern European countries, indicating the intense division of labour and economic integration within the EU in vehicles technology production. By contrast, the intra-export shares for the Netherlands and Belgium are more attributed to logistical aspects (harbour function) than to production linkages.

Figure 14: Share of EU-Extra-trade and EU-Intra-trade (in %) in country exports: Vehicles



Including EU countries with an export market share in vehicles higher than 0.5% in 2014.
Source: UN COMTRADE-Database. – NIW calculation.

2.2.4 Market outlook

In terms of market outlook, a distinction can be made between trends that positively and negatively influence the position of the EU industry with respect to the fuel efficient car industry. The fuel efficiency of cars will be strongly influenced by key global mega-trends such as climate change, urbanisation and demographic changes. In general, these mega-trends all steer towards increasing energy efficiency and emission reductions. The impact of these trends on the position of the EU industry is dependent however on various developments such as technological developments, global and local market developments, changing customer preferences etcetera.

The two major areas of technical developments in the automotive industry are the further improvements of the internal combustion engine and increasing electrification of vehicle powertrains. According to various technology roadmaps available internal combustion engines will continue to feature in the majority of vehicle sales till at least 2030. This could be seen as a positive trend for the EU, given its technological leadership in this area. In line with this trend, customer preferences are shifting towards smaller, more fuel efficient and low emitting vehicles, since a car's fuel economy is a major consideration for many customers. This is further encouraged by demand side policies aimed at increasing the demand for fuel efficient cars (Inman, 2014). Emission and energy efficiency regulation contributes towards meeting demand for those shifting customer preferences towards smaller, more fuel efficient and low emitting vehicles.

The shift towards electric or semi-electric vehicles however may pose a threat to the EU automotive industry, given the lack of coverage in key areas of the supply chain of electro-mobility such as lithium-ion battery manufacturing and hybrid powertrain technology. Provisional data of an EEA report showed that sales of plug-in hybrids and battery-electric vehicles have continued to increase in 2015. The relative share of plug-in hybrids and battery-electric vehicle sales was highest in the Netherlands and Denmark, reaching 12% and 8% respectively of national car sales in 2015. Still, sales of such vehicles still remain a small fraction of total sales, accounting for just 1.3 % of all new EU cars sold (European Environment Agency, 2016). According to an article on Transport & Environment (Hildermeier, 2016) however, electric vehicles are gaining momentum in Europe, illustrated by recent policy decisions such as the recently voted plan by the Dutch parliament to make 100 per cent of new car sales emissions-free by 2025, or a plan by the Norwegian parliament calling for the phase-out of combustion engine cars from new sales by 2025. According to the article, the real driver to accelerating electric vehicles sales in Europe could come from China. The major driver behind this development are the very high levels of air pollution in Chinese cities. Besides deciding to tackle emissions from internal combustion engines by setting strict on-road measurements, the Chinese government aims to accelerate the process of shifting to electric vehicles by considering to implement a gradually increasing zero-emissions vehicle mandate.

Coming along with the increasing electrification of vehicles, is a greater portion of value-added from areas outside the core competence of automotive producers. This increasing electrification of vehicle powertrains could therefore radically disrupt the traditional automotive value chain, opening up the market for players from other industries like ICT or telecommunications (PWC, 2014).

Another trend that could have negative consequences for the European automotive industry, and therewith for the sector related to technologies to realise efficiency gains in vehicle powertrains, relates to the increasing competition on the global market. The automotive industry is developing in emerging markets such as China, India, Russia and Brazil, and as a result European's position in the global market is expected to decline. On the long term an entry from low-cost mass market players from these emerging markets into the European market can be expected. Furthermore, suppliers and OEMs tend to locate their R&D facilities in proximity to their customers, so that there is a closer alignment to the needs of the market (AEA, 2012; Frigant, 2011). As a result, many new R&D facilities are located in emerging markets. This trend is supported by the higher availability of skilled employees and the lower labour costs in these regions. Finally, the European car market appears to be saturating in the longer term due to static or declining populations and personal car use per person per year and car ownership is declining in several key European countries.

In summary, with respect to implementing technologies to realise efficiency gains in vehicle power trains, Europe's automotive industry is thus expected to face some major challenges. Possibly the largest challenge is Europe's relatively weak position in key areas of electro-mobility such as hybrid technology and battery development. The internal combustion engine will likely continue to feature in the majority of vehicle sales till at least 2030, but eventually Europe's leading position may be challenged by the increasing share of electric vehicles. As a result, the strength of the European industry of fuel efficient cars will eventually decline, if no further action is taken.

Other trends, such as increasing global competition and a saturating internal market further contribute to challenging the traditional leadership of Europe in the automotive industry. It is paramount for the European automotive industry to carefully identify its strengths and weaknesses, as well as opportunities and threats following from the developments in the industry. Such an exercise will be conducted in this chapter, which will form the basis for identifying barriers hampering the sector, as well as suggestions for policy actions that can help to unlock the industry.

2.3 Assessment of the competitiveness aspects

2.3.1 Export potential

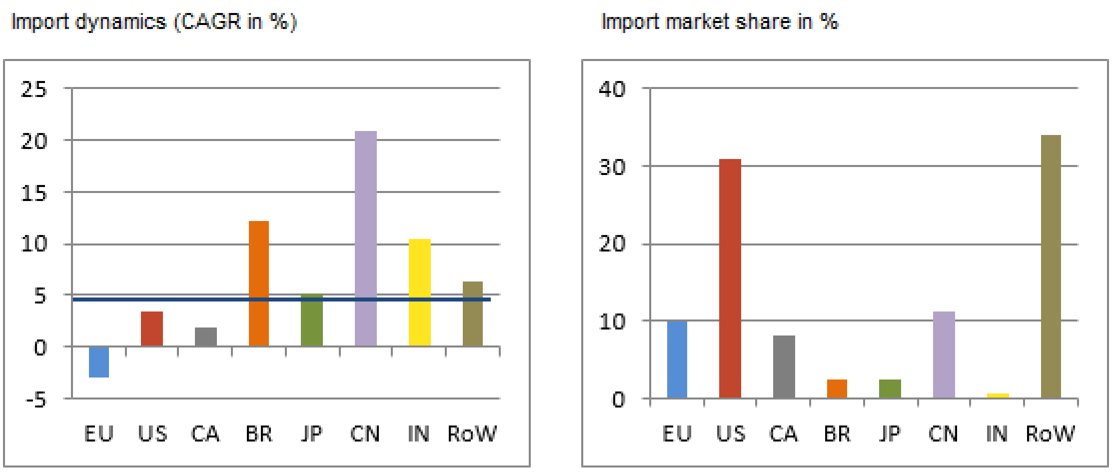
Box 4: Export potential

Export potentials emerge primarily in those goods and activities, in which the EU-28 already holds comparative advantages (measured in export specialisation or trade specialisation). In these goods and activities, trade volumes can be used as an initial indicator for market and growth potential. Hence, growing import rates of third countries may serve as a proxy for an increase in demand for Clean Industry goods in a specific country or world region that may subsequently translate into a growing export market for the EU and its Member States. At the same time, existing export advantages (indicated by RXA values) of the EU and its Member States in certain products may indicate promising preconditions for further growth and export potential.

Figure 15 reveals the global import market shares of the EU (excluding intra-trade) in comparison to other selected countries and the rest of the world (RoW) in Road vehicles, which is taken as an approximation for `Technologies to realise efficiency gains in vehicle powertrains.

It indicates that the US has been the by far largest single importer (31%) in 2014, followed by China (11%) and the EU (10%). Compared to its structural weight in total manufacturing imports, also Canada revealed a considerably high demand for vehicles (8%), whereas Japan (3%), Brazil (2%) and particularly India (0.6%) are distinctly falling behind. Besides China as the most dynamic import market with a medium term growth rate of 21% p.a., also Brazil (12%) and India (10%) yield clearly above average import dynamics in this period, indicating growing vehicles demand in these countries. Japan depicts an import growth of about 5.2%, only slightly beyond the world average (4.8%). Otherwise, also lower growth rates connected with a high absolute import volume, as can be seen in the US (3.4%) generate considerable import volumes. As Table 27 in Annex 1/ depicts, the EU constitutes high export market shares and almost balanced (US, BR) or high export specialization values (RXA) in all selected foreign countries except Canada. Particularly in the Asian countries the EU-28 holds an excellent export position. Thus, the successful implementation of `Technologies to improve energy efficiency in ICE powered vehicles' promises further export potential for the EU manufacturers although India is still falling behind.

Figure 15: Import market share 2014 and import dynamics 2007/08 to 2013/14 of the EU-28 and selected non-EU countries: Road Vehicles

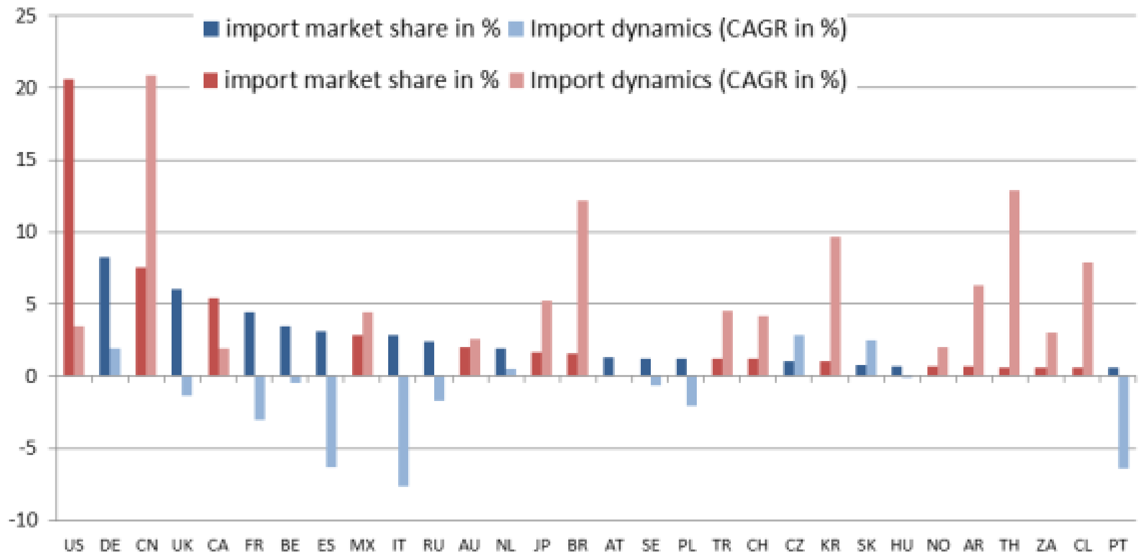


Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 15 also reveals that about one third of the global import demand for vehicles in 2014 applies to other than the selected countries (RoW). Furthermore, the import dynamics of RoW achieved 6.1% p.a., thus being higher than the global average (4.9%). Hence, Figure 16 illustrates import market shares and import dynamics for all countries with a global import market share higher than 0.5% in 2014.

This points out that besides the US, China, Canada, Brazil, Japan and some larger EU MS (Germany, Great Britain), also other European (e.g. Russia, Turkey) and overseas countries (e.g. Mexico, South Korea, Thailand, Malaysia, Chile, Argentina), constitute considerable import market shares and/or remarkable growth rates, hence creating additional sales respective export potential for the EU vehicles manufacturing industry. This has to be kept in mind since the import demand of most of the EU countries is still rather weak. Moreover, the recent recessive development in Brazil dampens future import growth expectations, at least in the short run.

Figure 16: Import market share 2014 and import dynamics 2007/08 to 2013/14 in Road Vehicles



Global imports including EU-intra-trade. - Regarding countries with a global import share higher than 0.5%. – EU MS: blue coloured; non EU countries: red coloured.
Source: UN COMTRADE-Database. – NIW calculation.

2.3.2 SWOT

Table 11: SWOT for the sector related to technologies to realise efficiency gains in vehicle powertrains

Strengths	Weaknesses
▸ Europe has technological leadership in the field of the internal combustion engine, particular diesel technologies. Furthermore, European car manufacturers are well known for their ability to design small vehicles and European suppliers are considered to be strong in the area of electronics. The absolute and relative technological strength in the vehicle sector is indicated in the patent analysis by the highest patent share (almost	▸ Europe has a weak position in the key areas of electro-mobility and its supply chain such as lithium-ion battery manufacturing and hybrid powertrain technology. ▸ The European market place is less uniform compared to other key automotive markets ▸ Europe's R&D position in ICT related sectors is lower compared to its major competitors in the automotive industry, an area which is important

40%). ▶ Europe maintains one of the most stringent regions with respect to passenger vehicle fuel economy and CO_2 emission standards around the world. ▶ Europe has a relatively high depth in terms of expertise across the value chain and across a broad range of technologies (e.g. from eco-innovation technologies to ICT). This high depth and excellent value chain coverage is not present in all world regions, and particularly the supply business is well established in Europe, with the strongest base of Tier 1 suppliers. ▶ The reputation of the European automotive industry is very high. Europe is leading in the premium brand segments and this is where technological innovations are initiated. Brands from other segments are therefore inclined to be present in Europe to experience the latest technological developments and trends. ▶ Trade analysis shows a clear comparative advantage of the EU-28 in vehicle manufacturing, realizing high export specialisation (RXA) and trade specialisation figures (RCA) that have further improved since 2008. Furthermore, the EU-28 shows the by far highest export market share of about 30% of global exports in 2014 compared to only 25% in 2008. The strong export position of the EU in vehicle construction is underlined by the positive trade balance (2014: 45%) that has nearly doubled since 2008 and the positive medium-term dynamics (6.6% p.a.).	for cross-fertilisation of technologies
Opportunities ▶ The two major areas of technical developments in the automotive industry are the further improvements of the internal combustion engine and the increasing electrification of vehicle	Threats ▶ Asian players dominate in the field of electro-mobility. Europe's automotive industry could eventually be dependent on the Asian players for

powertrains. According to various technology roadmaps available internal combustion engines will continue to feature in the majority of vehicle sales till at least 2030. Europe has technological leadership regarding the internal combustion engine and could further develop its expertise regarding the electrification of vehicle powertrains. ▶ Customer preferences area shifting towards smaller, more fuel efficient and low emitting vehicles, an area where Europe has a relatively strong position.	supply chain areas such as battery manufacturing. ▶ European's position in the global market is declining due to increasing global competition. On the long term an entry from loss-cost mass market players (e.g. China, Korea, India) into the European market can be expected. ▶ Due to static or declining populations, the European car market appears to be saturating in the longer term. Furthermore, personal car use per person per year is declining in several key European countries and younger generations are becoming less interesting in car ownership. ▶ Suppliers and OEMs tend to locate their R&D facilities in proximity to their customers, so that there is a closer alignment to the needs of the market. As a result, many new R&D facilities are located in emerging markets such as China, India, Russia and Brazil. This trend is supported by the higher availability of skilled employees and labour costs. This could threaten Europe's technological leadership in the field of fuel efficiency for cars.

2.4 Analysis of barriers

One of the biggest barriers for the fuel efficient cars sector is capital and finance. In the current industry, you would have to be a fairly big and profitable OEM or supplier in order to remain competitive, since the automotive industry currently isn't the most profitable in terms of margins. The margins of the automotive industry are pressured on many fronts on which manufacturers have to make expenses, ranging from adhering to regulatory standards to research and development on the areas such as self-driving cars. In order to remain competitive while attempting to realise efficiency gains, it is therefore essential to have access to sufficient capital and financing.

Contributing to the low margins are the costs and complexity resulting from the regulatory environment in Europe, such as strict environmental and safety regulations (McKinsey&Company, 2013; PWC, 2014). On the other hand, as has been concluded earlier in this report and has been confirmed in interviews, increasing vehicle powertrain efficiency is driven by regulation. Depending on the position of the organisation of the interviewees, a barrier is therefore seen in the regulation or the lack of even more stringent regulation. It could be stated that these costly conditions push towards operating in the more premium segments, because manufacturers can better bear the costs due to their higher margins. Indirectly, this might benefit increasing fuel efficiency, since innovations derive initially from the premium segments.

In an AEA report (AEA, 2012) on the economic performance of the automotive industry it is stated that Europe is characterised by slow decision making processes, a lack of coordination and a less uniform market place compared to other key automotive markets. Slow decision making processes regarding standards hamper the uptake of new technologies. Furthermore, the significant variations in the policy frameworks of the various Member States of the EU impose difficulties for car manufacturers on the European market. This barrier has also been highlighted in interviews. On paper the European market should be characterised as an internal market, however, the major elements of consumers' decisions are influenced by national policies, and those policies are not always harmonised. There are too many fragmented, isolated markets with different policies. For example, the Netherlands has great policies supporting the purchases of hybrid vehicles, but once you cross the border, there is not such policy at all. The Dutch hybrid vehicle market by itself is not attractive enough for the automotive industry, it has just too little sales. With these differences is policies it is difficult to operate, since these policies have implications on the business decision regarding cost structure, scale economics, marketing, et cetera.

A final barrier relates to the uncertainty about the prevailing technologies of the future in the automotive industry and the possible lock-in of the European automotive industry in the internal combustion engine technology. Path-dependencies could eventually result in a threat to the leadership of the European automotive industry on fuel efficiency once the demand for electro-mobility will overtake the demand for traditional internal combustion engine powered vehicles (Frigant, 2011). Significant investments are required for OEMs and their suppliers who will have to develop alternative powertrain technologies for lower-emission vehicles without knowing for certain what will end up being the prevailing technology of the future (McKinsey&Company, 2013). If the European industry wants to enter the electro-mobility market, it may face some resource dependencies, for example on China regarding batteries and rare-earth materials (Frigant, 2011).

2.5 Suggested actions

From the interviews the following points have been distilled on which Europe should centre its policy:

- Ambitious yet realistic regulation
- Owning the standards
- Regulatory harmonisation
- Technology neutrality
- The right R&D support
- Forward looking policy

According to the interviewees technological leadership is driven by the regulation, as stringent technology-forcing policies can strengthen the innovation capacity of the automotive industry and further drive the rapid penetration of advanced technologies (International Council on Clean Transportation, 2014). The regulatory environment should therefore remain ambitious, yet realistic. A proper balance should be found between pursuing ambitious objectives and maintaining jobs and value added in Europe. One of the identified barriers are the low operating margins in the industry, and the costs that come along with a stringent regulatory environment should not drive towards players leaving the European automotive industry. According to an economic study in 2013 (Cambridge Econometrics, Ricardo-AEA, 2013) on the effects of CO_2 legislation on the automotive industry, robust fuel efficiency standards for cars could create up to 443,000 new jobs by 2030 and add €16 billion per year to Europe's GDP. The report also indicated that efficiency improvements would add an extra €1,000-€1,100 to the cost of an average car in 2020, but that this would be offset for consumers by fuel savings in the long run. Furthermore, according to a 2015 study on transport emissions reductions (Transport & Environment, 2015), ambitious new vehicle emissions targets (2025 standards of 70g CO_2/km for cars and 100g CO_2/km for vans) could save European drivers €350 per year, and pay back the cost of the technology within three years. Also on Member State level, the uptake of efficient vehicles can be influenced through national taxation systems, including vehicle registration tax, circulation tax and fuel tax (European Environment Agency, 2015).

Europe should also aim to become the lead market in terms of regulation and standards with respect to fuel efficiency and emissions. Since Europe is a world leader in many technologies in this area, this would bring Europe competitive advantage, and in this way Europe can ensure their OEMs and suppliers to be able to sell their technology abroad. Regulatory harmonisation is one of the key ways that the EU can profit from developments in different technologies. At the same time it has to be made sure that companies are not constrained by regulation, and technology neutrality should be pursued. Furthermore, efforts towards regulatory harmonisation will contribute towards the barriers experienced regarding the fragmented markets still in place in the various Member States in the EU.

Fostering the industry in the EU will be a challenge, but the main game is about having technological leadership in a number of areas. A combination of forward looking policy, aimed at the mid- and long-term and proper R&D support would contribute to this objective. In terms of technology, Europe should consider betting on other technologies besides the internal combustion engine. Due to the fact that the potential improvements in the internal combustion engine are narrowing down, the potential for comparative advantage is limited on the long run. Bigger possibilities lie within technologies related to for example partial electrification and recovering waste energy, since it is expected that the market will eventually converge towards hybrid vehicles. Other technology areas in the automotive industry that should be stimulated are electronics, connected or automated vehicles, or light-weighting. A main reason for investing in the development of these technology areas is their applicability regardless of the type of powertrain, making them technology neutral. While it may take time for the internal combustion engine to be replaced, learning effects and first mover advantages may prove decisive once the shift takes place (PWC, 2014; Hildermeier, 2016; Frigant, 2011). A possible way of entering the electro-mobility market is to form joint ventures or close partnerships for example with Japanese or South Korean battery manufacturers (AEA, 2012; Frigant, 2011). More radical transformation are also possible: an article by (Gwosdz, Guzik, & Domański, 2011) describes the case of Solaris, a Polish family-owned bus manufacturer, which successfully adopted an aggressive, high-risk strategy of targeting a new unexplored market niche for buses with an alternative powertrain.

Finally, Europe should find innovative levers to maintain its technological leadership in the field of efficiency gains in vehicle powertrains. An example is the field of Key Enabling Technologies (KETs), which have been identified as one of the priority areas of European industrial policy. KETs provide the basis for innovation in a range of products across all industrial sectors. Examples are laser micromachining or additive manufacturing, technologies that can be applied for the cost-effective production of highly complex parts, such as fuel injection nozzles.

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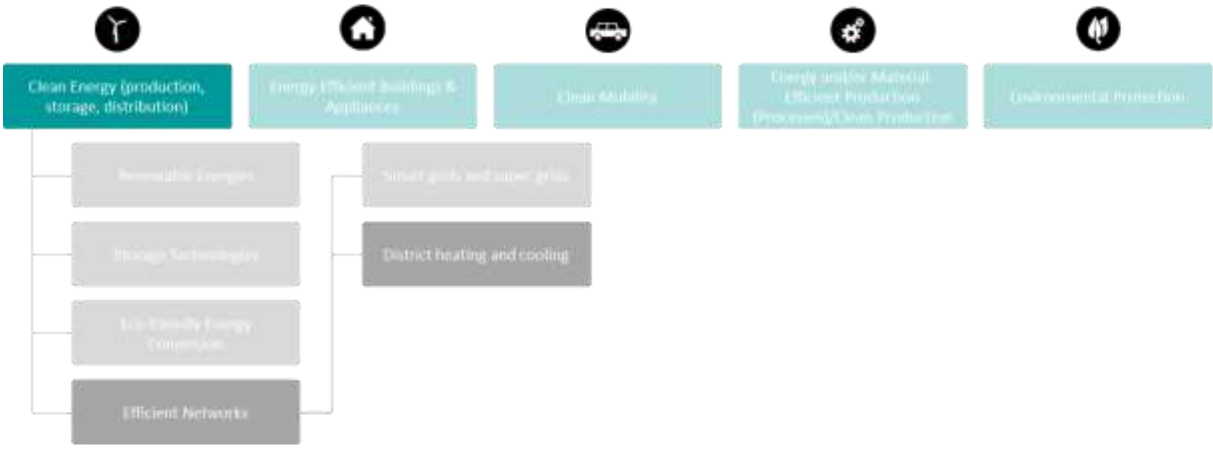
3/ District heating and cooling

Figure 17: Presentation of the selected priority sector within the Clean Industry taxonomy



3.1 Description and value chain

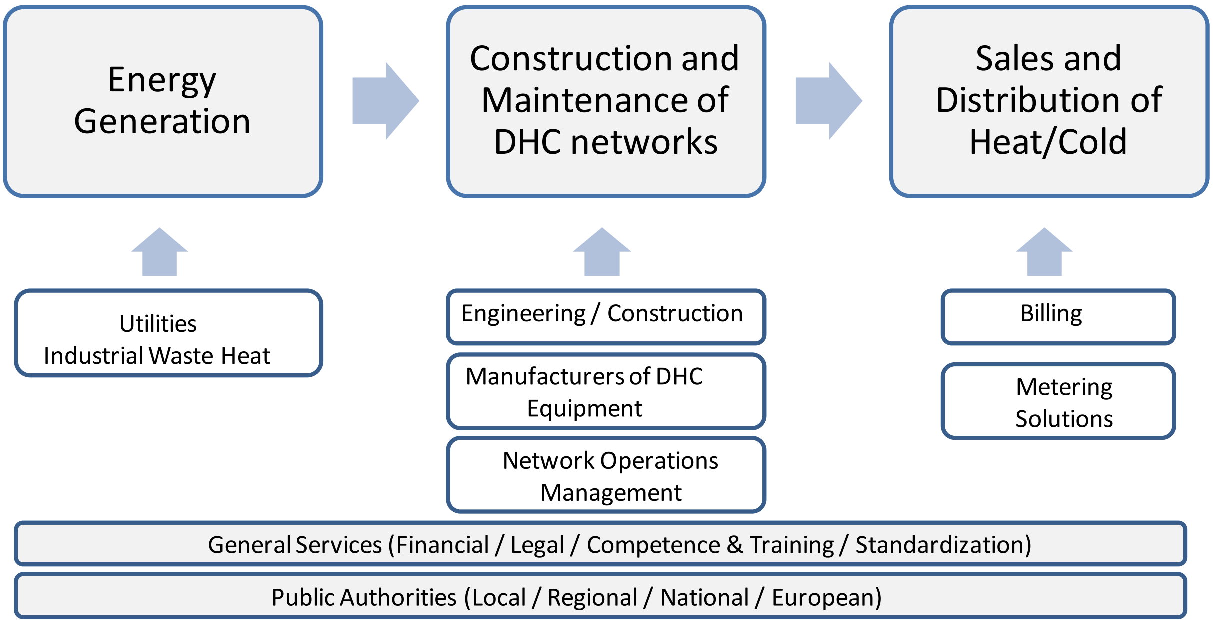
District heating and cooling (DHC) delivers heat or cold to customers via underground pipes. Since long transport is related to losses of thermal energy, DHC is delivered over shorter periods and mainly economic in densely populated areas. The value chain of DHC comprises the construction of the systems as well as production, distribution and sales of the thermal energy (see Figure 18). According to an interviewed expert, main actors in the EU regarding components and equipment are Danfoss (DK), Logstor (DK), Grundfos (DK), and Thermaflex (NL), furthermore Brugg (CH). Utilities involved are in particular Dalkia (FR), Veolia (FR), Vattenfall (SE), Engie (FR), and Fortum (FI). Also part of the value chain are consultancies among which Ramboll (DK) and COWI (DK) are named as important actors.

In a District Heating (DH) network one or more central sources provide hot water which is conveyed to the users (who can be domestic consumers, commercial buildings and appropriate industries) by means of insulated water pipes. Up to 2012, DH is responsible for avoiding at least 113 million tonnes of CO2 emissions per year representing 2.6 % of EU emissions (DHC+ Technology Platform, 2012, p. 13).

Sources of heat used for DH are reject heat from small engines or gas turbine generators in power plants, reject heat from refuse/waste combustion power generation plants, reject heat from large combustion electricity power stations, heat-only-boilers, industrial waste heat, geothermal heat, electrically driven heat pumps, gas or diesel driven heat pumps, large scale solar water heating, or biomass boilers (Andrews et al., 2012, p.52). DH systems among others make use of the following products: heat distribution pipes, heat exchangers, heat meters, valves, pressure limiters and return temperature limiters, hot water storage tanks, water leakage detectors, and products for co-generation.

In the EU-28 there are more than 10,000 DH systems supplying around 8 % of EU heat demand[31], whereof 45 % are used in the residential sector, 34 % in the industrial sector and 21 % in the tertiary sector. Total final DH consumption is highest in Germany, Poland, Sweden, and Finland (EC 2016). Shares of the population served by DH in different MS vary from zero to over 60 % as Figure 101 in Annex 6/ displays. According to Euroheat (2015), the total installed DH capacity in 2013 in EU countries was 279.2 GW.[32] Out of the many DH systems, only 177 are geothermal DH (geoDH) with a capacity of 1.5 GW and most systems installed in France, Iceland, Hungary, and Germany. Production of geoDH in EU MS in 2014 was 4.3 TWh (EGEC, 2016). Another ca. 65 DH systems are solar DH systems with nominal power larger than 1 GW. Thereof 31 are located in Denmark, 9 in Sweden, 8 in Germany and 3 in Austria but with close to three-quarter of the aggregate capacity being delivered in Sweden (SDH, 2013).

Figure 18: Value Chain of DHC sector



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[31] The share amounts to 12 % according to Conolly et al. (2012). (http://www.epo.org/news-issues/technology/sustainable-technologies/green-construction.html)

[32] Information is missing for Denmark, a country known to have a large number of DH utilities. Moreover, information for Sweden is from 2011 since the statistic for 2013 is missing.

Cogeneration (Combined Heat and Power, CHP) is the main technology used to produce the heat fed into DH systems. 82 % of the district heat in the EU is derived from sources of surplus heat whereof CHP delivers the largest part with about three quarters of the district heat energy supply. 14% of the total heat produced for DH stems from the use of renewable sources (biomass, geothermal, solar, waste), this share being higher than for primary energy demand (7 %) and for final energy consumption (8.5 %). With shares of 30-50 % deployment of renewables is highest in Sweden, Norway, Denmark, and Finland (DHC Plus Technology Platform, 2012, p. 11/12). By contrast, 80-100 % of the DH heat supply in Eastern European countries is covered by the use of fossil fuels (Conolly et al., 2012).

A particular form of DH is geoDH since the related industry and value chain partly differs from that of non-geothermal DH (see Figure 102 in Annex 6/). Due to the drilling related to the exploration and development of the geothermal resource this part of the industry is close to the oil, gas and mining industry. Furthermore and in contrast to DH fuelled by fossil resources, the operating costs are very small (similar to solar DH). The geoDH value chain is mostly local since local authorities are involved and construction requires heavy and case-specific tools. The companies executing design and construction are often SMEs. Typical project volumes are about 20-30 Mio EUR, thereof the majority for drilling the wells and setting up the network. Due to the capital intensive construction of DH systems, ownership and operation is often shared between public and private actors.

District Cooling (DC) uses chilled water distributed in buried pipes. DC can reduce emissions by as much as 75% compared to conventional electrical chillers (DHC Plus Technology Platform, 2012). Cold to chill the water is mainly derived from Free Cooling, Compressor Cooling or Absorption Chilling.[33] Moreover, DH and DC can be combined with heat pumps using excess cold from the DH system.

Today, DC has a market share of ca. 2 % of the total cooling market (ca. 10 PJ/3TWh) but is growing fast. Sweden already reaches a market share of 25 % of DC in the cooling market for industrial and commercial buildings and large European cities (Paris, Helsinki, Stockholm, Amsterdam, Vienna, Barcelona and Copenhagen) are on their way towards reaching 50 % DC shares (DHC Plus Technology Platform, 2012).

DHC provides a very important possibility to sustainably reduce CO_2-emissions in the EU. As Conolly et al. (2014) show the same decarbonisation goals as planned by the Energy roadmap 2050 can be reached with lower costs when a higher share of DHC is aimed for. This is due to the network effects of DHC as highlighted in Andrews et al. (2012). The required load in a DHC network is always smaller as the combined load of single buildings or flat

[33] Free Cooling uses river or sea water nearby. For Compressor Cooling, a gas is compressed, which causes it to become hot. The heat is then rejected with a fan coil unit. As a result of the cooling of the gas it condenses to liquid. The liquid is then pumped to a cooling fan coil unit where it evaporates. Thereby it absorbs the latent heat of vaporisation from the air being blown through the fan coil unit, thereby cooling it (Andrews et al., 2012, p.74). Absorption chilling derives cold from heat pumps using waste heat.

solutions that each has to provide the peak load. In addition to that, DHC provides a technically suitable solution to a gradually increasing the share of renewable heat or cold while individual systems often have to be adapted.

3.2 Assessment of the global environment

3.2.1 Main competitors outside the EU

IEA (2013, p. 182) quantifies the worldwide extent of DHC networks to 406,000 km. Russia and China dominate these figures, with 173,000 km and 110,000 km respectively. Yet, Europe has the largest DH network per inhabitant. Since DHC is mostly a local business, non-European companies do not easily set up production in the EU. No foreign company seem to compete on a global scale and they are only active on their home markets. Competition concerns in particular construction components that are traded on global markets such as heat exchangers, pumps or pipes. According to an industry expert, the US, China, New Zealand, and Japan are the main competitors with respect to these components.

The cooling market is much more developed in the US and Japan and DC systems are relatively larger than in the EU (1,337 MW). Figures from Euroheat (2015) indicate that the total capacity installed in Japan is 3,960 MW and in the US 16,234 MW. In relation to inhabitants, this is a larger per-capita capacity than in the EU.

3.2.2 Relative competitive strengths

Europe is leading the world in district energy technology with strength in the overall network design, performance, maintenance, and in technical components (RHC Platform, 2014). Leading experienced designers will generally be from countries such as Denmark, Germany, Sweden and Finland (Andrews et al., 2012, p.105).

The long tradition in some and growing uptake in other EU member states is also reflected in the technological competitiveness of these regions measured by patent applications.[34] Figure 19 shows patent shares with respect to all technologies and regarding the field of "Combustion technologies with mitigation potential", which comprises patents related to technologies for improved output efficiency such as combined heat and power,

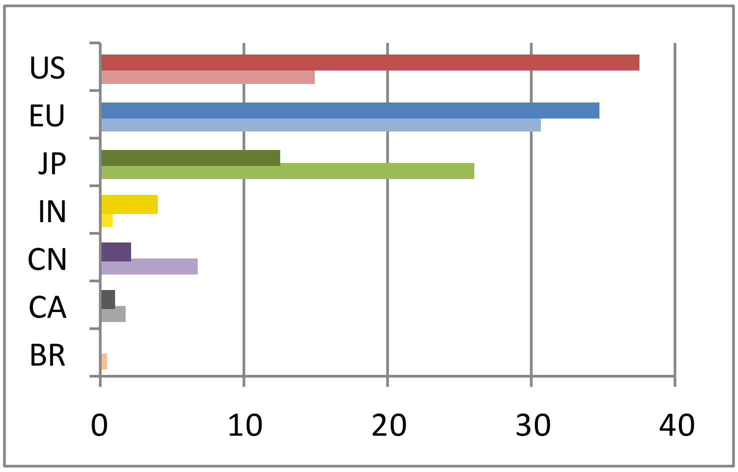
[34] The OECD Environment Directorate, in collaboration with the Directorate for Science, Technology and Innovation, has developed patent-based innovation indicators that are suitable for tracking developments in environment-related technologies. The patent statistics are constructed using data extracted from the Worldwide Patent Statistical Database (PATSTAT) of the European Patent Office (EPO).The relevant patent documents are identified using search strategies for environment-related technologies (Env-Tech: http://www.oecd.org/env/consumption-innovation/env-tech-search-strategies.pdf) which were developed specifically for this purpose. The data are available under http://stats.oecd.org/. The European Patent Office is also working with this definition, e.g. in the context of analysing the EU's patent performance in "Green Building" (http://www.epo.org/news-issues/technology/sustainable-technologies/green-construction.html).

combined cycles, or efficient combustion and heat usage. These technologies are important since CHP is the major source of heat delivered to DH networks and can therefore provide indication of the relative competitive strength of the EU compared to other countries.

As Figure 19 reveals, the US has the largest share (37.3 %) and a significant specialization in combustion technologies since their patent share in this field is much larger than their total patent share. The EU holds the second largest share (34.6 %) which is slightly larger than their share in total patents indicating some specialization in combustion technologies. The EU share is dominated by Germany (16.3 %), being specialized in combustion technologies, and France and Italy whose patent shares in this field however do not differ from those in total patents. Smaller MS like Finland (1.7 %) and Sweden (1.4 %) also show a strong specialization in combustion technologies. While India seems to be specialized since its share in combustion technology patents is much higher than that in total patents, the case is reversed for Japan, China, and Canada.

Overall, it seems as if the EU has only some specific strength in combustion technologies as an input to DH. Europe is, nevertheless, strong in expertise related to DHC. Regarding geoDH, Europe has available specialized research institutes such as the TNO in the Netherlands, the BRGM in France, and the IGG-CNR in Italy.

Figure 19: Patent share in the field of "Combustion technologies with mitigation potential" compared to total patent share 2010 to 2012



The upper bar shows the patent share in thermal insulation, the lower bar the total patent share (with respect to all technologies).

Source: OECD.stat; Theme Environment; Dataset: Patents - Technology Development - NIW calculation

3.2.3 International trade performance

International trade with respect to DHC refers to tradable components only as indicated above, hence to trade in heat exchangers, pumps, pipes and related products. The essential other parts of the value chain like design and construction as well as distribution and maintenance are traded to a smaller extent or even impossible to trade.

3.2.4 Market outlook

In general, DHC is a growing sector. However, the direction of development within the EU differs by country. Scandinavian, Baltic and Western European countries further expand their DH systems, some Eastern European countries modernize their old systems but some others see a decline in DH due to changed economic structure and population (DHC+ Technology Platform, 2012).

One driver of the market development is the rising urban population in the EU: meanwhile more than 70 % of the population lives in cities being suited for DHC and this share is estimated to rise to 80 % by 2030. Moreover, DHC provides an enormous potential for energy mix diversification and integration of renewable sources in the form of feed-ins into the system using, for example, heat pumps or seasonal storage. Expertise in the area knowledge indicates that a tripling of the DH share (12 % in 2015) by 2050 is feasible from a technical point of view. The share of renewable energy used to produce the thermal energy is estimated to increase to 25 %. Conolly et al. (2012) even consider expansion of DH supplies to 30-50 % by 2030 as being technically feasible. Implementation hinges of course on many political and economic factors. Investments of an expansion of DH of that kind, however, are estimated to create approximately 220,000 new jobs across the EU over the period from 2013 to 2050 (Conolly et al., 2012, p. 9).

Another driver of a growing DH supply is the rising awareness of industrial waste heat potential suitable as a heat source and the intention to make use of it. According to Pehnt et al., 2011, a waste heat potential for the German industry of 12% of the final industrial energy consumption at temperatures above 140°C is available. STRATEGO (2015) reports the EU-28 waste heat to amount to 11.3 EJ (270 Mtoe) in 2010, which is more than the EU residential sector's final energy consumption for heating and cooling in 2012 (248 Mtoe). Even if a decline of industrial waste heat due to improvements in heat recovery for the industry itself is assumed, the potential of excess heat for DH is large. The potential is even larger when lower degree heat sources are considered being sufficient for the 4th generation of DH systems adapted to buildings with low energy needs (DHC Plus Technology Platform, 2012).

GeoDH as a particular form of DH using a renewable resource is growing significantly. The current number of 280 geoDH systems in Europe (including Iceland, Turkey, Macedonia, Georgia, and Serbia) is assumed to nearly double to 455 in the next 4 to 5 years doubling the capacity as well according to an interviewed expert. About 25% of the population in the EU lives in areas directly suitable for geothermal DH. Germany, France, Italy, Hungary, Poland, Slovakia, and Romania are considered as mature markets having already installed several geoDH systems. The Czech Republic, Slovenia, and Bulgaria are transitional markets and Denmark, The Netherlands, Great Britain, and Ireland are rather juvenile markets. By 2020 nearly all EU countries will have geoDH as reported in GeoDH (2014). One driver of the development of geoDH is the low oil price. Companies from the oil and gas industry seek new business opportunities in times of low oil prices induced by the similarity and synergies of the geothermal industry with the oil, gas, and mining sector.

DC is expected to grow as well. According to the vision presented in DHC Plus Technology Platform (2012), the *DC share* could rise to 25 % by 2020. The overall European cooling market is still underdeveloped compared to Asia and the US and growing rapidly. This provides an opportunity to implement low-carbon technologies such as DC, the main potential of course lying in the service sector buildings (RESCUE, 2013). Drivers of the growth of DC are the awareness of possible synergies of DC and DH, permissions and legislations aiming at phasing out certain refrigerants, and the avoidance of electrical grid and power investments necessary if increasingly more local conventional cooling systems were installed (RESCUE, 2013, pp. 32-34).

For the future, Andrews et al. (2012, pp. 47-48) expect smart DHC systems especially with respect to the possibility of storing energy from renewable resources to stabilize the power grid. Those smart DHC systems can also provide interactions between buildings, substations and networks.

3.3 Assessment of the competitiveness aspects

3.3.1 Export potential

According to the DHC Plus Technology Platform (2012), Europe is the world leader in district energy. Export potential regarding services and technology arises from the increased interest for district solutions in the Middle-East, Asia and North America. China and Russia as particular foreign markets are however at the moment characterized by an uncertain and instable investment climate according to an interviewed expert. By contrast, RHC Platform (2014) lists China and Russia as particular markets among other world regions to be served by know-how and products.

3.3.2 SWOT

DHC is a sector where the EU has a leadership in expertise and technology. Regarding the decarbonisation of the economy, its potential is huge especially since energy from renewables can be fed into DH systems when transformed to heat. The local character of the sector similarly to the buildings sector is a strength regarding local growth and employment. Nevertheless, construction of DHC networks is very capital intensive so that decisions which are not based on life-cycle costs may neglect DHC solutions. Furthermore, DHC is only economically feasible if enough consumers are bundled. Currently, a large part of existing DH networks is relying on fossil energy and their pipes have large heat losses.

The large waste heat potential provides a good opportunity for an increase in DH as does the possibility of using DH networks to store energy derived from renewable sources. GeoDH projects are attractive in times of low oil prices since the technically related industry of oil, gas, and mining is seeking for alternative profitable businesses. Increasing awareness of energy-efficiency can provide export potential of knowledge and technology outside the EU. Still, the size of DHC projects and the related red tape in particular when missing harmonization threaten the implementation of projects. In the same vein, availability and price of suitable property within densely populated areas is an issue since the heat or cold should be transported over short distances only. Moreover, labour intensity of the sector requires higher productivity, particularly with respect to connecting pipes and manufacturing of substations, to maintain competitiveness with other heating solutions (RHC, 2011). Finally, when lower amounts of heat are traded in the future, the DHC sector needs to adapt its business models focused on selling heat and dependent on a certain purchase to remain profitable (RHC, 2014).

Overall, the strengths outnumber the weaknesses as do opportunities the threats. Yet, weaknesses are large and difficult to overcome. The opportunities, however, appear to outweigh threats which can be approached more easily than the inherent weaknesses of the sector.

Table 12: SWOT for the District Heating and Cooling sector

Strengths	Weaknesses
▸ DHC is locally oriented creating local jobs and growth ▸ Europe is strong in expertise and technology ▸ Europe has the largest DH network per inhabitant (IEA, 2013) and consumption is highest in Germany, Poland, Sweden, and Finland (EC, 2016) ▸ DHC networks can store energy from renewable sources making it part of the smart grid ▸ EU has technological leadership in software, ICT, exploration knowledge, drilling concepts, reservoir management and highly skilled personnel for geoDH according to an interviewed expert ▸ Low operating costs especially for solar DH and geoDH	▸ CAPEX are very high, this makes it difficult for DH to compete against technologies with lower CAPEX who might nevertheless have a worse life-cycle assessment in terms of costs and energy efficiency ▸ There need to be enough consumers interested in DH/DC in order to economically establish a system ▸ Large parts of the existing DH networks are old and fed by heat derived from fossil fuels ▸ geoDH requires suitable resources

Opportunities	Threats
▶ The existing (albeit old) network in many EU MS provides a good possibility to revive DH and feed in renewable energies ▶ There is a large waste heat potential that could be used as input to DH ▶ Rising cooling needs allow for implementation of efficient DC networks, leapfrogging less efficient solutions presenting lock-ins in more developed cooling markets ▶ Ahe low oil price attracts companies from oil, gas and mining industry to geoDH business ▶ Heat sources of lower degrees can be used in the 4th generation of DH (still under development) and may accompany the retrofitting of the building stock towards lower energy and especially heating demands ▶ Export potential resulting from the pioneering role of EU (only regarding know-how and components)	▶ Centralized networks require consolidated effort in planning and permission processes, missing regulation creates investment insecurities resulting in a lower number of projects undertaken ▶ Since DHC is mainly suitable for densely populated areas, tight property markets as well as high property prices may impede implementation since there is no property available or too expensive ▶ DHC is a labour intensive sector (connecting of pipes , manufacturing of substations) that needs to increase productivity ▶ Decreased amount of heat traded in future threatens existing business models

3.4 Analysis of barriers

Regulation mostly favours on-site solutions within the building envelope which is a barrier for DHC (RESCUE, 2013, p.36). For geoDH in particular, the regulatory framework is still in development leaving some uncertainties unaddressed. In some countries there is no certainty for the use of the licensor for geoDH, hence if a resource is found, the exploration license may not extend to deploying it, especially in UK, Ireland, the Czech Republic and Hungary as indicated by an interviewed expert and reported in GeoElec (2013a). Another interviewed sector expert also highlighted the role of regulation since it clarifies the political priorities in the energy and heating sector. According to this interviewee, foreign gas will remain the dominant energy source if too few political attention is attributed to energy dependence and CO_2 emissions. He further indicated that policy attention is mainly on electricity production although heating and cooling requires the largest energy amounts.

Regarding capital and finance, all DHC solutions require high capital expenditures (CAPEX), in particular for the upfront investent but also regarding maintenance of the network. Generally, an investment climate favoring fast returns is a barrier for DHC (DHC Plus Technology Platform, 2012). Geothermal DH moreover involves a high risk of the CAPEX investment, since exploration may not result in finding a resource sufficient to exploit for DH. For waste heat, which is an important source for DH, the same barrier exists. Most companies base their choices not on a life-cycle assessment but on fast returns to investment. In this way significant energy cost savings through waste heat utilisation, where the amortization time is over a period of many years, will not be sufficiently taken into account during investment decisions (Pehnt et al., 2011, p.694). Also being related to capital, an interviewee stated that although recently more funds are available for DHC related projects, the amount still remains limited compared to funding for other energy sectors.

One big obstacle for the further implementation of DHC is information. A general lack of knowledge regarding DH and DC is attested to all involved stakeholders as well as a lack of knowledge that cooling demand is growing (RESCUE, 2013, p.53). Also, many consumers do not know their expenses for heating and cooling so that they cannot appreciate the advantages of DHC (RESCUE, 2013, p.37). Regarding waste heat as an input to DH, Pehnt et al. (2011, p. 695) report that often companies do not have special staff for efficiency technologies in general and waste heat technologies specifically, who could point towards selling waste heat for DH. Moreover, language barriers exist and the hesitation of using experience from other countries. Lack of information also refers to the missing exchange between the DHC sector as well as neighboring sectors like urban planning or architecture providing a barrier to a holistic approach needed for DHC (EC/JRC, 2014).

Since some of the benefits of DHC as for example reducing the need of huge investments in electrical power production and distribution pay off on a society level but not necessarily on the company level, barriers related to the general market functioning exist as well. Also, if potential customers choose alternative solutions to DHC, no high connection density along the distribution grid is given and the economic outcome and attractiveness of DHC will be reduced. This in turn reduces interest of utility companies in DHC (RESCUE, 2013, p.38).

Barriers related to resources exist mainly for geoDH and for DC in the form of free cooling. Furthermore, the allocation of production sites can be an obstacle for the implementation of DHC, especially in densely developed areas most suitable for DHC (RESCUE, 2013, p.36).

Economic conditions are a potential barrier, too. Modernization of old DH systems and struggle with not losing DH customers to the gas market takes up all attention especially in those countries where DH has a long tradition but suffers from old and inefficient systems as well as unreliable services (RESCUE, 2013, p. 53).

3.5 Suggested actions

Relating to the general advantages of DHC compared to decentralised heating and cooling technologies mentioned at the outset, a larger focus of existing policies should be directed to install network solutions of heating and cooling. As one of the most important measures heat planning is suggested, connecting new as well as existing houses to the DHC networks. This is especially reasonable in densely populated areas and has been recognized already by the EED. The approach of intensified heat planning can be implemented when municipalities are provided with simplified rights to prescribe use of DHC in particular areas. In this way they generate a fait accompli nudging owners to choose the most efficient solution. And even if individual heating and cooling systems using renewable energies are becoming more efficient, DHC offers flexibility that individual systems do not have. Hence, while, for example, a micro-CHP based on biomass depends on the price of pellets for a long time, future (smart) DHC networks can incorporate energy from diverse sources and in the best case those with high shares of renewable energy.

Möller and Lund (2010) show for Denmark that switching from individual gas heating to DH is a suitable way together with continuing measures of increasing energy efficiency of buildings and lowering energy consumption. In particular, municipalities could be encouraged to provide climate concepts for their cities with designated areas. How municipalities deal with the form of ownership they implement for DHC is largely path-dependent. Different best practices all over Europe are reported in IFC (2015).

Another way of securing that DHC solutions are chosen is to include DHC as a viable option of renewable heating and cooling equipment when there is an obligation to include renewable heating and cooling during new built or refurbishment. Here again, the high level of flexibility offered by a DHC network is an argument for DHC in favour of individual heating and cooling systems even if they use renewable energies.

Despite reduced amounts of heat traded in the future this approach is still favourable as Persson and Werner (2011) report from a simulation study for cities in Belgium, Germany, France, and the Netherlands. Nevertheless, the trend towards smaller amounts of heat traded puts pressure on the profitability of DHC companies. RHC (2014) recommends adapting DH business models which to the moment rely too much on the amount of heat sold. Alternatively, the focus should change towards delivering flexibility and capacity, in particular when buildings are increasingly operating as energy producers and demand response is growing. To target the above mentioned need to increase productivity, RHC (2011) suggests that the industry develops a higher degree of standardisation of working methods and systems part. Technical requirements to increase the efficiency of DHC mostly encompass demonstration projects in the near-term future as for boosters of heat pumps, smart thermal grids, or improved substations for lower temperature networks (RHC, 2014). In this respect also the adaptation to NZEB heat and cold requirements can be mentioned as a technical adaption. From a policy perspective, support for demonstration projects can be highlighted.

Another important barrier to be addressed is the difficulty to purchase appropriate sites in densely populated areas most suitable for DHC. Here, a broader range of rights for DHC companies – especially in combination with the above listed designation of areas by municipalities – would mitigate the problem. As outlined in Andrews et al. (2012) these quasi-governmental rights would lower project risks which at the same time facilitates capital acquisition.

Fostering a more holistic, network approach, particular in cities, is a necessary prerequisite to let DHC be an efficient solution. Cross-fertilization of neighbouring disciplines like urban planning or architecture is suggested via integrating education and training of these skills (EC/JRC, 2014).

To establish a higher expansion of geoDH, more emphasis should be put on a fuel switch in DH since currently the majority of energy for DH comes from fossil fuels. Moreover, embedded insurances could address the financial risks associated with the exploration of the geothermal resource. Similarly structural funds could provide a solution as well.

The barriers related to the use of waste heat for DH can be addressed by adding the category of waste heat utilization to the companies' energy management system regulated by EN16001 standards in order to call attention to potentials (Pehnt et al., 2011, p. 696). Moreover, industry associations can advertise the selling of waste heat to their members and provide assistance and a communication platform on that. A reduced amount of waste heat due to e.g. better thermal insulation or increased efficiency in electricity generation would decrease the waste heat potential available for DHC in the long run. Nevertheless, the estimated potential is very large and likely to decrease slowly. In the meantime, renewable energy sources are expected to grow which could replace waste heat.

One of the barriers related to financing DHC and waste heat utilization, the focus on short term return to investments, can be addressed with the help of industry associations. They can recommend their member companies to include information on life cycle costs on offers and company brochures, flyers and presentations (Pehnt et al., 2011, p. 698).

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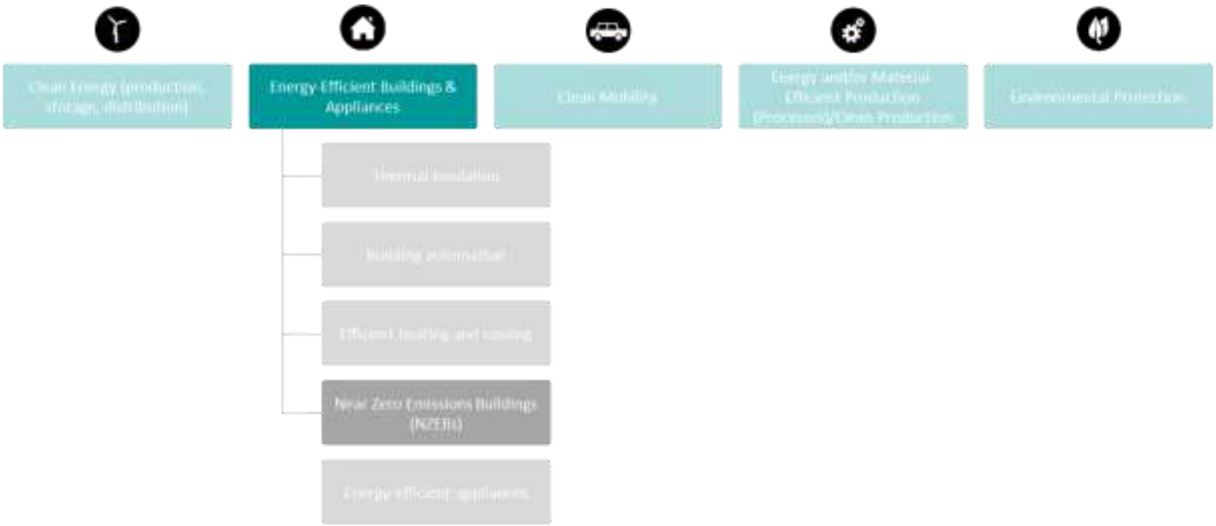
4/ Nearly zero energy buildings (NZEBs)

Figure 20: Presentation of the selected priority sectors within the Clean Industry taxonomy



4.1 Description and value chain

The concept of nearly zero energy buildings (NZEBs), also denoted as passive houses, net zero buildings, or low energy houses, refers to buildings that have a very high energy performance significantly below the standard. As defined in the Energy Performance of Buildings Directive (EPBD, Article 9), *"The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby."* Evaluating a sample of NZEBs in different MS, the Concerted Action EPBD publication (2016, p. 68) reports that the mean reduction in energy requirements compared to current national requirements is 74 %[35]. Average additional costs are 208 €/m^2 or 11 % of the total costs.

Since buildings are the largest consumers of energy in the EU they play a key role in the EU's decarbonisation strategy and the long-term goal is to reduce the building-related CO_2 emissions by 95 % until 2050 (Roadmap 2050) which essentially means to transfer the EU's building stock to NZEBs by 2050. In order to reach that goal two different segments have been targeted by the EPBD, Article 9. The first are newly built houses, which are required to fulfil the defined NZEB standard by the 31 December 2020[36]. The number of newly built NZEBs shall furthermore be increased by the help of particularly designed national plans. The second segment refers to the

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[35] A reduction by 100 % would indicate a net zero requirement.

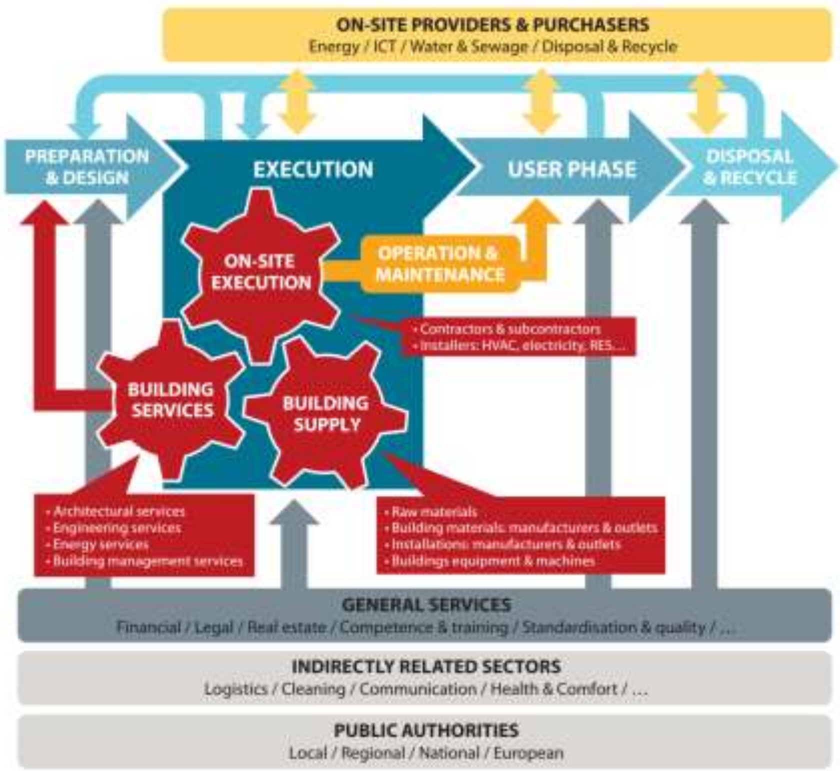
[36] New buildings occupied and owned by public authorities have to fulfil this standard already by 31 December 2018.

existing building stock. Article 9, paragraph 2, of the EPBD inquires the MS *to "develop policies and take measures such as the setting of targets in order to stimulate the transformation of buildings that are refurbished into nearly zero-energy buildings"*. The national plans shall articulate these strategies, too.

From an economic perspective the distinction of these two segments will be maintained since markets are not always overlapping. Moreover, with a demolition rate of 0.1 % of the existing stock per year and a new building rate of around 1 % per year in the EU, the renovation segment is the more important one since most of the existing building stock will still be standing in 2050. Mlecnik and Straub (2014) show, however, that the market for NZEB (single-family housing) renovation is just emerging and is not yet a volume market. Figure 104 in Annex 7/ shows that shares of low Energy Performance Certificate (EPC) labels are still high in the building stock.

Importantly, the topic of NZEBs covers all aspects of buildings encompassing envelope, windows, air sealing, building automation, renewable technologies and heating and cooling equipment. These single aspects will not be regarded in detail here and are partly analysed in other parts of the report (Thermal insulation in chapter 11/, Heating and cooling systems in chapter 6/). Figure 21 shows the value chain of the construction sector. Regarding newly built NZEBs as well as the renovation sector, all parts of the central (red) value chain are affected. Building services such as architectural, engineering and energy services have to adapt their work to the particularities to the new building codes. Suppliers will adopt the necessary materials and technologies, and on-site execution has to rely on trained personnel for the implementation.

Figure 21: Value Chain of the Construction Sector



Source: BPIE (2016), p. 7, figure 2

Specialized construction activities as depicted by Eurostat, which are relevant for energy renovation, created a value added of € 278 billion in 2013 and employed 7.60 million people. The construction of buildings amounted to a value added of € 133 billion with an employment of 3.12 million.[37]

Global investments in NZEBs[38] in 2012 were estimated to under € 0.8 billion by HSBC (2014). BMUB (2014) estimates the global market for technology lines such as passive houses and EnergyPlus houses to € 6.2 billion in 2013 growing at a CAGR of 12.6 % from 2013 to 2025. The variability of these estimates illustrates that data on NZEB activity is incomplete and difficult to isolate. A study based on detailed documentation of more than 2,000 projects in 10 European countries estimates that in the best case in 2015 about 260,000 objects with passive house standard will be built or renovated (passnet, 2010). While so far most of the dwellings fulfilling NZEB standards are newly built, the renovation market is growing. According to EUROCONSTRUCT (2015) the share of repair, renovation and maintenance has reached 60% of the total residential construction market. Nevertheless, NZEB renovation has only a minor share in this market as the study of COHERENO (2014) suggests.

For newly built houses, larger building companies have the lead role in the value chain, offering building concepts often comprising all the necessary work. Regarding the renovation market, installers and other small enterprises have the lead role. Home owners as well as housing associations approach installers when something brakes or when they plan to do renovations and installers advise the owners and subsequently buy the necessary products from a wholesaler and do the installation or renovation work. Hence, the value chain for new NZEBs can differ substantially from the value chain of renovating towards NZEBs.

Some companies have specialized in the industrialized construction of new buildings like, for example, Sommarnöjen (SE), Riko (SL), Syspro (D), Huf Haus (D), and Plegt-Vos (NL) (BPIE, 2016, p. 24). The process of industrialized production is mature all over Europe and has available innovative solutions and competences like automated production lines, business models, cost optimization and sales service. Large players from the Heating and Cooling segment have also entered the market since heating technologies are the most important defining part besides the insulation of the building. Bosch Thermotechnik/Buderus placed an Energy Plus house on the market. More generally, collaborations of traditional constructors and equipment suppliers are becoming more common. In Germany, Heinz von Heiden GmbH (brick-built house producer), Azur Solar GmbH (Photovoltaic) and Stiebel Eltron GmbH & Co. KG (HVAC) launched the EcoStar INDEPENDA, whose energy consumption complies with the KfW-70 energy standard.

[37] Source: Eurostat, annual enterprise statistics, [sbs_na_con_r2]. Specialized construction activities refer to the aggregate F43, construction of buildings to F41

[38] NZEB standard was defined as having an energy consumption below 20 kWh/m^2 per year.

Besides suppliers, also specialized services are related to the value chain of NZEBs. Among them are certification providers such as the BREEAM (Building Research Establishment Environmental Assessment Method) in Great Britain. Since 1990 they award certificates for levels up to zero carbon houses. Most of their services are carried out in their home market where between 2000 and 2012 13.5% of new residential dwellings were registered by BREEAM. In Europe, BREEAM has a market share of 80 % in green building certification (BREEAM, 2014).

4.2 Assessment of the global environment

4.2.1 Main competitors outside the EU

Buildings' construction and renovation is essentially a local activity; hence competition from outside the EU does not play an important role. Competition occurs mainly for building components such as thermal insulation material or HVAC technologies. As reported in chapter 6/, Asia is the main competitor for Heating and Cooling equipment outside the EU. Regarding Thermal Insulation (see chapter 11/ on Thermal insulation), only one of the leading four companies is non-European and comes from the US.

In case a higher industrialization of the renovation segment with prefabricated modules is going to be built, competition will rise because generally production can be outside the EU. Nevertheless, products are large and need to be moved which is why local production is more likely.

Competition arises from global actors outside the value chain offering customer-oriented solutions (business-to-client, B2C) thereby making traditional intermediary players in the value chain redundant. These are huge American players like Google offering ICT for energy monitoring ("Google Nest Learning Thermostat") or Tesla who launched a home energy storage ("Tesla Powerwall").

4.2.2 Relative competitive strengths

The EU obtains a pioneering role in energy-efficient buildings. The Passivhaus standard exists since 1990 and the majority of global NZEBs so far have been built in the EU. Also regarding the interplay with renewable energies as well as measuring and monitoring technologies, Europe has comparative strengths. The EU has world leader potential in smart management systems necessary for the future NZEB which will likely be integrated into the energy market.

Another strength of the EU NZEB construction and renovation sector can evolve from the different climate zones in the EU. Since European actors have to develop solutions for diverse climates, they can in principle sell these solutions globally as outlined by an interviewee.

4.2.3 International trade performance

Box 5: International trade performance

This section investigates the EU-28's trade performance in the respective CI products with regard to the development in six competitive countries in America (USA, Canada, Brazil) and Asia (Japan, China incl. Hong Kong, India). Six trade indicators are analyzed to observe how the EU-28 and its Member States (MS) succeed in commercializing internationally competitive CI products. Those are significance (i.e. how important the specific CI products are in a country's total manufacturing exports), export market share (i.e. how important a country is for total global exports in the relevant CI), medium-term dynamics (i.e. how exports have changed within the pre-crisis years 2007/08 and 2013/14), trade balance (TB, comparing the absolute volumes of exports and imports), and two specialization indicators, namely export specialization (RXA, i.e. whether a country's global export share in a certain CI is higher/lower than its export share in total manufacturing products) and trade specialization (RCA, considering a country's relative export/import ratio of a certain CI compared to its total export/import ratio). Four of these indicators (export market share, significance, RXA and TB) are illustrated in the following chapter, the other two (medium-term dynamics, RCA) in Annex 8/.

It is important to note that the analysis comparing the external trade performance of the EU-28 in a regional perspective only considers extra-EU trade flows. Otherwise, analysis that compares single Member States with non EU countries has to consider extra- and intra-trade. Hence, the calculated export market shares and export specialization figures (RXA) differ according to the respective perspective. Figures on the country level can be found in Annex 8/.

High but declining comparative advantage of the EU in a still small market

In productions or trade analysis only one special part of NZEBs, namely houses built of wood and other environmentally friendly material (e.g. straw) can be considered, statistically included in "prefabricated buildings of wood"[39]. These houses are a common basis used for the construction of passive houses; nevertheless this position may also include wooden buildings that do not fulfill NZEB or similar criteria. Yet, the absolute trade volume of prefabricated buildings of wood is very small, indicated by very low significance values. In the EU-28, this sector only accounts for less than 1‰ of total manufacturing exports. The other represented countries depict similar (Brazil, US, China, Canada) or even still lower values (India, Japan) (see Figure 21).

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[39] PRODCOM code 16.23.20.00 respective HS code 94.06.00, including family houses as well as other residential and commercial buildings, and other buildings (e.g. summer houses)

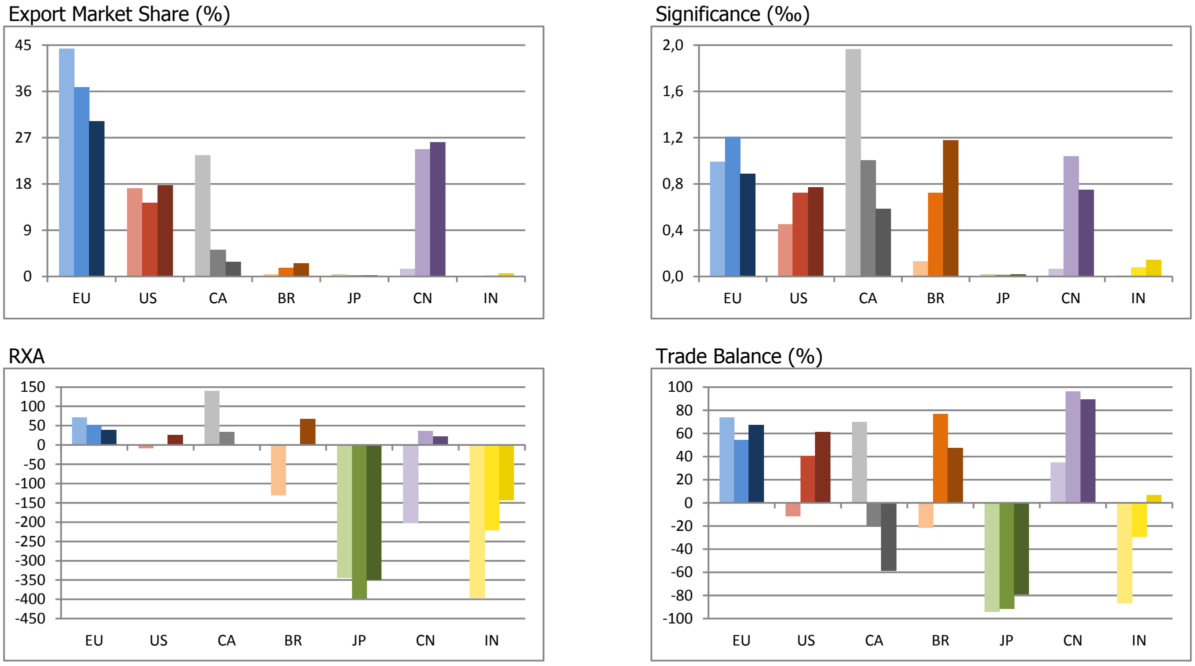
The EU-28 reveals high comparative advantages in the trade of prefabricated buildings of wood, indicated by high export specialization (RXA) and trade specialization (RCA) figures, a positive TB and the highest export share (about 30% of global exports in 2014). However, the EU's export position has mitigated over time, since its export volume 2013/14 hardly exceeds the level of 2007/08, whereas the US (with more than 8% p.a.) and China (4.5%) realized remarkable growth rates (Figure 22 and Figure 106 in Annex 8/).

China succeeded in superiorly extending its exports between 2002 and 2008, 2014 holding the second highest share (26%) behind the EU and prior to the US (18%) that has also improved its export performance (RXA) in those products over time (Figure 22). Also Brazil reveals a positive export specialization in prefabricated buildings with an export market share of nearly 3%. By contrast, Canada, also accounting for about 3% of global exports in 2014, has lost its former high comparative advantages and changed to a net importer in this field. Japan and India do not play any role in this global export market.

Smaller MS drive the export performance of the EU

Contrary to the other analyzed CI sectors, the on average still strong export performance of the EU-28 is not mainly driven by Germany (export market share 2014: 5.8%), but by other smaller MS, like the Netherlands (6.2%), the Czech Republic (4.0%), Sweden (2.6%), Finland (1.9%), and other Eastern and Southern European countries (Portugal, Poland, Hungary, Romania, Slovenia, the Baltic States, Croatia), all revealing above average export shares (RXA) and comparative trade advantages (RCA, TB; see Figure 107 to Figure 109 in Annex 8/). Indeed, the vast majority of MS are net exporters of prefabricated buildings of wood (positive TB; Figure 108). Besides Germany, also France, Great Britain, and Denmark reveal a comparably weak position. The good performance of high-tech countries like Sweden and Finland in the manufacturing of wood products is attributed to the availability of the whole value chain in these countries (large forests and a strong processing industry). On the other hand, the good trade performance of the Eastern and South Eastern Europe mainly depicts labor cost advantages that play a decisive role in low-tech industries like wood processing.

Figure 22: Trade indicators for the EU and selected other countries 2002, 2008 and 2014: Prefabricated buildings of wood



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

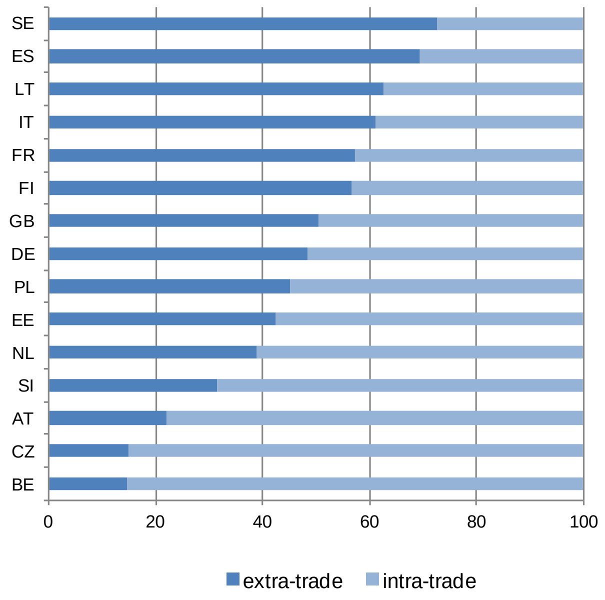
The stagnating export dynamics observed for the EU-28 above, is also reflected on the country level. Fifteen MS depict negative export growth rates between 2007/08 and 2013/14 (see Figure 109 in Annex 8/). Only the Netherlands, Austria and some small Eastern Member States (especially Estonia) could noticeably increase their export volume in this field.

Intra-trade is still dominating the exports of the MS, but non EU countries gain in importance

Most of the EU-28 trade of prefabricated buildings of wood happens within the community – in 2014 58% of the EU's exports refer to intra-trade and only 42% to extra-trade. Yet, the importance of external markets has significantly risen over time, since 2008 only 38% of the EU exports were designated to non EU countries.

Moreover, it is interesting to investigate possible differences on the country level. Figure 23 reveals that in 2014 half of the 21 MS with a global export market share of at least 1% reveal above-average extra-trade shares, with Sweden, Spain and Portugal on top with rates of about 70%. On the other hand, more than 80% of the exports from the Czech Republic, Belgium, Croatia, Romania and Hungary are designated to the internal market, indicating the intense division of labor and economic integration within the EU in the production of prefabricated buildings of wood.

Figure 23: Share of EU-Extra-trade and EU-Intra-trade (in %) in country exports: Prefabricated buildings of wood



Including EU countries with an export market share in 'prefabricated buildings of wood ' higher than 1% in 2014.
Source: UN COMTRADE-Database. – NIW calculation.

4.2.4 Market outlook

The building and renovation value chain in general but in particular due to the increasing role of energy efficiency up to NZEBs is predicted to change driven by several trends that started recently. Keift and Harmsen (2015) analyse the Dutch market for energy-efficient building renovation and conclude that installers and smaller contractors will likely lose their leading role in the value chain. Currently, installers and small contractors provide advice and perform the renovation work themselves. With the rise of renovation concepts using prefabricated products, renovation shops offering complete renovation solutions, energy cooperatives directly approaching clients, as well as wholesalers and product manufacturers taking over the lead role, installers and small contractors have to reposition themselves. This is an important market transformation since "the largest market value to capture in terms of renovation today is still represented by home-owners undertaking (stepwise) renovations by themselves" (BPIE, 2016, p. 27), which is so far linked mainly to installers and small contractors.

BPIE (2016) confirms this outlook beyond the Dutch case and estimates that installers will likely become sub-contractors of newly emerging actors. Moreover, they assume that producers of prefabricated new buildings are prone to enlarge their business towards production of prefabricated renovation modules to capture value. Countries with the best potential value to capture are Sweden, Germany and The Netherlands because they have a mature prefab construction market for new constructions and suitable building typologies for an aggregated prefab construction approach, such as (social) housing, apartment blocks and offices (BPIE, 2016, p. 27).

A sign that also large actors in the buildings value chain are reacting to the challenge to transform the building stock to low emissions buildings comes from the Prince of Wales's Corporate Leaders Group (LGL). During the Copenhagen climate summit they issued a statement committing to the GHG reduction and NZEB targets of the EU to foster these goals with the aim of increasing their business potential in the buildings' value chain. In the same line they demand public investments, effective carbon pricing and adequate financing schemes from policy makers. Main companies having signed are: Acconia, Doosan, Ferrovial, GlaxoSmithKline, Heathrow, Interface, Kingfisher, Lloyds Banking Group, Philips, Skanska, sky, Tesco, British Land, Hammerson, JLL, LandSecurities. These companies among others commit to reduce emissions and energy demand in their own properties.[40]

If the renovation rate were to increase to 3%, energy demand in the current building stock could be reduced by 80% by 2050 compared to 2005 levels as reported by BPIE (2016, p. 26). Potential revenues for the total construction sector are estimated to amount to around € 1,200-1,400 billion per year, which is a boost of ca. € 700-800 billion per year. If only prefabrication modules (material and equipment) are considered, which account for 25% of the total renovation cost, this still leaves an added value of around € 200 billion year.

However, the costs for deep renovation are an important aspect, which could also impede the market development. According to calculations by JRC (2015), costs below 200 €/m^2 for deep renovation of post-1945 built dwellings would be economically feasible only for France, the Benelux states, the UK, Ireland and the "younger" MS that have joined the EU since 2004. By contrast, unit costs of renovation are highest in Italy and Germany impeding large-scale renovation. Furthermore, even economically feasible costs may not be affordable for countries with per capita GDP below average in particular because these countries have a very high rate of owner-occupied buildings of more than 90 % (JRC; 2015, p. 57).

There is an important link between NZEBs and the energy market (see BPIE, 2015). Future buildings will be part of the smart grid; therefore their design should be adapted to this role. Besides producing renewable energy for their own use, buildings will become active players in the energy system with, e.g., building-to-building connections. Furthermore, links to electric mobility are foreseeable since the locally generated energy can be used to fuel electric vehicles instead of feeding it into the grid. To this end, technologies enabling demand response and power storage will also be increasingly needed. In the same line, an increase in demand for PV/solar thermal technologies as well as heat pumps can be expected since NZEBs require that the energy demand is met by energy produced mainly from renewable and nearby which makes PV/solar thermal systems and heat pumps a good choice.

40 Source: http://www.corporateleadersgroup.com/resources/pdfs/eu-industry-commitment.pdf/view.

4.3 Assessment of the competitiveness aspects

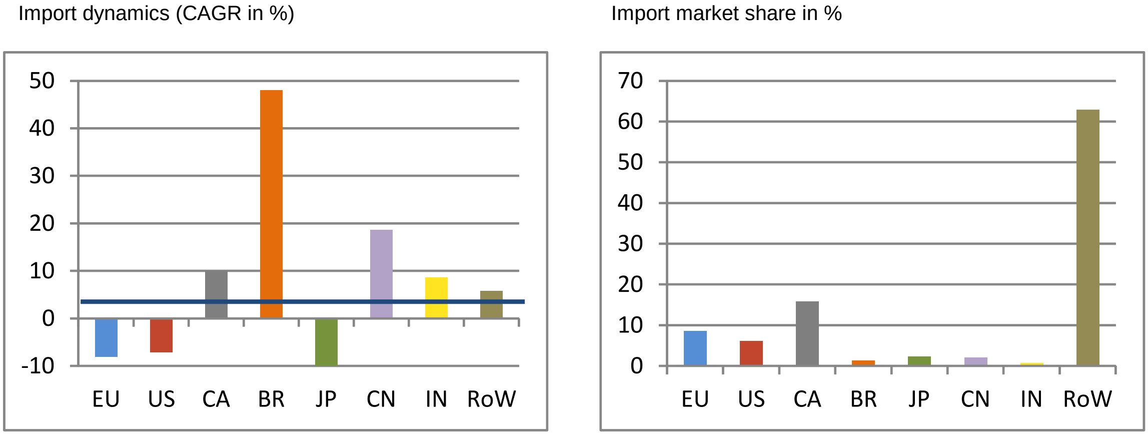
4.3.1 Export potential

Box 6: Export potential

Export potentials emerge primarily in those goods and activities, in which the EU-28 already holds comparative advantages (measured in export specialization or trade specialization). In these goods and activities, trade volumes can be used as an initial indicator for market and growth potential. Hence, growing import rates of third countries may serve as a proxy for an increase in demand for CI goods in a specific country or world region that may subsequently translate into a growing export market for the EU and its Member States. At the same time, existing export advantages (indicated by RXA values) of the EU and its Member States in certain products may indicate promising preconditions for further growth and export potential.

Figure 24 reveals the global import market shares of the EU (excluding intra-trade) in comparison to other selected countries and the rest of the world (RoW) in prefabricated buildings of wood used as an approximation for Passive Houses (see chapter 1.1.1.3). It indicates that more than 60% of the all in all comparably small import volume in 2014 is attributed to the RoW. Within the selected countries, Canada has been the largest single importer (16%). Compared to its structural weight in total manufacturing imports (3.9%), the country reveals a considerably high demand for those products. In contrast to this, the EU (9%), the US (6.5%), Japan (2.5%) and China (2%) depict rather low import market shares and, with the exception of China, in addition negative medium-term import dynamics. Also Brazil (1%) and India (0.5%) are falling behind. However, Brazil (48% p.a.) and China (19%), starting from a very low level, yield the highest import dynamics since 2007/08, indicating growing demand for prefabricated houses of wood. Otherwise, also a comparably lower growth rate connected with a higher absolute import volume, as can be seen in Canada (10%), can create considerable export volume for foreign manufacturers. Yet, Table 27 in Annex 1/ depicts, that the precondition of the EU on the Canadian market is rather weak, as can be seen by low export market shares and a highly negative export specialization (RXA). On the other selected markets, the EU mainly holds a strong or in the case of China a balanced export position in prefabricated wooden buildings.

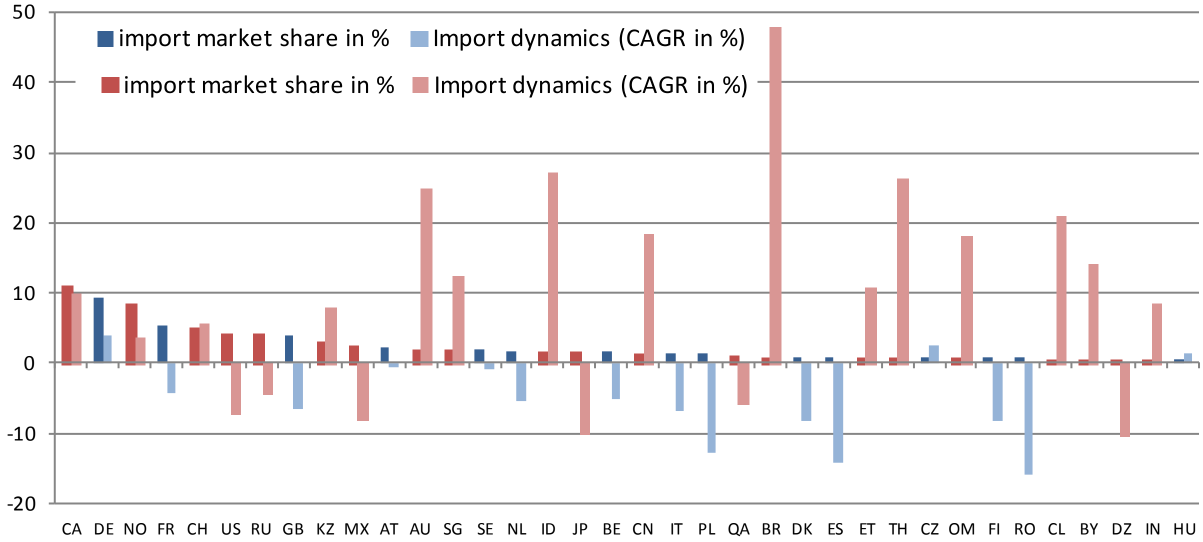
Figure 24: Import market share 2014 and import dynamics 2007/08 to 2013/14 of the EU-28 and selected non-EU countries: Prefabricated buildings of wood



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Considering the fact that almost 60% of the import demand for prefabricated wooden buildings in 2014 applies to other than the selected countries (RoW), which moreover showed an import dynamics of 6% p.a., it is reasonable to take a closer look at the import demand of this remaining group as well as the EU MS total (extra- and intra-EU-imports). Hence, Figure 25 illustrates import market shares and import dynamics for all countries with a global import market share higher than 0.5% in 2014. It depicts that Canada as the largest importer is directly followed by Germany and Norway, whose import demand has also increased over time. Furthermore, also other European (Switzerland, Kazakhstan) and overseas countries (e.g. Australia, Singapore, Indonesia, Thailand) constitute considerable import market shares and/or remarkable growth rates hence creating additional sales respective export potential for prefabricated wooden buildings (Passive Houses) manufactured in the EU.

Figure 25: Import market share 2014 and import dynamics 2007/08 to 2013/14 in prefabricated buildings of wood



Global imports including EU-intra-trade. - Regarding countries with a global import share higher than 0.5%. – EU MS: blue coloured; non EU countries: red coloured.
Source: UN COMTRADE-Database. – NIW calculation.

4.3.2 SWOT

The European NZEB sector (new buildings and renovation) provides quality solutions and is innovative regarding its processes. Due to the local character of building, it is in a strong position which is furthermore enhanced since the EU has comparative advantages in MON and renewable energies being an important ingredient to the implementation of NZEBs. Comparative advantages in international trade can be shown to exist for prefabricated houses of wood. Demonstration projects have furthermore shown that large-scale deep renovation is possible.

Nevertheless, the structure of the sector comprising mainly micro-enterprises impedes innovation on the product level and is not offering sufficient product-service solutions. The low level of collaboration and also the low level of training can impede efficient advice regarding the whole construction sector which is necessary to avoid lock-ins and stimulate demand for energy-efficient renovation. Moreover, the sector was hit hardest by the economic crisis and is still recovering.

The stronger regulation of buildings in the EU is likely offering a growth opportunity for the sector especially regarding the renovation segment. A shift towards larger industrialization in particular of renovation components will lower costs of deep renovation and increase demand as well as a strong export position. In addition, integration of buildings into the smart grid can be encouraged in the course of new built NZEBs and renovation to NZEB standard advancing the European grid development.

The sector is threatened by the restricted lending in particular to SMEs. Moreover, shifts in the value chain are foreseeable so that installers and small contractors will have to reposition themselves in the newly arising business models and are likely to lose their advising role. High rates of owner-occupied buildings in countries with below average GDP per capita depict a threat to the decarbonisation of the EU building stock since financial constraints are naturally larger there. Finally, still incomplete definitions of NZEBs in some MS provide investment insecurities and a single definition of NZEBs for a small region only can be a hurdle since markets may be too small for operating profitable.

Overall, strengths and weaknesses as well as opportunities and threats seem to balance each other. It is therefore important to push the sector's development and reorganization in such a way as to reinforce strength and seize opportunities, in particular increasing the number of deep renovations to NZEB level.

Table 13: SWOT for the NZEB sector

Strengths	Weaknesses
▶ Local character of construction sector ▶ Interviewed expert highlights quality of solutions provided by EU companies ▶ Building automation related to MON and renewable energies where the EU has high comparative advantages are parts of the NZEB ▶ The EU has a high comparative advantage in the trade of prefabricated houses of wood mostly driven by smaller MS (NL, CZ, SWE, FI) and other Eastern and Southern European countries ▶ Demonstration and publicly funded projects such as the "Stroomversnelling" project in the Netherlands show how refurbishment at larger scale is possible ▶ Enterprises are good at process innovation (BPIE, 2016)	▶ EU companies provide no product-service solutions and generally have a low professionalism of services as indicated by an interviewed expert ▶ 94% of enterprises in the buildings sector are micro-enterprises (at most 9 employees), which are known to be less innovative regarding products (BPIE, 2016) ▶ Specialized installers miss the resources to train their employees to offer whole-building-advice (Kieft and Harmsen, 2015) ▶ The sector is not enough attractive for young job seekers (low professional level, hard work) ▶ Construction sector was hit hard by the economic crisis, still recovering ▶ Low level of collaboration in the sector (BPIE, 2016)
Opportunities	**Threats**
▶ The sector is likely to benefit from the regulation regarding buildings increasing the need for renovations ▶ Off-site industrialization of the construction of prefabricated building elements for the	▶ More restricted lending to SMEs after economic crisis, stricter requirements for loans ▶ Installers and smaller contractors are threatened in their leading (advising) role in the renovation sector: likely to become sub-

renovation market; lower labour costs are to be expected lowering the overall (and still too high) costs of deep renovation ▶ The role of buildings as an active part of the smart grid can be supported during the process of building and renovating to NZEBs ▶ Export position of the EU is strong in the selected comparison countries except for Canada and in selected other European countries such as Switzerland and Kazakhstan ▶ Change of the traditional value chain may enable the sector to attract young job seekers as well as job seekers with higher degrees (increasing technical and knowledge requirements) an interviewee indicated ▶ In 2016 the Commission will review the EPBD and the EED; define additional measures on energy efficiency in buildings needed to meet the 2030 targets	contractors of newly entering actors (BPIE, 2016; and Kift and Harmsen, 2015) ▶ EU-28: 70% live in owner-occupied dwellings, D: 52%, RO: 96%[41], hence renovations and retrofits from individual owners is a very important topic, but since the highest owner-occupied shares are in countries with below average per capita income in the EU, financing constraints are likely to be ▶ Some MS still have no definition of NZEBs; since planning for (in particular public) buildings starts already very soon, an interviewed expert rated this essentially as a market failure which leads at least to investment uncertainties ▶ Smaller member states and region-specific definition of NZEBS (e.g. in Belgium) could be a threat to local companies since their market with specific NZEB solutions may be too small

4.4 Analysis of barriers

While cost reduction of NZEB new built remains an important aspect, the refurbishment of the existing building stock to NZEB level might be the main challenge. Regulations regarding the transformation of existing buildings into NZEB will probably interfere heavily with ownership rights. MS have been ascribed to make progress with respect to the introduction of measures aiming at the transformation of the building stock. But although in line with the EPBD requirements, these measures only rarely refer to clear definition of an NZEB renovation (Castellazzi, Zangheri, Paci, 2016), which can be seen as a major barrier.

Regarding the barriers of refurbishment to NZEB level there are barriers to the supply as well as to the demand side.[42] Considering the demand side, the most important is clearly financial. It involves the generally high upfront

[41] Data source: EU-SILC 2013, [ilc_lvho02].

[42] Regarding in particular the demand side barriers Bürger (2013), in the course of the ENTRANZE project, reports on these in detail additionally differentiating between different owner structures of buildings.

costs as well as difficulties to access capital, the cost of capital and the unwillingness to take up a loan. Another demand side barrier of high relevance, although with varying degree at the MS level, are high shares of owner-occupied dwellings. This goes along with many refurbishment projects being staged do-it-yourself not necessarily aiming at a deep level of renovation and possibly causing lock-in effects. The income distribution between and within MS suggests that "there are some segments of the population for whom loans will never be appropriate and the public sector will need to substantially fund these renovations" (EEFIG, 2015, p. 34). In particular, those MS where the share of owner-occupied buildings is highest are countries with below average per capita GDP in the EU such as Romania and Bulgaria. Different strategies will therefore be needed to address the financing constraints in different MS.

Other very important demand side barriers are the lack and/or mistrust of information as well as missing quality guaranties of accomplished works. Kieft and Harmsen (2015) list mistrust of home owners towards energy companies and installers as a barrier to energy-efficient renovation of buildings. The mistrust may well be related to the issue of quality. Overall, the construction companies, installers and other related actors have a bad reputation regarding quality and this can be seen as a "gigantic market barrier for NZEBs". This lack of quality pertains to products, design, execution as well as monitoring. The low collaboration between different actors in the sector complicates the matter since all quality aspects are related to different actors in the system as highlighted by an interviewed expert.

National Energy Performance Certificates (EPC) schemes have created a demand-driven market for energy efficient buildings by providing information on their energy performance. However, the role of the EPC recommendations in informing on effective ways to improve buildings and building systems through renovation works, hence stimulating higher renovation rates (not necessarily to NZEB), has been limited. This could be due to lack of enforcement of good quality EPC schemes and to the absence of appropriate accompanying measures in some MS.

On the supply side there are three main barriers to the major uptake of refurbishment to NZEB level. The most important barrier is the lack of a defined and easily identifiable product which is visible to the consumer. In this line there is a need to bring nearer to the market ready-made or off-the-shelf (available) solutions, possibly based on 'one-stop-shop' approach for the consumer (e.g. integrator or market player) that integrates the results of all the involved trades/parties and a sufficient coverage of demonstration of success stories at 'business case' level for the different categories of buildings. This would imply 'new' profiles of companies whose core business would be similar to the one of an ESCO (e.g. ESCO for refurbishment to NZEB level) with commitments on the energy performance results ex-post (e.g. EnPC, Energy Performance Contracts). This could inspire and build on similar and existing approaches like 'turn-key' contracts in the industrial sector (e.g. conventional power plants contracts signed in the last decades) that might as well cover obligations under the operational phase.

Secondly, and as mentioned at the outset, the sector's main actors primarily consist of small companies (contractors and installers) lacking the resources for larger product innovations and often also lacking knowledge on holistic refurbishment approaches. Thirdly, the non-existing formulation of a mandatory renovation target is a barrier to a large scale energy renovation. Particularly private owners have no guidance as to which energy saving level they should invest.

Besides, there is a high amount of red tape hindering renovation incentives. For example, spatial planning regulations regarding the look and size of buildings may impede certain renovations because these would not fit the regulations. Moreover, MS-specific definitions of NZEBs can provide additional regulation barriers especially in smaller countries or regions like in Belgium where three different NZEB definitions exist. Regarding the production of prefabricated components, lack of harmonization is also an issue. Experts argue that multinational players can adjust their production lines. Smaller companies may, however, do not have the resources to do so.

4.5 Suggested actions

Large-scale market uptake of refurbishment to NZEB level is the key to address most of the barriers since it above all involves a cost reduction of deep renovation. To reach this goal, the above mentioned barriers have to be addressed in the best way. Since it is beyond the scope of this report to provide a detailed discussion of each possible policy measure as in Bürger (2013), we concentrate on the most promising measures that aim for an increase in the refurbishment rate while at the same time securing sufficient depth of the renovation to reach the NZEB level[43].

The first option is mostly regulatory in character and addresses demand side reluctance. It is deemed attractive to tie refurbishment obligations to the change of ownership. Such a measure resolves several of the existing barriers at the same time. So far, refurbishment obligations are used sparely since they always are a restriction to ownership rights. This issue would be mitigated when it comes at the time of purchasing property. Often, renovations are carried out anyway after purchasing property. Regarding the barriers related to financial constraints, unwillingness to take up a loan for refurbishment is met by the fact that purchase of property mostly goes along with taking up a loan anyway. Hence the suggested measure timely fits into this window of opportunity. Of course, the financial burden can be much higher when purchasing and refurbishment fall into the same time horizon. This can be cushioned by measures like preferential loans. The suggested measure also mitigates the well-known owner-tenant dilemma where it is unclear how costs and benefits of a refurbishment project shall be shared between the owner and the tenants paying the energy bill. In case that refurbishment is done right after purchasing of property, it is still likely that an owner not wishing to occupy the property himself will pass on occurred costs to tenants. Still, the conflict is more severe in case of a refurbishment project started during an ongoing rental contract. If the NZEB level cannot be targeted within one renovation project, a staged renovation plan has to be agreed upon (possibly in the course of the purchase agreement). In case the building is sold before the NZEB level is reached, the next owner again is required to refurbish it. The suggested measure will have different impacts across MS dependent on the property markets and the share of owner-occupied

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43 Further options for increasing the effectiveness of the measure are discussed by many respondents to the public consultation under the review process, i.e. better linking NZEBs with EPCs, making NZEB a specific certification class, and with finance, referring to NZEB in financial support schemes.

buildings. But even for countries with high shares of owner-occupied buildings, the suggested measure will likely lead to annually rates of renovation higher than the current one of about 1 %.

Another suggested action refers to energy performance contracting (EnPC) as a kind of financing deep renovation. An EnPC involves that a contractor finances and conducts a refurbishment measure while owners pay on a regular basis like on their energy bill. The contract is profitable via the occurred cost-savings that over an agreed period are assigned to the contractor. EnPC addresses the main demand side barriers: owners shy away from high upfront costs and are unwilling to take up a loan. The important aspect of the measure is that EnPC has to be combined with the NZEB target. This so far has been observed to be difficult since deep renovation incurs very long-term payback periods. Therefore the market for EnPC in this respect is not developed since short-term profitability is missing (see also Labanca et al., 2015). It is conceivable that here, public support can help to create that market. As Fawkes (2013) stresses, EnPC was initially used in the US with municipal debt as financing. The slow uptake in Europe[44] is explained with the missing low-cost and long-term financing. This could be provided by public authorities at any level. Labanca et al. (2015) name local governments or social housing organizations as potentially taking the lead in stimulating diffusion of contracting models. Financing is possible via different ways. With the aim to trigger a higher rate of refurbishment a carbon tax as present in some Scandinavian countries would put additional pressure on owners' investment decisions. Without elaborating on a detailed tax system, the introduction of additional levies on carbon emissions increases prices for energy from fossil sources and hence provides a means to reduce the use of fossil fuels.

In principle, this suggested action can be combined with the first one. Importantly, introduction has to be accompanied with a large scale information campaign raising awareness and highlighting the stabilizing role of governmental support. A specific form of EnPC was the Green Deal in the UK (already ended). It had the desirable feature that the loan was tied to the property, not the owner so that change of ownership or tenancy was not providing any additional conflicts of interest.[45] Another favourable aspect of the EnPC kind of measure is that collaboration of small actors in the renovation sector is encouraged and new networks are likely to be built and small actors do not carry the risk of large projects. Moreover, collaboration can be levered in case more standardized protocols and software for modelling purposes is used (BPIE, 2016).

A best practice example has been found to exist in the Netherlands. The "Stroomversnelling"[46] project brings together demand and supply side to reach large-scale renovation to NZEB level. Social housing corporations have

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44 So far, EPC is mostly used in the non-residential sector and mature only in some countries. The EU-funded project Eurocontract aims to identify common best practice for EPC in Europe.https://ec.europa.eu/energy/intelligent/projects/en/projects/eurocontract. Labanca et al. (2015) summarize market maturity and promising contracting types across the EU as well.

45 http://www.greendealinitiative.co.uk/

46 http://www.stroomversnelling.net/

agreed to reach an energy efficiency label B of their building stock by 2020, implemented as a fast renovation using prefabricated modules (see BPIE, 2015a, for details). Without going into details, the favourable features of the project are that a large-scale demand is generated and innovative concepts of prefabrication for deep renovation are developed. Across a series of similar projects, costs per building go down quickly creating competitiveness in the mass market. Recently the project is also extended to privately owned single houses and is also carried out in the UK. Payback is without additional costs to tenants who contribute to pay their usual rent and initial funding is provided by a social bank. Hence, this project is similar to the proposed EnPC measure with public support. It is in particular deemed possible, that an initial project like "Stroomversnelling" - bringing together demand and supply side at larger scale - is able to create a demand for EnPC on the larger level, especially when such demonstration projects enable to reduce costs.

Generally, the market for energy renovation seems to sustain mainly moderate renovations so far. As JRC (2014) shows, existing national policy instruments[47] that were made use of in 2013 were mainly targeted at minor and moderate renovation. This evaluation is in line with the estimation of Castellazzi, Zangheri, Paci (2016), where a missing definition of NZEB renovation is assigned to most of the MS National Plans. Therefore policy instruments should put more emphasis on deep renovation. Furthermore, 80% of the financial support instruments were unrelated to the ambition level of the renovation. There is hence a lot of scope to enhance renovation depth by adapting the design of financial instruments. Moreover, assessment of the results did not happen in one third of the examined cases and only in 27% ex post. Policy instruments should therefore be tailored more to (ex-post) performance, in particular to prevent windfall gains, which have been shown to be of relevant size (Steinbach, 2015).

Up to now, several Member States have adopted tax incentives for energy renovations and taxation mechanisms as a tool to support building renovations towards deeper, NZEB levels. It is also worth mentioning that the Commission is launching the Smart Finance for Smart Buildings Initiative, as a part of its Energy Union Strategy and "Energy Efficiency Package" in 2016 with the view of pursuing the mobilisation of private capital financing, also unlocking the investment potential towards NZEB[48].

[47] See: https://ec.europa.eu/energy/en/topics/energy-efficiency-directive/buildings-under-eed

[48] The Initiative contains investment-related measures embedded in the review of the Energy Efficiency Directive and Energy Performance of Buildings Directive and complementary measures along three key pillars: i) Better use of public funds, ii) Aggregation and assistance and iii) De-risking.

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5/ Advanced manufacturing technologies

Figure 26: Presentation of the selected priority sectors within the Clean Industry taxonomy

5.1 Description and value chain

Advanced manufacturing technologies (AMT) have been identified along with five other technologies in 2009 as Key Enabling Technologies (KETs) for the EU. KETs are characterized by a high economic potential, through their core industries as well as their enabling role for a wide range of products and services, as well as a high R&D and capital intensity. Specifically, Advanced Manufacturing Technologies are defined by the EU Task force on advanced manufacturing as "manufacturing technologies and production processes which have the potential to enable manufacturing industries to improve productivity (production speed, operating precision and energy/materials consumption) and/or to improve waste and pollution management in a life-cycle perspective".

AMTs play a dual role in the transition towards a green economy. Firstly, improvements in terms of energy and material consumption in the process they execute provides a direct environmental benefit. Secondly, by enabling novel product characteristics, AMTs indirectly support environmental benefits in downstream industries. It interesting to distinguish in this respect between applications inside and outside the field of renewable energy. In the field of renewable energy, the role of AMT is evident as it enables the production of clean energy technologies. For example, the production of solar panels overlaps partially with semiconductor manufacturing and has benefitted greatly from evolutions in this area, making photovoltaics based energy production cost competitive nowadays. Similarly, advances in several of the complex components of wind turbines have been enabled by better material processing technologies.

Outside the renewable energy domain, AMT has a major impact as well. For example, advances in fuel injection nozzles that have resulted in major improvements in automobile fuel consumption (enabling the switch from port fuel injectors (PFI) to the more efficient gas direct injectors (GDI) engines), have been enabled by developments in the femtosecond laser field. As another example, 3D printing is being applied in the aerospace industry in order to save weight and hence transport fuel costs49. As the environmental benefits enabled by AMT cut across many different sectors and applications they are hard to fully quantify, yet it is clear that the AMT sector will be a cornerstone in the transition towards a more sustainable economy.

In order to illustrate the variety contained by the AMT sector, a summarising taxonomy with a multitude of concrete example of AMTs has been developed in the context of the KETs Observatory project, which is presented in Figure 110 in Annex 9/ to this report. Considering the wide variety of technologies understood under AMT, this report focuses on general trends observed across different AMTs, but provides examples from various specific value chains.

A generic value chain for AMT is drawn in Figure 27. The first phase in the value chain is the supply of raw materials, which include basic materials such as plastics, steel, aluminium etc., but for several applications such as laser based processing also includes specialty materials such rare earth metals. The second step in the value chain concerns the system components, including low, medium and high complexity components. The precision and reliability, especially of the high complexity components, greatly affects the overall performance of the system, and the production of these components is typically done by specialised suppliers. The third part of the value chain concerns the integration of different components to generate an operational system. Considering the high demand for precise and stable production flows, maximal coordination of the different working components is necessary through system design and operating software.

When finalised, AMTs are deployed by industrial clients for production. Some of key user industries of high tech equipment include automotive, aerospace and electronics. While strictly speaking not part of the AMT value chain, it is also important to keep track of this as well for AMT the ties with their clients are very strong, and the success of AMT also critically depends on uptake by downstream industries, as will be elaborated further on in this chapter.

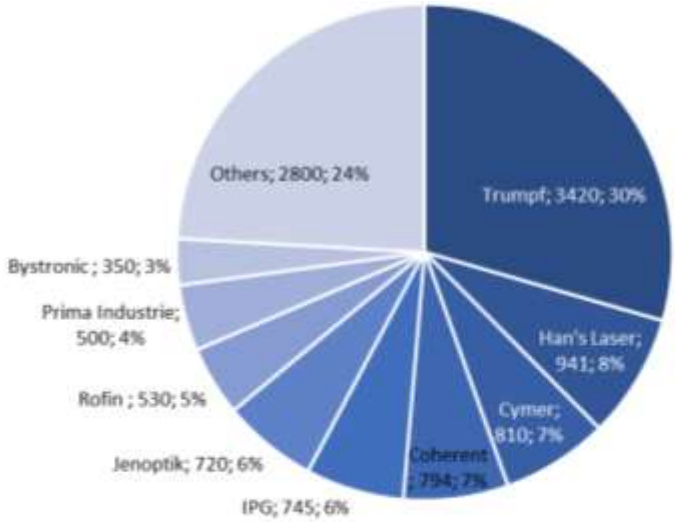
Figure 27: AMT value chain

[49] See e.g. http://www.airbusgroup.com/int/en/story-overview/Pioneering-bionic-3D-printing.html

The solid international position of the EU is demonstrated by its market share in international AMT related export. As will be discussed in more detail in section 5.2.3, Europe holds a considerable higher market share than the main competing regions. It represents 29.7% of global exports in 2014, well ahead of Japan (24.7%) and the US (18.6%). It is also a strong net exporter of AMTs, as illustrated by its highly positive trade balance.

It is worthwhile to look in more detail into performance in some specific AMT markets underlying this overall result. One of the best EU performances is observed in the laser processing market. The major laser companies providing laser systems engaged in material processing are shown in Figure 28. Except for Han's Laser and Cymer Laser, all the companies displayed in this figure have a strong design and manufacturing presence in Europe. Key in this market is the capability to adapting the laser system to the specific process of the customer, which according to EPIC is also the phase is the value chain where most value added can be reaped[50].

Figure 28: Major laser systems providers (name; revenue, market share – adopted from EPIC[51])

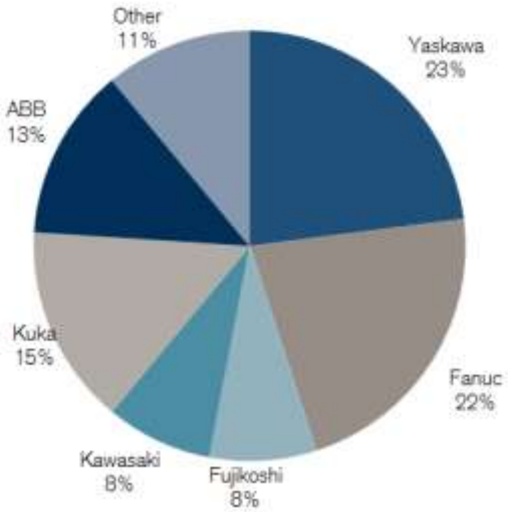


In the robotics market, Europe is also well represented with two companies among the top 5: Kuka, based in Germany, and ABB, based in Switzerland but with activities across the EU (Figure 29). They were estimated to present together about 28% of the market. In addition, the EU also hosts some smaller robotics companies, active in particular on the automotive market, such as Dürr (DE) and Comau (IT).

50 European Photonics Industry Consortium (EPIC) (2015) – The European Laser Ecosystem

51 European Photonics Industry Consortium (EPIC) (2015) – The European Laser Ecosystem

Figure 29: Industrial robots market share, 2011[52]



As for the semiconductor equipment market, ASML (The Netherland)s holds a solid position, as witnessed by its market of above 80% in the photolithography segment[53], making it the second largest player in the overall semiconductor equipment market, just after Applied Materials (US), both realising around 16% of the overall market[54]. In addition, ASM international (based as well in the Netherlands) is also a global player in semiconductor equipment.

5.2 Assessment of the global environment

5.2.1 Main competitors outside the EU

Overall speaking, major competitors are mostly based in the USA and Japan. This is related to the presence of major customer industries of AMTs such as automotive and electronics sector in these countries, as well as the strong R&D&I capabilities of these countries. Notably in the robotics market Japanese companies are very well

[52] Credit Suisse (2012). Global Industrial Automation.

[53] https://staticwww.asml.com/doclib/investor/asml_8_Investor_Day-Financial_Model_WNickl.pdf

[54] http://www.gartner.com/newsroom/id/2701117

represented, a result from their long tradition and strong technological position in the development of robotics. In the semiconductor equipment market, all non-EU companies based in the top-10 are either US or Japan based.

In addition to this, countries such as China, Taiwan and South Korea also have significant activity in AMT. Interviewees indicated that many of these companies are situated at the beginning of the value chain as they deliver raw materials, parts and components at much more competitive prices than European companies

However, as will be elaborated further on, emerging economies have so far not managed to penetrate AMT market as they have for example done in the electronics market. This is related among others to the fact that economic success of new AMTs strongly rests on a deep understanding of the challenges and requirements in the clients' markets which typically needs a long market experience and close interaction with clients. In this respect, AMT markets are harder to break into by outsiders.

5.2.2 *Relative competitive strengths*

Being competitive in the AMT market, which involves the fabrication of complex systems, requires being capable of integrating different technologies such as electronics, photonics, advanced materials into a functional system. The design of these machineries requires in-depth knowledge of different technologies, including managerial capacities to design complex innovation processes that involve experts from different fields. European companies have demonstrated being capable of delivering world-class equipment, and to continuously being able to deliver innovations to the market. Hence, the key competitive strengths of the EU are the R&D and innovation aspect of the value chain. Certain photonics based segments of AMT are known to have very high R&D intensities, in the order of 9-10%[55]. A recent study shows that companies in laser related value chains have higher R&D intensities than companies from other industrial segments[56].

Supporting this solid R&D capabilities of EU companies is the technical skills available at RTOs and universities and the good collaboration between knowledge centres and industry. Moreover, the emphasis on rigorous mathematical and scientific curricula in education makes available highly skilled personnel for the AMT industry. The strong technological position of the EU is demonstrated in patent statistics. As can be seen in Figure 30, the EU has held continuously over 40% of new patents application in AMT over the period 2000-2011, while shares of North America and East-Asia are below 30%. Overall speaking, the EU market shares appear to be rather stable over time.

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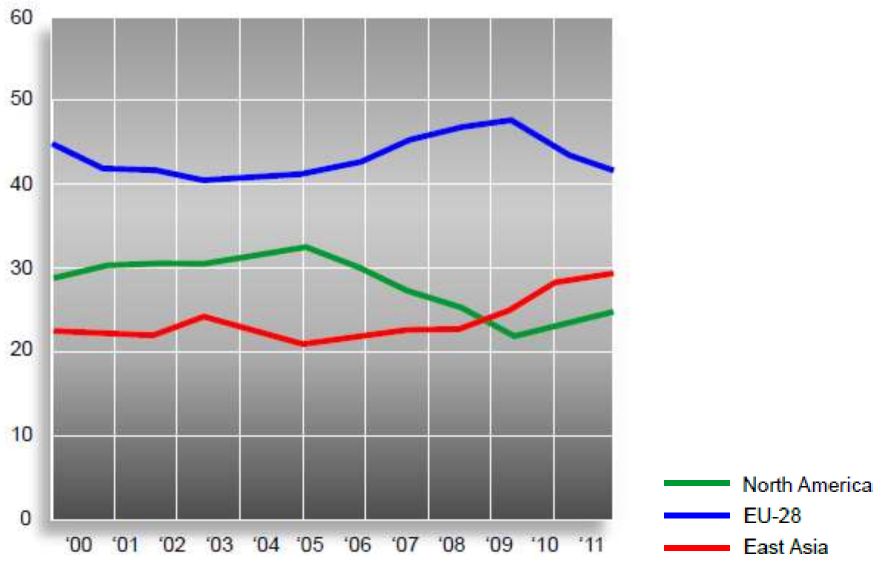
[55] Spectaris, VDMA, ZVEI, BMBF (2013). Photonics industry report.

[56] Van de Velde, E., Debergh, P., Greeven, S. (forthcoming). Study on Assessing innovation capability of EU companies in developing Advanced Manufacturing Technologies. Study for the Joint Research centre- Institute for Prospective Technological Studies.

Figure 30: Share in total patenting in Advanced Manufacturing Technology (in %)[57]



Apart from the technical capabilities, EU companies have also have the advantage of a strong history in AMT. Apart from integrating different technologies into high performing systems, economic success of new AMTs also rests on a deep understanding of the challenges and requirements in the clients' markets which typically needs a long market experience and close interaction with clients. Compared to competitors from emerging markets, EU companies hence have the advantage of the incumbent, and can rely on a dense network of AMT producers and users. Especially for end user industries that are well represented in the EU such as automotive, an extensive network of high-tech suppliers has developed.

Illustrative of the strong ties between AMT producers and users is the microelectromechanical systems (MEMS) industry, a subfield of the electronics industry which is focused on integrating a mechanical micro component with an electronic unit, leading to smart electronics such as sensors used in automotive (e.g. pressure sensors) or consumer electronics (e.g. accelerometer responsible for screen rotation of smart phones). Processes in this industry are very products and company dependent, and require significant degree of developing and testing. Once operational, equipment from one supplier is unlikely to be substituted by equipment from a competitor unless in case of very major deficits, as the costs of changing to other equipment are very high.

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[57] KETs Observatory first annual report

In this respect is the geographical location of AMT users very important, and the relocation of users to other regions can break the incumbent advantage of EU companies creating instead a physical and cultural distance to potential buyers. An interviewee indicated that when companies move abroad the main reason for that is not so always a matter of high labour costs in the EU, as is often assumed, but to be closer to their clients.

5.2.3 International trade performance

Box 7: International trade performance

This section investigates the EU-28's trade performance in the respective Clean Industry products with regard to the development in six competitive countries in America (USA, Canada, Brazil) and Asia (Japan, China incl. Hong Kong, India). Six trade indicators are analysed to observe how the EU-28 and its Member States (MS) succeed in commercializing internationally competitive Clean Industry products. Those are significance (i.e. how important the specific Clean Industry products are in a country's total manufacturing exports), export market share (i.e. how important a country is for total global exports in the relevant Clean Industry), medium-term dynamics (i.e. how exports have changed within the pre-crisis years 2007/08 and 2013/14), trade balance (TB, comparing the absolute volumes of exports and imports), and two specialisation indicators, namely export specialisation (RXA, i.e. whether a country's global export share in a certain Clean Industry is higher/lower than its export share in total manufacturing products) and trade specialisation (RCA, considering a country's relative export/import ratio of a certain Clean Industry compared to its total export/import ratio). Four of these indicators (export market share, significance, RXA and TB) are illustrated in the following chapter, the other two (medium-term dynamics, RCA) in the Appendix.

It is important to note that the analysis comparing the external trade performance of the EU-28 in a regional perspective only considers extra-EU trade flows. Otherwise, analysis that compares single Member States with non EU countries has to consider extra- and intra-trade. Hence, the calculated export market shares and export specialisation figures (RXA) differ according to the respective perspective. Figures on the country level can be found in the Appendix.

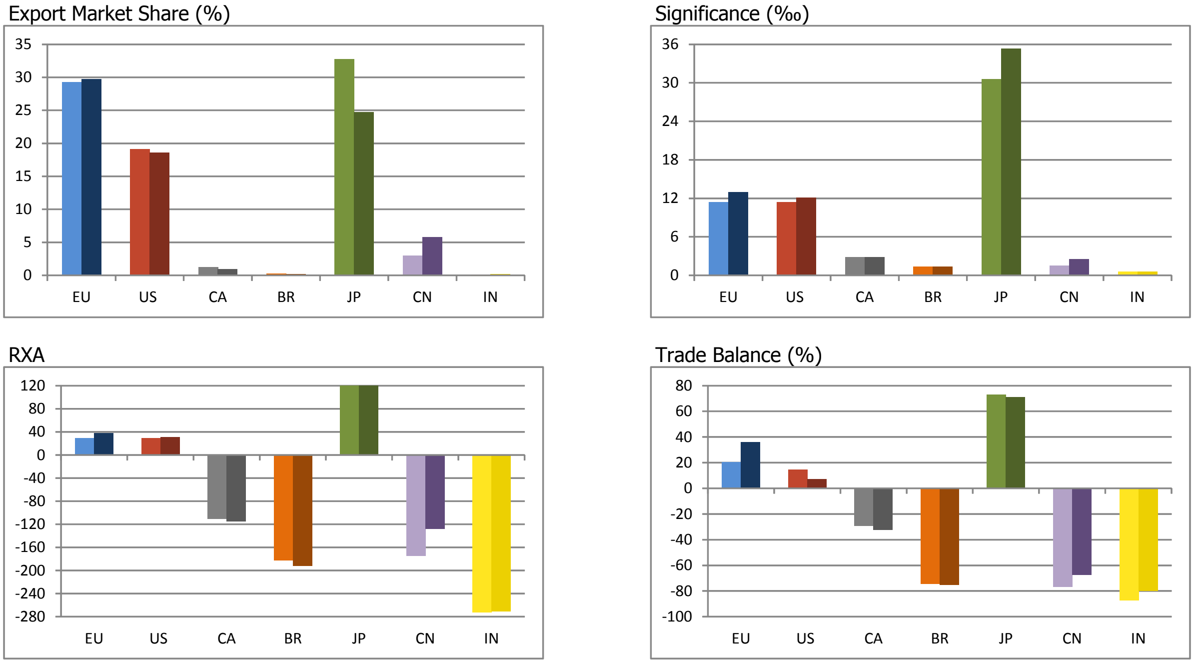
High and growing comparative advantage for the EU in AMT trade

Trade analysis for AMT shows a clear comparative advantage of the EU-28, realizing high export specialisation (RXA) and trade specialisation (RCA) figures. Furthermore, the EU-28 has the highest export market share (29.7%) of global exports in 2014 ahead of Japan (24.7%) and the US (18.6%). The strong export position of the EU in AMT is underlined by the positive trade balance that has increased by nearly 16 percentage points between 2008 and 2014 and the positive medium-term dynamics (5.3% p.a., see Figure 31 and *Figure 111* in Annex 10/). The EU's significance of AMT exports in total exports applies to nearly 1.3%, similar to the US (1.2%), but significantly less than in Japan (3.5%).

Moreover, the EU's export (export market share, RXA) and trade specialisation (RCA) has further improved since 2008 (Figure 31 and *Figure 111* in Annex 10/). By contrast, Japan depicts a stagnating export growth between 2008 and 2014 and has significantly lost export market shares on AMT markets during this time period. In this case, the still improved specialisation figures indicate that Japan's trade performance for other manufacturing goods has even more deteriorated over time. On the other hand, the US could approximately hold its export position, but has to face higher import competition on the domestic market (TB, RCA).

As indicated earlier, economic success of new AMTs, that include mainly smart machineries and production systems, requires a deep understanding of the challenges and requirements in the clients' markets which typically needs a long market experience and close interaction with clients. This may explain why emerging countries face more difficulties in establishing a competitive AMT industry as compared to more standardized products (e.g. electronic components). Hence China still holds a comparably weak export position in AMT (export market share: 5.8%, negative RXA) and is a clear net importer of those products (TB, RCA), although its exports have increased significantly over time (16.8%). Canada, Brazil and India are also net importers of AMT and only play a very minor role in the global production and export of these products.

Figure 31: Trade indicators for the EU and selected other countries 2002, 2008 and 2014: AMT



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Also other sources indicate a strong trade performance by the EU. According to CECIMO did the EU machine manage to increase its global production share in 2012-2013, and maintained this level in 2013-2014[58,59]. Also for 2015, the trade figures are positive, as exports grow with about 2% despite declining demand in Asia and Russia[60].

Outstanding performance of Germany, the Netherlands and Austria

Out of the EU-28 countries, Germany has the highest export share (2014: 16.7%) ahead of the Netherlands[61] (7%) and Italy (3.7%) followed by Great Britain (2.6%), France (2%) and Austria (1.7%; see *Figure 111* in Annex 10/). Only Germany, the Netherlands and Austria reveal an above average export share in AMT products (RXA), but a larger group of MS are net exporters (TB) and depict a comparative trade advantage (RCA): besides Germany, the Netherlands and Austria this also applies to all larger exporting countries (with an export share of at least 0.5%) except Belgium, Hungary and the Czech Republic (*Figure 111*, *Figure 112*, *Figure 113* in Annex 10/) In the Netherlands (1.5%), Germany (1.3%) and Austria (1.2%), AMT products also apply for the highest shares in each country's total manufacturing exports. In the other MS, the structural weight of AMT related products is comparably low (*Figure 112* in Annex 10/).

All MS with the exception of Sweden and Malta managed to increase their AMT exports in the medium term (see Figure 113 in Annex 10/). Starting from a very low level, especially several Eastern European MS as well as Portugal succeeded in expanding their AMT exports impressively.

Exports are mainly attributed to non EU countries

Contrary to total manufacturing goods and most other Clean Industry products (except Measuring and Monitoring and Traffic Control Systems), the intra-EU-exports share of AMT is comparably low (37% in 2014). On average, 62% of EU exports are designated to non EU countries, indicating that the export potential for those products in other world regions is particularly high and moreover, has significantly risen over time: in 2008 the share of intra-trade still accounted for 45% of total EU AMT exports.

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[58] CECIMO (2013). Press release: The European machine tools share of the global production is increasing - Trade shows offer good prospects. http://www.cecimo.eu/site/publications/news/?tx_ttnews[tt_news]=110&cHash=c3f4640ec7bd0cc8182b787abfb087d1

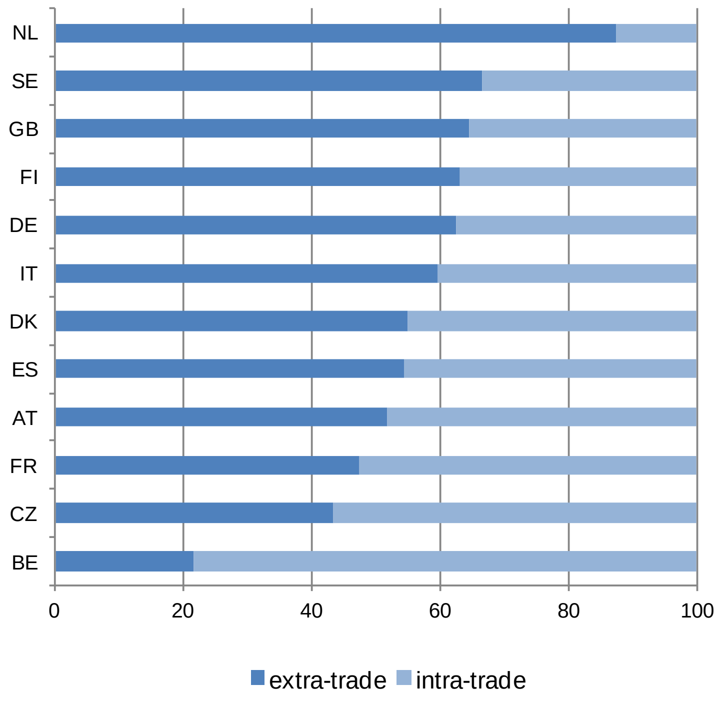
[59] CECIMO (2015). CECIMO Statistical Toolbox – July 2015 edition.

[60] CECIMO (2016). CECIMO Statistical Toolbox – April 2016 edition.

[61] The high export share of the Netherlands is mostly attributed to ASML, one of the global players for photolithography systems for the semiconductor industry (see KETs Observatory, Annual Report I).

Figure 32 represents those MS with a global export market share of at least 0.5% in 2014. It reveals that particularly the Dutch AMT exports are strongly attributed to non EU countries, indicated by an EU-Extra-trade share of nearly 90%. Sweden, Great Britain, Finland, Germany and Italy reach average extra-trade shares between 67% and 60% and Denmark, Spain, Poland and Austria reach shares of at least 50%. Only in Belgium, nearly 80% of AMT exports remain within the community.

Figure 32: Share of EU-Extra-trade and EU-Intra-trade (in %) in country exports: AMT



Including EU countries with an export market share in AMT higher than 0.5 % in 2014.
Source: UN COMTRADE-Database. – NIW calculation.

5.2.4 Market outlook

For AMT as a whole, no market growth projections are available. However, data from the KETs Observatory indicate that in the period 2003-2013 the production of AMT sector in Europe has increased at an annual growth rate of about 5,4%, hence implying significant real market growth. Moreover, as indicated in section 5.2.3, all but two EU member states have increased exports in the medium term (2007/2008-2013/2014). As for the future, interviewees expect that moderate market growth will continue, especially in top AMT regions such as the EU. However, growth will depend strongly on the global economic climate, as discussed earlier.

Among the main drivers behind growth are the increasing demand for automated and high precision, high throughput processes, as well as safer and less energy/material using processes. From an environmental point of view, two drivers need to be distinguished. On the one hand, there are improvements in the production process itself, leading to lower environmental impact of the process without necessarily changing the output characteristics. This is relevant especially for production of basic materials, e.g. steel, glass or plastics.

Secondly, there are the improvements in manufacturing technology which enable novel product characteristics, which in turn have a positive environmental impact. The example of better engine fuel economy enabled by femtosecond lasers was already presented above. As another example, 3D printed lightweight components can reduce transport costs e.g. when applied in aerospace context, or reduce need for cooling and reduce material wear through better product geometry. Advances in semiconductor equipment in turn allow for electronic chips that consume less energy and require less materials. As a result, the demand for AMTs not only relates to process efficiency driven by energy and material prices, but also by various sector-specific trends and targets for products of downstream industries.

Highest grow is expected in cases where the whole value chain is present, from R&D to the main clients. Indeed, innovation happens best in close presence to the clients, and when one of them moves (innovation or the clients), the other may do so as well. An interviewee stressed that in this respect it is of utmost importance to try to keep the main clients here in the EU. Europe has many policies supporting the SMEs, but it is also important to keep the large anchor companies in Europe, as they are core to these ecosystems.

5.3 Assessment of the competitiveness aspects

5.3.1 Export potential

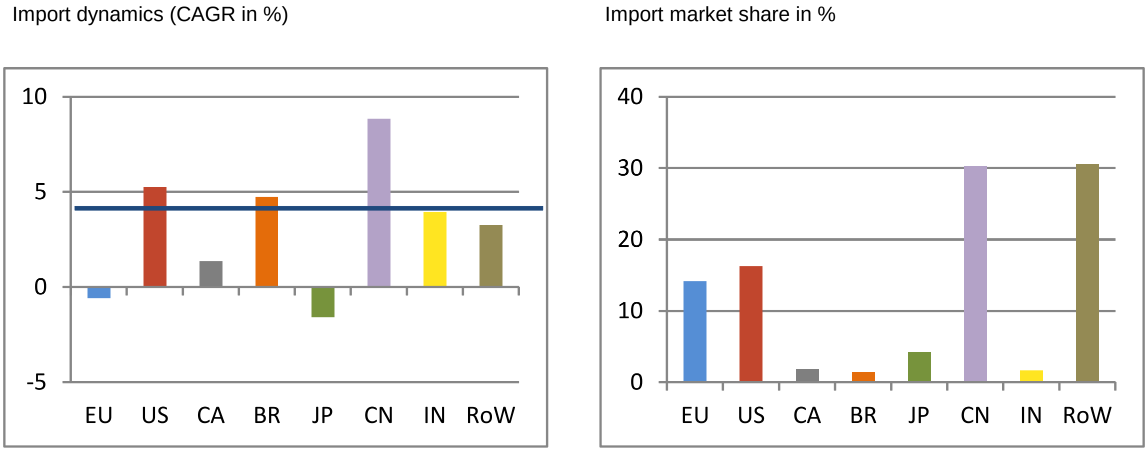
Box 8: Export potential

Export potentials emerge primarily in those goods and activities, in which the EU-28 already holds comparative advantages (measured in export specialisation or trade specialisation). In these goods and activities, trade volumes can be used as an initial indicator for market and growth potential. Hence, growing import rates of third countries may serve as a proxy for an increase in demand for Clean Industry goods in a specific country or world region that may subsequently translate into a growing export market for the EU and its Member States. At the same time, existing export advantages (indicated by RXA values) of the EU and its Member States in certain products may indicate promising preconditions for further growth and export potential.

Figure 33 reveals the global import market shares of the EU (excluding intra-trade) in comparison to other selected countries and the rest of the world (RoW) in AMT products (mainly smart machineries and production systems), indicating that China has been the largest single importer (30%) followed by the US (16%) and the EU (14%). Compared to its structural weight, China therefore revealed an extremely high demand for AMT products, whereas Japan (4%), Brazil (1.4%), India (1.6%) and particularly Canada (1.8) are still falling behind. However, Brazil (4.7% p.a.) and India (4.0%) yield comparably high import dynamics since 2007/08 indicating growing demand for AMT products in these countries albeit starting from a low level. Otherwise, with the US (5.2%) and

China (8.8%) two of the already large importers show the highest growth rates. By contrast, imports of the EU (-0.6%) and Japan (-1.6%) are decreasing which could point to lower demand for AMT as well as a substitution with internal products. As Table 27 in Annex 1/ depicts, the EU constitutes high export market shares and export specialisation values (RXA) for AMT related products in each of the five selected foreign countries. Thus, they basically all promise further export potential for the EU AMT manufacturers as well as related services in case of growing import demand for AMT driven production, although Japan and Canada are actually falling behind in this field.

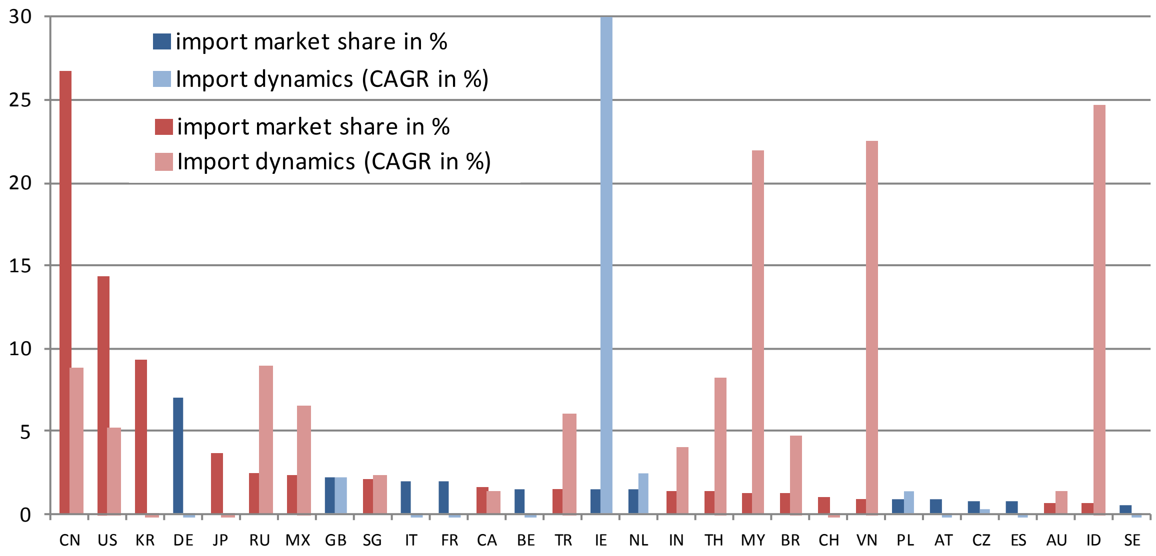
Figure 33: Import market share 2014 and import dynamics 2007/08 to 2013/14 in the EU-28 and selected non-EU countries: AMT



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

On the other hand, Figure 33 reveals that roughly 30% of the import demand for AMT in 2014 applies to other than the selected countries (RoW). Import dynamics of the RoW (3.2% p.a.) are slightly below the global average (4%). Hence, Figure 34 illustrates import market shares and import dynamics for all countries with a global import market share higher than 0.5% in 2014. This points out that besides China, the US, Japan, and some larger EU MS (Germany, Great Britain, Italy, and France), also Russia and some overseas countries (South Korea, Mexico, and Singapore), constitute considerable import market shares while others show remarkable growth rates (Ireland, Myanmar, Vietnam and Indonesia), hence creating additional sales respective export potential for the EU AMT industry.

Figure 34: Import market share 2014 and import dynamics 2007/08 to 2013/14 in AMT on the country level



Global imports including EU-intra-trade. - Regarding countries with a global import share higher than 0.5%. – EU MS: blue coloured; non EU countries: red coloured.
Source: UN COMTRADE-Database. – NIW calculation.

5.3.2 SWOT

Below the strengths, weaknesses, opportunities and threats (SWOT) for the European AMT industry that could be identified by literature, own data analysis and based on expert interviews, are specified in bullet points.

Table 14: SWOT for the AMT sector

Strengths	Weaknesses
▸ EU companies have a very solid technological position, as indicated by the patent analysis in the KETs Observatory as well as several interviewees and other studies ▸ Long history in advanced manufacturing, given the EU the advantage of the incumbent in several industries ▸ The EU is very successful on export markets: trade analysis for AMT shows a clear comparative advantage of the EU-28, realizing high export specialisation (RXA) and trade	▸ Production and labour costs are higher than outside of the EU ▸ An interviewee indicated that another key reason for companies moving to Asia is because of the location of their clients (e.g. the electronics industry) ▸ Also the better availability of technical profiles in non-EU countries and the less risk-adverse mentality negatively affects investment in the EU ▸ Lack of dedicated training programs to assist

specialisation (RCA) figures. The EU-28 has the highest export market share (29.7%) of global exports in 2014 ahead of Japan (24.7%) and the US (18.6%). ▶ Good performance along the value chain, notably in high complexity components as well as full systems ▶ Strong knowledge institutes (RTOs, universities) and good collaboration with industry (e.g. in Germany) ▶ Culture of environmental awareness compared to rest of the world ▶ The entire supply chain is present in Europe, but there is an increasing reliance on Asia for electronic units	companies to deploy AMT. ▶ Whereas EU producers of advanced manufacturing products and technologies have a strong position on the global market, low demand in the European market is currently an important constraint for deploying advanced manufacturing products and technologies by the European industry
Opportunities ▶ Growing awareness and measures worldwide about need to reduce energy and material consumption, and the enabling role that AMT can play in this respect ▶ AMT has an important role to play in the increasing digitalisation of industry e.g. Industry 4.0, Factory of the future, … ▶ Exports to industrialising economies across the world offer a great potential. Rising wages in emerging economies as well as growing environmental concerns and attempts to move up in the quality ladder, all reinforce demand for high-tech equipment. ▶ Disruptive technologies such as 3D printing offer both an opportunity and a threat for the EU industry, as they can reshuffle the competitive landscape, especially in areas where the larger companies are not active (yet).	Threats ▶ Certain AMT topics, e.g. laser processing, 3D printing, robotics, automation, etc are increasingly being recognised as of high strategic important by competing (emerging) economies. High government funding in these countries may increase substantially competition for EU companies. For example, automated machine tools and robotics is one of the 10 strategic sectors comprehended under the 'Made in China 2025' plan, and Singapore is investing heavily in 3D printing in the context of its Future of Manufacturing (FoM) programme. ▶ Significant barriers to important (tariff and non-tariff) in several industrialising countries ▶ Relocation of downstream industries pose a threat to EU suppliers, considering the strong ties between AMT producer and user. ▶ Uncertain economic outlook reduces prospects for investments in (capital intensive) AMT fields, which include a number of very cyclical

	markets.

In conclusion the EU holds a solid position in the AMT market. This position results from the excellent technical capabilities of EU AMT producers and the long history of the EU in this domain. This translates in significant economic success on global markets, with the EU being the largest single exporter of AMTs. At the same time, a number of challenges remain for the industry. Since the financial crisis of 2008-2009, uncertain economic outlook have hampered investment of user industries in new equipment. Moreover, relocation of certain user industries to other global regions such as Asia can have significant repercussions for EU AMT producers, causing a shift in AMT market share to foreign AMT producers, or a relocation of EU suppliers to other regions.

5.4 Analysis of barriers

Regulation: since 2009 the machine tool sector falls under the Eco-design directive. Specific, sector oriented activities started in 2010 and are still on-going. Companies in the sector would like to have more certitude when the process would be finished. Secondly, the machine tool industry has proposed self-regulation on quality and safety control on the machine tools, but achieving the necessary market coverage (80%) would require the inclusion of non-European machine tool builders and importers. As there are no sanctions foreseen for not joining the voluntary agreements and there is a lack of market surveillance, creation of a successful initiative faces a serious obstacle. This can result in an unequal level playing field.

Capital and finance: as indicated earlier, the current uncertain economic outlook hampers investments in new equipment. The barriers to investment correlate with the cost of the equipment and the extent to which it can be smoothly integrated in existing facilities and processes. Especially in some process industries (e.g. the chemical or steel industry) the integration of clean technologies is easier when building up a new infrastructure rather than when then replacing existing equipment. This hampers investments in clean technologies. So far, few member states have undertaken action in order to tackle this barrier. Moreover, payback time for clean technologies depend on the price (including taxation to correct for externalities) of energy and raw materials, which have been fairly low in recent times due to several macro-economic factors.

On the AMT producer side, it needs to be noted that this sector is characterised by a relatively high share of SME and mid-sized companies, specialised in specific niches. Illustrative for this is that the average number of employees in the machine tool sector amounted to less than 100 in 2011[62]. These companies, especially those in

[62] CECIMO (2011). Study on the competitiveness of the European Machine Tool Industry.

high growth segments such as 3D printing, need substantial (risk) capital to grow but this is not always available in the current economic context, whereas the US offers more possibilities on this point.

A recent study commissioned by the European Investment Bank (EIB) shows that there is a clear lack of finance for KETs companies[63]. This applies especially to companies that have a rather high investment needs compared to their (current) income flows, referred to as 'post start-ups' and 'quantum leap companies'. Due to their often entrepreneurial nature, young KETs companies often fail to meet banks' preconditions for debt financing (the most prevailing type of financing used by banks): an adequate track record and collateral. The banking sector is assessed to be rather conservative and not able to cater the needs of KETs (including AMT) companies.

Market functioning: One of the core activities of a properly functioning internal market is control of the products put on the market. Manufacturers and suppliers who do not comply with European regulations gain an unfair competitive advantage in the market. Machine tool sector market surveillance activities seem to be too limited, leading to a risk of incompliant imported machinery and/or circulation of non-compliant machinery in the EU.

The AMT sector relies heavily on exports. In the EU machine tool subsector, some 46% of production is exported[64]. European AMT companies experience several tariff and non-tariff barriers when exporting, especially to emerging companies who want to develop a domestic AMT sector. Examples include complicated and discriminatory health and safety regulations, certification requirements, lengthy customs and administrative procedures, frequent changes in government policies, poor IPR rights protection, explicit and implicit government support to local actors, unclear procurement channel, etc.[65]

Another important element of optimal market functioning is the match of supply and demand in the absence of incomplete information. Yet, for many industrial companies, especially SMEs, it is difficult to keep track of the different evolutions in available AMTs and what would be the precise costs and benefits of adopting certain novel technologies. Such costs and benefits can often only be assessed after in-depth analysis and testing with new equipment. There is however a clear lack of mechanisms that support SMEs in this respect, hindering maximal uptake of AMTs.

Labour market: whereas the skill level of personnel in the EU AMT is very good, companies have troubles finding sufficient employees, which constrains the growth of the industry.

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63 Di Pietro, P., Hammermann, H., Wollgam, G. (2016). Access to finance conditions for KETs companies.

64 CECIMO (2015). CECIMO Statistical Toolbox – July 2015 edition

65 CECIMO (2011). Study on the competitiveness of the European Machine Tool Industry.

5.5 Suggested actions

Actions in several domains could further strengthen the EU AMT sector, which are discussed below per domain. As general note however, it is clear that a combination between supply side policies (funding, R&D support) and a regulatory (norms and standards) approach would is to be preferred. Standards create a level playing field for all the actors present on the market, while funding and R&D support sets a ground for development of more 'green' and efficient products.

In the field of **research and innovation**, a key difficulty is the information barriers regarding the costs and benefits of adopting novel AMTs. As indicated earlier, especially for SMEs it is difficult to be fully informed on the various existing manufacturing solutions. Government initiatives can help overcome this information barriers, through programs that support SMEs in this respect, providing them with access to expert consultation, self-scans, etc. that help to assess the possibility of adopting novel equipment. Also, they should have easy access to physical infrastructure where they have the possibility to test certain novel equipment without having to bear all purchase costs of it. A good example of this has been implemented in Belgium in the form of the MADE DIFFERENT program[66], which provides free expert support for SMEs in developing novel production strategy. Afterwards SMEs poses much better information to make investment decisions.

From an EU perspectives, experts (associated to research institutes or other specialised organisations) who conduct these supporting tasks should be well aware of different manufacturing solutions that exist across Europe, and not only of those within their own country or from the large established players. In this respect, it would be best if this could be done in the context of an integrated EU wide network. The Commission is already working along this line, e.g. through the launch of an INNOSUP call in the area of clean AMT, and by planning the funding of an EU-wide network based on the Made Different program approach under COSME 2017.

Ties between AMT producer and user are very important, and innovation develops best at the interface of these two. A major challenge for especially the small/medium-sized machine tool companies is accessing their customers for joint technology development[67]. As a second point therefore, it is important that innovation support involves and benefits also directly the user side. Innovation programs could facilitate this by providing more funding or incentives for 'production chain' type of projects, in which both sides are involved directly. In general, considering the threat of relocation of AMT users to other regions as e.g. happened in electronics, it is important to let these users benefit in the most direct way from support to the AMT industry, by supporting projects that not only increase AMT producer capabilities but also simultaneously increase competitiveness of AMT users.

Thirdly, cooperation possibilities between research institutes (universities, RTOs) and companies are still not fully exploited. It is noted that in countries where there are intermediate structures focused on innovation, such as in

[66] http://www.madedifferent.be/en

[67] CECIMO (2011). Study on the competitiveness of the European Machine Tool Industry.

Germany and Spain, cooperation between the university and business side is best[68]. Research infrastructures are not always open to SMEs and the sharing of research results and managing of IPR is not always dealt with fluently. Further strengthening this cooperation, through stronger promotion by national government or the EC could be a major improvement for smaller companies in the sector. Cooperation with larger research institutes often also helps in providing them access to public innovation funds.

As a fourth point, it is noted that the internal function of the EU market could be further strengthened, both as regarding research and innovation as well as full scale commercial activities. Actors are often not aware of capabilities that exist in other regions/countries. For example, CECIMO SME members indicate that they have little knowledge about the existence and/or competences of machine tools research centres in other EU countries, and indicate that they almost never receive offers for technology transfer from institutes outside their home country[69]. Mechanisms that promote networking and collaboration across EU actors should therefore be further strengthened.

As regarding **market functioning**, an important concern is access to emerging economies, notably in Asia, which have become major users of AMT. It is experienced that these countries deploy more protectionist measures as the EU, in the form of both tariff and non-tariff barriers such as health and safety regulations or complex administrative procedures for export. Therefore, it is recommended that the EU tries to guarantee a level playing field with competing countries. As for particular trade distorting product characteristics imposed by other countries, the increased promotion of EU/ISO standards in other countries could provide a way out.

As for the EU market, it is stressed by CECIMO that limited market surveillance on performance of AMT goods is promoting unfair competition with non-compliant machinery being imported and taking market share from EU producers. This also renders the possibility of a self-regulation measure, preferred by the sector for the implementation of the eco-design directive, very difficult.

As for **regulatory aspects**, companies can encounter various obstacles that block adoption of clean solutions, e.g. an unintended consequence of environmental legislation that does not allow for certain new solutions. In the Netherlands, the 'Green Deal' initiative has been launched to create a platform where government and companies that face these kind of obstacles can meet and discuss how the obstacle can be eliminated.[70] Inspired on this, the EU Innovation Deals which focus on the circular economy field have been launched[71]. Such initiatives should be further strengthened, and the EC could also play a role as coordinator between member states, by promoting best practices sharing leading to faster adoption of better regulation.

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[68] Idem

[69] Idem

[70] http://www.greendeals.nl/english/

[71] https://ec.europa.eu/research/innovation-deals/index.cfm

At the **financing** level, a recent study conducted by the European Investment Bank (EIB) sheds light[72]. The study concludes that there is a clear need for improving financing conditions for KETs companies. It is recommended that awareness about existing funding mechanisms should be increased and that advisory services around these should be expanded. Moreover, it calls for development of instruments beyond traditional debt financing to significantly improve the financing conditions. The EIB is well positioned to undertake a more leading role in this area in the future. It may be interesting to better interlink novel financing mechanisms to improvements in the research and innovation area (see discussion above), i.e. making sure that actors involved in successful EU innovation projects are swiftly informed about / brought into contact with (EU) financing instruments relevant for their case, such that the novel technologies are deployed on commercial scale as soon as possible.

The AMT sector also faces a lack of **skilled personnel** and for several specific position it relies to an important extent on attracting engineers from abroad. Addressing this should be done through a constant revision of curricula and dual learning programmes or apprenticeships (which are a big success in Germany), and through promotion of the benefits of STEM educations.

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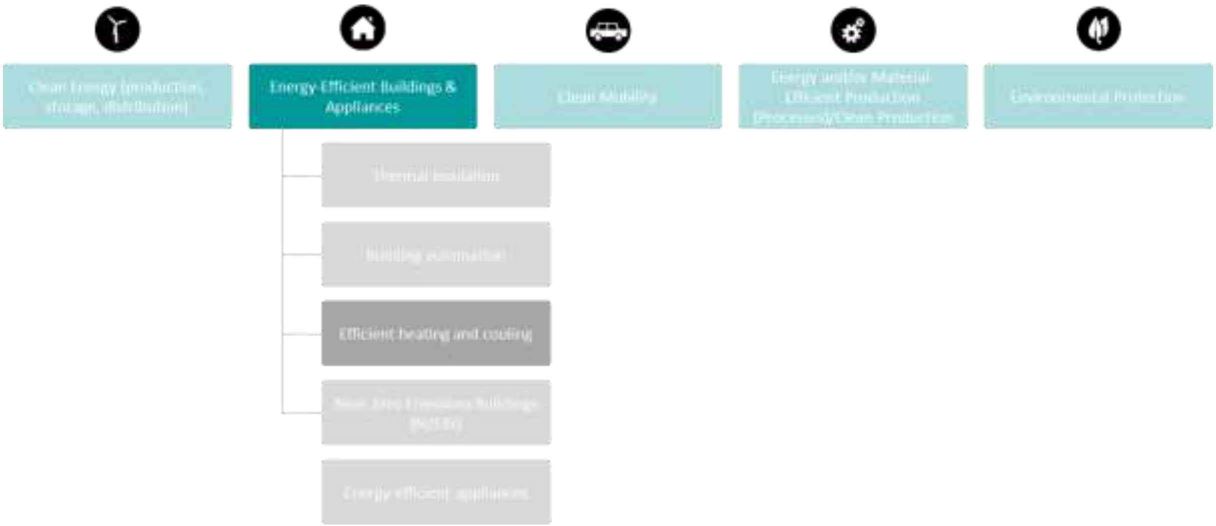
6/ Heating and cooling systems

Figure 35: Presentation of the selected priority sectors within the Clean Industry taxonomy



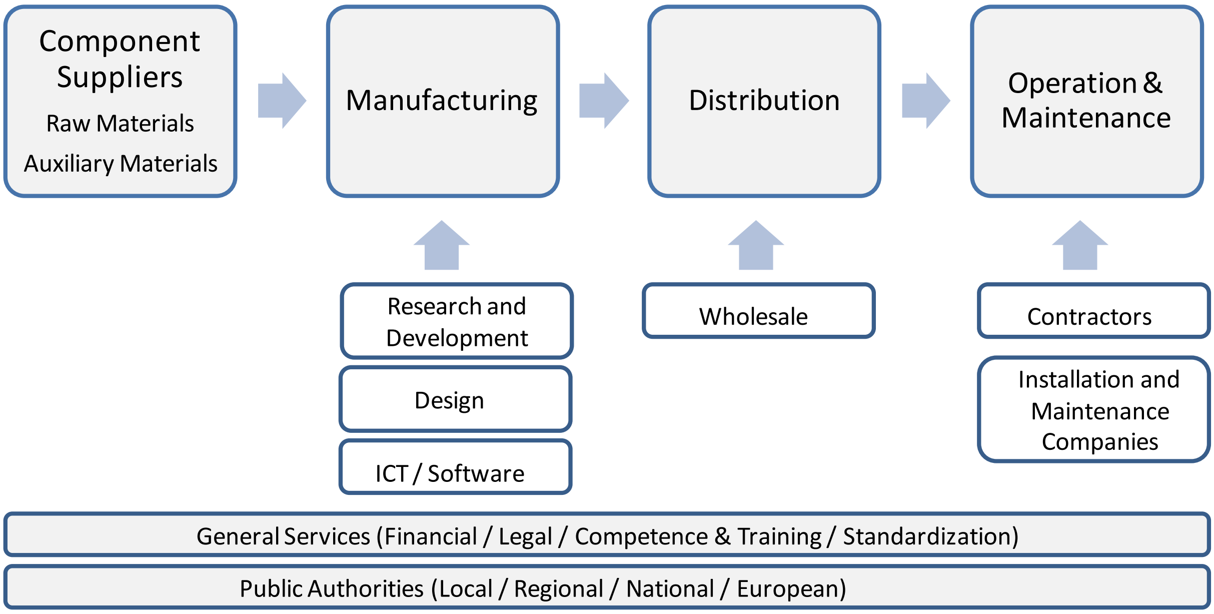
6.1 Description and value chain

About 23% of the EU-28's annual energy consumption in 2012 was related to energy used for Heating and Cooling consumption in the residential sector. To achieve the targets set in the EU energy strategy for 2050, Heating and Cooling has to decrease its contribution to the final energy demand above average. To achieve this goal, increasing use of renewable heating and cooling (RHC) is aimed for. In the context of reaching near zero emission building (NZEBs), Heating and Cooling technologies play a dominant role since 85% of final energy consumption in buildings is used for space Heating and Cooling.

Heating and Cooling in the Clean Industry Taxonomy is defined as technologies producing thermal energy with the purpose of consuming it as space heating or cooling as well for hot water in buildings. Heat and cold for industrial purposes is not regarded here. An overview of the sector's value chain is depicted in Figure 36. Differentiation arises since the heat or cold can be generated from various sources and can be delivered in various temperatures depending on the demanded use (e.g. residential vs. industrial or urban vs. rural residential demand). This as well as the characteristic of local production leads to small and fragmented markets implying a demanding environment for holistic approaches particularly for RHC.

In 2014 17.7% of the energy used for Heating and Cooling in the EU-28 was derived from renewable resources, rising from 16.5 % in 2013.[73] Thereof biomass is the most important resource accounting for 92 % of renewable heat provided (RHC Platform, 2014). Wood pellet consumption for residential heat in the EU-28 in 2014 amounted to 8.2 million tonnes with Italy, Germany, Sweden, France and Austria as the most important markets (AEBIOM, 2015). By contrast solar thermal in Europe is delivering less than 1 % of the overall heat demanded (RHC Platform, 2014).

Figure 36: Value Chain of Heating and Cooling Sector



Display: NIW.

Technologies encompass boilers (gas, electric, biomass, condensing), pellet stoves, condensing furnaces, advanced catalytic combustion wood stoves, high-efficiency fireplaces and masonry heaters, micro CHP units, heat pumps (electric or gas-driven ground-source and air-source), and solar-thermal units for the production of heat. Regarding cold, air conditioning and packaged unit cooling and chillers are the main technologies used (IEA, 2013).

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[73] Eurostat (2014), Share of energy from renewable sources: heating and cooling (nrg_ind_335a), ec.europa.eu/eurostat/statistics-explained/images/6/69/Energy-from-Renewable-sources-2014_updated.xlsx

Market shares of heating technologies in the EU-25 in 2012 are depicted in Figure 115 in the Annex 11/ showing that almost two third of space heaters are non-condensing boilers, hence a non-efficient technology reaching at most energy label C. Another 26% are condensing boilers (label A). The remaining technologies cover biomass boilers (6%), heat pumps (2%) and others (2%). Across member states, the shares differ widely, which is further represented in Figure 116 and Figure 117 in Annex 6/. In the UK as well as in the Netherlands, condensing boilers accounted for more than half of the space heating technologies, hence the share is more than twice as large as for the EU-25. 44% of the Italian buildings are cooled and heated by aero-thermal heat pumps, whose share is very small on the aggregate level. Poland stands out due to its large share of newly sold pellet stoves (13%) used for heating. Often, these national differences are the consequences of market incentive programmes such as the "Boiler Scrappage Rebate program" in the UK.[74]

In total, the global market for Heating and Cooling is estimated by BMUB (2014) to be worth € 45 billion in 2013 with an annual growth rate of 7.7 % from 2013 to 2025. HSBC (2014) values the global investments in condensing boilers and heat pumps in residential buildings in 2012 to about € 24 billion. Regarding the European market, only technology-specific information is available. Information is used from industry association such as the Association of the European Heating Industry (EHI), the European Heat Pump Association (EHPA), EurObserv'ER or research and consultancy institutes such as BSRIA.

According to EHPA (2015a) data focusing mainly on heat pumps used for heating, the European heat pump market registered sales close to 800,000 in 2014. Thereof about 48 % refer to air-to-air heat pumps, another 41 % to air-to-water and 11 % to ground-source heat pumps. In 2014 a total heat pump capacity of 6.6 GW was installed producing approx. 13 TWh of energy and integrating 8.15 TWh of renewable (aggregated: 66 GW since 1995). Regarding sales from 1995 onwards, it is estimated that about 7.5 million units are in operation. Sales are highest in France, Italy, Sweden, Germany, Finland, Norway and Spain and sanitary hot water heat pumps are the fastest growing segment showing double-digit growth. Comparing sales in 2013 and 2014, eight EU-21 countries did show losses while four did show growth rates larger than 20 % (Ireland, Lithuania, Poland, and France). The EurObserv'ER (2015a) heat pumps barometer reports on heat pump sales in Europe referring to heating as well as cooling purposes. Sales in Europe amounted to 1.7 Mio. units in 2014 and a total of about 26 million units in operation is estimated. European heat pumps and heat pump components manufacturers lead the world with respect to technological knowledge. Main players in the European heat pump market according to EurObserv'ER are BDR Thermea (NL), Bosch Thermotechnology (D), Daikin Europe (B), Danfoss (DK), Nibe (SE), Vaillant Group (D), Viessmann Group (D), Buderus (D), Ochsner Wärmepumpen (D), Stiebel Eltron (D), Waterkotte (D), and Wolf Heiztechnik (D).

Solar thermal technologies (flat plate collectors, vacuum collectors and unglazed collectors) are further possibilities to employ renewable energies for producing thermal energy. Although the European market shrank

[74] See Heiskanen et al. (2013) pp 22. for a detailed review of differences in heating solutions across MS of the EU.

from 2013 to 2014 according to EurObserv'ER (2015b) by 3.7 %, there is hope that new incentive programmes in Germany, France, Italy, and the UK as well as the end of the recession in construction revive this technology in order to reach the decarbonisation goals. Main players in the manufacturing of solar thermal technologies in Europe are GREENoneTEC, Bosch Thermotechnik (D), Viessmann (D), Vaillant Group (D), BDR Thermea Group (NL), Dimas (GR), Riposol (AT), Wolf (D), Nobel Xilinakis (GR), Cosmosolar (CH), and Ariston (IT).

The European market for water heating in 2015 was dominated by electric storage technologies followed by combi boilers and electric and gas instantaneous boilers. Solar thermal as well as heat pumps played only a minor role so far (BSRIA, 2016).

6.2 Assessment of the global environment

6.2.1 Main competitors outside the EU

Regarding heat generation, European companies are the global leaders (EPEC, 2011). Asia dominates the heat pump market with respect to the total number of installed units (IEA, 2013). These encompass to more than three quarters heat pumps used for air-conditioning, hence cooling. Moreover, the European market has attracted air-conditioning specialists from Asia (Japan: Daikin, Mitsubishi, Panasonic, Hitachi; Korea: LG, Samsung), mostly regarding air-to-air heat pumps. The largest national market for air-to-air heat pumps is Japan: it covers close to three quarters of the global market while the rest is almost equally divided between the US and the EU (HSBC, 2014). The overall air conditioning market is dominated by Asian companies as well with about two third of the market shares pertaining to companies from Japan, South-Korea and China (BRSIA, 2016). When looking at single- and multi-split conventional air conditioners, Asian brands dominate the European market (Armines, 2008) accounting to more than two thirds of the sales in 2006.

Competition in ground-source heat pumps comes mainly from China and the US but with Europe being the world leader with about 1.2 million units installed (RHC Platform, 2014).

Regarding solar thermal, China dominates the market. In 2010, it accounted for 81.4% of the sales of glazed and unglazed collectors (IEA, 2013, p. 174). Europe was second with 9.3%.

6.2.2 Relative competitive strengths

An inspection of patent[75] shares in Heating and Cooling technologies[76] can shed light on the relative competitive strength of the EU compared with other countries. The EU holds 46.3 % of all patents in Heating and Cooling in

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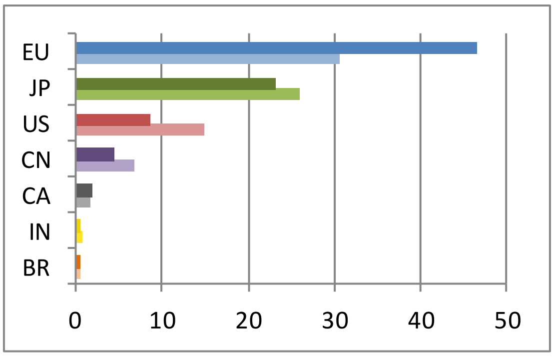
[75] The OECD Environment Directorate, in collaboration with the Directorate for Science, Technology and Innovation, has developed patent-based innovation indicators that are suitable for tracking developments in environment-related

the period analysed (see Figure 37) followed by Japan (23.1 %) and the US (8.5 %). As the comparison with these countries' shares in total patents indicates, the EU is highly specialized in Heating and Cooling technologies since the share in Heating and Cooling patents is much higher than the EU's share in all patents. For Japan, the US, and China the reverse is true – revealing lower competitiveness compared with the EU. Among the other countries considered, the shares in Heating and Cooling technologies very much resemble those in total patents pointing no specific competitive strength in Heating and Cooling technologies. Looking at single MS in the EU-28, Germany (14.7 %), France (8.8 %), Italy (6.2 %), Great Britain (5.3 %), and the Netherlands (2.7 %) have the highest patent shares in the field of Heating and Cooling, all except for Germany showing a high specialization in Heating and Cooling.

Figure 37: Share of patents in the field of Heating and Cooling and in total patents 2010-2012



The upper bar shows the patent share in thermal insulation, the lower bar the total patent share (with respect to all technologies).

Source: OECD.stat; Theme Environment; Dataset: Patents - Technology Development - NIW calculation

technologies. The patent statistics are constructed using data extracted from the Worldwide Patent Statistical Database (PATSTAT) of the European Patent Office (EPO). Patent data based on family size "two and greater" were used to count only the higher-value inventions that have been applied for protection in the home market and at least one foreign market. The relevant patent documents are identified using search strategies for environment-related technologies (Env-Tech: http://www.oecd.org/env/consumption-innovation/env-tech-search-strategies.pdf) which were developed specifically for this purpose. The data are available under http://stats.oecd.org/.

[76] In the Env-Tech classification thermal insulation is covered by segment 7.2.2: Heating, ventilation or air conditioning (HVAC).

According to RHC Platform (2014), the EU offers a greater diversity in solar thermal products than do other markets. This is, for example expressed in applications designed for solar-active-houses. Furthermore, European manufacturers of heat pumps are often technological leaders due to a strong know-how in R&I and a developed value chain. In general, the RHC platform sees its industry and the research facilities well prepared for future market growth in particular relating to increased laboratory and manufacturing capacities. The sector's companies typically invest about 1 to 4 % of their turnover into R&I.

6.2.3 International trade performance

Box 9: International trade performance

This section investigates the EU-28's trade performance in the respective CI products with regard to the development in six competitive countries in America (USA, Canada, Brazil) and Asia (Japan, China incl. Hong Kong, India). Six trade indicators are analyzed to observe how the EU-28 and its Member States (MS) succeed in commercializing internationally competitive CI products. Those are significance (i.e. how important the specific CI products are in a country's total manufacturing exports), export market share (i.e. how important a country is for total global exports in the relevant CI), medium-term dynamics (i.e. how exports have changed within the pre-crisis years 2007/08 and 2013/14), trade balance (TB, comparing the absolute volumes of exports and imports), and two specialization indicators, namely export specialization (RXA, i.e. whether a country's global export share in a certain CI is higher/lower than its export share in total manufacturing products) and trade specialization (RCA, considering a country's relative export/import ratio of a certain CI compared to its total export/import ratio). Four of these indicators (export market share, significance, RXA and TB) are illustrated in the following chapter, the other two (medium-term dynamics, RCA) in Annex 12/.

It is important to note that the analysis comparing the external trade performance of the EU-28 in a regional perspective only considers extra-EU trade flows. Otherwise, analysis that compares single Member States with non EU countries has to consider extra- and intra-trade. Hence, the calculated export market shares and export specialization figures (RXA) differ according to the respective perspective. Figures on the country level can be found in the Annex 12/.

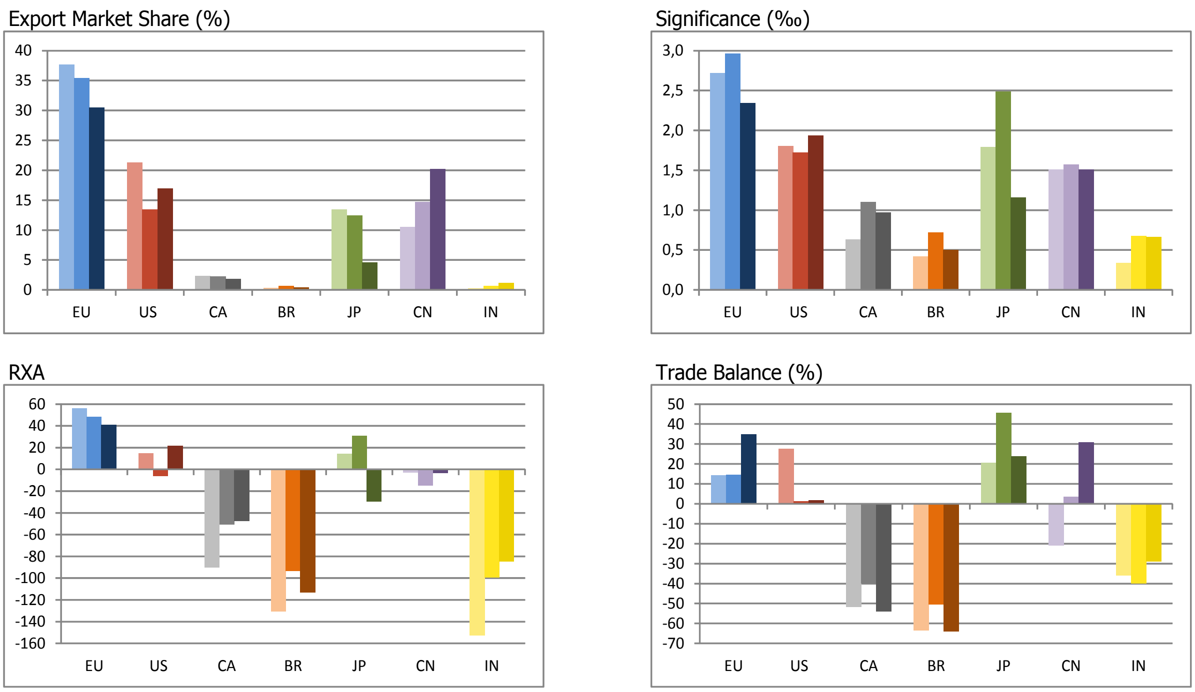
High, but declining comparative advantage of the EU-28

Trade analysis for products related to Heating and Cooling Systems (e.g. reversible heat pumps, heat exchangers) shows a clear comparative advantage of the EU-28, realizing the highest export specialization (RXA) and trade specialization (RCA) figures compared to the other represented countries. Furthermore, the EU-28 has the by far highest export market share (30.5% of global exports in 2014). Also the significance of exports related to Heating and Cooling Systems for buildings in total exports is higher than in all of the other countries, (2.3‰; see Figure 38. The strong export position of the EU in Heating and Cooling related products is underlined by the positive trade balance. However, the EU's export performance (export market share, RXA) has declined over the last decade, because other countries succeeded in realizing much higher export growth rates (Figure 38 and Figure 118 in Annex 12/. In contrast to this, the trade specialization (RCA) and TB has increased during this period, because the import shares of non EU suppliers in the European market have declined even stronger than the EU's export shares.

China has nearly doubled its export market share between 2002 and 2014. Now it holds the second highest share (20%) behind the EU and prior to the US (17%), that depicts an improving trade performance in products related to Heating and Cooling Systems since 2008 (Figure 38). Japan now just holds an export market share of 4.6% (2008 still 12.5%). Canada (1.8%), India (1.1%), and particularly Brazil (0.3%) only play a very minor role in the production and export of those products and have no specialization advantages in this field.

Both, China and the US, showed particular strong export growth between 2007/08 and 2013/14 of about 7% p.a. whereas the EU only revealed low dynamics (0.5%), and Japan even depicts an extreme export decline (-12.6%, Figure 118 in Annex 12/). Sinking export volumes, decreasing export market shares, as well as long-term declining specialization figures and trade balances indicate that the country significantly lost ground especially on the Asian market that is more and more dominated by Chinese firms. On the other hand, China meanwhile reveals a positive TB and an almost balanced export specialization (RXA) in products related to Heating and Cooling Systems (see Figure 38).

Figure 38: Trade indicators for the EU and selected other countries 2002, 2008 and 2014: Heating and Cooling Systems



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Germany, Italy and France dominate the European exports

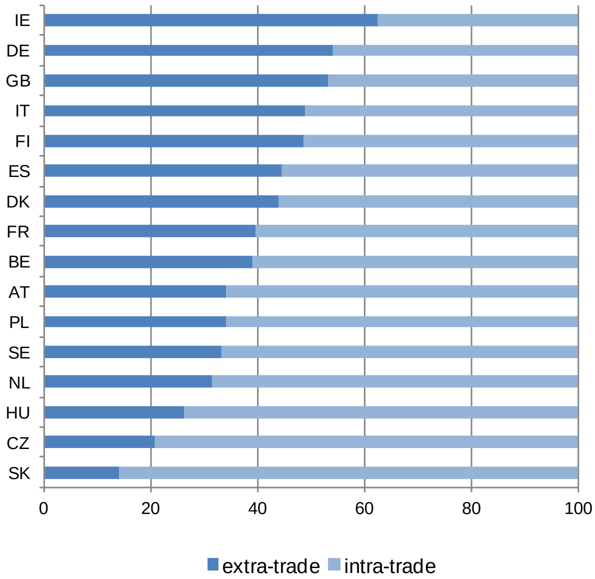
Within the EU-28, Germany (2014: 10.3%), Italy (9%) and France (8,2%) reveal the highest export market shares in products related to Heating and Cooling Systems, far above of the shares of Sweden (3.3%) as well as the Czech Republic, Great Britain, the Netherlands and Austria with rates between 3% and 2% (Figure 119 in Annex 12/). With the exception of Germany and Great Britain, all of these larger exporters also depict comparative advantages (measured by RXA and RCA values, Figure 119 and Figure 120 in Annex 12/). The same applies to Denmark, Hungary and Bulgaria.

With regard to the significance of Heating and Cooling exports in total manufacturing exports, Sweden, Denmark and Italy show the highest values (>4‰). In the Czech Republic and France they account for about 3.5‰ (Figure 120 in Annex 12/). Yet, one has to consider, that the significance of these products has declined in most of the larger exporting EU countries due to weak export dynamics (Figure 121 in Annex 12/). Hence, most of the larger exporters also show declining export market shares and a deteriorating export/import ratio over time (TB, RCA). However, starting from a very low level, some smaller Eastern and Southern MS succeeded to gain significantly high export growth rates higher than 10% p.a. (Bulgaria, Hungary, Slovakia, Latvia, Lithuania, and Cyprus).

More than half of the exports are designated to the internal market

Although the importance of external markets for EU producers is significantly increasing, most of the EU-28 trade happens within the community. With respect to Heating and Cooling Systems, 2014 on average 57% of the EU's exports refer to intra-trade (2008: 63%) and 43% to extra-trade (2008: 37%). However, the country perspective reveals some differing results. Figure 39 shows the extra-trade and intra-trade shares for those MS that apply for more than 0.5% of global exports of products related to Heating and Cooling Systems. It reveals that particularly Irish (with an extra-trade share of more than 60%), but also German, British, Italian and Finnish' exports are above-average designated to non EU countries. Spain and Denmark represent the above mentioned average rates. All other countries illustrated here rely on intra-trade more strongly. This refers to all Eastern European countries, particularly the Czech Republic and Slovakia for which the share of intra-trade amounts to 80% and more, indicating the intense division of labor and economic integration within the EU in those products.

Figure 39 *Share of EU-Extra-trade and EU-Intra-trade (in %) in country exports: Heating and Cooling Systems*



Including the EU countries with an export market share in products related to Heating and Cooling Systems higher than 0.5% in 2014.
Source: UN COMTRADE-Database. – NIW calculation.

6.2.4 Market outlook

The generally high requirements of legislation regarding energy efficiency in combination with the still high level of old and inefficient Heating and Cooling technologies in use suggests a favourable market outlook for Heating and Cooling technologies in the EU. Another regulatory influence comes from the new regulation regarding fluorinated greenhouse gases, which is assumed to accelerate refurbishment of Heating and Cooling systems (EU Commission, 2016b, p. 67).

Besides, the overall demand for Heating and Cooling will change. As a consequence of more stringent building codes demanding sophisticated insulation up to NZEBs, less heating will be required but more cooling. This matches the projections of Entranze (2014) or RHC Platform (2011) showing a still growing EU market in terms of the share of the cooled area of heated area until at least 2030. This main market trend is also driven by increasing urbanization, raising cooling demand in densely populated areas as well as by rising disposable incomes in emerging economies. Moreover, investments into H&C equipment relate to the oil and gas prices whereby the recent lower prices work as a constraint to the general market growth of more efficient and renewable Heating and Cooling since the benefits are valued less.

One of the important market developments is the rise of RHC fuelled by the regulatory framework on renewable energies and buildings. By 2020, biomass is expected to contribute 124 Mtoe of energy, solar thermal 13 Mtoe, and geothermal 10.5 Mtoe. By around 2040 renewable sources are expected to meet the entire heat demand in the EU (RHC platform, 2013). To reach these goals an implementation roadmap has been worked out by the related associations (RHC Platform, 2014) drawing upon strategic research agendas for each of the energy carrier.

Regarding newly built houses, part of the energy demand has to be met by renewable sources already today. Since often heat and hot water demand within a home cannot be met by one single renewable source alone, combined systems – that is a combination of renewable and fossil or of several renewable sources – are identified as a long-term trend (RHC Platform, 2014, or BSRIA, 2016). These encompass, for example, PV and heat pumps or solar thermal and heat pumps. Besides the insufficiency of one renewable source to meet the complete demand, simply adding two or more components can lead to overall inefficient operation. Therefore one of the important aspects of the combined systems is to provide turnkey solutions with a combined control of the equipment (link to Measuring and Monitoring) where all components have been adjusted to maximize efficiency (RHC Platform, 2014, or BSRIA, 2016).

While combined systems are a solution for the market of newly built houses, single components will stay important in the market for retrofitting. The resulting complexity of solutions, especially regarding the centralized control of different components, is another important market driver. Furthermore, increasing shares of decentralised energy generation are a driving force of Heating and Cooling solutions including storage of thermal energy.

The heat pump market has lost pace during the last years, mainly through recession which had hit construction the hardest. EurObserv'ER (2015a) estimates a slightly better outlook for the coming years, increasingly encouraged by regulation. The main potential for the installation of heat pumps lies in the renovation sector (EHPA, 2015a, and Ecofys, 2013). Sales figures and trends show that Belgium and Great Britain are strongly growing markets, Germany, Austria and France are growing, Italy and Spain are stabilizing and Sweden is a mature market (EHPA, 2015a, and Ecofys, 2013).

The solar thermal market is expected to profit from the introduction of energy labels for Heating and Cooling systems since solar thermal technologies are the only ones able to reach the highest label A+++. Heat pumps or condensing boilers, which are also more efficient than older systems need an external energy source when used and therefore cannot be rated higher than A++, the second highest label. Moreover, the large drop in the European solar thermal market has been assessed as a reorientation phase. EurObserv'ER (2015b) argues that the focus on individual houses will have to change in order to get the market back on track. Data from a survey conducted by the European Solar Thermal Industry Federation (ESTIF) in 2014 supports this view. Here, European manufacturers indicate that single family houses (so far the dominant market segment) will lose relevance and account for less than half of the sales in 2020 (ESTIF, 2015). Another impulse for solar thermal can be provided by the development of storage technologies: thermal energy storage combined with heat pumps can be used for Heating and Cooling also leading to an increased demand of solar thermal technologies and heat pumps (BSRIA, 2016).

6.3 Assessment of the competitiveness aspects

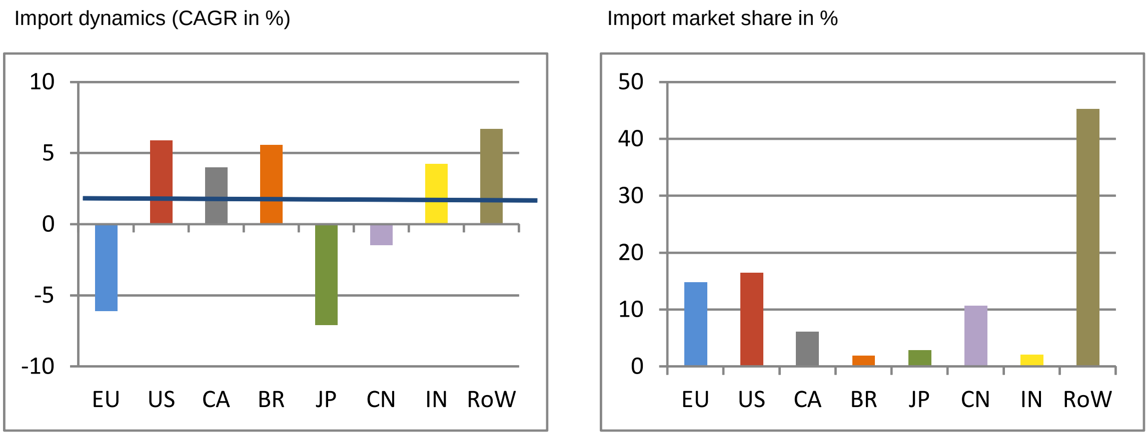
6.3.1 Export potential

Box 10: Export potential

Export potentials emerge primarily in those goods and activities, in which the EU-28 already holds comparative advantages (measured in export specialization or trade specialization). In these goods and activities, trade volumes can be used as an initial indicator for market and growth potential. Hence, growing import rates of third countries may serve as a proxy for an increase in demand for CI goods in a specific country or world region that may subsequently translate into a growing export market for the EU and its Member States. At the same time, existing export advantages (indicated by RXA values) of the EU and its Member States in certain products may indicate promising preconditions for further growth and export potential.

Figure 40 reveals the global import market shares of the EU (excluding intra-trade) in comparison to other selected countries and the rest of the world (RoW) in Heating and Cooling products (e.g. reversible heat pumps, heat exchangers), indicating that the US has been the largest single importer (16%) followed by the EU (15%) and China (11%). Compared to its structural weight, also Canada revealed a considerably high demand for Heating and Cooling products (6%), whereas Japan (3%), Brazil (2%) and India (2%) are still falling behind. However, Brazil (5.6% p.a.) displays the second highest import dynamics after the US (5.9%) since 2007/08, suggesting growing demand for Heating and Cooling systems. By contrast, the EU (-6%) and Japan (-7%) both experienced a significant drop in imports since 2007/08 pointing to a lowered demand. As Table 27 in Annex 1/ depicts, the EU constitutes high export market shares and export specialization values (RXA) for Heating and Cooling products in all selected foreign countries except Canada. Thus, the others basically all promise further export potential for the EU Heating and Cooling systems manufacturers as well as related services in case of growing import demand, although Japan is actually falling behind in this field.

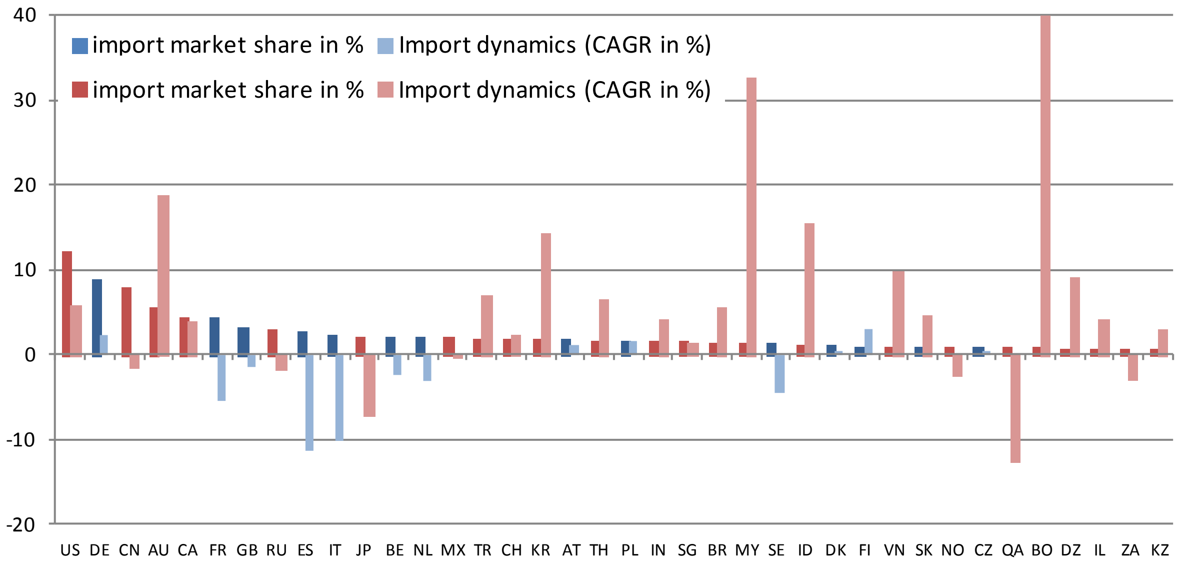
Figure 40: Import market share 2014 and import dynamics 2007/08 to 2013/14 in the EU-28 and selected non-EU countries: Heating and Cooling Systems



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

On the other hand, Figure 40 reveals that 45% of the import demand for heating and cooling products in 2014 applies to other than the selected countries (RoW). Furthermore, the import dynamics of the RoW achieved almost 7% p.a., thus being significantly higher than the global average (2%). Hence, Figure 41 illustrates import market shares and import dynamics for all countries with a global import market share higher than 0.5% in 2014. This points out that besides the US, China, Canada, and some larger EU MS (Germany, France, Great Britain, Spain and Italy), also Russia (and Turkey to a lesser extent) and overseas countries (Australia, Mexico, and Korea) constitute considerable import market shares while others display remarkable growth rates (Bolivia, Myanmar, and Australia), hence creating additional sales respective export potential for the EU Heating and Cooling industry.

Figure 41: Import market share 2014 and import dynamics 2007/08 to 2013/14 in Heating and Cooling Systems on the country level



Global imports including EU-intra-trade. - Regarding countries with a global import share higher than 0.5%. – EU MS: blue coloured; non EU countries: red coloured.
Source: UN COMTRADE-Database. – NIW calculation.

6.3.2 SWOT

The European Heating and Cooling sector benefits from its strong and world leading technological position resulting in a clear comparative advantage in international trade (largest export share). Exports from Eastern and Southern MS are hereby growing significantly mostly reinforcing the internal market.

The trade performance has however declined in the last years compared to an improvement for the US, China and India. The market for cooling technologies is furthermore dominated by Asian companies as is the market for solar thermal where China has a market share of 80 % and more.

The recent regulatory framework does, nevertheless, provide an opportunity to increase demand, e.g. by introducing energy labels for complete packages. The technological leadership and proficiency in service engineering also promise export potential for European products in non-EU countries. Moreover, retrofitting activities are local and promise jobs and growth at the local level. Regarding the low carbon potential, solar energy is a promising energy source for rising cooling demands since there is a high load match of cooling demands and solar radiation reducing the grid requirements.

Yet, retrofitting of Heating and Cooling technologies is impeded by a low oil price leading consumers to postpone investments. Generally, a focus on capital expenditures (CAPEX) may hamper low carbon potential since consumers choose the lower investment but disregard life-cycle costs which are favourable for renewable energy solutions having low operational expenditures (OPEX) instead. The so produced lock-ins are a serious threat since technologies are in place at least for a decade. Moreover, split incentives in buildings not occupied by owners hamper investments into retrofitting. The entering of Asian companies into the European heat pump market can also mitigate the perspective of European companies.

Overall, the European Heating and Cooling sector's strengths seem to outweigh the weaknesses. All of the weaknesses, however, seem to have grown in relevance over the last years so that keeping the strong position is an important task for the future. Opportunities are large and can outweigh threats if those are appropriately approached.

Table 15: SWOT for the Heating and Cooling sector

Strengths	Weaknesses
▸ Clear comparative advantage (RXA, RCA) in trade with Heating and Cooling technologies for EU-28 and highest export market share (30%) ▸ Growing exports from Eastern and Southern MS (BG, HU, SL, LV, LI, CY) mostly on internal market ▸ EU is technical world leader regarding heating technologies and in particular heat pumps; the EU-28 holds 46 % of all patents in Heating and Cooling and is highly specialized	▸ Trade performance of EU-28 has declined while that of China, the US and India has increased ▸ Dependency of the industry on the construction sector: retrofit of heating or cooling equipment is often only economical when the building is refurbished/renovated ▸ Market for cooling technologies is dominated by Asian companies ▸ Solar thermal is dominated by China (80% market share)
Opportunities	**Threats**
▸ Legislative framework (e.g. Energy Labels for heating packages) can increase demand ▸ Export potential to non-EU countries as a consequence of technological leadership due to the pioneering role of EU: especially regarding service engineering ▸ EU-28 has high export market shares and specialization values for Heating and Cooling in JP, US, CN, IN and BRA; export potential is also expected for Russia, Turkey and some overseas countries (Australia, Mexico, and Korea) ▸ High level of local job creation for investments in energy-efficiency of buildings (Better	▸ Low oil price could slow down refurbishment since consumers postpone investments ▸ Fragmented market (different suppliers of technologies, different national requirements with the need for certification) ▸ Asia is entering the European heat pump market ▸ Split-incentives in buildings that are not owner-occupied can restrict retrofitting ▸ Consumers mostly focus on CAPEX, not OPEX ▸ Lock-in effects from technologies not being best practice (at least 10 years in use!), e.g.

regulations for R&I at EU level, 2015, EU COM RTD) ▸ Solar energy has a high load match potential to serve cooling loads because cooling demand and sunshine generally coincide (Ecofys, 2015)	EuroACE (2015)

6.4 Analysis of barriers

There are some regulatory barriers locking the potential of Heating and Cooling technologies in reducing the carbon foot-print of buildings. In general, the outcomes from energy efficiency improvements strongly depend on the country context. Several factors can play an important role in determining the level and type of outcomes that an energy efficiency measure will deliver, such as the geographic situation, the level of economic development, energy resource endowments and demographics. The geographic situation of the country will influence the climate and hence the energy needs of households, so e.g., hot countries may require cooling services while buildings in cold countries will have heating needs. Thus, each MS has its own scheme, when it comes to calculating energy efficiency of buildings. Moreover, in the past energy efficiency was seen as a low consideration for buyers compared to factors such as location, amenities, design and layout (DG RTG InnovREFIT Task Force, 2015, 138f.). Also, the EPC schemes required by the Energy Performance in Buildings Directive (EPBD) are not fully implemented in all MS nor sufficiently enforced, yet (BPIE, 2014b).

Furthermore, the financing of retrofits suffers from adverse incentives especially when dwellings are not owner-occupied. In the case of rented apartments or houses, incentives for retrofits are split between the owner and the occupant (EU Commission, 2016). This barrier is also recognized by EuroACE, the European Association of Companies for Energy Efficiency in Buildings (EuroACE, 2015).

With respect to the actual Heating and Cooling Equipment, not all technologies are consistently defined across member states. While for solar thermal a European key mark ensuring comparability of products and services exists, this is still in development for heat pumps (EHPA, 2015b). Missing key marks instead require costly certification processes that constitute a barrier for consumers choosing between different technologies.

One of the most important barriers relates to the technological readiness of the different Heating and Cooling equipment. Especially those technologies labelled the most efficient such as solar thermal would benefit from a combination with not yet enough developed storage technologies impeding their installation.

When choosing between different Heating and Cooling technologies, many consumers are interested in short run return on investments. This can result in choosing technologies which are cheaper in investment (lower capital expenditures: CAPEX) but have larger operating expenses (OPEX) and hence higher life-cycle costs. Lower life-cycle costs are often reached via a lower energy consumption in use of these technologies (reducing OPEX) which is favourable in terms of energy efficiency. A more stringent focus on life-cycle costs/OPEX in buying decisions should therefore be aimed at (see also BPIE, 2016).

Another very severe barrier to overcome is consumer behaviour. Heating and Cooling technologies are usually bought when a new house is built or when the old system brakes down. In the latter case, decisions are often made ad hoc and may underlie more severe financial constraints than those planned for a longer period.

Finally, as reported in BPIE (2014), only one third of all renovations undertaken in Germany are used to improve the energy performance. Similar developments can be assumed in other MS as well. Regarding the longevity of buildings and many of their components such as Heating and Cooling equipment these missed opportunities are a severe barrier to the potential decarbonisation and economic potential linked to Heating and Cooling Technologies.

6.5 Suggested actions

Generally, the retrofit of Heating and Cooling technologies to more energy-efficient solutions can be leveraged via integrated business models combining energy consulting, selling of the actual equipment, installation and maintenance. In particular, this can also prevent individual home owners from choosing inferior solutions leading to lock-in effects for 10 to 20 years. Moreover, such a consolidation of the supply side can facilitate putting more emphasis on OPEX instead of CAPEX when choosing a new Heating and Cooling solution.

Another possibility to strengthen the consideration of OPEX is to tie financial instruments to it, e.g. provide preferential loans related to increases in energy efficiency (see also BPIE, 2016. p. 21) or in the share of renewable energies. Similarly, high CAPEX can be tackled via energy performance contracting.

Consumption of renewable heat and cold generated within the building should be aimed for in order to circumvent problems of grid stability when the share of renewable energy sources increases. This can be reached by combined systems using renewable as well as fossil energy sources. Pushing these combined systems allows on the one hand increasing the share of renewable energies while on the other hand reducing fossil fuel demand. In the long term storage technologies can be used to extend the combined systems. These provide a convenient way since they are controlled like a single system. In particular this aspect of consumer friendliness can be advertised, for example via the integrated business models mentioned above.

The barrier of spontaneous decision of consumers in case of a brake-down can be tackled by information alone. This could be done during the mandatory inspections of heating equipment like gas boilers executed by chimney sweepers. Part of this inspection can be the informing about a suitable follow-up system, perhaps only in case the system is in place for several years so that it is unlikely that only some components have to be replaced. Application of such a mandatory information furthermore allows to aim for the expansion of network solutions since these are always less costly per unit and also provide the opportunity for integration of renewable energies (see Chapter 3/ on District Heating and Cooling).

As highlighted in the report from Entranze (2014), policies aiming to increase RHC cannot be a single instrument but rather have to address heterogeneous target groups and technology specific barriers, which in addition can vary considerably across MS.[77] Generally, it seems promising to promote demonstration projects tailored to the important target groups as, for example, owners of single-family houses or rental companies owning a larger number of (similarly built) multi-family apartments. The learning taking place in these projects can then more likely be used in further projects and can be the starting of a longer-term cooperation between different actors involved.

As the experience from different MS shows, incentive programs for replacement of old equipment have been successful. In the UK and Northern Ireland, for example, replacement of old and inefficient boilers in lower income households has been supported by government. While this strategy is reasonable to meet renewable targets within Heating and Cooling, it may impede a more sustainable long-term development related to district heating (see above).

Taxation of fossil energies is another measure that seems promising in the light of the experience in Northern Europe (Finland, Denmark and Sweden). Here, too, a measure to support low-income households would be appropriate to prevent fuel poverty. The advantage of such a tax is that external costs of solutions relying on fossil fuels that are not included and bias the competitiveness of RHC equipment can be incorporated. Moreover, it can help to reduce the overall regulatory level since owners can decide what solution they aim for.

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7/ Measuring and monitoring

Figure 42: Presentation of the selected priority sectors within the Clean Industry taxonomy

7.1 Description and value chain

The Measuring and Monitoring (MON) industry provides solutions for sensing/monitoring, supervising, controlling and automating everything from objects/systems to industrial processes/systems and infrastructures. Specific benefits include improved plant throughput and productivity, enhanced worker safety, increased energy efficiency, higher process yields and waste product minimization, improved product consistency and uniformity. MON products and services play a key role in elevating worldwide living standards by increasing the availability and reducing the cost of basic materials and energy while insuring adherence to sound environmental practices.[78]

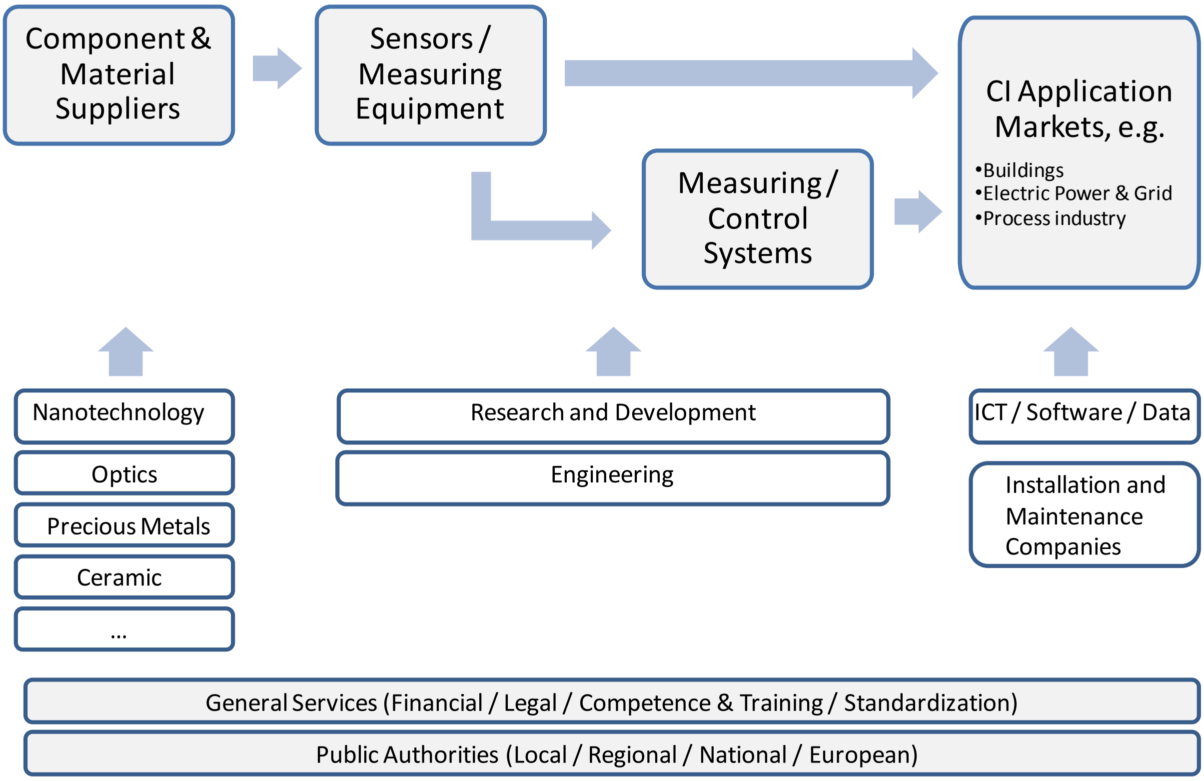
Typical application markets for MON in the context of the underlying CI taxonomy include (following EC 2009, p. 56ff.):

- Factory and business automation in manufacturing industries (clean production)
- Building (construction, services automation, facility management)
- Home (automation, safety, energy management)
- Electric power and grid (generation, transport, and distribution; focus renewable energy, smart grids, metering, etc.)
- Vehicle systems (embedded solutions for e.g. ABS braking, air conditioning, engine control, etc.).

[78] https://measure.org/general-info/industry-overview

This numeration already indicates the high importance of MON systems for Clean Industries. As energy efficiency and the broader usage of renewable energy sources and CO_2 savings gain more and more importance, not only in Europe, but also in other world regions the demand for energy-intelligent, energy-efficient and climate-friendly MON solutions will further increase. A value chain of the MON sector is depicted in Figure 43 below.

Figure 43: Value Chain of Measuring and Monitoring sector



Display: NIW.

The MON industry consists of equipment (products including components like sensors), related software and services (e.g. application design; integration, installation and training; communication and networking; maintenance and repair), whereas the economic weight of related software and services is estimated as even double as high as this of the respective products/equipment (EC 2009). MON products are statistically defined as NACE 2007 26.51: "Manufacturing of instruments and appliances for measuring, testing and navigation". This includes e.g. automotive emissions testing equipment, radiation detection and monitoring instruments, physical properties testing and inspection equipment, surveying instruments, thermometers, humidistats, hydronic limit controls, flame and burner control, spectrometers, consumption meters (e.g., water, gas, electricity), flow meters and counting devices; search, detection, navigation, aeronautical, and nautical equipment; radar equipment, GPS devices, environmental controls and automatic controls for appliances, measuring and recording equipment, motion detectors, radars, laboratory instruments and apparatus for measuring and testing etc. as well as components like any kind of sensors (ECSIP 2013, p.43; EC 2009).

The European position for MON solutions (products, software and services) is generally strong with leaders such as Siemens (DE), ABB (SE/CH), and Schneider Electric (FR), that are global players in several application fields and particularly leading with respect to industrial process automation in terms of systems and applications development, supply and usage (processit.eu 2013, p.6). These companies are more or less European based with headquarters in Europe but R&D centers and manufacturing facilities all over the world (Table 16). They have decades of development experience behind them in standard or more specific technologies and provide the sensors, the control layers, and all the programming software, development tools and operating systems to complete an automation system. Other European global players are Invensys (UK), Legrand (FR) and in the vehicle application field Bosch (DE), Continental (DE), Thales (FR), Alstom (FR), BAE Systems (UK) and EADS (FR/DE). Manufacturers of transport vehicles establish specifications of MON solutions and often design in-house. They then have their subcontractors (Bosch (DE), Delphi (US), Johnson Controls or Denso (JP)), assemble and deliver the systems. MON services are generally more localized in the user neighbourhood, with some software giants such as SAP (DE), Cap Gemini (FR), IBM (US) and smaller and more specialized companies locating close to markets (EC 2009, p.53).

Table 16: Global MON players and market shares of European suppliers in CI related application fields

Application field	European gobal players	Non European leaders with strong bases in Europe	Other leaders	European suppliers	
				European market shares	World market shares
Manufacturing Industry	ABB (SE/CH) Siemens (DE) Schneider Electric (FR)/Invensys (UK)*	Rockwell (US) Honeywell (US) Emerson (US)	Mitsubishi (JP), FANUC (JP) Yokogawa (JP)	60%	30 % – 35 %
Environment Building Logistics and Transport	ABB (SE/CH) Siemens (DE) Schneider Electric (FR)/Invensys (UK)*	Honeywell (US), Emerson (US), Johnson Control (US)	Mitsubishi (JP)	50 %	35 % – 40 %
Electric Power and Grid	ABB (SE/(CH) Siemens (DE) Schneider Electric (FR)	GE (US)	Mitsubishi (JP)	80 %	> 50 %

Vehicle	Bosch (DE), Continental (DE) Thales (FR), Alstom (FR), BAE Systems (UK) EADS (FR/DE)	Delphi (US), Johnson Control (US)	Boeing (US) Denso (JP)	50 % – 70 %	40 % – 50 %
Smart Home (e.g. to improve energy efficiency in buildings)	Legrand (FR), Schneider Electric (FR) Siemens (DE)	GE (US)	Home Automation (US)	50 % - 60 %	20 % - 30 %

* since 2014 Invensys is part of Schneider Electric

Source: Own compilation based on EC 2009

Based on a comprehensive study about the measuring and control market in 2007 (EC 2009), European firms are the leading suppliers on their home market with market share of at least 50%, with respect to Electric Power and Grids even 80%. In this field they are also dominating the world market (>50%). In the other fields they mostly gain shares between 30% and 50%. Only in the field of MON solutions to improve energy efficiency in residential buildings (smart home) European supplier just attain world market shares of 20 to 30% (Table 16).). For 2007, the global MON market has been estimated at about € 188 billion, thereby € 65 billion for equipment/products, € 22 billion for software and € 100 billion for services (EC 2009, p. 46). Recent market studies only refer to single sub-segments, and not to the whole MON industry (c.f. chapter 7.2.4).

7.2 Assessment of the global environment

7.2.1 Main competitors outside the EU

Figure 43 above also reveals the main non European suppliers of MON solutions based on a study performed in 2008 (EC 2009): e.g. Rockwell, Honeywell, Emerson, GE, Johnson Control, Delphi, Boeing, Home Automation (all US based) or Mitsubishi, Yokogawa, FANUC, Denso (from Japan). The more recent list of the 12 largest firms for process control and factory automation worldwide in 2013 also sees Siemens (DE), ABB (SE/CH), Emerson (US), Rockwell Automation (US) and Schneider Electric (FR), General Electric (US), Mitsubishi Electric (JP), Yokogawa

Electric (JP) and Honeywell (US) in a leading position and names further Danaher (US), Endress+Hauser (CH) as leading companies in flow meters, and Omron (JP).[79] The MCA Association estimates the global volume of products and services for process control and factory automation in process industries and utility power at about € 46.7 billion in 2014. The US (27%), Canada (3%) and Europe (23%) still accounted for 53% of the global market, although market shares continue to shift to other regions of the world. China accounted for 10%, Japan for 8%, India for 4% and Brazil for 3% of the global market in this field in 2014.[80]

7.2.2 Relative competitive strengths

In 2013, the structural business statistic reports 11,112 companies that produce MON products (NACE 26.51) in the EU-28. The value added to factor costs of the industry was about € 28.5 billion in the same year, what accounts for 1.7% of the EU's total manufacturing value added, with Germany on top (40.5% of total EU value added in MON products) far ahead of France (16%) and Great Britain (15.2%[81]). Furthermore, above average value added shares in MON products apply to Sweden (4.1%) and Denmark (2.6%). Total employment in MON products amounted to almost 387,000 (2013) in the EU-28[82], what accounts for about 1.3% of total manufacturing employment. Compared to 2008, this implies an increase of more than 50,000 jobs in MON products (CAGR: 2.9%), whereas total manufacturing depicts a job loss of more than -2.1% p.a. during the same period. Particularly Germany (6.6%), but also Romania (3.6%), the Netherlands (3.3%) and Denmark (3.2%) show an above average employment growth in MON products between 2008 and 2013. Thus economic figures for MON products in the EU-28 show a considerably more favourable picture and development than total manufacturing or the electrical engineering industry as a whole (ECSIP 2013).

In all market applications, thereby also the strongly CI related fields, the leading European MON suppliers appear to be amongst the world leaders Table 16. Particular strengths lay in embedded applications (e.g. vehicles, buildings), factory automation as well as energy power and grid solutions, based on strong experience in technological development and implementation of application-oriented MON products and services.

The high technological strength of EU and US companies in MON is reflected in the global distribution of Research and Development (R&D) expenditures and patent applications in this field (Figure 44 and Figure 45). For both regions, their shares of global R&D investments in MON are comparably higher than for total manufacturing R&D. Besides, the EU managed to hold its share of about 30% over time, whereas the US (2013: 42%, 2008: 48%)

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[79] https://measure.org/general-info/industry-overview

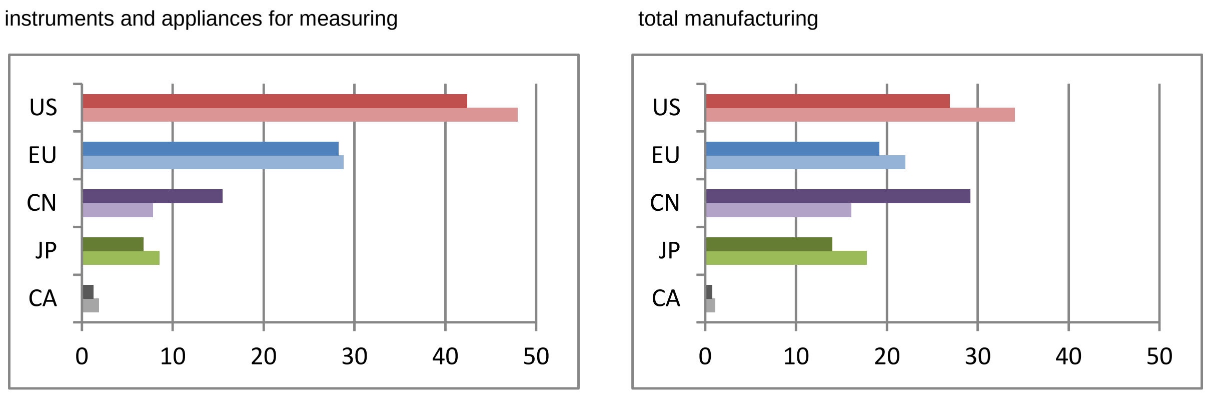
[80] https://measure.org/general-info/industry-overview

[81] 2012

[82] For 2007, total employment (including software and related services) was estimated at 750,000 in the EU (EC 2009).

and Japan (2013: 6.5%, 2008: 8.5%) significantly lost ground. Although China nearly realized to double its share to 15.5% in 2013, it is still clearly under-specialized in MON R&D (Figure 44). The same is true for Japan.

Figure 44: Business Enterprise Research and Development Expenditure (BERD) by industry 2008 and 2013 (world=100, share in %)



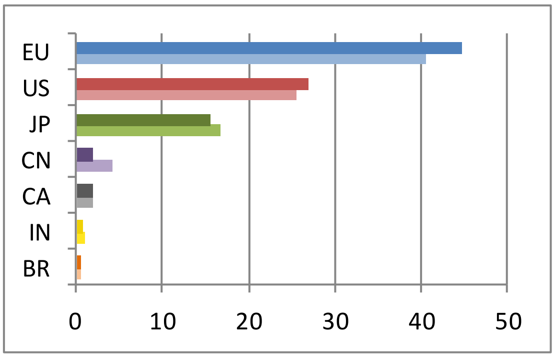
The upper bar (lower bar) shows the share of each region/country on global BERD in this field in 2013 (2008). No data available for India and Brazil.

Source: OECD Science and Technology statistics; Statistical Yearbook China. - NIW estimation and calculation.

The good technological performance of the EU and the US is underlined by above-average patent shares in MON compared to total patent applications (Figure 45). The significantly lower patent share of the US compared to its highest share in global BERD[83] in this field, is attributed to the focus on applications at the European Patent Office (EPO), which implies a bias in favour of European applicants on their important home market for MON solutions. Similar to the results for business R&D Japan and China only show a below average patent specialization in MON fields. The EU's success in transforming MON R&D in patent applications is mainly attributed to Germany (with a patent share of 17.8%), France (7.5%), Great Britain (5.5%) and the Netherlands (3.3%). Besides these MS, also Austria (1.3%) and the Czech Republic (0.2%) gain above average patent shares in this field.

[83] BERD is only available for 26.5 (including 26.51: MON and 26.52: manufacture of watches). Since this sector is distinctly dominated by MON, BERD for 26.5 can be taken as an approximation for BERD in 26.51.

Figure 45: Patent share in the field of Measuring and Monitoring compared to total patent share 2010 to 2012



The upper bar shows the patent share in Measuring and Monitoring based on the IPC codes G01 (measuring, testing) and G05 (controlling, regulation), the lower bar the total patent share (with respect to all technologies). Source: Eurostat Database. – Patent applications to the EPO (pat_ep_nipc) and PCT applications designated to the EPO (pat_ep_npct). - NIW calculation.

7.2.3 International trade performance

Box 11: International trade performance

This section investigates the EU-28's trade performance in the respective CI products with regard to the development in six competitive countries in America (USA, Canada, Brazil) and Asia (Japan, China incl. Hong Kong, India). Six trade indicators are analyzed to observe how the EU-28 and its Member States (MS) succeed in commercializing internationally competitive CI products. Those are significance (i.e. how important the specific CI products are in a country's total manufacturing exports), export market share (i.e. how important a country is for total global exports in the relevant CI), medium-term dynamics (i.e. how exports have changed within the pre-crisis years 2007/08 and 2013/14), trade balance (TB, comparing the absolute volumes of exports and imports), and two specialization indicators, namely export specialization (RXA, i.e. whether a country's global export share in a certain CI is higher/lower than its export share in total manufacturing products) and trade specialization (RCA, considering a country's relative export/import ratio of a certain CI compared to its total export/import ratio). Four of these indicators (export market share, significance, RXA and TB) are illustrated in the following chapter, the other two (medium-term dynamics, RCA) in the Annex 13/.

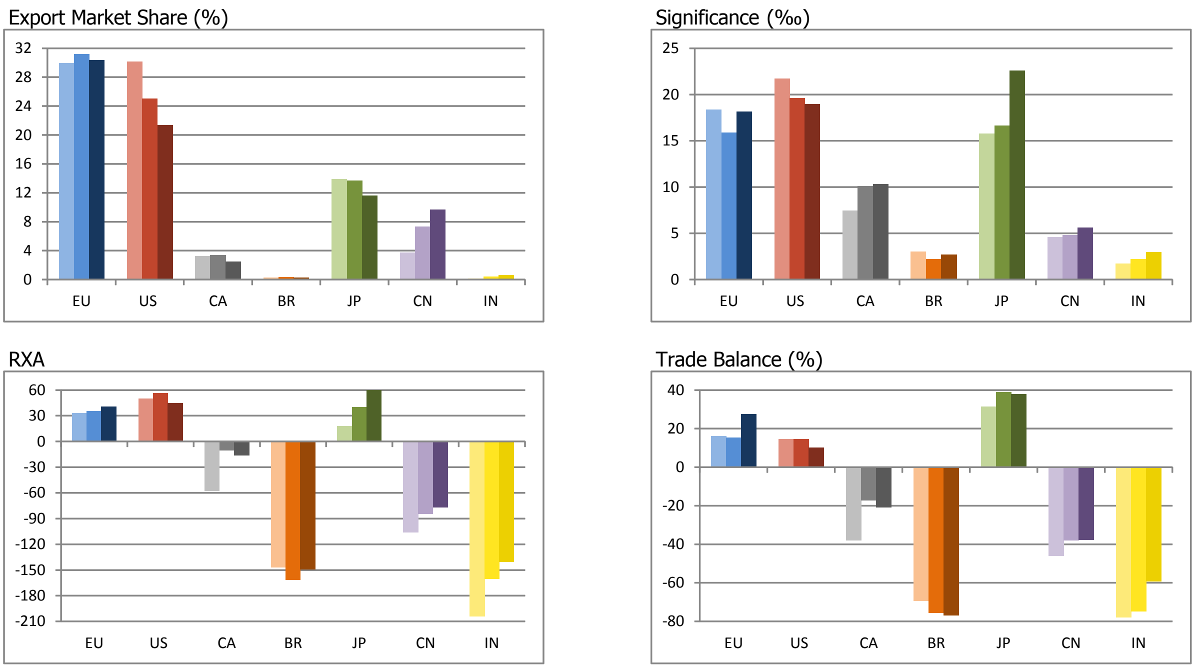
It is important to note that the analysis comparing the external trade performance of the EU-28 in a regional perspective only considers extra-EU trade flows. Otherwise, analysis that compares single Member States with non EU countries has to consider extra- and intra-trade. Hence, the calculated export market shares and export specialization figures (RXA) differ according to the respective perspective. Figures on the country level can be found in the Annex 13/.

High and improved comparative advantage of EU in MON

Although a high amount of the European MON market is made out of services, trade analysis can only consider manufactured goods which are namely measuring, control and navigation instruments and equipment.

The trade analysis reveals a clear comparative advantage of the EU-28, realizing high export specialization (RXA) and trade specialization figures which have continuously improved since 2008. Furthermore, the EU-28 has by far the highest export market share of around 30% in 2014. The strong export position of the EU is underlined by a positive trade balance that improved remarkably from around 15% in 2008 to nearly 30% in 2014 and positive medium-term dynamics (5.9% p.a., see Figure 46 and Figure 122 in Annex 13/). The EU's significance of MON exports in total exports applies to 1.8%, similar to the US (1.9%), but less than in Japan (2.3%). The other represented countries depict significance values equally to or less than 1%.

Figure 46: Trade indicators for the EU and selected other countries 2002, 2008 and 2014: Measuring and Monitoring



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

The US has lost significant export market shares since 2008 (2008: 30.2%, see Figure 46) but still holds the second highest export market share (21%) and reveals high export specialization and trade specialization figures, as well as a positive trade balance albeit figures of all trade indicators have deteriorated since 2002 indicating that competition outside the US has increased higher-than-average. In contrast, the positive export and trade specialization figures plus the trade balance of Japan's MON sector have majorly increased since 2002 even though its export market share decreased to 11.6%.

China succeeded in gaining significant export market shares (9.7%) which also translate into high medium-term export dynamics of more than 11% (Figure 122 in Annex 13/). However, China still reveals negative export and trade specialization figures as well as a negative trade balance. Canada (2.5%), India (0.7%) and Brazil (0.3%) only play a minor role in the export market of MON goods and have no specialization advantages in this field.

High comparative advantages for Hungary and all high-developed MS

The strong performance of the EU-28 is mainly driven by Germany which holds the highest export market share (18%) prior to the US (17%). Within the EU-28, Great Britain (5.6%), France (4.2%), the Netherlands (2.7%), Italy (2.1%) and Hungary (2%) attain export market shares of at least 2% as well. Especially Hungary, but also Germany, France and Great Britain reveal explicit comparative advantages, indicated by positive RXA and RCA figures (Figure 123 and Figure 125 in Annex 13/).

Furthermore, other highly developed MS (Austria, Denmark, Finland, and Sweden) with market shares over 0.5% depict distinct export and trade specialization. The strong position of those countries mentioned is also underlined by positive trade balances, positive medium-term dynamics and a large significance of MON exports (>1%, see Figure 124 in Annex 13/), however, the structural weight of MON products is particularly high in Hungary (3%, see Figure 124 in Annex 13/).

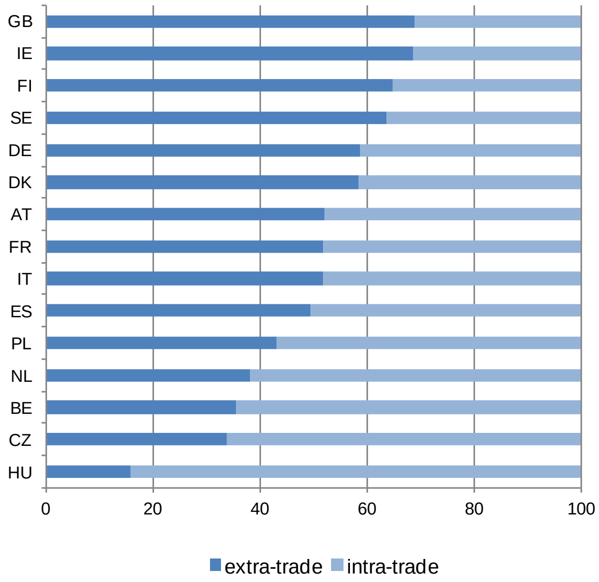
Some smaller MS (Estonia, Luxembourg, Malta and Slovenia) also have comparative advantages in this field according to their trade specialization, indicating that domestic manufacturers succeed in competing against international manufacturers. Moreover, apart from Bulgaria, Greece and Luxembourg, all EU MS show positive medium-term dynamics in their exports. Starting from a very low level, especially Estonia, Luxembourg, Poland, Portugal and Romania achieved high export dynamics of over 10% per year.

Large and growing weight on exports to non EU countries

Contrary to total manufacturing goods and most other CI products (except AMT and Traffic Control Systems), the intra-EU-exports share of MON products is comparably low (46% in 2014). On average, 54% of EU exports are designated to non EU countries. This indicates that the export potential for those products in other world regions is particularly high and moreover, has significantly grown over time: in 2008, the intra-trade share still accounted for more than 51% of total EU exports.

As Figure 47 reveals, six out of the 15 MS with export market shares larger than 0.5% are more orientated towards non EU. Most notably Great Britain, Ireland, Finland and Sweden export less than 40% to other EU countries. Also Germany, with the highest export market share in the world, reveals a high share of EU-Extra-trade (59%). Contrary to this, Hungary only exports around 17% into non-EU countries. A low share of EU-Extra-trade (less than 50%) is also true for the Czech Republic, Belgium, the Netherlands and Poland.

Figure 47: Share of EU-Extra-trade and EU-Intra-trade (in %) in country exports: Measuring and Monitoring



Including the EU countries with an export market share in Measuring and Monitoring products higher than 0.5% in 2014.
Source: UN COMTRADE-Database. – NIW calculation.

7.2.4 Market outlook

MON as a cross-sector is more or less relevant for all CI segments. Hence growing demand for innovative CI solutions will also stimulate the demand for MON products and related services: Key drivers are regulations, rising energy prices and savings from energy efficiency, technological developments (e.g. rising automation, more complex solutions), end user demands (attitudes and education), but also incentives and rewards to install energy saving respective energy efficient technologies (EPEC 2011). In general, the demand for MON services is expected to grow much faster than the demand for equipment. This is driven both by price pressures and technological improvements, as well as by increasing demand from individuals, companies and governments related to increased safety, security, energy or environment concerns (EC 2009, p.8).

On the other hand, innovative MON solutions will improve the efficiency, safety, and comfort of specific CI applications (e.g. smart grids and smart metering, smart building applications, traffic control systems), thus making them more attractive for potential use in households, industry, utilities or communities.

A comprehensive study performed in 2008 (EC 2009) estimated the global market volume of the MON industry (excluding sensors) at almost € 188 billion, from which € 65 billion was attributed to products/equipment, € 22 billion to software and € 100 billion to services. The European market was estimated at € 61.5 billion, thus accounting for nearly one third of the world market.[84] At that time, without knowing the effects of the financial crisis, global market growth till 2020 was estimated 8% p.a. Due to some more mature European MON markets European demand was expected to increase slightly lower with 7% p.a. (EC 2009, p.8), but at a much higher rate than the overall economy. Particularly high demand dynamics was forecasted for CI application fields as "electric power and grids" (9.9% p.a.) and "homes" and "buildings" (including energy efficiency improvement in buildings and energy management, about 7.5% p.a.); see chapter 7.1). More recent market prospects only refer to single sub-segments of the global MON sector, expecting CAGR of 6 to 11% between 2014/15 to 2019/20 worldwide. North America and Europe usually account for the largest markets, but other regions, specifically Asia Pacific, but also Middle East and Latin America are expected to reach higher growth rates in the near future. Some examples are listed below:

- Depending on different definitions and methodologies, estimates for the global market for sensors vary between more than € 90 billion (2015)[85] and about € 120 billion (2011)[86]. Based on the projections of BCC Research the global market for sensors (valued € 92 billion in 2015) is projected to reach an outstanding high CAGR of 11% for the period 2015-2020. The strongest growth rates within this market are estimated for smart sensors (36% p.a.), acoustic wave sensors (25% p.a.) and motion sensors (13% p.a.).[87]. Germany and Japan are the main drivers for sensors demand for machinery, followed by the US. On the other hand, the US is the main driver for innovation and the strongest market for sensors in the information and communication technologies as well as the leading market for sensors in process industries. However, China, India, and Southeast Asia are catching up.[88]

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[84] The sensor market was excluded from this analysis because it had been analyzed in a study from Decision (2008) that estimated the European sensor market at € 10 billion in 2007, accounting for 28% of the global sensor market (€ 36 billion) in the same year.

[85] http://www.bccresearch.com/market-research/instrumentation-and-sensors/sensors-tech-markets-report-ias006g.html

[86] http://www.intechnoconsulting.com/ic/reports/detail/sensor-market-report-2016.php

[87] http://www.bccresearch.com/market-research/instrumentation-and-sensors/sensors-tech-markets-report-ias006g.html; https://www.electronics.ca/smart-sensors-industry-report-2014.html; http://www.marketsandmarkets.com/PressReleases/acoustic-wave-sensor.asp; http://www.marketsandmarkets.com/Market-Reports/Motion-Sensor-Market-614.html

[88] http://www.intechnoconsulting.com/ic/reports/detail/sensor-market-report-2016.php

- The global flow meters market, valued € 4.1 billion in 2014, is estimated to grow at a CAGR of 7.2% from 2014 to 2019. The Asia-Pacific region remains the largest market for flow meters, which are used to measure greenhouse gas emissions, followed by North America and Europe. Asia-Pacific market continues to be the key growth area due to new investment backed by increasing demand for innovative technology for flow meters from different end-user industries.[89]
- The global liquid analytical instruments market is witnessing a significant growth due to the rising demand of real-time data monitoring and enhanced industrial process requirements. Moreover, stringent environmental standards along with increased demand for liquid analyzers in wastewater and water quality management industry as well as biotechnology industry are expected to boost the growth of overall liquid analytical instruments market in the near future (CAGR 6.2% 2014-2019[90]).
- The data acquisition market (valued € 2 billion in 2015) and the electronic test and measurement instruments market (valued € 4.7 billion in 2015) are estimated to grow at a CAGR of about 6% during 2015 to 2020 period.[91]

Technology and production development of meters will be highly complementary to high-tech grid components, power system automation, interfaces, and measurement devices (ECSIP 2013, p.45). Major trends in electromechanical measuring are the increasing use of micro- and nano-electromechanical systems (MEMS, NEMS) and of silicon measuring elements, multi-sensors for mass application, direct sensor-actuator coupling, more robust process coupling, lower measuring uncertainty and increased long-term stability (AMA 2010 p.13).

Key research fields in sensor technology concern multiple measurement sensors (heterogeneous material integration and nanostructures), smart and interconnected sensors (sensor networks, self-diagnostic and configuration capabilities), energy autonomy (low power consumption and energy harvesting techniques), etc. (EC 2009 p.314). Market drivers are thin film integration technologies, new product segments (e.g. bio-sensors), and increased need for energy saving and control (EC 2009 p.84/85). Equipping disposable sensors with wireless communication capabilities will enable new measurement possibilities and support improved process monitoring and control, as measurements from the process core will become available in real time (proccessit.eu 2013, p.24).

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89 http://marketsandmarkets.com/Market-Reports/flow-meters-market-1191.html

90 http://www.prnewswire.com/news-releases/global-liquid-analytical-instrument-market-2015-2019-300035555.html

91 http://www.prnewswire.com/news-releases/global-data-acquisition-daq-market---market-size-share-and-forecasts-2015-2020-300150240.html; https://www.electronics.ca/electronic-test-and-measurement-instruments-market.html

7.3 Assessment of the competitiveness aspects

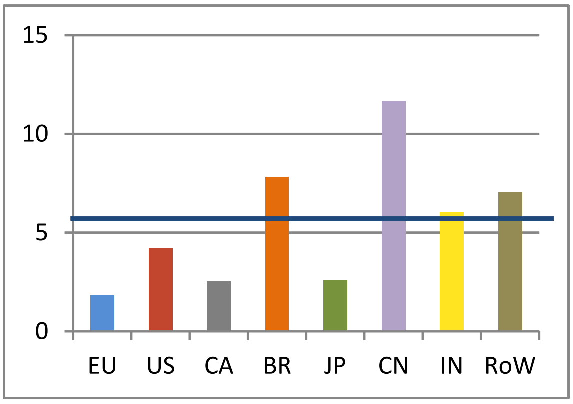
7.3.1 Export potential

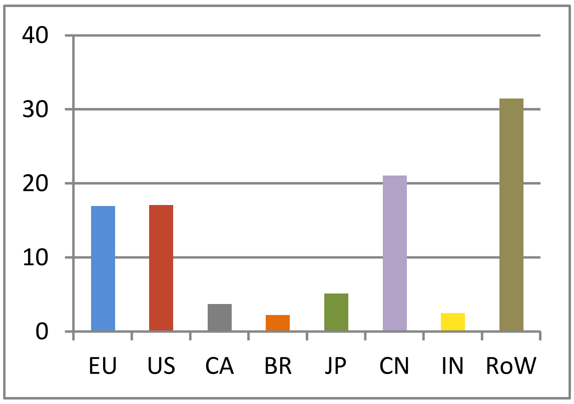
Box 12: Export potential

Export potentials emerge primarily in those goods and activities, in which the EU-28 already holds comparative advantages (measured in export specialization or trade specialization). In these goods and activities, trade volumes can be used as an initial indicator for market and growth potential. Hence, growing import rates of third countries may serve as a proxy for an increase in demand for CI goods in a specific country or world region that may subsequently translate into a growing export market for the EU and its Member States. At the same time, existing export advantages (indicated by RXA values) of the EU and its Member States in certain products may indicate promising preconditions for further growth and export potential.

Figure 48 reveals the global import market shares of the EU (excluding intra-trade) in comparison to other selected countries and the rest of the world (RoW) in Measuring and Monitoring equipment (MON, i.e. measuring, control and navigation instruments and equipment), indicating that China is the largest single importer (21%) and did also show the highest import dynamics (11.7% p.a.) since 2007/08. The US (17.1%) and the EU (16.9%) are almost at par on second and third place in terms of import volume. Japan (5%), Canada (3.7%), Brazil (2%) and India (2.5%) do not display any noticeable import shares compared to their structural weight. However, Brazil (7.8% p.a.) and India (6%) yield the second and third highest import dynamics since 2007/08, indicating growing demand for MON equipment in these countries. Otherwise, also lower growth rates connected with a high absolute import volume, as can be seen in the US (4.2%) or the EU (1.8%), from whose perspective external imports could be substituted by internal production, are of importance. As Table 27 in Annex 1/ depicts, the EU constitutes high export market shares and export specialization values (RXA) for MON equipment in each of the five selected foreign countries. Thus, they basically all promise further export potential for the EU MON equipment manufacturers as well as related services in case of growing import demand for MON products, although Canada and Japan are actually falling behind in this field.

Figure 48: Import market share 2014 and import dynamics 2007/08 to 2013/14 in the EU-28 and selected non-EU countries: Measuring and Monitoring

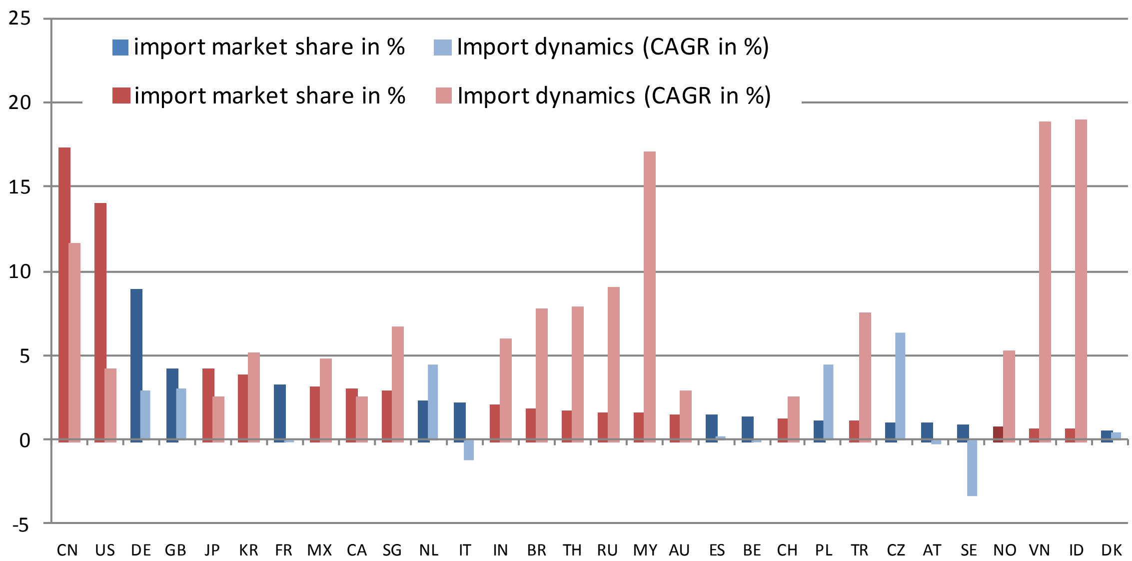




Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

On the other hand, Figure 48 reveals that roughly 31% of the import demand for MON products in 2014 applies to other than the selected countries (RoW). Furthermore, the import dynamics of the RoW achieved 7% p.a., thus being slightly higher than the global average (6%). Hence, Figure 49 illustrates import market shares and import dynamics for all countries with a global import market share higher than 0.5% in 2014. This points out that besides China, the US, Japan, Canada, and some larger EU MS (Germany, Great Britain, France, the Netherlands and Italy), also some overseas countries (South Korea, Mexico, and Singapore) constitute considerable import market shares while others did show remarkable growth rates (Vietnam, Indonesia and Myanmar), hence creating additional sales respective export potential for the EU MON industry.

Figure 49: Import market share 2014 and import dynamics 2007/08 to 2013/14 in Measuring and Monitoring on the country level



Global imports including EU-intra-trade. - Regarding countries with a global import share higher than 0.5%. – EU MS: blue coloured; non EU countries: red coloured.
Source: UN COMTRADE-Database. – NIW calculation.

7.3.2 SWOT

Below the strength, weaknesses, opportunities and threats (SWOT) for the European wind industry that could be identified by literature, own data analysis and based on expert interviews, are specified in bullet points.

Table 17: SWOT for Measuring and Monitoring (MON) sector

Strengths	Weaknesses
▶ High technological strength of European companies, long experience, reflected in the above average shares in global Business R&D expenditures (BERD) as well as patent applications in MON ▶ In 2013, the value added to factor costs of the MON manufacturing industry (NACE 25.51) was about € 28.5 billion (1.7% of the EU's total manufacturing value added), with Germany on top (40.5%) far ahead of France (16%) and Great Britain (15.2%). Furthermore, above average value added shares in MON products apply to Sweden (4.1%) and Denmark (2.6%). Total employment in MON products amounted to almost 387,000 (2013) in the EU-28. Compared to 2008, this implies an increase of more than 50,000 jobs in MON products (CAGR: 2.9%), whereas total manufacturing depicts a job loss of more than -2.1% p.a. during the same period. ▶ In all market applications, the leading European MON suppliers appear to be amongst the world leaders. Particular strengths lay in embedded applications (e.g. vehicles, buildings), factory automation as well as energy power and grid solutions, based on strong experience in	▶ High production costs in Europe: job growth mostly in high-skilled jobs

technological development and implementation of application-oriented MON products and services. ▶ The EU reveals a clear comparative advantage in MON trade (RXA and RCA), that has further improved since 2008 ▶ On the MS level, especially Hungary, but also Germany, France and Great Britain reveal explicitly high comparative advantages (RXA and RCA), less distinctly also Austria, Denmark, Finland, and Sweden	
Opportunities ▶ Growing demand for innovative CI solutions (within the EU and worldwide) will also stimulate the demand for MON products and related services, creating value added and additional jobs in manufacturing industry, and particularly in related software and services ▶ A regulation or standardization can stimulate demand amongst equipment suppliers and installers ▶ Future market growth will be stronger in Asia-Pacific, Middle East and in Latin America than in the EU and North America: additional export potential for European suppliers ▶ Contrary to total manufacturing goods and most other CI products (except AMT and Traffic Control Systems), in 2014 54% of the European exports are designated to non EU countries (46%: intra-trade). Thus, the export potential is particularly high has significantly grown over time ▶ The EU constitutes high export market shares and export specialization values (RXA) for MON equipment in each of the five selected foreign countries. Thus, they basically all promise	Threats ▶ New competitors from Asia will arise, meaning growing price competition for more standardized products on the European as well as on the global market ▶ A regulation on standardization could be very helpful in stimulating demand amongst equipment suppliers and installers (see opportunities), but can also have side effects such as the development of new players outside Europe

further export potential for the EU MON equipment manufacturers and related services ▶ Furthermore some larger EU MS (Germany, Great Britain, France, the Netherlands and Italy) as well as overseas countries like South Korea, Mexico, and Singapore constitute considerable import market shares or remarkable import growth rates (Vietnam, Indonesia and Myanmar), creating considerable sales respective export potential for European MON suppliers	

With respect to the EU's performance and future development potential in MON, strengths and opportunities are distinctly predominating weaknesses and threats. The industry provides innovative solutions for monitoring and optimizing more and more complex, mostly ICT-based processes in a vast variety of application fields, thereby also playing a major role for CI segments like energy generation, storage and transformation (smart grid), clean production, clean mobility or the improvement of energy efficiency in buildings. The EU reveals a high technological competitiveness and long experience in complex and high-quality MON solutions. In spite of high production costs, European products are strongly and increasingly successful within the internal as well as on international markets and - in contrast to other manufacturing industries - the number of jobs in MON products has been growing over time. Thus, European suppliers have a good precondition in participating in the growing demand for MON products and services that will be connected to the increasing demand for clean technologies within Europe, but also worldwide, creating additional export potential, value added and jobs in MON equipment, and particularly in related software and services.

7.4 Analysis of barriers

MON as a cross-sector is an elementary segment in the Clean Industry since it enables energy efficiency in various ways as well as the application of new technologies. Hence all barriers hindering the development of CI MON application markets also hamper the demand for MON products and related services.

Firstly, economic or financial reasons can reject the decision for innovative, energy-saving technologies with embedded or related MON solutions. This can be the case if the installation costs are higher compared to traditional solutions or if purchasing decisions are rather based on total installed costs than on long term benefits. This is particularly a decisive barrier to the adoption of new technologies of home automation systems by the mass-market. Secondly, regulatory and institutional barriers like the lack of regulatory enforcement, differences in regulatory frameworks across countries and a slow acceptance of new technologies by regulators play a major role. Less strictly environmental regulations in foreign countries can also hinder the development of the global market for smart environmental protection technologies or clean production solutions. In this context, also the absence of an infrastructure to promote new technologies or applications and provide training, marketing and design tools can be mentioned (EPEC 2011). Another barrier can be that end-users show a lack of environmental awareness and reluctance to adopt new technologies. Furthermore, technical barriers can hinder the installation of new technologies e.g. in the case that they require a certain pre-existing infrastructure. The lack of compatibility and standardization between products can be a decisive barrier for the mass market uptake of technology, particularly in home and buildings applications and between countries. Besides, the MON industry requires a large amount of high-skilled workers with typical STEM[92] skills. In order to meet growing global competition, the demand for STEM workers will increase in all industries across Europe, so that the already existing gap between supply and demand is estimated to rise.

According to selected CI applications fields, furthermore the following specific barriers can be identified:

Barriers for innovative MON solutions in manufacturing industries (clean production) mainly refer to the complexity of the systems (simulation, modelling and optimization) and high development and installations costs (EC 2009).

Obstacles for the stronger distribution of innovative MON solutions with respect to electric power and grid are financial constraints for long term investments, legacy systems with long life cycles, a large number of actors to be convinced in installing new interregional grid structures (super grids) and the lack of networking solution standards for the distributed generation of energy.

Barriers listed in the context of more automation and ICT in vehicle systems mostly refer to network security and customer's behaviour (lack of adoption), also including the still low market share of electric vehicles that require more and high-quality electronic control than conventional vehicles.

Barriers to MON solutions in home and buildings are very similar to these listed under other selected CI sectors under the priority sector "Energy efficiency in buildings" (thermal insulation, heating and cooling, NZEBs): Innovative solutions have high prices in comparison to incumbent technologies, preventing end-users to use new technologies, and investors to apply new technologies to retrofitting projects (EPEC 2011). Home automation and energy issues are not a priority for households. Furthermore, knowledge and information deficits have to be considered: Architects and designers tend to focus on what technology is capable to do rather than customers' demand and their capacity to use the devices. There are no real "plug and play solutions" yet, and electricity installers often are not educated for complicated solutions.

92 STEM is an acronym for the fields of study in the categories of science, technology, engineering, and mathematics.

7.5 Suggested actions

As all kinds of energy-intelligent, energy-efficient and climate friendly solutions need MON, innovative MON solutions can contribute decisively to energy savings and efficiency gains in all CI sectors, thus improving the cost-benefit ratio of investments as well as reducing CO_2. In this view, the high technological and market competitiveness of the European MON industry is a decisive lever to unlock the potential of CI.

On the other hand, all policy recommendations that aim at the strict implementation of the EU's energy performance targets will directly push the demand and market for innovative MON solutions (products and services).

Therefore, all actions already mentioned in the context of the selected CI segments are relevant. Especially clear and ambitious targets (e.g. for building energy codes or the decarbonisation of vehicles) that impedes the distribution of new technologies are highly important for the broader implementation of innovative and sustainable MON solutions. To overcome high cost barrier for users, those regulatory targets have to be combined with financial incentives for investors and users (e.g. financial support in form of grants). The funding used for this purpose could inter alia be provided by carbon taxes as already used in some Northern European countries.

Other suggestions refer to the awareness towards the direct and indirect benefits of energy-efficiency. In this context instruments to improve information and knowledge of all actors involved (e.g. information campaign, training for on-site workforce etc.) play a major role.

A more explicit relation to the MON industry itself is applied to the development of European and global standards, removing market entry barriers and stimulating competition and innovation between MON suppliers within the EU and worldwide. To achieve this target, the EU should on the one hand push the development of EU wide standards in all CI application fields. On the other hand the EU should promote the use of EU/ISO standards in trade. This helps to avoid export barriers, especially vis-a-vis emerging economies (see also chapter 5/: AMT).

Furthermore, the challenging technological competition with the US, Japan and – continuously progressing – China, will require more R&D investments and high-skilled employment. The education and availability of these skilled people (e.g. electrical engineers and technicians, IT specialists and technicians with STEM education) will be essential for assuring that the European MON industry as well as other CI industries will be able to participate in domestic and global growth opportunities. Although a recent study (Cedefop 2015) depicts that actually only a small subset of European firms face genuine skill deficits, defined by the ability to find job applicants with the right skills despite their willingness to pay the competitive price. However, the affected firms are particularly dynamic, internationally oriented EU companies that have greater and more demanding skill needs that can be found particularly in specific economic sectors, thereby ICT and advanced manufacturing, including the MON industry and other selected CI sectors such as the wind industry, AMT, smart grids or cleaner mobility.

Highlighting STEM as a priority for education in the EU in general and increasing the understanding of career pathways of STEM graduates in MON (as well as in other growing CI fields) could contribute to stronger attractiveness for this study field.[93] Furthermore, a mix of human resource policies by companies and policy-makers, creating the right incentives and institutional frameworks would strengthen the employers in developing and implementing vocational education and training arrangements. Examples are the offer of better and stable jobs and high quality apprenticeship places, a greater cooperation between companies, employer associations, and education and training institutions, exploiting the talent of females and older workers, etc. Further measures address the improvement of transnational and cross-sector mobility between businesses, education and training institutions and research institutes, e.g. by stimulating lifelong learning, fostering joint education and training projects and programs across Europe, and strengthening the mutual recognition of qualifications as well as harmonizing the assessment of learning outcomes (EC / JRC 2014).

7.6 Bibliography measuring and monitoring

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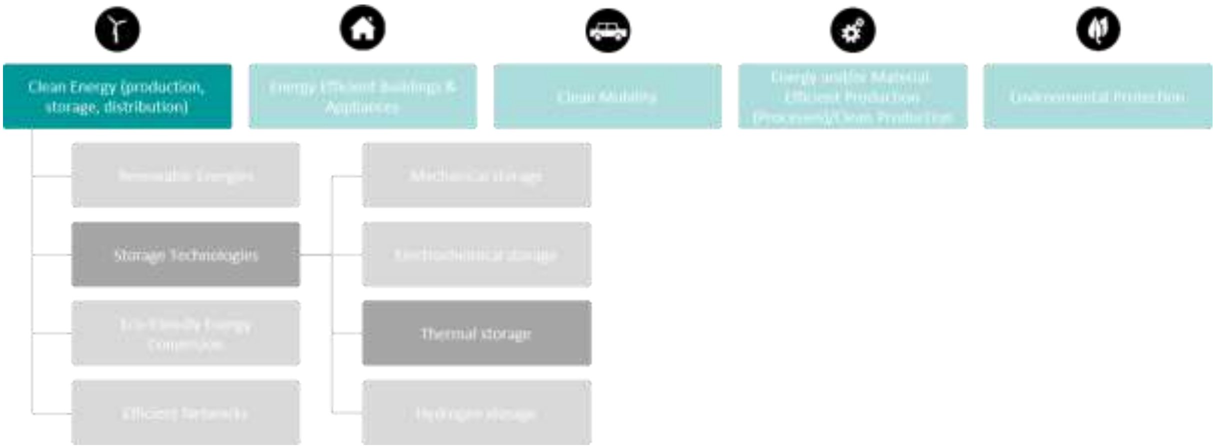
8/ Thermal energy storage

Figure 50: Presentation of the selected priority sectors within the Clean Industry taxonomy



8.1 Description and value chain

Thermal energy storage (TES) offers the opportunity for effective and efficient generation and utilisation of heat where heat supply and heat demand do not match spatially and in time[94]. The future electricity grid will integrate more renewable energy, especially wind and solar including decentralised supplies. So supply and demand must become more flexible, through wider use of demand reduction, demand response mechanisms and energy storage. Linking heating and cooling with electricity networks will reduce the cost of the energy system – to the benefit of consumers. For example, off-peak electricity can be used to heat water in lagged tanks which can store energy for days and even weeks[95].

TES promotes both more effective thermal management in such as sectors heating and cooling as well as process heat and power generation and enables an increased utilisation of renewable energy. A specific feature of TES is that they are diversified with respect to temperature, power level and use of heat transfer fluids and that each application is characterised by its specific operation parameters. Indeed, TES covers a series of different technologies and materials, making it suitable for different purposes, ranging from residential heating to large scale electricity production. Heat storage is currently by far the largest single energy storage application field in Europe, making it a key enabling sector in the transition towards a more sustainable economy.

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94 EASE/EERA (2013). European Energy Storage Technology Development Roadmap towards 2030.

95 An EU Strategy on Heating and Cooling COM(2016) 51 final and Staff Working Document SWD(2016) 24 final

Heat can be stored in three main ways[96]:

- **Sensible heat storage** results in an increase or decrease of the storage material temperature, whereby the stored energy is proportional to the generated temperature difference of the storage medium (which can be as simple as water). When needed, this sensible heat is released again by radiation and convection.
- **Latent Heat Storage** utilises a phase transformation of the storage materials (phase change materials - PCM), in most cases from solid to liquid and vice versa. The phase change is always coupled with the absorption or release of heat and occurs at a constant temperature. As such, the heat added or released cannot be sensed and is therefore said to be latent. The amount of energy stored is equivalent to the heat (enthalpy) for melting and freezing. Media used can be again as simple as water, but include also more advanced organic and inorganic compounds.
- **Thermochemical Heat Storage** is based on reversible thermochemical reactions. The energy is stored in the form of chemical compounds created by an endothermic reaction, and can be recovered again by recombining the compounds in an exothermic reaction which yields surplus energy.

TES is a comprehensive term, encompassing various different applications, technologies and materials. Drawing a single value chain structure for TES is therefore not straightforward, yet Table 18 present a simplified version which contains examples for four specific value chains (VCs). Generally speaking, a TES VC is composed of four major building blocks, i.e. the supply of thermal energy to the system, the storage system itself (which can be divided in the storage medium and its physical surroundings) and the heat delivery for further use. As will be illustrated, the technical challenges (and hence costs) can lie at different parts of the VC.

VC1 relates to conventional storage of hot water for residential heating and for domestic hot water use, which is a well-known technology for thermal energy storage. Hot water tanks can serve the purpose of energy saving in water heating systems based on solar energy and in co-generation (i.e. heat and power) energy supply systems, and can reduce peak loads in case of electric heating as has e.g. been shown in France. Sensible heat storage is a mature technology, since it has been commercially available for many years in the form of domestic and industrial hot water storage systems[97],[98].

VC2 concerns the underground thermal energy storage, which is a widely employed storage technology, which makes use of the underground as a storage medium for both heat and cold storage. UTES include borehole storage, aquifer storage and cavern/pit storage[99]. Larger UTES systems, including aquifer thermal energy storage

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[96] Idem

[97] EASE/EERA (2013). European Energy Storage Technology Development Roadmap towards 2030.

[98] IEA-ETSAP and IRENA (2013). Thermal Energy Storage. Technology Brief E17

[99] Idem

(ATES) and borehole thermal energy storage (BTES), have been successfully commercialised in order to provide both heating and cooling capacity in countries such as the Netherlands, Sweden, Germany, and Canada. These applications make use of moderate temperatures in the underground in order to preserve temperature better than above surface, and can be used even for seasonal storage (e.g. retaining heat from summer to be used in winter)[100]. Good knowledge of local geology is a key factor in this domain.

VC3 relates to the integration of thermal energy storage in concentrated solar power (CSP) plants. Many of these plants are equipped with TES based on molten salts, and is one of the most important examples for large scale **centralised** TES[101]. A CSP plant often involves flat or parabolic mirrors that reflect incoming sunlight to a collector, which can e.g. be a large solar tower in the middle of the plant where two molten salt tanks are installed (see *Figure 51* for an example). The heat from the molten storage drivers a turbine, which generates electricity. Thanks to the storage capacity, such a plant can generate electricity from one to several hours when there is no sunshine.

Figure 51 Example of a CSP plant[102]

VC4 relates to use of phase change materials for HVAC (heating, ventilation, air conditioning). Essentially, the advantage of PCMs is that they help stabilise ambient temperatures around their melting points (e.g. materials with melting points of 21°C or 23°C are on the market). When the temperature increases above this melting point, they change phase to liquid state, adsorbing heat in this process. Conversely, when the temperature decreases, the material goes back to solid state, thereby releasing heat. As such, PCMs can reduce ambient

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[100] International Energy Agency (2014). Technology Roadmap Energy storage.

[101] Idem

[102] Source: Sandia National Laboratories

temperature on hot summer days, while supplying heat at colder moments (e.g. in evening, night and morning). They thereby limit energy use for both air-conditioning as well as heating. In order to execute their temperature controlling role, PCMs can e.g. be integrated in building materials such as plasterboard.

This fourth VC contrasts with e.g. the VC1 and VC3 in that materials involved are not necessarily cheap and bulky (such as water or molten salt) but can be rather high-tech special purpose developed materials. Hence, competition here lies more on technological capabilities with regarding to developing and encapsulating high performance PCMs with high latent energy storage capacity at acceptable cost.

Table 18: Generic representation of TES value chain, with examples for specific value chains

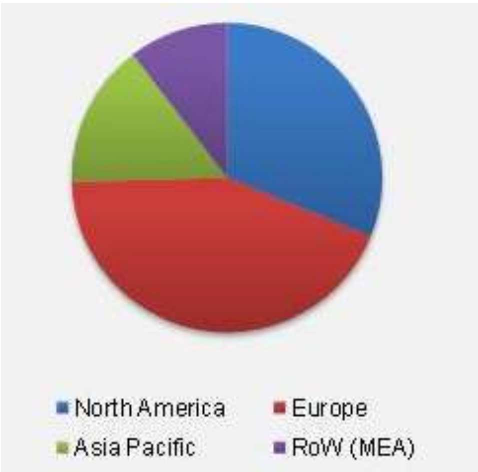
	Heat collection and supply	**Energy storage medium**	**Isolation and physical container**	**Heat delivery & valorisation**
VC1: sensible heat storage residential heating	Conventional boiler, heat pump, …	Water	Storage tank with conventional isolation	Heated water is delivered upon request
VC2: underground thermal energy storage (UTES)	Various sources, e.g. waste heat, renewable energies, …	Water	Underground holes, sealed with isolating material	Heated/cooled water is pumped up when needed and run over heat exchanger to bring the heat/cold into circulation
VC3: concentrated solar power (CSP)	Mirrors such as parabolic trough collectors	Molten salts	Solar tower which contains a two tank system for salts	Thermal conversion processes (steam turbine, ORC, …) converting heat into electricity Utility companies
VC4: phase changing materials for HVAC	Heat from the surroundings is absorbed by the PCM	Parafin, Na-acetate Trihydrate, erytritol, …	E.g. construction materials such as plasterboard, packaging materials, textiles, …	Heat is released again to surroundings when ambient temperature decreases below melting points

Considering the large variety of applications falling under TES, this study will focus on three domains, namely the underground TES, concentrated solar power and phase change materials (PCM). These are key high growth applications of sensible and latent heat storage. Applications based on the third form of TES, thermochemical storage, have high theoretical energy storage capacities, but are as of yet still in research phase and will therefore not be discussed in the rest of this chapter[103].

For the UTES value chain no figures on market share are available, however it is clear that the EU is a frontrunner in this area. For example, The Netherlands and Sweden are considered leading in terms of number of implemented ATES projects. Also for borehole energy storage a number of operational plants have been developed, e.g. in Germany[104].

In the CSP market, Europe is market leader in terms of installed capacity. In 2013, about 43% of all capacity worldwide was in Europe (Figure 52). By far the EU country with the largest installed base is Spain, which has known a major series of investments in CSP in the south of the country in the period 2008-2012. Whereas CSP value chains are global, the important home market of CSP projects has enabled several EU companies active in project development, light receivers, power block, operation and maintenance, etc. to grow in this market and to gain expertise, a result of which they are world-class today.

Figure 52: Global CSP market share by region, 2013[105]



[103] Decourt, B. and R. Debarre (2013), "Electricity storage", Factbook, Schlumberger Business Consulting Energy Institute, Paris, France and Paksoy, H. (2013), "Thermal Energy Storage Today" presented at the IEA Energy Storage Technology Roadmap Stakeholder Engagement Workshop, Paris, France, 14 February

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[105] Transparency Market Research (2014). Concentrated Solar Power Market for product segment (Parabolic Trough, Tower, Fresnel and Dish Sterling) - Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2012 - 2020

In the PCM markets, the EU holds a solid position especially in the applications that relate to HVAC and housing, whereby PCMs serve to absorb heat when temperatures rise above a certain threshold, and to release heat again when the temperature decreases again. Europe boasts the leading manufacturers of organic PCMs which are used for these type of applications (see section 8.2.2 for more details). More generally, Europe is currently the most important market for PCM (energy and non-energy storage related), providing a home market for EU suppliers of PCMs, which include both larger chemical companies as well as companies smaller dedicated companies. One of the key challenges for these PCM materials is the dissemination of the benefits amongst professionals involved in the value chain for buildings (e.g. architects, early adopters, installers), increasing its reliability and confidence towards these professionals would ease the uptake. In this regard ensuring adequate and fair treatment within the building codes at the National level and the relevant calculations would be of most relevance for its deployment and overall awareness.

8.2 Assessment of the global environment

8.2.1 Main competitors outside the EU

In the area of UTES, apart from the EU and Norway, also in Canada several commercial projects have been implemented, mostly for heating purposes. For example, in the province of Alberta a first of its kind solar based heating system has been created, which includes hundreds of solar collectors on the roofs of the houses in the community and a borehole storage facilities that support year-round heating[106]. Also examples in the US and China exist[107], however EU is generally acknowledged being the industry leader.

In the CSP value chain, most competition comes from the U.S., which counts key players such as BrightSourceEnergy and SolarReserve (project developers) and Babcockcpower (technology supplier for light receiving). Apart from overall technological capabilities present in the U.S., this good presence of US companies is also a direct consequence of the important home market that the US (and in particular the state of California) has been for CSP.

In the PCM market, the major competitor is again the U.S., thanks to both large companies such as DuPont which are active on this market as well as dedicated companies such as Change Energy Solutions. The U.S. is particularly well positioned in the field of use of ice for cooling purposes. According to the DoE thermal energy storage database[108], more than 100 ice-based projects have been implemented in the United States, while only

106 http://www.dlsc.ca/

107 International Energy Agency (2014). Technology Roadmap Energy storage.

108 http://www.energystorageexchange.org/

very few are recorded in Europe. Two key technology providers active in this area, Calmac and Ice Energy, both are US based. In the U.S., an estimated 1 GW of ice storage has been installed to reduce peak energy consumption in areas with high numbers of cooling-degree days. In addition to the US, also Japan counts significant amounts of installed thermal storage based on ice[109].

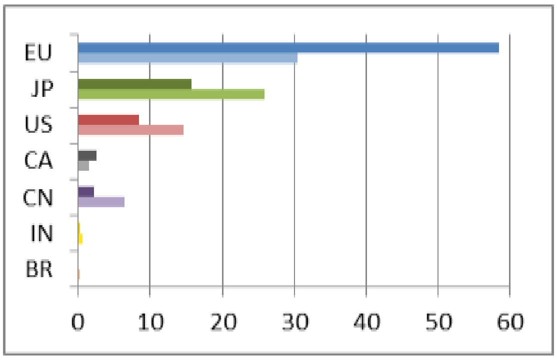
8.2.2 *Relative competitive strengths*

The technological leadership of the EU is reflected in an analysis regarding transnational patent applications[110]. Figure 53 shows that the EU has an absolute leadership in the field of thermal storage showing a patent share of 58.4%. EU's relative comparative strength in this area is illustrated when the patent share is compared with its overall patent share of 30.5%. Except for Canada, all other world regions show below average patent shares in this field. EU's main competitors in terms of patent shares are Japan (15.8%) and the US (8.4%). Within the EU, the largest share of patents is held by Germany with a patent share of 30.1%. Besides Germany, Italy (5.8%), France (3.8%), Sweden (3.2%), Austria (2.6%), and the UK (2.2%) have a notable share in patents.

[109] International Energy Agency (2014). Technology Roadmap Energy storage.

[110] The OECD Environment Directorate, in collaboration with the Directorate for Science, Technology and Innovation, has developed patent-based innovation indicators that are suitable for tracking developments in environment-related technologies. The patent statistics are constructed using data extracted from the Worldwide Patent Statistical Database (PATSTAT) of the European Patent Office (EPO). Patent data based on family size "two and greater" were used to count only the higher-value inventions that have been applied for protection in the home market and at least one foreign market. The relevant patent documents are identified using search strategies for environment-related technologies (Env-Tech: http://www.oecd.org/env/consumption-innovation/env-tech-search-strategies.pdf) which were developed specifically for this purpose. The data are available under http://stats.oecd.org/. The European Patent Office is also working with this definition, e.g. in the context of analysing the EU's patent performance in "Green Building" (http://www.epo.org/news-issues/technology/sustainable-technologies/green-construction.html).

Figure 53: Patent share in the field of thermal storage[111] compared to total patent share 2010 to 2012



The upper bar shows the patent share (%) in thermal storage, the lower bar the total patent share (with respect to all technologies).

Source: OECD.stat; Theme Environment; Dataset: Patents - Technology Development - NIW calculation

The solid technological position translates to an overall good performance of the EU in the market place. However, considering the variety of VCs entailed by TES, we discuss competitive strengths by VC separately.

In the UTES value chain, Europe is a frontrunner with several projects up and running. On the one hand, this good position is thanks to extensive geological surveys that have been held in the EU over the past decades, providing a solid database to start with. In addition, there are several service providers that have expertise in developing underground projects. In part, all of this is a historical consequence of the well-developed activities of the oil and gas sector in (North-Western) Europe. In addition, some countries have a geology which lends itself well for development of UTES. For example, much in the development of Aquifer based TES has been done in the Netherlands, which has extensive, permeable aquifers.

Moreover, Europe has good expertise in smartly connecting energy storage to electricity and heat networks of distributers an users, especially in North-Europe and Scandinavia. For example, pit storage – where hot water is stored in a covered pit – is used throughout Denmark's district heating networks [112]. The expertise on district

[111] The graph is based on IPC code Y02E 60/14 (Thermal Storage), which encompasses following subcodes:

Y02E 60/142	. . .	Sensible heat storage
Y02E 60/145	. . .	Latent heat storage
Y02E 60/147	. . .	Cold storage

[112] International Energy Agency (2014). Technology Roadmap Energy storage.

heating and cooling in the EU is hence also an asset for development and integration of UTES in the energy system. Also the active support from both national governments as well as the European Commission, which have actively encouraged and funded research and development of geothermal applications for energy conservation, have played a beneficial role.

In the CSP value chain, Europe has substantial expertise, mostly concentrated in Mediterranean areas where many CSP projects have been developed. The United States DoE database on thermal energy storage, there is one clear global hotspot for CSP (molten salt based) visible, namely the south of Spain. About 24 of the 41 CSP projects worldwide have been installed here. These projects have been realised to a significant extent by EU technology suppliers and project developers, such Abengoa Solar (ES), SENER (ES), Novatec Biosol (DE), MAN Ferrostaal AG (DE), …. Various technological developments such as the molten salt technology were developed by EU companies, together with research institutes. European companies are well represented across the different phases of the value chain, ranging from project developers over suppliers of light reflectors and collectors over power block to EnPC (engineering, procurement and construction) companies[113].

Underscoring EU expertise is that several EU technology providers are involved in projects abroad. For example, a Spanish consortium of engineering companies and technology providers including SENER is helping to develop worlds' largest CSP plant in Morroco[114], while Abengoa has helped to build CSP plants in the US, Chile and south Africa[115]. At the same time, the financial problems this company currently is facing entail a potential loss of expertise in the EU[116].

In the PCM value chain, Europe holds a solid position especially with regard to applications in HVAC and buildings. PCMs cover a number of different materials, both organic materials (parafines) as well as anorganic (various salts). Organic PCM mainly includes paraffin- and fatty acid-based materials that are derived from non-renewable sources, such as crude oil and slack wax. The advantages of organic-based PCM are chemical stability, non-corrosive and non-toxic property, high latent heat of fusion, and almost negligible super cooling. Another key advantage of organic PCM is that they can be microencapsulated, which makes them viable in many applications, such as textile and building & construction. Organic PCMs sell for higher prices than others PCMs and constitute the biggest share of the PCM market. Organic PCMs are also expected to achieve highest growth rate towards 2019[117].

[113] GMT Research (2011). Concentrating Solar Power 2011: Technology, Costs and Markets.

[114] http://www.worldbank.org/projects/P122028/ma-ouarzazate-concentrated-solar-power?lang=en&tab=results

[115] http://www.abengoasolar.com/web/en/plantas_solares/plantas_propias/

[116] On Abengoa's financial problems, see e.g. http://www.irishtimes.com/business/energy-and-resources/renewable-energy-giant-abengoa-wins-bankruptcy-reprieve-1.2589884

[117] MarketsAndMarkets (2014). Advanced phase change material (PCM) market - Global Trends & Forecasts to 2019

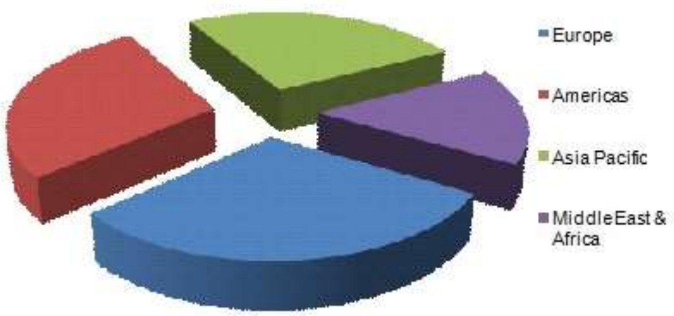
In this key PCM submarket, Europe holds a solid position. As can be seen from Table 19, which lists the leading companies in this market, 3 out of the 4 leading companies are EU based. These are BASF- the world's largest chemical company - and two smaller companies, Rubitherm and PCM Products, whose activities are focused on PCMs. As indicated earlier, competition is mostly based on product innovation and deploying material sciences for better product performance.

Table 19: Leading companies manufacturing organic PCM[118]

Company	**Headquarter**
Rubitherm Technologies	Germany
BASF- Micronal	Germany
Microtek	U.S.
Phase Change Material Products Ltd.	U.K.

A general strength of Europe is that it is the largest market for PCM application (see Figure 54). While not all PCM applications support energy savings (e.g. in the context of packaging, PCMs serve to control the temperature inside a package to protect the content, but this does not lead to significant energy savings as it does in the context of HVAC), the large *home market* for PCMs help create critical mass and support developments which also indirectly enable energy saving PCM applications.

Figure 54: PCM market share 2013[119]



[118] Idem

[119] MarketsAndMarkets (2015). Advanced Phase Change Material (PCM) Market by Type (Organic, Inorganic & Bio-based) and Application (Building & Construction, HVAC, Shipping & Packaging, Cold Chain, Thermal Energy Storage (TES), Textile, and Electronics) - Global Trends & Forecasts to 2019.

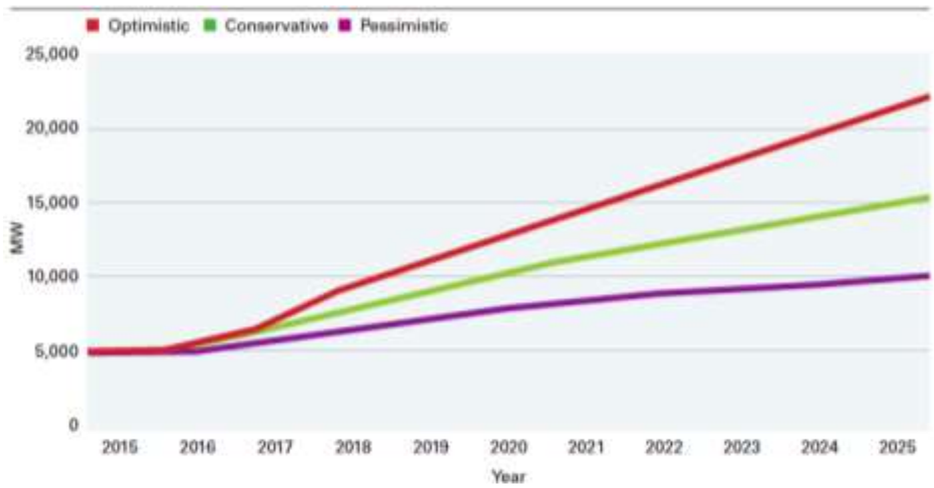
8.2.3 International trade performance

For TES, no trade indicators are available.

8.2.4 Market outlook

Global installed CSP capacity has hiked from 355 MW in 2005 to more about 5 GW in 2015[120]. Market forecasts suggest growth rates of 20% annually to 2020, reaching a market value of about 8,6 billion USD[121]. In terms of electric power, projections indicate a growth from 5 GW in 2015 to between 10 and 22 GW in 2025 (Figure 55).

Figure 55: Global market forecast for installed CSP capacity[122]



Behind these figures however, lies a considerable amount of uncertainty and geographical disparities. Some countries and regions who have been strong holders in CSP development such as Spain and California (USA) have witnessed a great fall back of new projects over recent years. In Spain, this has been attributed to the public incentives being cut, even though the national renewable energy action plan (NREAP) envisages CSP capacity of 5 GW by 2020. In California, opposition to new projects from environmental (wildlife protection) concerns but

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120 CSP Today (2015). Market forecast to 2025.

121 Transparency Market Research (2015). Concentrated Solar Power Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2012 - 2020'

122 CSP Today (2015). Market forecast to 2025.

also particularly weakened cost competitiveness of CSP has reportedly led to withdrawal of CSP projects[123]. Indeed, the sharp decline in PV as well as wind energy prices has made investment in CSP less attractive[124].

At the same time, in other countries across the globe, major investments in CSP are foreseen. This is driven by increasing awareness and willingness to address climate change as well as energy dependence challenges by imposing more robust policies and ambitious renewable energy targets. Countries that are implementing or have announced ambitious development plans, include India, Australia, Israel, Jordan, Kuwait, Morocco, Saudi Arabia, Chile and South Africa[125]. In Morocco, the Ouarzazate Solar Power Station is being developed, which will be the worlds' largest CSP complex[126].

The global PCM market was valued at about 560 million dollar in 2015, and is expected to increase to about 1,6 billion dollar by 2020, which represents a compound annual growth rate of about 20%[127]. This high growth comes on account of increasing applications, technological advancements, and growing concerns over environmental regulations on reduction of green-house gas emissions. With growing global focus on energy saving, phase change materials are expected to play a pivotal role in the near future. They are currently being used in applications such as HVAC, building and construction and energy storage itself among others. As indicated earlier, Europe is the largest market for PCMs, and is also expected to achieve the highest growth over the next five years[128]. North America ranks second in terms of market size, followed closely by Asia Pacific. The growing construction industry in emerging countries such as India, Brazil, China, Russia, and South Africa is expected to boost the demand for these products over the next couple of years.

New product developments, including improved macro and micro-encapsulation techniques will eventually decrease the advanced PCM prices, which will be instrumental to create new opportunities in PCM market and support larger scale energy storage possibilities[129]. Competition in this emerging market is still rather limited,

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[123] https://www.kcet.org/redefine/are-solar-power-towers-doomed-in-california

[124] Idem

[125] International Energy Agency (2014). Technology Roadmap: Solar Thermal Electricity.

[126] http://www.theguardian.com/environment/2015/oct/26/morocco-poised-to-become-a-solar-superpower-with-launch-of-desert-mega-project

[127] Mordor Intelligence LLP (2016). Global Phase Change Material Market - Segmented by Material Type, Product Type, Application, and Geography - Trends and Forecasts (2015-2020)

[128] Idem

[129] MarketsAndMarkets (2015). Advanced Phase Change Material (PCM) Market by Type (Organic, Inorganic & Bio-based) and Application (Building & Construction, HVAC, Shipping & Packaging, Cold Chain, Thermal Energy Storage (TES), Textile, and Electronics) - Global Trends & Forecasts to 2019.

however companies need to make considerable efforts to increase awareness about potential and benefits of PCMs as this is currently still limited.

8.3 Assessment of the competitiveness aspects

8.3.1 Export potential

For TES, no trade data is available.

8.3.2 SWOT

Below the strengths, weaknesses, opportunities and threats (SWOT) for the European thermal storage industry that could be identified by literature, own data analysis and based on expert interviews, are specified in bullet points.

Table 20: SWOT for the thermal storage sector

Strengths	Weaknesses
▶ Excellent technological base across different VCs ▶ Environmental awareness and policies at EU and MS level that encourage renewable energy and heating ▶ Frontrunner in UTES, building on geological expertise developed by the oil & gas sector in North-Western Europe ▶ UTES can be combined with district heating and cooling, for which world class expertise is available in EU ▶ Strong home market for CSP (first mover advantage), which has enabled companies to become world-class in CSP and reaping gains of export ▶ EU is largest home market for advanced PCMs ▶ Top position in HVAC segment of PCMs	▶ Valorisation of research results is still far from maximal ▶ Weakened cost-competitiveness of CSP projects compared to photovoltaic, in which Europa has a less strong position. ▶ Regulations impeding underground TES application in some countries ▶ Incentives for CSP have dried up in key EU market (Spain) ▶ Lack of awareness about possibilities of PCMs among consumers ▶ EU largely absent in ice-based cooling segment of PCM market
Opportunities	Threats

▸ Growing concern over climate change challenges and energy security worldwide, leading to increased demand for renewable energy in both developed as well as emerging economies ▸ Increasing awareness about importance of heating and cooling in overall energy demand, especially in the EU ▸ Trend towards zero-emission housing ▸ Increased urbanization and construction activity in Asia Pacific and Latin America is a boosting factor for the organic PCM market	▸ Sustained low fossil fuel prices delaying investment in clean alternatives ▸ Uncertain economic outlook hampering investments in large scale heat storage ▸

In conclusion, Europe is a leading region in the deployment of TES. It owes this solid position among others to first/early mover advantages in several TES applications. In UTES, Europe has historically been a frontrunner, having pioneered among others the subfield of aquifer based TES. Also the good availability of geological data (especially for North-Western Europe) and the encouraging efforts of several member states and the EU have promoted the development of UTES in the EU. In CSP, Europe was also among the first to implement several large scale projects, together with the U.S. As a result EU companies have built up expertise which is now being deployed across the globe. At the same time, outlook for CSP remains somewhat uncertain considering its weakened cost competitiveness with photovoltaic energy, and the stalling of new projects in key markets Spain and California (U.S.). In the PCM market, Europe excels in the HVAC/building market where it can boast a number of leading material manufacturers, as well as a number of top research institutes.

8.4 Analysis of barriers

Regulation: for UTES, some legislative frameworks make it difficult to realise thermal energy storage projects. As an example, in some countries it is not allowed to inject water warmer than 25 degrees into the ground. On the other hand, the negative influence of potential regulation such as capacity markets is expected to be limited with respect to thermal energy storage.

In general, development in thermal storage largely depend on the regulatory framework and in particular on the incentives for renewable energy. So far, most policy focus (with an exception for the Scandinavian countries) has been laid on renewable electricity, while more than 50 % of the final energy demand in the EC is used for generating heat and already now heat storage is utilised in water-based systems for domestic and district heating. Interviewees indicated that there are still large environmental gains to be reaped in the heating market, in which TES can play a key enabling role by supporting various renewable energy sources. For instance combined generation of heat and power (CHP) with ad-hoc TES increases the efficiency of CHP as heat production can be stored rather than curtailed if not needed at that moment. Many CHP technologies are capable of using renewable energy (geothermal, biogas), alternative fuels (e.g. hydrogen) and waste heat. Tri-generation (simultaneous generation of three forms of energy - heating, power and cooling) should also be exploited to use the heat production for cooling in summer and here TES can also play a pivotal role.

Currently the European Commission is looking into rules to integrate TES (in buildings and district heating) into flexibility and balancing mechanisms of the grid and will study in particular how to expand the use of TES in the electricity system.

Capital and finance: the business case for energy storage is currently not always strong enough due to the low energy prices and capital costs. In order to make energy storage economically viable one needs energy price fluctuations. Some types of energy storage require considerable investments with rather long payback times.

R&D and innovation: UTES does not yet fit in existing paradigms, actors in the energy market are not yet used to storage installations and the uncertainties in the subsurface that are involved. While public resistance is overall very low and many projects have been implemented so far in NW Europe, it remains however important to involve stakeholders (competent authorities, public, local organisations etc.) early in the process.

Several demonstration projects in UTES show that the different storage technologies (pit storage, borehole storage, and aquifer storage) are not all suitable for the same purpose: some technologies are well-suited for short term flexibility, but have limited capacity, whereas other technologies are exactly the other way around. The technologies by itself are fairly well-developed, with TRL scales around 6, 7 or 8, however integrating them optimally in the energy system (heat, electricity grid) or the building stock is a different story and needs a balanced approach with a forward looking perspective. How to combine and optimize such technologies on large scale is one of the most challenging R&D issues.

In the PCM market, a key challenge is to reduce the costs of these materials. Currently PCMs are still too expensive to be used as heat storage media on large scale, while large scale storage would be needed for a complete breakthrough of TES. A key challenge in this respect is to increase the storage density of TES based on PCM or TCM in order to enable the implementation of TES in applications with less available volume and to enable the cost-effective long-term (up to seasonal) storage of renewable heat. Hence, barriers are here largely technology related, but also increasing the overall awareness about potential of PCM is a key challenge.

8.5 Suggested actions

As a general remark, all policy actions that stimulate renewable energy technologies and energy conservation (e.g. waste heat utilisation) indirectly stimulate storage technologies, due to the strong interdependencies involved. At the same time, the value of the storage function is sometimes still overlooked. Often

A key aspect of thermal storage is its ability to time shift excess heat as well as electricity to moments when it is more needed, thereby stabilising the grid. Some renewable energy forms are capable to produce continuously energy while others are intermittent. The intermittent forms include wind and PV, which record among the lowest marginal cost of all renewable energies and which are hence more competitive than e.g. CSP. Yet, from a government point of view, it is important to consider the complete societal costs and benefits associated with renewable energies, including auxiliary measures needed to stabilise the grid (e.g. natural gas fired power plants) and provide back-up for intermittent forms. The EU and its member states should ensure correct support levels for renewable energies in line with these societal costs and benefits in order the reach the most optimal and efficient outcome.

Generally it is felt that the idea of storing thermal energy, especially underground, is still looked at in a rather reluctant way by the energy sector, although minds are gradually evolving. In this respect, it can be stressed both the EC and its member states have a very important signalling function. One the one hand, this can be done in very practical support measures (e.g. removing regulatory obstacles, promoting R&I in thermal storage, creating investment incentives) but also by providing a long term vision to the sector in which thermal storage has its place.

Cross-country learning can be very useful in this respect. This cross-country learning on regulatory aspects (and beyond) could accelerate adoption of TES. For example, in Denmark an examples exists of agreements between thermal storage parties (implemented in district heating) and the TSO and DSO's in the electricity grid, simplifying the exchange of electricity and heat and providing flexibility to the electricity grid. These kind of new forms of business models and organisation should be further explored.

Growth of thermal storage could be also promoted by addressing some particular regulatory aspects. For UTES, there are a number of technical constraints in deploying this technology. Policies that impede use of the underground for thermal storage functions should be eliminated. Also related to these regulatory issues, it would be very relevant to promote best practices sharing between member states, as some have a good history in promoting UTES, while other are still in early stage of development.

In some countries there are measures to reduce underground applications such as geothermal energy, which always bear a certain level of uncertainty as it is not predictable with 100% certainty what the precise underground conditions will be found after (expensive) drilling. For example, in The Netherlands there are certain funds for geothermal energy that cover companies when the results are below expectation. These insurance policies help covering the risks involved, something that is necessary given the fact that it is often SMEs and regional authorities that are involved with these projects. Such de-risking policies could also be applied to UTES projects.

Policies concerning the discharging of waste heat can also be very important regarding thermal energy storage. If companies are not allowed/limited to discharge waste heat, companies have to start thinking about how to better use this waste heat. This can bring many other advantages as well (e.g. less heat pollution of rivers, higher operating flexibility and cost savings).

As for the PCM applications, awareness among its applications is still insufficient. Ensuring adequate and fair treatment within the building codes at the National level and the relevant calculations of its impact on energy savings would be of most relevance for its deployment and overall awareness.

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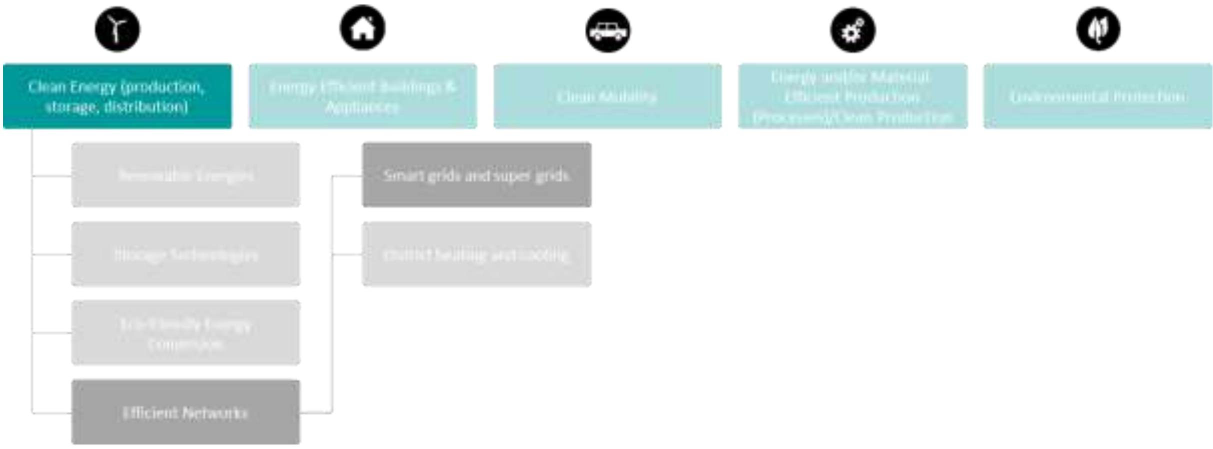
9/ Smart grids and super grids

Figure 56: Presentation of the selected priority sectors within the Clean Industry taxonomy



Smart grids are an essential part of the EU Clean Industry because they are pivotal for the deployment of the EU's energy policy. Especially in the context of providing an enabler for increasing the share of renewable energy generation, and for increasing energy efficiency they could be considered clean *per se*. Smart grids are also one of the six priority areas of the Commission's 2012 Industrial Policy Communication. It is expected that within the EU € 56 bn. will be invested in smart grids between 2010 and 2020[130]. On a global scale smart grid investments are expected to surpass € 350 bn. by 2020 with a CAGR of more and 8%[131].

9.1 Description and value chain

A clear view on the smart and super grid value chain starts with a clear focus of its definition. However, as argued by Niesten and Alkemade (2016) a common functional and technical definition of a smart grid has not yet emerged and a consensus on the concept has not been reached. Indeed, various definitions about smart grids can be found in the literature and among the relevant stakeholders. Instrumental for our analysis is the typology made by Crispin et al. (2014). These authors distinguish two types of definitions for the term smart grid:

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[130] European Commission (2014) p 63.

[131] GreenTechMedia (2013), http://www.greentechmedia.com/articles/read/smart-grid-market-to-surpass-400-billion-worldwide-by-2020, accessed 24-05-2016.

1. Definitions based on technological building blocks, illustrating the use of technology to increase grid intelligence by integrating communication and electronic equipment installations on the premises of the network user, and;
2. Definitions based on the outputs and services delivered and problems solved by the smart grid. These definitions describe a smart grid as an electricity network that integrates in a cost efficient manner the behaviour and actions of all users connected to the grid in order to obtain an economically efficient and sustainable power system with high levels of quality, low losses, security of supply and safety[132].According to the authors the second definition is the one that is used by the European regulators (Agency for the Cooperation of Energy Regulators).

Another example of the second type of definition is the one from the European Smart Grid Task Force. This defines Smart Grids as "*electricity networks that can efficiently integrate the behaviour and actions of all users connected to it — generators, consumers and those that do both — in order to ensure an economically efficient, sustainable power system with low losses and high quality and security of supply and safety*"[133]. Implementing smart grids is not only a matter of installing new physical assets and technologies, but equally involves new business models, adjustment of regulations as well as behavioural consumer changes such as the move from consumer to prosumer[134].

From a value chain perspective both type of definitions provide two relevant dimensions: the first type of definitions provide a view which is relatively more focussed on the input and operational side of the smart grid stressing the goods and services that embody the technologies and the related actors such as the technology providers, and users of the technologies. The second type of definitions bring into focus the functionalities, characteristics and services and therefore relate more to the operational and output side of the chain, with an emphasis on the users, including the end-users.

In comparison to the value chain of the conventional energy sector which runs from generation, to transport to distribution and finally consumption, the value chain of a smart grid is more complex and the roles and activities of the various existing actors have changed and new actors have stepped in. As indicated by the International Energy Agency, the development of a smart and super grid is a transitional process starting from the classical energy value chain and gradually moving towards smart grids. This process is depicted in Figure 57. Compared to conventional energy grids, smart grids integrate communication and ICT applications, renewable energy sources, storage facilities and allow for new functionalities, services and benefits which are unattainable with conventional grids. Precisely the integration of ICT with energy infrastructures to allow for a bi-directional flow of energy and

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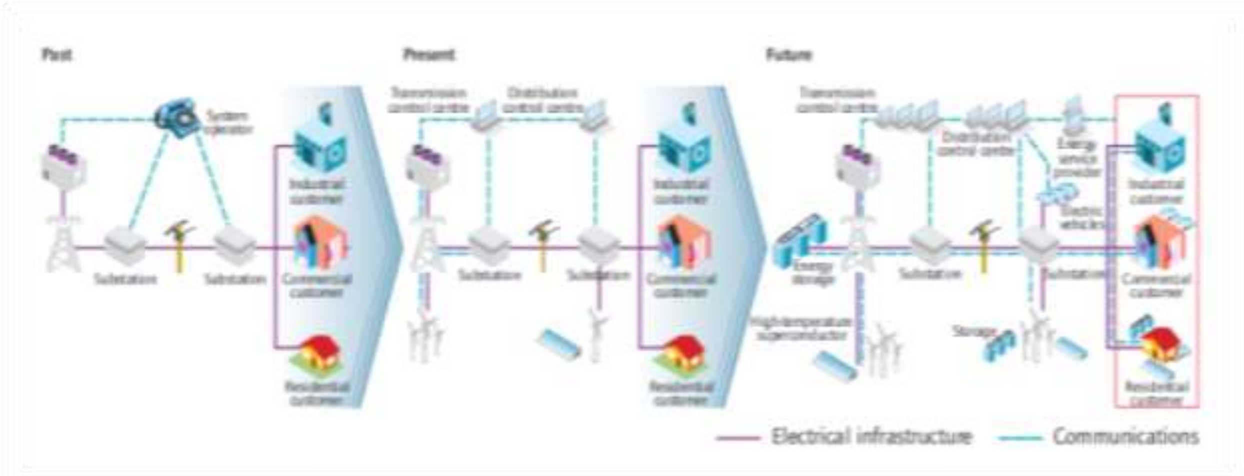
132 Crispin et al. (2014) p.86.

133 European Commission (2011), p. 2.

134 See also European Commission, JRC (2011)

information lies at the heart of the smart grid evolution, see e.g. Mourshed et al. (2015), Niesten and Alkemade (2016).

Figure 57: Transition towards smart grids



Source: IEA (2011) p. 6.

Table 21 provides a comparison of conventional and smart grids for various aspects. In essence the value chain of smart grids can be considered as an expanded conventional energy supply chain with elements from the ICT, renewable energy value chains, resulting in larger functionality and variety in assets, services and actors. In terms of activity the smart grid sector does not just provide electricity power over the grid, but for instance integrates distributed power generation from the renewable energy sector, offers solutions for attaining more energy efficient behaviour by consumers, and offers opportunities for new applications, such as the grid connection of electric vehicles, and new business models. The smart grid sector also encompasses the solutions for attaining reliability, quality and security of the services provided, which is a crucial ingredient since distributed renewable energy generation in combination with optimisation of energy use by clients, both industry and households, together with the increasing use rate of electric vehicles fundamentally alters the peaks and valleys on the electricity network.

Table 21: A comparison of features between a conventional power grid and a smart grid

Aspect	Conventional grid	Smart grid
Energy	Focus on fossil-based, centralised, plannable and stable one-way energy production	Focus on renewable energies and distributed, intermittent, flexible and bi-directional energy production
ICT	Relatively little use of ICT, weak	Widespread use of ICT, strong preventive mechanisms ('self-

	preventive mechanisms Infrastructure with scarce intelligence	healing'); bi-directional Information inference and decision making features
Data	One-way information stream, offline scarce data.	Online (Internet Protocol network), big data, two-way interchange.
Business models	Static business models, fixed price regimes Producers and consumers	Dynamic business models, dynamic pricing Producers, prosumers and consumers
Functionalities/services	Transmission, distribution, control of electric power from producers to consumers. No transparency Manual recovery, manual checks and tests	Demand response, demand side management, aggregation, V2G, G2V, energy storage Consumer/prosumer information and awareness Self-monitoring, remote checks and tests, automatic grid reconfiguration
Assets/enabling technologies	Power generation, transportation and distribution grid, conventional meters; electromechanical structure	Conventional assets plus smart meters, smart metering infrastructures, digital sensors, intelligent control systems, communication networks (hardware and software), data management systems, cyber security
Actors	(Concentrated) power generators, Transmission system operators (TSO), Distribution system operators (DSO), retailors, regulators, equipment providers, end-users	Conventional actors plus renewable energy producers, prosumers, virtual power plants, aggregators, ESCOs; strong potential for new actors with (yet to be invented) business models and services

Based on Rodríguez-Molina et al. (2014), Mourshed et al. (2015), Niesten and Alkemade (2016), Reddy et al. (2014), Ringmar (2015)

It is evident that the deployment of smart grids has ramifications for a wide set of industries and that its operational success will impact the workings and business models of other sectors. In terms of supplying industries to the smart grid sector one can identify the ICT industry (hard- and software, cyber security), electrical equipment manufacturers (production, transformation, transport and protection equipment), but also the infrastructure building sector and engineering. On the downstream client side the consumer products industry (electronics, appliances) providers of energy management services and systems, as well as the automotive sector (electric vehicles) and the building sector (smart and energy efficient buildings) are active[135]. Well-functioning smart grids may incentivise other industries to develop new applications that create customer value and as such capturing value for their own industry. As such the smart grid will become more mature with increased functionalities and value creation.

The actors of the smart grid sector can therefore also be identified in these aforementioned industries. Evidently the number of companies involved is enormous ranging from giant full service companies such as Siemens, ABB, Schneider Electric to specialised SMEs. For the big players the smart grid market is only one particular market segment from many. Due to the diverse and integrated nature of smart grids, the wide scope of services offered is definitely a competitive advantage for these large players. One of the strategies of the big players to reinforce their services in the smart grid segment is to take over specialised smaller companies, often SMEs, e.g. the take-over in 2012 of the US-based eMeter by Siemens. Yet the 2014 takeover of Alstom's thermal, renewables and grid business by General Electric provides the latter with a strong foot in the EU market and a portfolio of solutions covering various interrelated value chains: power generation, grid solutions and renewable energy production (Petit, 2015).

Companies that are specialised in a particular smart grid segment often use another strategy by making partnerships with other companies to be able to offer a wide portfolio of services to the clients, as well as to enter new markets. An important client group for the smart grid vendors is the utility industry with electricity generators, TSOs and DSOs that want to sustain their position in their respective markets, upgrade infrastructure, and seek to create value added from the grid potential by offering new services, such as demand response, integration of distributed energy production, and deliver value added to the customer further down the value chain.

Table 22 provides an overview of the major smart grid companies in the EU and the rest of the world in the grid market supply chain. For the EU companies a selection of smaller enterprises has been identified on the basis of various publicly funded pilot and demonstration projects. Two main broad segments are distinguished: the network hardware and the ICT solutions. Within these several sub-segments can be identified. The companies are classified according to the two main supply segments. Examples of the largest EU players that are active on the EU smart grid market are given below.

- ABB is the biggest manufacturer of power transmission and distribution equipment and solutions to enhance grid reliability. It was a pioneer in FACTS, and provides solutions for HVDC, network management such as SCADA, EMS, DMS, power cable systems and services, power transformers and substation solutions.

[135] Concerning the role of smart grids in the building sector, see e.g. Kolokotsa (2016)

- Siemens offers a broad scope of products, services and technology solutions across the entire smart grid value chain including generation, transmission, distribution and consumption. Applications range from demand response, micro grids, smart metering, transmission grid applications, smart distribution grids to various IT platforms and support and consulting services. According to GTM Research (2013) it is one of the few suppliers that can claim offering a complete smart grid solution portfolio.
- Schneider Electric is a global EU company providing integrated solutions for energy management, infrastructure, industrial processes, building automation, data centres and network management. In 2014 Schneider Electric counted 170.000 employees worldwide generating a turnover of € 25 billion, of which 45% coming from newly developing economies.

Further downstream in the smart grid sector one can identify the TSOs, DSOs, as well as the electricity generators. These players are mainly incumbents in the electricity generation and distribution value chain that developed their market position in the past mainly on the basis of conventional energies (oil, gas, coal and nuclear energy). Yet given the positive market prospects for renewable energies, partly sustained by favourable regulatory framework conditions and an increasing public interest and environmental and climate awareness, the incumbent players increased their share of renewable energy production. Furthermore in the same wave of renewable energy technologies, new vendors of renewable energy appeared on the market, thereby widely expanding the scope of energy suppliers including also non-energy producing companies, SMEs and households, the latter often being categorized as prosumers.

Table 22: Supply side segments of the smart grid value chain and major EU companies

Supply side segment (1)	Description	Major EU companies(2)	Major non-EU companies(2)
Network hardware:		ABB, Siemens, Alstom (now GE), Schneider Electric, Vattenfall, ***Selection of smaller companies***: Ampacimon, STRI, Nexans, Tecnalia Research & Innovation, Columbus Superconductors, De Angeli Prodotti, BME Viking, DNV-GL, ZIV Smart Grid Solutions,	**USA**: Aclara Technologies Silver Spring Networks, General Electric, SEL, Itrón, eMeter (US – since 2012 Siemens), Trilliant, Elster (now Honeywell), Smart Wires, **Australia**: Tendrill **Switserland**: Landys+ Gyr (since 2011 Toshiba Corporation), **Japan**: Toshiba, NGK,
• ***Advanced metering infrastructure (AMI)***	Smart meters, in-home displays, communications and networking (servers, relays), meter data management;		
• ***Transmission enhancement applications***	Substation automation FACTS, HVDC, DC transmission, wide area monitoring and control (phasor measurement units);		
• ***Smart distribution, distribution grid management***	Switching, monitoring and control applications, power quality monitoring and control (e.g. voltage regulators, capacitor switches), wire and cable sensors,		

	automated re-closers, electrical vehicle charging infrastructure (batteries, converters);	KiWiPower, Ormazabal Velatia, Selta, UPL, Laborelec – GDF Suez, Efacec Engenharia e Sistemas, Saft, Made,	Sanyo, **South Korea**: LS Industrial Systems, Nuri Telecom **Brazil**: ELO Electronic Systems
ICT: • ***Communication technologies*** • ***Smart grid data analytics*** • ***Network operations software and systems*** • ***Cyber security***	**Wireless**: ZigBee, WiMAX, GSM/GPRS/UMTS/LTE, radio frequency mesh network **Wireline**: DSL, Fiber Communications, Power Line Communications (PLC); Analytics for prosumers, enterprises and grid operators; Geographic information systems (GIS), outage management systems (OMS), demand management systems (DMS), energy management systems (EMS), SCADA Software, processes and techniques	SAP, Siemens ***Selection of smaller companies:*** Cybergrid GmbH, Joule Assets, Vaasa ETT, Gemalto, 3E, Cassidian (CCS), Telecom Italia, Engineering Ingegneria Informatica, SICS, ECRO, Hypertech Information Technology, Powel, Atende,	**USA**: Oracle, IBM, Microsoft, Osisoft, Cisco, Opower **China**: Huawei **India**: Infosys, Wipro **Japan**: Fujitsu, Toshiba **South Korea**: SK telecom

Based on GTM Research (2013), and own research

(1) Supply-side segments may partly overlap
(2) The distinction of EU and non-EU companies is based on location of the corporate headquarter. The distinction between network hardware activity and ICT is based on the company's main activity. Systems operators are not included in this table, although they are part of the smart grid value chain.

Figure 58 provides an overview of the implementation sites of smart grid projects in the EU since 2002. It essentially follows the urban concentration, yet with a relatively larger representation in the old Member States and especially in Denmark and the Netherlands. The European Commission JRC website on the Smart Grid Projects Outlook 2014 indicates that according to the project registrations in the Commission's data set, 459 smart grid projects have been launched since 2002, with represents a cumulative investment of € 3.15 billion[136]. Yet in the meantime these numbers have grown as indicated further in section 9.2.4 dealing with the market outlook.

Figure 58: Implementation sites of smart grid projects in the EU since 2002 according to development stage

Source: European Commission, JRC (2016) Smart grid projects map: implementation sites of EU smart grid projects since 2002, projected by development stage. O Development sites; O R&D sites; situation at 20/05/2016.

9.2 Assessment of the global environment

9.2.1 Main competitors outside the EU

Smart grids are high on the policy agenda of various non-EU countries. This covers established economies such as the United States, Canada and Japan, as well as fast growing economies such as Brazil, China, Korea and India. Referring to the right column of Table 22, it is evident that important global players in each of afore

[136] See European Commission, Joint Research Centre, Institute for Energy Technologies, Smart Grid Projects Outlook 2014, http://ses.jrc.ec.europa.eu/smart-grids-observatory accessed June 2016.

mentioned countries (may) operate on the EU market, and definitely are mature competitors on the global smart grid scene. The market stakes are not insignificant. For instance according to Pica et al. (2011) since 2008 in many Latin American countries utility companies have undertaken pilot projects to advance the smart grid. Taking Brazil as a lead country in that geographic area, the authors indicate that in Brazil is mostly being implemented through the large scale adoption of electronic meters as a strategy of DSOs to increase operational efficiency through remote meter readings and to reduce commercial costs connected with energy losses[137]. Similar evidence can also be found for countries like China and India[138]. Evidently given the combination of the sheer population size with economic growth and wealth creation, the potential for smart grid development in these markets is substantial.

The United States Department of Energy (2014) reports that in the context of the American Recovery and Reinvestment Act of 2009, since 2010 up to 2015 a total of $ 9 billion (approximately € 8 billion) public-private investment in smart grid projects was committed. This is twice as much as the total amount invested in Europe if we base our estimate on the results of the European Commission JRC smart grid data base. The report indicates that an estimated 65 million smart meters would have been installed by 2015, which covers more than one third of the electricity consumers. Steady progress is being made in other areas of smart grids such as consumer-based technologies, sensing, communication and control, implementation of high-speed data communications technologies, and cyber security yet the uptake differs across states depending on state policies, regulatory incentives and technology expertise within the TSOs and DSOs.

Both the example from Brazil and the USA illustrate that, as it is equally the case with the major EU players, a strong home market provides a good anchor basis for developing smart grid solutions elsewhere in foreign markets. The home market allows experience, skill and business models to be tried and tested in an operational environment that is well understood. Once these are mastered the challenges of a foreign environment can be dealt with more easily.

The following paragraphs present a concise description of a selection of non-EU global players in terms of main smart grid services and products in order to get a flavour of the product portfolio and type of solutions offered[139]. The information is taken from respective company websites.

- Aclara Technologies is a US-based global player in smart infrastructure solutions to electric utilities as well as for gas and water companies. By incorporating smart metering, sensors, communications and

[137] Pica at al. (2011) p. 94.

[138] For a global overview of smart grid policies, including China, South-Korea and Japan we refer to Brown and Zhou (2012).

[139] It is not the intention to present a representative geographical overview of all major global players which is beyond the scope of the study.

analytical technologies, the clients of Aclara Technologies can monitor their distribution networks, optimise operations, and respond more quickly to problems or pre-empt them.

- Elo Electronic Systems is a Brazil-based electric power equipment and solutions provider specialised in smart metering, data gathering and analyses for electric power trading, and network and power management. It serves mainly the 40 largest electric power distributers in Brazil, representing more than 50 million consumer points. It also supplies to the USA market and to South-American markets such as Chile.
- Itrón is a US – based company providing solutions and products for utilities and smart city solutions. In the area of electricity it offers smart grid solutions such as smart meter data management, advanced metering infrastructure, and energy analysis, consulting and forecasting. Itrón provides electricity meters and modules, network management services, smart payment management, analysis software, and data collection services.
- Nuri Telecom is a specialised provider of smart grid and energy management systems and solutions, as well as advanced metering and smart grid applications over wireless and electrical networks. It is based in Seoul, South-Korea, and was founded in 1992. It has deployed more than 500,000 smart energy meters worldwide, including large-scale deployments for commercial, industrial and residential use. Nuri Telecom is currently working together with other companies on a $58 million smart grid pilot programme that was launched by the Korean government on Korea's Jeju Island to establish a fully integrated smart grid system for 6000 households including wind farms.
- Opower is a relatively small US headquartered company providing cloud-based enterprise software to the utility industry. Opower provides grid solutions for demand side management, energy efficiency and demand response to more than 100 energy suppliers worldwide. A core asset of Opower is its big data platform containing data of more than 600 billion meter reads from 60 million utility end consumers worldwide. In combination with a cloud-based platform, the company provides an integrated service based on data analytics which allows utility companies to proactively meet regulatory requirements, decrease the cost to serve, and thereby improve customer satisfaction. Opower's software allows utility companies to send targeted customer communication automatically and across various channels such as web, mobile, e-mail, paper mail, phone and SMS messages to motivate end users to take utility-defined actions from saving energy to adopting new products and services.
- SEL – Schweitzer Engineering Laboratories, is a US headquartered employee owned company providing a wide set of technological and engineering solutions for power generation, grid optimisation and demand side industries such as distribution network automation, micro grid control systems, solutions for critical infrastructure security, SCADA systems, metering solutions, energy efficiency solutions for buildings, synchronised phasor measurements, sensors, as well as support and consulting services.
- Silver Spring Networks is a US - based global company providing solutions and platforms for smart energy networks including advanced metering, demand side management solutions, distributed energy resource network solutions, grid management, and customer services.

Similar to the EU market, also in the non-EU market large companies seek to reinforce their market position for providing grid services through mergers and acquisitions. An interesting case in this respect is the recent take-over of Opower by Oracle. Opower was founded in 2007 in Arlington Virginia and has recently been taken over by Oracle, allowing it to become together with Oracle '*the largest provider of mission-critical cloud services to the $2.3 trillion utilities industry*'[140]. According to one of the co-founders of Opower through the takeover Opower and Oracle do a strategic move in providing cloud-based solutions for the global utility business that cover the entire utility value chain from meter to grid and further on to the end consumers. Opower's consolidated revenues in 2015 were approximately $ 150 million. Between 2012 and 2015 the company revenues virtually tripled. This was mainly driven by expanding into new markets. The company grew from 162 employees in 2010 to 599 employees in 2015. Opower invested heavily in R&D with an average investment rate over 33% of total operating expenses since 2013.

9.2.2 Relative competitive strengths

The fact that the smart grid sector is not delineated as such in official statistical classifications such as NACE or ISIC makes assessing the sector's relative competitive strength on the basis of comprehensive sector data virtually impossible. Companies operating in the smart grid sector have their main activity in other sectors while not all companies of those sectors offer smart grid solutions. Furthermore, for many of the (large) smart grid suppliers the smart grid market is a particular market niche amidst many others. Therefore we have based the analysis of the relative competitive strengths on interviews and on a qualitative approach bearing on the relative competitive strengths of the underlying industries notably the EU electrical and electronic engineering industries (EEI) and the EU ICT industry. We did however find hard data on the technological competitiveness using transnational patent data.

The key experts that we interviewed indicated that the competitive strength of the EU companies lies in the production of electric and electronic hardware components. The EU is a world exporter of original energy components and systems. Indeed as can be derived from Table 22 the EU has recognized world players in this segment of the smart grid sector, such as ABB, Siemens, Schneider Electric, and Alstom (yet now part of General Electric). USA companies tend to be relatively stronger in the ICT segment and have also a relatively strong position in offering large scale solutions based on integrated ICT and grid technologies. Another area of relative

[140] Opower: http://investor.opower.com/company/investors/press-releases/press-release-details/2016/Oracle-Buys-Opower/default.aspx, accessed May 2016. The transaction was announced May 2nd 2016 and is expected to be finished by the end of 2016.

competitive weakness of the EU players is that of small-scale battery production[141]. The major companies offering batteries based on the chemical-electric technology route are mainly based in Asia (China, Japan, South-Korea) and in the USA.

This evidence from interviews is consistent with that of previous studies. The 2013 competitiveness study on the EU Electrical and Electronic Engineering Industries (EEI) indicated that this industry is one of the most competitive manufacturing industries in the EU and that this industry services market segments for which a significant growth is expected such as mobile devices and wireless applications[142]. According to the report the EEI represents 10% of EU manufacturing gross output and has a workforce of virtually 3.5 million employees. Evidently the development of the EU smart grid is a significant long-term demand boost for the EEI.

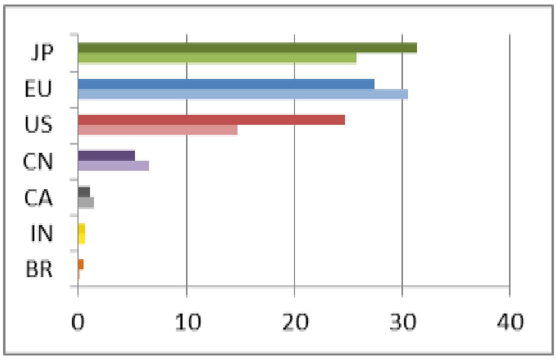
Figure 59 illustrates the technological competitiveness of major world regions measured by transnational patent applications[143] in the field of smart grids in the energy sector. The figure shows that there are three leading world regions in terms of patent share: Japan, with a patent share of 31.7%; Europe with a patent share of 27.4%, and the US with a patent share of 24.7%. Japan and the US however show relative technological strength in this field when comparing their patent shares with their total patent share. Within Europe, the patent shares are mainly distributed between Germany (16.0%), the UK (6.2%), France (5.5%), Italy (3.0%), Sweden (3.0%), and Austria (1.4%).

[141] Yet in the area of large-scale energy storage the EU is considered by experts as in a relatively strong competitive position, which is linked with its comparatively strong position in (civil) engineering, and electric and electronic hardware components.

[142] Ifo Institute et al. (2013)

[143] The OECD Environment Directorate, in collaboration with the Directorate for Science, Technology and Innovation, has developed patent-based innovation indicators that are suitable for tracking developments in environment-related technologies. The patent statistics are constructed using data extracted from the Worldwide Patent Statistical Database (PATSTAT) of the European Patent Office (EPO). Patent data based on family size "two and greater" were used to count only the higher-value inventions that have been applied for protection in the home market and at least one foreign market. The relevant patent documents are identified using search strategies for environment-related technologies (Env-Tech: http://www.oecd.org/env/consumption-innovation/env-tech-search-strategies.pdf) which were developed specifically for this purpose. The data are available under http://stats.oecd.org/. The European Patent Office is also working with this definition, e.g. in the context of analysing the EU's patent performance in "Green Building" (http://www.epo.org/news-issues/technology/sustainable-technologies/green-construction.html).

Figure 59: Patent share in the field of smart grids in the energy sector compared to total patent share 2010 to 2012



Note: the upper bar shows the patent share (%) in the field of smart grids in the energy sector, the lower bar the total patent share (with respect to all technologies).

Source: OECD.stat; Theme Environment; Dataset: Patents - Technology Development - NIW calculation

9.2.3 International trade performance

Sector-specific international trade performance indicators are not available for the EU smart grid sector. Yet building further on the approach used in previous section one can use the performance of the EEI as a proxy of the smart grid sector, save for the ICT part. The competitiveness report from Ifo et al. (2013) indicates that the EEI relies relatively more on sales to third (non-EU) markets than other sectors of manufacturing, with an export ratio[144] in 2012 of 35% compared to 25% respectively. Within the EEI the international trade performance differed across the three main segments of the EEI. Given this observation and the fact that not all sub-sectors deal with smart grids, further detailed comparison cannot be done on the basis of this report. Therefore finding out the international trade performance of the EU smart grid sector would need a separate study.

9.2.4 Market outlook

The main drivers for the smart grid development in the EU, and to a large extent elsewhere, can be summarised as follows:

- Increasing share of renewable energy production in the EU and;
- The perceived benefits of the smart grid's new functionalities – flexible demand response, distributed energy generation, strong potential for greenhouse gas reduction;

[144] The export ratio is defined as sales to non-EU markets divided by total sales.

- Expectations of value creation for customers and value capturing for new business models;
- Building up a home market as a basis for export;
- Gaining first-hand expertise and developing of new products and solutions which can be applied elsewhere.
- Replacement of obsolete parts and need for upgrading of the existing electricity grid.
- General public support and interest (demand, willingness to pay) for increasing energy efficiency and for electricity from renewable (clean) energy sources.

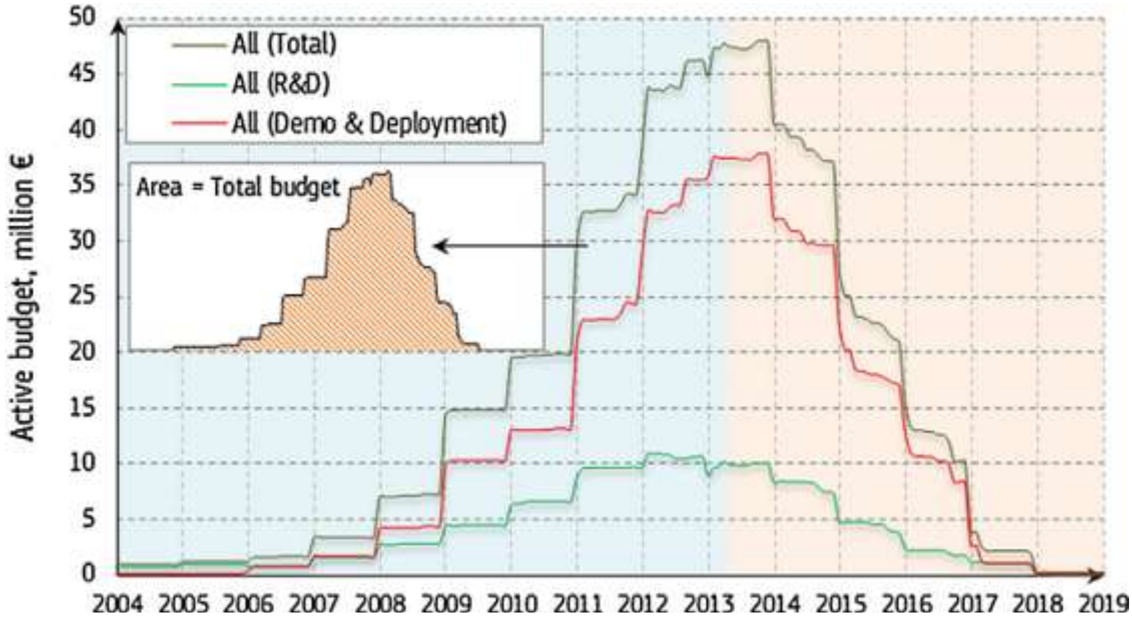
The EU smart grid sector is becoming more mature. Yet looking at the expected and required functionalities with an increasing share of renewable energy production in the near future and viable business cases for energy efficiency, still substantial ground has to be covered, see e.g. Colak et al. (2016), Mourshed et al. (2015), and Palensky and Kupzog (2013). This not only holds for the EU, but for other leading economies as well. A global race for market share, dominance of solution systems and proprietary standards, and contest for technological leadership in one or the other smart grid niche can be perceived.

The Joint Research Centre's Institute for Energy and Transport registered since 2002 up to today 503 smart grid projects in the EU-28 Norway and Switzerland, accounting for 3.7 billion Euro[145]. Collak et al. (2015) analysing the 2014 version of the same data set find that most of the projects will be finished by the end of 2016, as shown Figure 60 in terms of allocated budgets. The authors predict a definite growth in the coming years with up to 60 to 160 projects in 2017 depending on the estimation method used. The authors emphasise that the progress strongly depends on a number of factors such as the development of the interoperability and industrial standards, innovative regulatory and legislative arrangements, appropriate consumer engagement and acceptance strategies, and technological progress.

It is encouraging to observe that the active budgets for demonstration and deployment (D&D) have overtaken those of research and development (R&D). The authors report that in 2014 the D&D budget was approximately four times higher than the R&D budget. It was also found that the majority of the old Member States are transitioning from the R&D to the D&D phase for specific segments such as smart network management, smart customer and smart home services and the integration of distributed energy resources (DER), while the new Member States tend to focus relatively more on the R&D phases.

[145] JRC – IET http://ses.jrc.ec.europa.eu/survey-collection-european-smart-grid-projects Accessed April 2016.

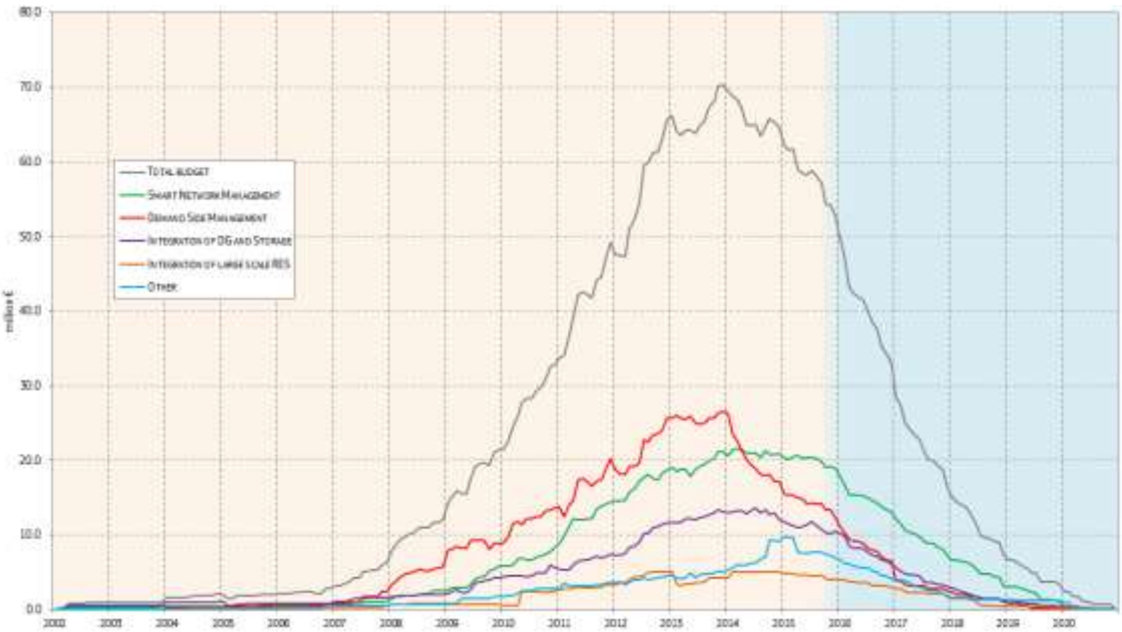
Figure 60: Cumulative value of the total active budget of smart grid projects in the EU over the years as of 2014



Source: Collak et al. (2015) using the 2014 version of the JRC smart grid projects catalogue

Figure 61 shows a more recent figure obtained from the JRC providing more detail in terms of area of investment over the years. It appears that up to 2014 major investments went into solving the demand side management aspects of smart grids while in more recent years investments in smart network management are being targeted. This more recent figure confirms that after 2014 the total amount of investments seem to lose momentum. However this needs still to be confirmed in the future and may change in later updates of the figure by the JRC.

Figure 61: Cumulative value of the total active budget of smart grid projects in the EU over the years as of 2016 by area of investment



Source: Interview, JRC May 2016

Provided that the smart grid sector is in continuous development, new actors with new business models and services are bound to appear, giving rise to new market niches. Niesten and Alkemade (2016) investigated the value creation process in smart grids, using literature and a review of a set of 240 EU and 194 US smart grid projects. The authors found three particular types of services that are extensively researched and discussed in the literature: 1) vehicle to grid and grid to vehicle services, 2) demand response services and 3) services to integrate renewable energy resources. According to key experts the market outlook for these services mainly depends on the development of an appropriate regulatory framework.

9.3 Assessment of the competitiveness aspects

9.3.1 Export potential

No data are available allowing calculating the export potential for the EU smart grid sector.

9.3.2 SWOT

Table 23 provides an overview of the strengths, weaknesses, opportunities and threats that have been derived in the course of the analysis. Most of the elements indicated in this SWOT table are self-explanatory and have been treated elsewhere in this chapter. Yet one particular observation we would like to elaborate in this section.

Table 23: SWOT for the smart grids and super grids sector

Strengths	Weaknesses
• Improved energy performance with distributed generation, flexible demand response • Strong EU position in engineering and power technology industry • Strong potential for increasing clean energy production	• Remaining technological challenges • Relative weaker comparative position of the EU players on the ICT side of the smart grid and in small battery production • Strong dependence on the development of an adequate regulatory framework
Opportunities	**Threats**
• New business models such as aggregators, G2V, V2G, services • Value creation and capture based on increased functionalities and services • Export market potential in the network hardware segment due to increased global demand	• Technological path dependencies: preference to 'invest in copper' rather than in smart grid management solutions, over-reliance on conventional energy production to buffer imbalances • Unresolved security, privacy and reliability issues

A particular threat to the development of the EU smart grid can be summarized as technological path dependencies. Even when renewable energy production is higher than ever before in Europe, appropriate grid management can still be done with rather conventional methods. These include in the first place international grid reinforcements improve the capacity of energy exchange across countries. Local production and consumption imbalances can be compensated by exporting excess capacity and importing loads for compensating short capacity. However when countries share the same weather conditions exchanging capacity may be not sufficient. Alternatively TSOs may purchase ancillary services from conventional power plants to ensure the necessary back-up capacity. DSOs may prefer to invest in reinforcing their distribution grids to avoid congestion management problems. The conventional techniques are well understood, bear less risks in terms of costs and return on investments and in terms of technological application.

It is clear that the EU smart grid sector has a strong potential for value added creation, sustaining business growth and job creation in the EU. Yet a number of weaknesses should be overcome and threats should be minimized in order to realise the jobs and growth potential. Although this is not only the responsibility of the authorities, given the strong dependency on the regulatory framework policy makers and regulators have an important role to play, both at Member States level and at EU level. The following sections will elaborate this further.

9.4 Analysis of barriers

Luthra et al. (2014) identified on the basis of an extensive literature review and consultations with experts a set of barriers for the adoption of smart grid technologies. The authors listed 12 barriers:

1. High upfront investment needs with long payback periods;
2. Market uncertainty, partly due to yet to be established universal standards, business models ;

3. Lack of a regulatory framework;
4. Low public awareness and engagement;
5. Lack of innovativeness in the industry;
6. Lack of infrastructure;
7. Technology immaturity;
8. Lack of skills and expertise;
9. Integration of the existing grid with large scale renewable electricity generation;
10. Need of advanced bi-directional communication systems;
11. Lack of open standards;
12. Cyber security and data privacy.

The authors analysed the interdependencies among the barriers and concluded that regulatory barriers can be considered as the most important ones that co-determine the effects of other barriers. In particular the authors distinguish 1) the lack of a regulatory framework and 2) the lack of open standards. The lack of a regulatory framework points to the obsolete regulatory framework which does not provide clear incentives for incumbent and new market players to invest in smart grid infrastructure and applications. The lack of open standards refers to the myriad of proprietary standards that are used today and which prevent interoperability of services.

In a more recent study Lunde et al. (2016) bearing on the findings of a detailed case study of the Danish smart grid R&D platform iPower, illustrate that regulatory barriers are still at the forefront and provide more detail about their nature. The findings from Lunde et al. (2016) are of particular interest since Denmark is one of the leading Member States with regard to renewable (wind) energy production and with ambitious renewable energy targets. Lunde et al. (2016) indicate that the current regulation and market design are lagging behind in the sense that rules and regulations in the electricity markets seem to favour larger and more complex technical units. For example the regulated electricity power market has a minimum bid threshold of 10 MW, which excludes virtually all bids from aggregators with the exception of the most integrated ones. Also the lack of a variable time-of-use tariff blocks incentives for flexible consumption.

In the area of standardisation, Lunde et al. (2016) reported that existing standards seem to favour larger and more complex units. As an example it was indicated that the technical implementation of the IEC 68 150 standard for substations is virtually impossible to comply with for smaller products such as PV inverters and heat pumps[146]. As an alternative to resolve this problem proprietary standards are developed especially since the standards for smaller units take a relatively long time to develop. Evidently this creates a segmented market, increases the incentive for trying to reach market dominance, hinders competition and ultimately drives up costs, which in turn

[146] The IEC presents an overview of standards that it considers as very relevant for smart grid development, see http://www.iec.ch/smartgrid/standards/#top , accessed June 2016. The standard referred to by Lunde et al. (2016) does apparently not occur in this list.

slows down the uptake of particular smart grid solutions. This implies that standards promoting interoperability are at the very heart of the smart grid development.

The unadjusted regulatory framework has also ramifications for the smart grid market development. Without an adjusted clear regulatory framework the roles of all different actors in the smart grid remain uncertain, which in turn hinders investment that is needed for further roll-out. Leiva et al. (2016) identifies the additional costs that are associated with the management of the new and more abundant information that will be available through integration of smart meters into the grid and point to the new competences that operators of the grids and meters need to take on board. According to the authors for each of the smart grid stakeholders the obligations need to be clearly established as well as the incentives for developing new business models.

Although open platforms for new smart grid services are considered by many as a key enabler for the further development of smart grids, Lunde et al. (2016) report that in Denmark none of the industry participants in their research was willing to develop, own and manage an open platform for new smart grid services. Companies were reluctant to take up the responsibility for the quality and reliability for products and services that other actors would launch through their platform. This suggests that platform owners should be able to exert regulatory control over their platform to avoid low quality services, cyber security threats as has been argued by Giordani and Fulli (2012).

Lunde et al. (2016), Niesten and Alkemade (2016), and Crispim et al. (2014) point to the role of aggregators. Aggregators provide a key smart grid service by aggregating the remaining loads in a flexible consumption setting from smaller distributed energy resources and bid them into the market for flexibility services which are demanded by TSOs, DSOs and parties responsible for balancing the grid. Niesten and Alkemade (2016) reviewing the existing evidence on value creation and value capturing in a set of more than 400 EU and US smart grid projects, conclude that a necessary condition for aggregators to operate in a viable manner is to operate on a large scale. This implies that in order to effectively created and capture value aggregators need to have access to a large number of EV batteries for V2G and G2V services, aggregate a big amounts of consumer load to offer flexible demand response services and need to have access to a substantial amount of renewable energy capacity[147]. Given the minimum threshold size, this requires substantial investments. Without a clear regulatory framework that clarifies the roles of both old and new actors, the business community has relatively little incentive to develop aggregation services. The uncertainty about the future potential role adds to the business risk, which from an investor's point of view, requires relatively higher rates of return, which in turn implies that one would need aggregators of even larger scales. Given the current structure of the electricity market where TSOs and DSOs have local, yet regulated, monopolies a solution may be still far away under sub-optimal regulatory conditions.

[147] Niesten and Alkemade (2016) p. 630

Indeed as indicated by Palensky and Kupzog (2013) smart grid technology is new and relatively expensive. High up-front investment costs in combination with uncertain rates of return are a substantial barrier for the further development of smart grids. Yet the authors do report cases where it was less costly to invest in smart grid management solutions with intelligent controls that help to exploit the existing infrastructure's potential better, rather than investing in conventional grid reinforcement – also known as "investment into copper"[148].

A specific barrier for the smart grid sector lie exactly at the intersection of energy and ICT: security, privacy and reliability. Mourshed et al. (2015) identifies it as one of the key areas of future research that is necessary to foster the development of smart grids. Palensky and Kupzog (2013) indicate that despite the large amount of research performed in this field, the smart grid security challenge is still far from being resolved. From their review of smart grid projects in the EU and in the US, Niesten and Alkemade (2016) conclude that security, privacy concerns are largely absent and that projects mainly on the technical feasibility. Yet a survey done by Curtius et al. (2012) showed that more than one quarter of the respondents have a great concern about their security and privacy. Other concerns on the demand side for smart grid services may be the introduction of wireless smart metering solutions. These concerns may decrease the willingness to pay for smart grid applications, as indicated by Gerpott and Paukert (2013). Also from the operators side unresolved security and reliability problems are barriers for the development of the smart grid. From a business perspective the security of supply cannot be compromised. Traded flexible services must be delivered as promised, avoiding imbalances and voltage fluctuations or penalties from other actors in the grid may follow.

The last barrier we want to highlight is potential technology problems. In a recent article Colak, et al. (2016) indicate that the surmounting share of demonstration and deployment smart grid projects in the EU together with the increased share of very large projects suggest that smart grid technologies are reaching a phase of maturity, yet point at the same time at a number of critical technology issues that are important for the further smart grid development. Hossein et al. (2016), in the context of reviewing literature on the role of smart grids in renewable energy, argue that still some ground has to be covered and that the smart grid technologies are not mature enough for the efficient use of renewable energies. The critical technology issues identified by Colak et al. (2016) are grouped along three technological areas: 1) information and communication technologies, 2) sensing, measurement, control and automation technologies, and 3) power electronics and energy storage technologies. Concerning the first group routing protocols, transport protocols and quality of service support are according to the authors still considered as the major research challenges. Also the inflexibility in communication is highlighted as an important barrier in the deployment of new technologies. The steady and timely reaction of smart grid components requires that jittering, disconnection, packet corruption, packet loss, packet re-ordering and time delay properties of communication networks should be optimized. Also technologies for dealing with security

[148] Palensky and Kupzog (2013) p. 218

aspects such as denial of service, attack detection and mitigation, key management, authentication and encryption remain challenging barriers.

In the area of sensing, measurement, control and automation technologies Colak et al. (2016) identify challenges with respect to smart meter design, deployment and maintenance, demand management, the uncertainties related to the generation pattern of renewable energy sources, and the unbalances between user requirements and energy saving requirements in energy management systems. The authors point to the importance of policies of authorities and utility companies' strategies for smart meter roll-out as well as the implementation of flow-based congestion control algorithms to reduce peak loads and therefore mitigate power congestion, as well as cloud computing methods for improved forecasting, multi-agent control systems for distributed system automation.

For the third group, power electronics and energy storage technologies, the authors identify the need for better reliability analyses of power electronic interfaces, and improved energy storage technologies. With respect to the latter the authors point to the lack of support for investments from the regulatory framework, however without further detail.

9.5 Suggested actions

The main barrier is the one related to the regulatory framework. One of the main policy actions to be done in the near future is optimising the regulatory framework with respect to the new smart grid functionalities. The regulation in the electricity market needs to be adapted to smaller and less complex technical units. A notable example in this respect is the minimum bid threshold of 10 MW. Although this is relatively small in terms of conventional energy production, in renewable energy terms it represents nevertheless a sizeable production unit representing a park of minimum four large offshore wind turbines[149] or a solar power plant of 44,000 solar modules, covering an area of 7.5 hectare[150]. 10MW is enough to cover the electricity demand of approximately 3,000 average 4-person households. For aggregators that use the surpluses of smaller renewable energy producers to offer flexible grid management solutions, the 10 MW threshold puts a substantial minimum entry condition in terms of network size.

Other actions with respect to regulation relate to introducing dynamic tariffs. This would provide the necessary incentives for flexible consumption and also for investing in infrastructures, goods and services enhancing the

[149] Based on an average offshore wind turbine size of 3.7 MW as reported by the European Wind Energy Association (2015), p. 3. According to the same source the average size of a grid-connected offshore wind farm in 2014 was 368 MW.

[150] Referring for instance to a 10MW solar power plant close to the city of Aachen in North Rhine-Westphalia see: http://cleantechnica.com/2012/06/14/watch-the-construction-of-a-10-mw-solar-power-plant-in-germany/

benefits of flexible consumption. This would imply a leverage effect across the entire smart grid value chain from grid management services for combining flexible demand response with distributed energy production to NZEBs and smart consumer durables and in particular electric vehicles.

The adjustment of the regulatory framework should also focus on the market regulation aspect. New technologies generate new potential business opportunities. Yet without a clear and adapted regulatory framework indicating who has to or can do what and under which minimum performance criteria, which should be set to safeguard public interest, there is little incentive left for investing in more advanced smart grid solutions, let alone rolling them out on a larger scale. An obsolete regulatory framework generates a market environment with a high systemic business risk which is not conductive to investing further in smart grid solutions. Examples in this respect are the regulatory framework for open platforms, and that for aggregators.

Standards for enhancing the interoperability of smart grids between Member States but also within Member States between local so-called micro grids, even inter-regional, need to be defined and elaborated. Interoperability is not only for the TSO high-voltage energy exchange at country level. Yet it has also a clear regional and local dimension since the integration of the renewable energy is primarily at that level forming micro-grids with local prosumers, EV owners, DSOs and smart grid service providers. Beside the geographic dimension, interoperability has also a value chain dimension in the sense that devices, platforms, services all need to be able to communicate with each other ranging from renewable energy generation, storage capacity, to flexible consumption. Currently proprietary standards are used to overcome the problem but this creates a segmented market. A point of attention is that the new interoperability standards should not only focus on large and more complex units but are 'user-friendly' for the smaller units as well. As such new interoperability standards would not only contribute to the further development of the EU internal renewable energy market in terms of geographic coverage, but also in terms of scope of services and functionalities.

Sustained support for R&D and innovation as well as for the deployment of new smart grid technologies, products and services remains essential since many of the envisaged services still are not for today and require a substantial research efforts. These can be partly covered by private investments, mainly focussing on applications and deployment, yet a set of critical technologies have been identified that are necessary to further improve the functionality of the EU smart grid particularly when it comes to the efficient integration and use of renewable energies. These critical technologies are situated in the areas of ICT, sensing, measurement and automation, power electronics, and energy storage technologies. For these continued government funding e.g. through the EU Horizon 2020 programme, remains essential, especially given their rather fundamental research nature and since the envisaged benefits do have a societal value through improved energy efficiency and its contribution to climate mitigation, as well as knowledge creation. Also support for research focussing on solving problems concerning security, privacy and reliability is an important lever in this respect.

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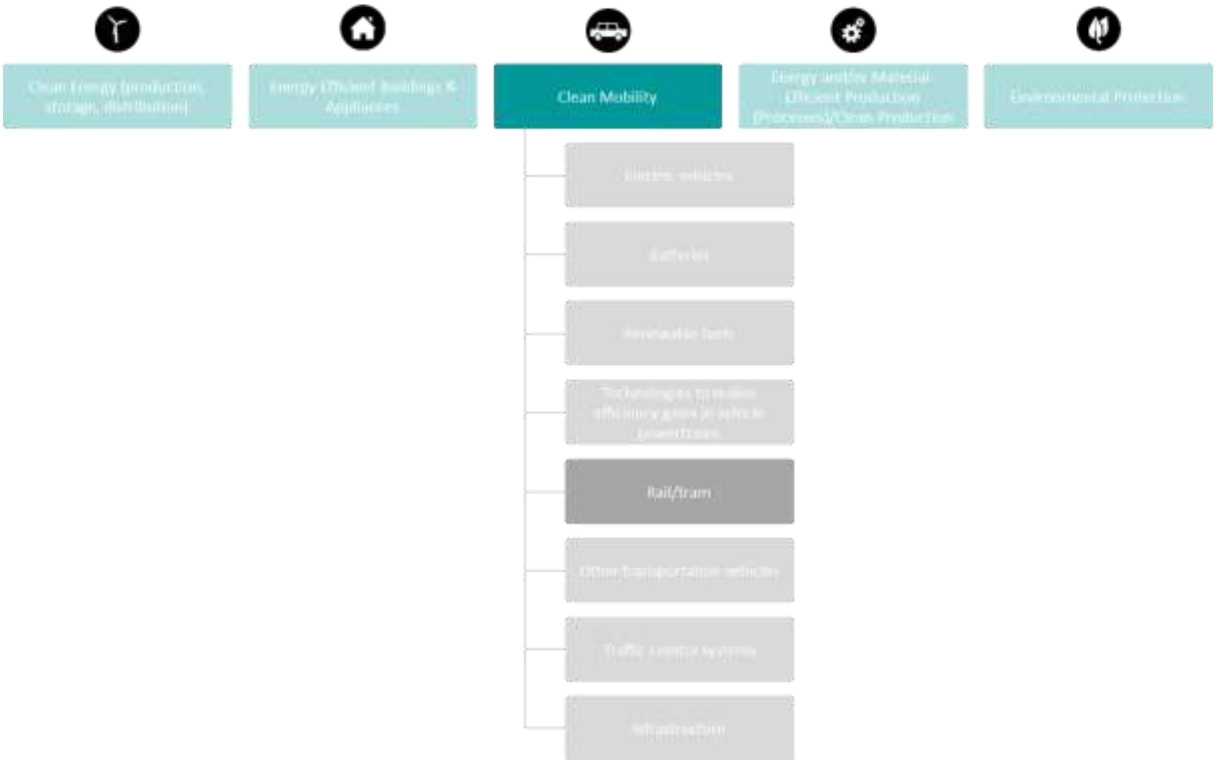
10/ Rail and tram

Figure 62: Presentation of the selected priority sectors within the Clean Industry taxonomy



10.1 Description and value chain

The European rail industry is a diverse industry, incorporating thousands of SMEs as well as major industrial champions, and a supply chain ranging from infrastructure, to rolling stock to signalling systems. The European rail industry has absolute sales of €47 billion, accounting for 46% of the accessible global market for rail products, and employs approximately 400.000 people all over Europe. If the workforce of the rail operators and infrastructure managers are included, the industry employs approximately 1.8 million Europeans. The high export of the European rail industry is derived from its technological leadership in many areas of the value chain. The industry has a long tradition of R&D, currently investing 2.7% of its annual turnover in R&D, resulting in innovations such as the high speed train, the ERTMS (European Rail Traffic Management Systems) and automated metro systems. The accessible market is expected to grow with a compound annual growth rate (CAGR) of 2.8%, with major growth markets in NAFTA (3.7%), Asia Pacific (4.2%) and Latin America (5.7%).

The rail industry entails a wide range of economic activities provided by a variety of actors, including (Ecorys, 2012):

- Rail Undertakings that run rail passenger and line services

- Rail infrastructure managers that are responsible for the safety, planning, construction, operation, management and maintenance of the rail infrastructure
- Rail vehicle leasing companies or rolling stock companies that own the actual trains that run on the rails and lease these out to the rail transport operator
- Rail Regulatory and Safety bodies that are responsible for promoting and/or enforcing competition and health and safety on the railway.
- Rail supply industry which encompassed manufacturers of all products for the railway operation – i.e. manufacturers of vehicles, control and safety technologies, infrastructure as well as the suppliers and service companies belonging to them.

In a more concise way it could be stated that the railway sector can be seen as the sum of three types of actors: infrastructure managers, railway operators and the rail supply industry. The 2010 production value of the railway supply industry in Europe was about €40 billion, with gross value added being around 30% of the production value. The rolling stock and locomotives, and rail infrastructure are the most important markets in terms of production value, followed by the segment of signalling and electrification. The rolling stock and locomotives market is most globalised market in terms of trade, and has traditionally been dominated by three major players, Bombardier (Canada), Alstom (France) and Siemens (Germany). Despite the fact that Bombardier is headquartered in Canada, it has numerous production activities in Europe. According to an Ecorys report (2012), industry data showed that these players employed approx. 78,000 people of which 9% are outside the EU. However, the Chinese rolling stock manufactures have grown substantially, which will be discussed further in the chapter (Ecorys, 2012). The rail infrastructure is characterised by a high degree of specialisation and local production of a high number of components. Among the largest companies are three EU companies: Voestalpine (Austria), Delachaux (France) and Vossloh (Germany). The signalling market is rather fragmented and served by various companies such as Alstom (France), Ansaldo (Italy, acquired by Hitachi (Japan) in 2015), Bombardier (Canada), Invensys (taken over by Schneider Electric (France) in 2014), Siemens (Germany), Thales (France) and Toshiba (Japan). The main players in the electrification market are Alstom (France), Balfour Beatty (UK), Bombardier (Canada) and Siemens (Germany) (Ecorys, 2012). According to an expert, the know-how, research and innovation in the railway industry have shifted over the past decennia from national railway companies to the current suppliers. Furthermore, the rail supply industry can be compared with the automotive industry, where the final manufactures, or so called Original Equipment Manufacturers (OEMs), work together with thousands of sub-suppliers, and where the market is composed of a mix of some world-class ”system integrators” and of many more specialised rail suppliers, including thousands of SMEs (UNIFE, 2016). Some relevant associations and organisation are the following:

- UNIFE (Association of the European Rail Industry)
- CER (The Community of European Railway and Infrastructure Companies)
- EIM (European Rail Infrastructure Managers)
- UIC (International Union of Railways)
- UIP (International Union of Wagon Keepers)
- UIRR (International Union of Combined Road-Rail Transport Companies)

Over the past decennia the European Commission has aimed to restructure the European rail transport market in order to strengthen the position of the rail transport with respect to other transport modes. The ultimate aim is to create a Single European Railway Area: an interoperable European railway system without technical barriers. The Commission's efforts have concentrated on three major areas which all deemed crucial for developing a strong and competitive rail transport industry: (1) opening the rail transport market to competition, (2) improving the interoperability and safety of national networks and (3) developing rail transport infrastructure. In Europe the rail industry is also expected to continue growing, among other reasons due to the policy objectives set for changes in the European transport sector. The Commission’s Transport White Paper published in 2011 aims to shift 30% of road freight over 300 km to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050, facilitated by efficient and green freight corridors. Another objective is to triple the length of the high-speed rail network by 2030, and to develop a complete high-speed rail network in Europe by 2050. In January 2013, the Commission adopted its proposals for a Fourth Railway Package covering the issues of rail governance, market opening for domestic passenger rail transport, competitive tendering for Public Service Obligations contracts and a new role for the European Railway Agency. The Fourth Railway Package is currently waiting for the adoption from the European Parliament (UNIFE, 2016; UNIFE, 2014; European Commission, 2016). Furthermore, a public-private partnership between the European Commission and the railway industry has been established in the form of the Shift2Rail initiative. Shift2rail is a joint European undertaking for rail research aiming to leverage or promote a shift to rail by accelerating the integration of new and advanced technologies into innovative rail product solutions. The Shift2Rail initiative aims to double the capacity of the European rail system and increase its reliability and service quality by 50 %, all while halving life-cycle costs. The initiative was established in 2014 under the Horizon 2020 programme, amounting a budget of at least €920 million for the period 2014-2020, of which a maximum of €450 million will be contributed from the Horizon 2020 Framework Programme. To access this funding, the rail industry had to commit to a contribution of at least €470 million. The rationale for this public-private partnership is the transnational nature of the infrastructure and technologies to be developed in support of the Single European Railway Area, and the need to achieve a sufficient mass of resources (European Commission, 2016; Shift2Rail, 2016).

Rail transport sector is the greenest and safest mode of transport. As illustrated in Figure 126 in Annex 14/, the rail sector generates only 0.9% of energy related CO2 emissions, compared to 22% by other transport modes, while it meets 9% of the total transport demand (UNIFE, 2015). The railway sector has strong incentives to reduce energy consumption. Energy costs are a principal cost driver for railway operators. In the freight sector, and especially the high-volume/low-value market, energy is an important part for the unit prices. But also in the passenger segment increasing comfort demands lead to an increase in energy consumption. In 2006 the European Commission therefore initiated the FP6 project RailEnergy, an integrated project, supported by railway manufacturers and operators, infrastructure managers, sub suppliers, universities, institutes and consultants, aiming to cut the energy consumption in the railway system thus contributing to the reduction of life cycle costs of railway operation and the carbon dioxide emissions. The project targeted to achieve 6% reduction of the specific energy consumption of the European rail system by 2020. (European Commission, 2012). Another initiative around that time was the training programme INcrease Energy-efficiency by Railways (TRAINER) aimed to improve energy efficiency of the railways, by focussing on energy efficient driving (ecodriving) as well as energy saving possibilities concerning technology (rolling stock and infrastructure) and organisation (European Commission, 2016). Between 1990 and 2010, the energy consumption of vehicles has decreased by 20% (CER, 2016). The sector is still committed to further improve its energy efficiency through different technologies and methods, such as hybrid technologies, weight reduction, regenerative braking, energy storage, new traction technologies, optimised operational parameters or alternative green power supply solutions. In 2015, the European Railway committed to reducing their specific CO2 emissions from train operations by 40% by 2020 compared to 1990. Further energy savings can be achieved to the application of lighter materials in vehicles (see the REFRESCO project, supported by the European Commission under the Seventh Framework Programme and co-ordinated by UNIFE[151]), a wider use of energy recuperation devices (e.g. regenerative braking or energy storage technologies, eco-driving, and parked train management (reducing energy consumption of parked trains). Finally, further electrification of rail transport is probably the most cost-effective way to increase the renewable energy use in transport (given an increase in renewable electricity generation) and thereby reduce total transport GHG emissions (CER, 2016). According to UNIFE, the Association of the European Rail Industry, the share of rail in transport usage is still lower than it should be, and there is still a great need in increasing this share in order to meet the decarbonisation target of a 60% reduction in CO2 emissions in the transportation sector by 2050 (UNIFE, 2016).

10.2 Assessment of the global environment

10.2.1 Main competitors outside the EU

Well-known companies in the rail industry outside of the EU are Bombardier (Canada) and Hitachi (Japan). Over the past decennium, Europe has succeeded in improving its competitive position with respect to Japan and the US (Ecorys, 2012). According to UNIFE (UNIFE, 2016) the European rail industry is facing a pivotal moment as industrial competition from Asia and particularly China is increasing rapidly. CRRC Corporation Limited, the world's largest train builder after a 2015 merger between CNR Corporation Ltd (CNR) and CSR Corporation Ltd (CSR) – the two previous biggest Chinese manufacturers with combined sales amounting to USD $31.7 billion in 2013, has significant export ambitions, including within the EU (UNIFE, 2016).

Access to some of key markets such as China is becoming more and more restricted or effectively non-existent for the European rail industry due to the increasing position of these domestic companies. Even in Japan, for which market opening has been agreed during the EU-Japan Free Trade Agreement (FTA) negotiations, European companies are having difficulties of effectively entering the market, while Japanese companies face less

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151 http://www.refresco-project.eu/about/

difficulties in Europe (UNIFE, 2016). In the interviews, the threat of the Chinese rail industry as well as the unequal playing level field issues regarding market access to the Japanese rail industry have been acknowledged.

10.2.2 *Relative competitive strengths*

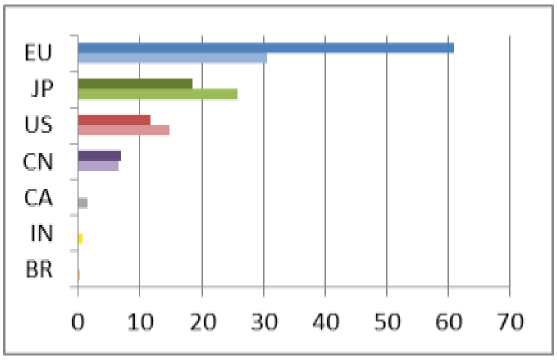
There are two mains strengths of the EU in the railway sector that can be distinguished. First, Europe still has an absolute leadership in the fields of know-how, innovation, research and technology. Innovations such as the high speed train, the ERTMS and automated metro systems have all derived from the European rail industry. The technological leadership of the EU in the rail industry will be further illustrated in this section in an analysis regarding transnational patent applications.

A second key strength of the European railway sector according to the expert relates to the regulatory environment and legislation. Over the past decennia, legislation has been established aiming to deal with the complexity of the European environment with its different countries, laws, institutions and technologies. However, the export potential here is limited due to the fact that Europe is relatively unique in that sense. Europe is starting however to export its know-how in this area to some of the golf countries that want to establish some sort of a Pan-Arabic railway system and are interested in ways that Europe has solved some of its cross-border problems.

In literature some other key competitive strengths are mentioned. A first key strength of the European rail electrification industry is the deployment of the European Rail Traffic Management System (ERTMS), which is also being implemented outside of the EU. The ERTMS which was developed by the European Rail Supply Industry with significant support from the EU, is widely considered as the most advanced rail signalling system in the world. The ERTMS is becoming the train control system of choice for countries outside of the EU, and is therefore one of the major export products of the European rail industry (UNIFE, 2014). Another strength relates to highly integrated solutions that are being deployed in the EU, such as merging of vehicle technology with intelligent track/signalling and optimum operations and service management. Furthermore, the European rail industry is characterised by specialised, long term experienced suppliers of high qualified key components like brake systems. Also in infrastructure, the EU is leading in developing special long-life steel for rail, fastening systems and turnouts and high quality concrete or plastic sleepers to keep maintenance cost within limits and to guarantee safe operation. The European rail industry is fed by a strong domestic market, but also holds a lead position in global trade. Europe has technological leadership in complex technological solutions and advanced technologies, characterised by well-developed design and production methods, a high level of quality and quality control processes leading to a high reliability, the ability to smartly integrate services into product delivery and a long experience in general in improving operational and maintenance processes (Ecorys, 2012).

The absolute technological leadership of the EU in the field of rail transport is reflected in an analysis regarding transnational patent applications[152]. Figure 63 shows that the EU has an absolute leadership in the field of rail transport showing a patent share of 60.8%. EU's relative comparative strength in this area is illustrated when the patent share is compared with its overall patent share of 30.5%. Except for Canada, all other world regions show below average patent shares in this field. EU's main competitors in terms of patent shares are Japan (18.6%), the US (11.8%), and Canada (6.8%). Within the EU, the largest share of patents is held by Germany with a patent share of 21.9%. Besides Germany, Austria (9.4%), Sweden (9.4%), France (6.3%), Czech Republic (4.2%), and the UK (2.1%) have a notable share in patents.

Figure 63: Patent share in the field of rail transport compared to total patent share 2010 to 2012



The upper bar shows the patent share (%) in rail transport, the lower bar the total patent share (with respect to all technologies).

Source: OECD.stat; Theme Environment; Dataset: Patents - Technology Development - NIW calculation

[152] The OECD Environment Directorate, in collaboration with the Directorate for Science, Technology and Innovation, has developed patent-based innovation indicators that are suitable for tracking developments in environment-related technologies. The patent statistics are constructed using data extracted from the Worldwide Patent Statistical Database (PATSTAT) of the European Patent Office (EPO). Patent data based on family size "two and greater" were used to count only the higher-value inventions that have been applied for protection in the home market and at least one foreign market. The relevant patent documents are identified using search strategies for environment-related technologies (Env-Tech: http://www.oecd.org/env/consumption-innovation/env-tech-search-strategies.pdf) which were developed specifically for this purpose. The data are available under http://stats.oecd.org/. The European Patent Office is also working with this definition, e.g. in the context of analysing the EU's patent performance in "Green Building" (http://www.epo.org/news-issues/technology/sustainable-technologies/green-construction.html).

10.2.3 International trade performance

Box 13: International trade performance

This section investigates the EU-28's trade performance in the respective Clean Industry products with regard to the development in six competitive countries in America (USA, Canada, Brazil) and Asia (Japan, China incl. Hong Kong, India). Six trade indicators are analysed to observe how the EU-28 and its Member States (MS) succeed in commercializing internationally competitive Clean Industry products. Those are significance (i.e. how important the specific Clean Industry products are in a country's total manufacturing exports), export market share (i.e. how important a country is for total global exports in the relevant Clean Industry), medium-term dynamics (i.e. how exports have changed within the pre-crisis years 2007/08 and 2013/14), trade balance (TB, comparing the absolute volumes of exports and imports), and two specialisation indicators, namely export specialisation (RXA, i.e. whether a country's global export share in a certain Clean Industry is higher/lower than its export share in total manufacturing products) and trade specialisation (RCA, considering a country's relative export/import ratio of a certain Clean Industry compared to its total export/import ratio). Four of these indicators (export market share, significance, RXA and TB) are illustrated in the following chapter, the other two (medium-term dynamics, RCA) in the Appendix.

It is important to note that the analysis comparing the external trade performance of the EU-28 in a regional perspective only considers extra-EU trade flows. Otherwise, analysis that compares single Member States with non EU countries has to consider extra- and intra-trade. Hence, the calculated export market shares and export specialisation figures (RXA) differ according to the respective perspective. Figures on the country level can be found in the Appendix.

EU keeps leading position and comparative advantages despite declining market share

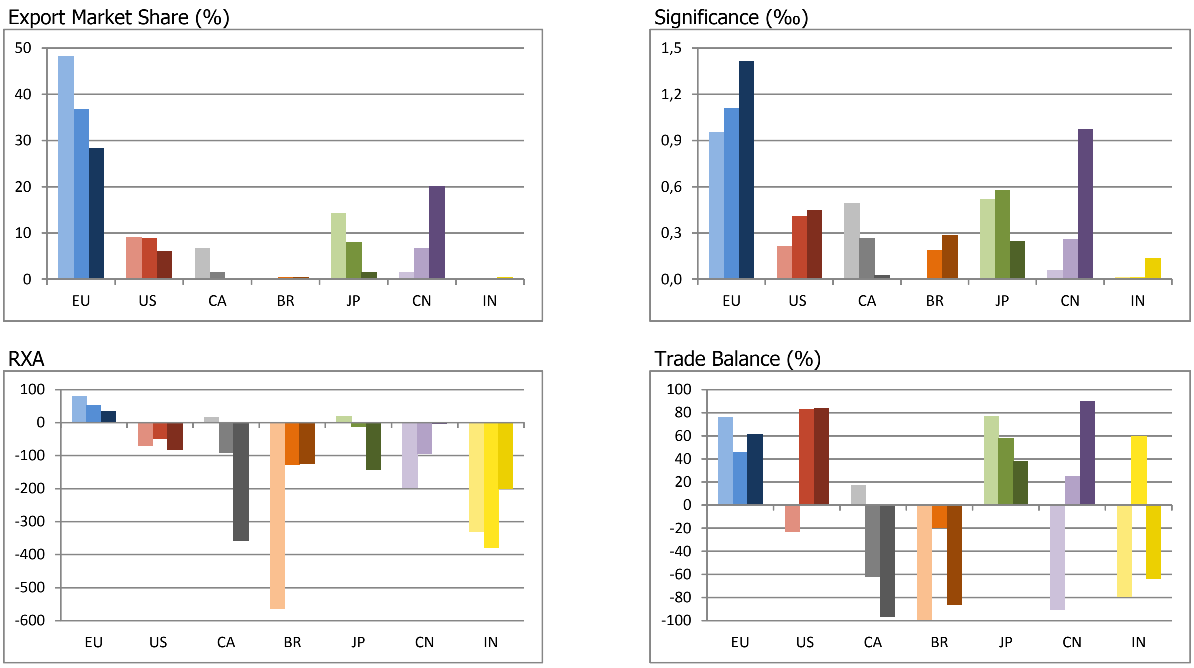
With respect to the "clean industry concept" trade analysis for the Rail and Tram industry (locomotives and rolling stock) exclusively refers to electrically driven locomotives. Although the demand for clean and congestion-relieving trains is globally on the rise, with Western and Central Europe in a pioneer position, less cleaner systems (using e.g. diesel-electric locomotives) are still dominating in most world regions, thereby also in North America. This is also reflected in the absolute and relative trade figures in electrically driven locomotives and rolling stock and explains the comparably low export share of the US, which is instead dominating the global export market for diesel-electric locomotives.

The analysis of `Electrically driven railway and tramway vehicles, wagons, and coaches' shows a clear comparative advantage of the EU-28, realizing high export specialisation (RXA) and trade specialisation (RCA) figures. Although the export market share has been declining by almost 20 percentage points over the analysed period, the EU-28 still holds the highest export market share (28.4%, see Figure 64). Contrary, the significance of these Rail and Tram exports has increased remarkably (0.14%) even though the absolute trade volume is quite small. The strong position of the EU-28 is underlined by a positive trade balance and a positive medium-term export growth (8%, see *Figure 130* in Annex 15/).

China succeeded in gaining significant market shares, holding the second highest share in 2014 (20%). Consequently, China reveals considerable medium-term export dynamics (35% p.a., see *Figure 130* in Annex 15/), an almost balanced export specialisation and high trade specialisation, indicating that domestic manufacturers succeed in competing against international manufacturers.

Unlike China, the US, Canada, and Japan lost substantial market shares. But while the US still holds the third highest export market share (6.1%) and shows positive medium-term export growth (5% p.a., see *Figure 130* in Annex 15/), Canada and Japan only play a minor role in the export market for `electrically driven railway and tramway vehicles, wagons and coaches' and moreover depict negative export growth. Howsoever, it can be concluded that, both in the US and Japan, the domestic demand is met by local suppliers for the most part which is indicated by a positive trade specialisation and a positive trade balance. India and Brazil on the other hand are net importers of Rail and Tram products and therefore only represent a small share in the export market, too.

Figure 64: Trade indicators for the EU and selected other countries 2002, 2008 and 2014 and export dynamics 2007/08 to 2013/14: Rail/Tram



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Good trade performance is mainly attributed to Germany, Spain, Austria and Italy

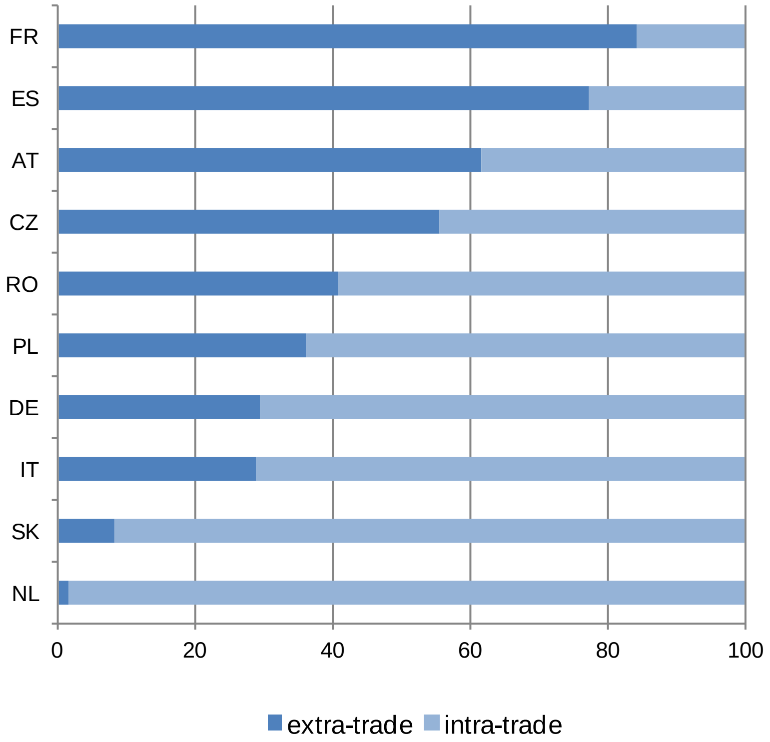
Out of the EU-28 MS, Germany has the highest export market share (13.9%), followed by Spain (7.8%), Austria (7.1%) and Italy (4.1%). But also some Eastern European countries (Czech Republic, Poland, Romania and Slovakia) hold export market shares of more than 0.5% (*Figure 131* in Annex 15/). The declining EU export market share may be based on the likewise declining export market share of Germany which dropped by 13 percentage points. However, all of the larger exporters (>0.5%) reveal clear comparative advantages in terms of export and trade specialisation. Bulgaria, although only holding a relatively small export market share, reveals an export specialisation and trade specialisation, too. By contrast France (1.4%) and the Netherlands (1.3%) show no export specialisation but depict a positive trade specialisation going along with a positive trade balance. Yet, the majority of MS are net importers of Rail and Tram products.

With regard to the medium-term export dynamics, eight MS realize high medium-term growth of more than 10% per year (see Figure 133 in in Annex 15/). Especially countries like Belgium, Finland, the Netherlands and Ireland accomplished to expand their exports impressively. Yet, also Spain and Poland achieved high medium-term export growth higher than 10%. However, the structural weight of Rail and Tram exports is quite low at an average of 0.11% *Figure 132* in Annex 15/). Austria shows by far the highest significance value (0.6%) prior to Spain (0.4%) and Romania (0.4%).

Shares of intra-trade and extra-trade vary strongly between the larger EU exporters

On average, 55% of the EU's exports refer to intra-trade and 45% to extra-trade. However, in 2008 the intra-trade share still accounted for 66% of total exports indicating the growing importance of external market for European Railway/Tramway producers. Therefore it is interesting to compare the share of EU-intra trade exports with the share of EU-extra trade exports on the country level. As Figure 2 reveals, France, Spain, and Austria reveal above average EU-extra-trade shares within the small group of exporters holding global export market shares higher than 0.5%. On the other hand, Germany's high export market share is based on an extensive intra-EU trade. Only 30% of German exports are directed towards non-EU countries. The same applies for Italy, Slovakia and the Netherlands, whilst the share of EU-intra-trade in the Netherlands is close to 100%.

Figure 65: Share of EU-Extra-trade and EU-Intra-trade (in %) in country exports: Rail/Tram



Including EU countries with an export market share in Rail/Tram products higher than 0.5 % in 2014.
Source: UN COMTRADE-Database. – NIW calculation.

10.2.4 Market outlook

Rail markets will continue to grow, both in Europe and outside of Europe (UNIFE, 2016). There are several trends that have driven this growth in the past and are likely to continue doing so. First, mega-trends such as population growth, urbanisation and increased demand for mobility, climate change and environmental concerns, deregulation, and liberalisation will further contribute to the growth of the sector. Second, the competitiveness of the European rail industry will be enhanced by several initiatives at EU level, examples being the Shift2Rail programme, trade agreements and a possible future Resolution of the European Parliament's Industry, Research and Industry Committee on the competitiveness of the European rail supply industry. Finally, order volumes for the European railway supply industry are likely to increase due to increasing demand in emerging markets and continuing efforts in remaining demand stable in mature markets. Regions that will be important for the export of the European rail industry are Latin America, Asia/Pacific, Africa/Middle East and NAFTA (Roland Berger, 2014). This global market growth will thus provide great business opportunities for the European railway industry. However, the European railway industry will face a critical challenge to their global market leadership with increasing industrial competition from Asia and especially China (UNIFE, 2016).

A large part of the global market growth takes place in regions with a strong own production base and therefore a relatively low import penetration, which implies that domestic suppliers will benefit larger from this growth. Europe's rail industry might benefit from a possible change in global future demand towards safer, cleaner and higher energy efficient transport, due to its technological leadership position in this area (Ecorys, 2012).

10.3 Assessment of the competitiveness aspects

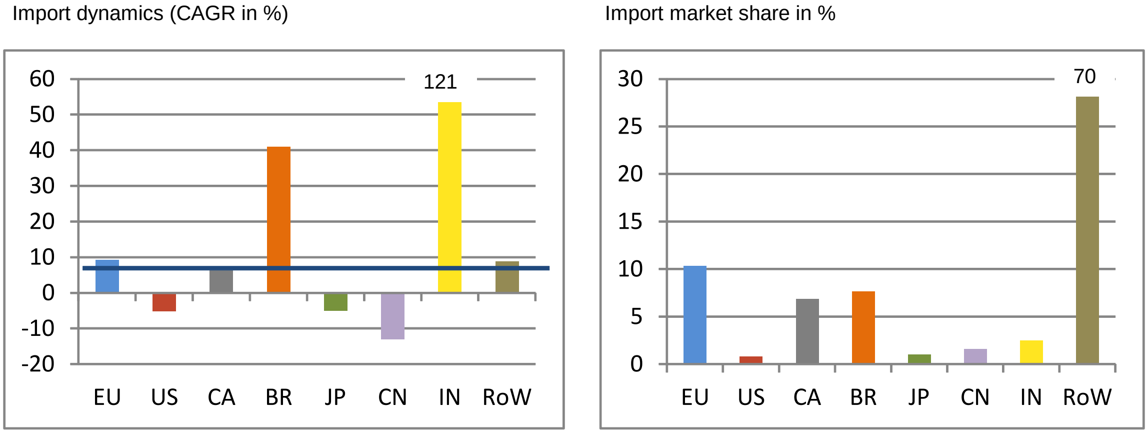
10.3.1 Export potential

Box 14: Export potential

Export potentials emerge primarily in those goods and activities, in which the EU-28 already holds comparative advantages (measured in export specialisation or trade specialisation). In these goods and activities, trade volumes can be used as an initial indicator for market and growth potential. Hence, growing import rates of third countries may serve as a proxy for an increase in demand for Clean Industry goods in a specific country or world region that may subsequently translate into a growing export market for the EU and its Member States. At the same time, existing export advantages (indicated by RXA values) of the EU and its Member States in certain products may indicate promising preconditions for further growth and export potential.

With respect to the "clean industry concept" trade analysis for the Rail and Tram industry (locomotives and rolling stock) exclusively refers to electrically driven locomotives, and not to other (e.g. diesel-electric) congestion systems, that are still dominating in most world regions, also in North America. This is also reflected in the absolute and relative trade figures in electrically driven locomotives and rolling stock and explains the comparably low import shares of the US and China (Figure 66). Out of the represented countries, the EU (excluding intra-trade) has been the largest single importer (10%) followed by Brazil (8%) and Canada (7%), both revealing a considerably high demand for those products compared to their structural weight in total manufacturing imports. India constitutes 2.5% of global Rail and Tram imports in 2014, whereas Japan and particularly China and the US only play an unusually minor role as importers of these specific products and even depict a negative medium-term import growth between 2007/08 and 2013/14. All in all, the EU and the other selected countries only account for a rather small amount of global import demand in this field, since more than 70% of the imports in 2014 apply to RoW.

Figure 66: Import market share 2014 and import dynamics 2007/08 to 2013/14 in the EU-28 and selected non-EU countries: Rail/Tram

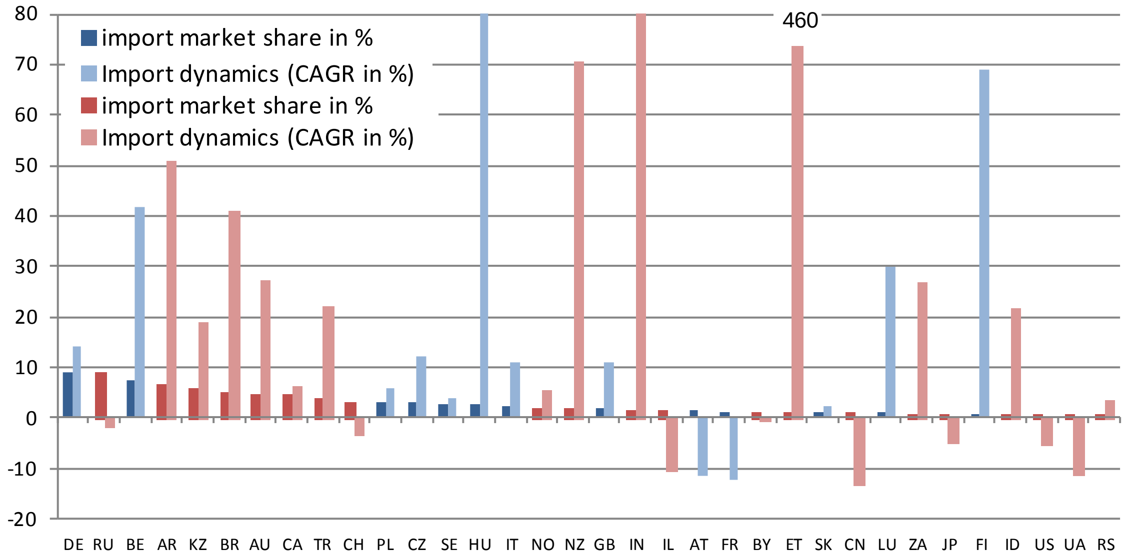


Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Starting from a low level, particularly India (121% p.a.) and Brazil (40%) yield very high import dynamics since 2007/08, suggesting high investments in rail infrastructure and equipment. However, as Table 27 (in Annex 1/) depicts, the EU actually only holds a comparably weak position on these two markets, indicated by low export market shares and negative export specialisation values (RXA). In contrast to this, also lower growth rates connected with a high absolute import volume, as can be seen for Canada (6.5%) and RoW (9%) can create further export potential for the European Rail and Tram industry. Except for the Canadian and Indian market (Table 27), the EU in general has a strong export position on those specific Rail and Tram products (see chapter 1.1.1.3), providing a good precondition for further exports in the RoW, that accounts for nearly 70% of global imports in 2014.

Hence, Figure 67 illustrates import market shares and import dynamics for all countries with a global import market share higher than 0.5% in 2014. On the one hand this illustrates a high and/or considerably growing import demand of several EU MS (e.g. Germany, Belgium, Czech Republic, Hungary, Italy , Finland), that is mostly attributed to sales within the internal market (see chapter 1.1.1.3). On the other hand, also other European (e.g. Kazakhstan, Turkey) and overseas countries (besides Brazil and India e.g. Argentina, New Zealand, Ethiopia) constitute considerable import market shares and/or remarkable growth rates often due to large infrastructure projects, hence creating additional sales respective export potential for the EU Rail and Tram industry.

Figure 67: Import market share 2014 and import dynamics 2007/08 to 2013/14 in Rail/Tram on the country level



Global imports including EU-intra-trade. - Regarding countries with a global import share higher than 0.5%. – EU MS: blue coloured; non EU countries: red coloured.
Source: UN COMTRADE-Database. – NIW calculation.

10.3.2 SWOT

Table 24: SWOT for the rail and tram sector

Strengths	Weaknesses
▸ Europe still has an absolute leadership in the fields of know-how, innovation, research and technology. Innovations such as the high speed train, the ERTMS and automated metro systems have all derived from the European rail industry. ▸ Europe has managed to establish legislation able to deal with the complexity of the European environment with its different countries, laws, institutions and technologies. ▸ The ERTMS is widely considered as the most advanced rail signalling system in the world and is one of the major export products of the	▸ The export market share has been declining by almost 20 percentage points over the analysed period of 2002 - 2014

European rail industry ▶ The EU deploys highly integrated solutions characterised by well-developed design and production methods, and a high level of quality and quality control processes leading to a high reliability	
Opportunities ▶ Europe could export its knowledge about the regulatory and legislative environment to regions that also aim to create a cross-border rail industry ▶ Regions that will be important for the export of the European rail industry are Latin America, Asia/Pacific, Africa/Middle East and NAFTA ▶ Europe's rail industry might benefit from a possible change in future demand towards safer, cleaner and higher energy efficient transport, areas in which Europe has technological leadership	Threats ▶ The European railway industry will face a critical challenge to their global market leadership with increasing industrial competition from Asia and especially China. China succeeded in gaining significant market shares, and reveals considerable medium-term export dynamics, an almost balanced export specialisation and high trade specialisation, indicating that domestic manufacturers succeed in competing against international manufacture ▶ A large part of the global market growth takes place in regions with a strong own production base and therefore a relatively low import penetration, which implies that domestic suppliers will benefit larger from this growth.

10.4 Analysis of barriers

Regulation: Highlighted in interviews, one of the barriers in the European railways system relates to the many different strategic choices that have been made and the different laws, different technologies that are in place in the Member States hampering the interoperability of the rail industry in Europe. As an example of negative consequences, these differences make the authorisation of rolling stock in Europe a costly, lengthy and complicated process. Furthermore, given that the railway system is a complex and interconnected system, a single supplier, operator or infrastructure manager (as large as they may be) cannot tackle the energy management issue for the entire network alone. Relating to these interoperability issues, is the issue of fragmentation in the production, which results in a low level of collaboration and partnership among the rail industry players, a lack of system approach, a lack of appropriate consideration of customer needs, etc.

Internal market: Europe's export potential is limited by different non-tariff barriers to enter non-EU markets, especially in the major competing economies. Examples of such barriers in China are related to standardisation and technical regulations, insufficient IPR enforcement and heavy certification procedures. However, also within the EU there are still improvements to be made with respect to creating a single market in the EU for railway supply (Ecorys, 2012).

Capital and finance: A financial barrier in the rail industry relates to the capital intensive railways assets: the lifecycle for vehicles is about 40 years and the lifecycle for infrastructure is up to 100 years. As a consequence, investments cannot be made overnight, an issue which is magnified by the European complexity of making large scale investments that cross borders (Wiesenthal, Condeço-Melhorado, & Leduc, 2015). Furthermore, one of the major measures to further decreasing emissions of the rail sector is to further electrify rail transport. Currently, about 60% of the European rail network is electrified, with 80% of the traffic running on these lines. There are no technical obstacles to further electrification; the main barrier is the cost for upgrading and electrifying the existing rail infrastructure (CER, 2016).

R&D: As identified earlier in this chapter, Europe thanks its technological leadership partly to the successful innovations being a result of the R&D investments of the industry. According to an Ecorys report (Ecorys, 2012), the lower gross operating rate of the industry in recent years limits the ability to raise the necessary funds for R&D activities to maintain its technological lead. Innovation costs are relatively high in the rail industry. Finally, the process of entering innovations into the market is a very complex process of acceptance and homologation, hampering innovation in the industry (Wiesenthal, Condeço-Melhorado, & Leduc, 2015).

Technology: Despite the efforts of improving interoperability of the European railway system, there seems to be still quite some physical barriers at the borders such as differences in electrification system and other technologies on interoperability in the rail industry.

Another barrier relates to the competitive pressure of other transport modes on the rail sector. This competitive pressure should not be undermined, since it may create a vicious circle: higher competition could pressure profit margins, which in turn pressures investments, which in turn results in a higher exposure to competition. This problem is mainly driven by financial barriers: the high capital intensity of investments, the long lifecycle of assets, expensive product customisation. However, besides the financial barriers, flexibility issues such as the last mile issue also play a role, as well as reliability issues such as a poor customer satisfaction, and a lack of information in the freight sector. The rail sector is committed to promoting inter-modality, however, a current barrier for further development of electric rail is a lack of public investment in inter-modality (CER, 2016).

Labour market: As highlighted in interviews, there are concerns regarding the labour market. Shortages are already experienced, and these shortages are expected to increase due to an ageing population in many member states. The lack of skilled labour is further driven by the trend towards more sophisticated railway technologies (Ecorys, 2012). The European Railway Agency (ERA) is working on improving the labour market conditions through measures such as developing a scheme for EU driving licenses, standardisation of staff competencies, and providing trainings and education.

10.5 Suggested Actions

One of the most important barriers relates to many differences between Member States hampering the interoperability of the rail sector. The 4th railway package legislation aims to address these issues. The package will enter into force this year, and from 2019 onwards the European Railway Agency will be the agency authorising vehicles in cooperation with the national railway systems, aiming to mitigate such problems as described above. With respect to collaboratively work on improving the energy management in the rail industry, platforms or collaborative approaches are needed to bring together the key rail stakeholders from across Europe. An example is the FP7 funded project MERLON, aiming to improve rail transport's sustainability through smart decision-making tools (MERLIN, 2012).

The second barrier that was mentioned was related to market functioning issues. Especially the trade barriers with non-EU markets is limiting Europe's expert potential. Creating a level playing field and open market access is regarded essential in maintaining the competitive position of the European railway industry, and recommendations in the report were to continuously monitor address barriers to market access, in particular non-tariff barriers and procurement strategies; monitor and encourage competing countries (in particular China) to introduce the necessary measures to protection IPR; and to stimulate early relationship building with countries that are expected to face a significant market demand but do not have their own production capacity (Ecorys, 2012).

The third barrier mentioned related to capital and finance. European funding support remains necessary. A good initiative is the public-private partnership between the European Commission and the railway industry has been established in the form of the Shift2Rail initiative, aiming to leverage or promote a shift to rail by accelerating the integration of new and advanced technologies into innovative rail product solutions. In the interviews it was highlighted that there is always a need for more public funding, more advantageous taxation, and loans or structural funds for big structural projects. The interviews also discussed mechanisms to encourage investors should be developed in order to solve these issues of profitability. There are some organisations such as the Bank of Japan that invest in vehicles, buying vehicles and loaning it to other companies to provide the transport and services (like investments in real estate). It would be interesting for the European railway industry to take capital outside from Europe.

The earlier mentioned 2012 study by Ecorys 'Sector Overview and Competitiveness Survey of the Railway Supply Industry' discusses recommendations regarding innovation, access to skilled labour, and the modal shift towards environmentally friendly rail transport, are for which barriers have been identified in this study. With respect to innovation it was regarding key to maintain the technological advanced position of Europe in retaining its future competitive positions. Key recommendations related to further introducing progressive regulation driving innovation and market adoption of innovations in Europe and continued R&D support.

With respect to maintaining sufficient supply of skilled labour, some of the key recommendations of the European Railway Review were to intensify cooperation of companies with universities, including a continuous adaption of curricula of training and education programmes to address new technological developments and trends such as the drive towards higher energy-efficiency; to develop progressive formal career paths by companies and their associations and improve the skills of medium qualified labour (e.g. through the introduction of apprenticeships or similar vocational schemes); and to improve labour mobility by regular monitoring of supply and demand across Europe.

Finally, with respect to the area of stimulating a modal shift towards environmentally friendly rail transport, it was recommended to introduce measures that aim to internalise the external costs of transport thus improving the competitive position of rail; and to actively pursue the ongoing intervention that aim at increasing the relative competitive position of rail transport vis-á-vis other modes of transport (Ecorys, 2012). The interviews also covered the topic of the developments in recent years related to the 'uberisation' of society (Uber, Blablacar, etc.). The railway system has a huge potential to contribute to the objectives pursued by this movement (environmentally friendly, no car ownership, free movement). However, there remain problems in terms of reliability, accessibility, price, and regarding the so called last-mile. These problems cannot be solved by addressing the railway section alone, instead, we should address more the complementarity of the different modal transports. The Community of European Railway and Infrastructure Companies (CER) is committed to contribute to door-to-door mobility including the promotion of active modes and inter-modality, with rail as the backbone of sustainable mobility. With respect to the lack of public investment in inter-modality, CER and UNIFE suggest actions such as fitting railway stations with electric vehicle charging facilities where justified by forecast demand, and state that European funding (e.g. from Structural and Cohesion Funds and CEF) for inter-modality, including information and ticketing, could have a strong leveraging effect (CER, 2016). Policy cooperation between the rail and road sector should be stimulated, as there is now some sort of a policy gap. Especially regarding the freight segment it would be beneficial to combine these two modes of transport.

Figure 129 provides an overview of policies, centred on three pillars that are, according to UNIFE, pivotal in maintaining Europe's competitiveness in the rail industry. CER and UNIFE also propose a set of actions regarding the contribution of the rails sector towards decarbonising transport (CER, 2016):

- Develop a reporting mechanism for Member States to monitor and facilitate their progress in reducing transport emissions. Annual reports should be published so as to incentivise Member States to achieve progress.
- Confirm in legislation the 60% reduction target for transport emissions by 2050 compared to 1990 levels (Transport White Paper 2011), with an additional binding target for 2030.
- Where carbon savings and the economic case of a project are positive, further electrify and upgrade the rail network (regional as well as main lines), as electrified railway transport is by far the most efficient form of e-mobility.
- Promote rail as the backbone of sustainable mobility and its interconnectivity with other low-carbon modes, e.g. with bicycle sharing and parking facilities at railway stations.
- Support the development and market introduction of energy-efficient solutions and new vehicle concepts like hybrid locomotives and battery-operated vehicles for short sections of track where electrification is not viable.
- Encourage the use of electric transportation by fair framework conditions for competing transport modes.
- Continue and intensify support to rail research and innovation.

Figure 68: Overview of policies by (UNIFE, 2016)

10.6 Bibliography rail and tram

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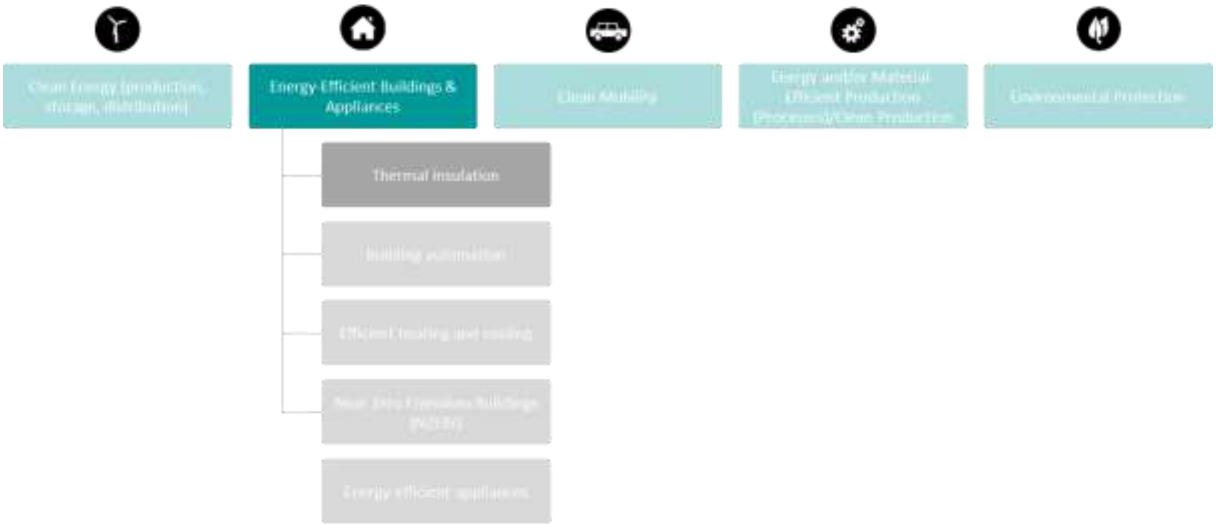
11/ Thermal insulation

Figure 69: Presentation of the selected priority sectors within the Clean Industry taxonomy



11.1 Description and value chain

Thermal Insulation is an important technology to reduce energy consumption in buildings by preventing heat gain/loss through the building envelope (i.e. floor, walls and roof), thus being the most cost-effective measure to combat climate change.[153] Following the 2°C Scenario (2DS), in which energy-related CO_2 emissions are halved by 2050, helping to limit the global average temperature rise to no more than 2°C, global savings from envelope improvements in residential buildings will amount to 5.8 EJ – 4.3 EJ" by 2050, because effective air sealing can reduce heating and cooling energy by 20% to 30% (IEA 2013, 2015). Buildings represent 40% of the EU energy consumption and 36% of its CO_2 emissions. According to the European Insulation manufacturers Associations improved efficiency in buildings could cut Europe’s total energy use by over 20%, reduce energy bills by € 270 billion and CO_2 emissions by 460 million tonnes yearly. This concerns new buildings as well as improvements for existing buildings, both in the public and private sector. With respect to new buildings, optimizing building designs and advanced window and glazing systems can decisively contribute to passive heating. Air sealing alone can reduce the need for heating by up to 30%. Tightly sealed structures with proper ventilation control can

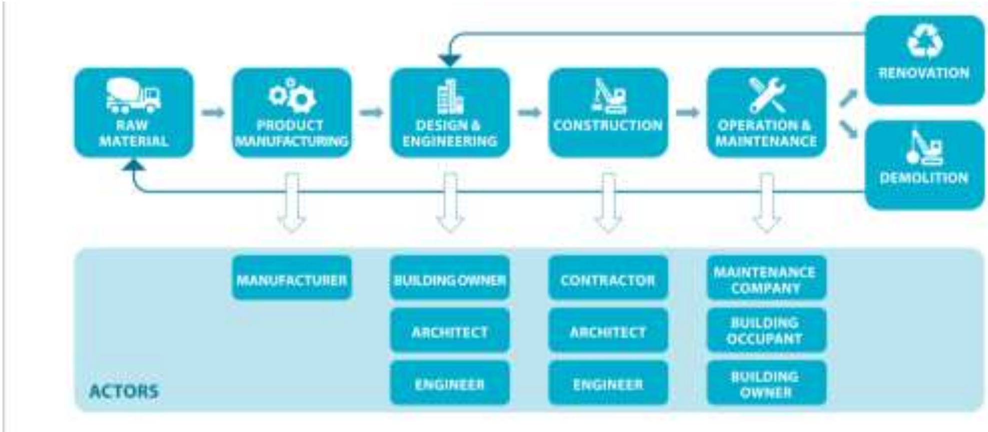
[153] Although this sector focuses on Thermal Insulation in (mainly) residential buildings, information regarding industrial insulation will partly also be included, because many aspects considering technologies, products, market characteristics or barriers are similar to those concerning Thermal Insulation in buildings.

ensure that indoor climate is healthy. In hot climates, reflective roofs and walls, exterior shades, and low-emissivity window coatings and films can curtail energy consumption for cooling (IEA 2013).

Particularly building renovation is an economic activity entailing a huge potential in terms of job creation and growth. According to a JRC study launched by the European Commission (2015) value added by activities linked to Thermal Insulation of buildings (building envelope) was €166 billion in 2011, or 60% of total value added in the EU construction sector. In terms of employment, such activities represented 6.88 million jobs, 58% of total sector employment. Up to 2020, all in all nearly 2 million additional jobs could be created in the construction sector, including its extended value chain (Figure 70), most of them in SMEs and at the regional and local level, if the required investments in renovation will be performed (EuroACE Press Release, 14th March 2016, DG RTG InnovREFIT 2015, p. 35).

In contrast with other value chains, the kind and amount of involved actors vary heavily during a single building process according to projects scale, planned works and consumer preferences. Hence, when renovating existing buildings small-scale contractors or installers often act as gatekeepers between suppliers of products and building owners (BPIE 2016, p. 6).

Figure 70: High-level overview of the traditional construction sector and its main actors



Source: BPIE (2016, p. 6).

Other non-construction actors, such as service providers (e.g. financial, legal, real estate, communication, competence and training, or cleaning) are directly or indirectly also involved in the construction value chain. Furthermore, local, national and European authorities also have a key role in developing the legal framework, creating incentives and rising awareness on both the demand and supply side (BPIE 2016, p. 7).Thus buildings are a strategic sector for achieving the EU's energy efficiency goals, driven by legislation (Energy Performance of Buildings Directive: EPBD, Energy Efficiency Directive: EED, Renewable Energy Directive: RED) and supported by associations like the Buildings Performance Institute Europe (BPIE). E.g. Article 9 of the EPBD requires MS to develop strategies to stimulate the transformation of buildings that are refurbished into NZEBs, Article 5 sets a 3% annual renovation target for buildings owned and occupied by central governments, and in Article 4 of the

EED MS were required to draw national long-term renovation strategies for residential and commercial buildings, both public and private, by April 2014 (Castellazi, Zangheri, Paci 2016).

Similar regulations for minimum energy performance standards and retrofit construction are active in the US, but are also beginning to cover the emerging economies in Asia (markets and markets, 2015). Green buildings with very low energy consumptions are provided with tax benefits by several governments around the world, which also promotes the building insulation market (FMI 2016).

All in all, this has resulted in increased applications of Thermal Insulation materials that are largely classified into three groups[154]:

- *Mineral fiber* products include rock wool, slag wool and glass wool, which can be sourced from recycled waste. These materials are melted at high temperatures, spun into fibre and then have a binding agent added to form rigid sheets and insulation batts. If removed in appropriate conditions, mineral fibre can be reused and recycled at the end of its life.
- *Cellular plastic* products are oil-derived and include rigid polyurethane, phenolics, expanded polystyrene (EPS), and extruded polystyrene (XPS). The products are available as loose fill, rigid sheets and foam. Under climate change aspects, it is important to ensure the specified products have production processes that do not use ozone depleting agents. Cellular plastic products can be recycled but it is a cumbersome process. It is more suitable for cellular plastic products to be incinerated for energy recovery at their end of life. Polystyrene is flammable, requiring proper placement in any assembly.
- *Plant/animal derived* products include cellulose fibre, sheep wool, cotton, and flax. These products have low embodied energy, as the materials can be sourced from renewable raw materials. The products are in the form of fiber, batts or compressed board. Their production involves chemical treatment to ensure appropriate properties, such as fire resistance and no vermin infestation. As such, at the end of life, it is difficult to use it for energy recovery through incineration.

Whereas rock mineral wool was the most preferred insulation method in the past years, nowadays fibreglass and foamed plastic are the major insulation types that dominate the global market. New methods of insulation, super insulation materials (SIMs), such as vacuum insulation panels (VIPs) or aerogel based products, are expected to witness growth in the future (FMI 2016, BPIE 2016).

According to IAL Consultants (2015) the total market for Thermal Insulation products in Europe stood at just under 235 million m^3, equating to an approximate market value of €11.5 billion. Commercial and domestic buildings represent the bulk of the demand for Thermal Insulation materials in Europe (87%), with the overall use in industrial applications remaining smaller (13%). 59% of the market is attributed to Western Europe 25%

[154] http://www.climatetechwiki.org/technology/building-envelope-thermal-insulation

Eastern Europe and 16% Central Europe. Interesting growth is particularly reported in Germany, Italy, UK, Turkey (IAL 2015). Glass wool (36%) and stone wool (22%) combined represent 58% of the European Thermal Insulation market, the remaining market is nearly exclusively attributed to cellular plastic products.[155] Manufacturers of mineral fibres are promoting their 'natural' fire protection characteristics compared to other plastic foam insulation materials, especially EPS that has started suffering from its unfavourable behaviour in case of fire in many Western European countries. However, this is not necessarily the case in Eastern Europe, where the lower price of EPS continues to favour its use in construction.

Large and globally acting European companies involved in the production of Thermal Insulation products are e.g. BASF (Germany), Knauf Insulation (Germany), Rockwool Technical Insulation (The Netherlands) and Saint-Gobain Isover (Germany), furthermore Bayer (Germany), Recticel S.A. (Belgium), Pitsburgh Coming Europe (Belgium), British Vita Unlimited (Great Britain), Kingspan Insulation NV (Belgium), Paroc Group (Finland), Velux (Denmark), Armacell (Germany), L'Isolante K-Flex (Italy) and Kaimann (Germany) belong to the group of main European manufacturers.[156]

11.2 Assessment of the global environment

11.2.1 Main competitors outside the EU

The global insulation market of Thermal Insulation products is highly fragmented with top four companies, namely, Saint-Gobain (France), Rockwool (Denmark), Johns Manville (US), and Knauf Insulation (Germany), accounting for over 25% of the overall revenue in 2013. Major companies such as Knauf and Johns Manville are actively involved in mergers and acquisitions in order to increase their revenue share. Further major non European companies operating in the global insulation market include among others Woodbridge Foam Corp. (Canada), Mitsui Chemical Inc. (Japan), and Owens Cornings (U.S.). The main competitor country is the US (EPEC 2011).

Particularly the global polyurethane market is highly competitive and dynamic with top multinational companies leading the list. The presence of a large market in Asia Pacific poses a threat to large MNCs in terms of product

155 PU Europe estimates, that 61,800 companies, representing an economic value of 42,2 bn € and a total employment of 258,000 people, are involved in the production of polyethane based Thermal Insulation products (EPS, XPS, Phenolics, PU/PIR) for buildings and technical installations.

156 According to an interviewed expert from the European Industrial Insulation Foundation (eiif), the main European contractors for the implementation of large, mainly industrial, insulation projects are Kaefer Isoliertechnik, Bilfinger OKI Isoliertechnik, G+H Insulation, Bohle Gruppe and Lindner Isoliertechnik (all located in Germany), CAPE plc (UK/Singapore) and Hertel Holding B.V. (the Netherlands).

quality and price offered to customers. Market participants strive to achieve technological advancements, product and application developments in order to gain competitive advantage over their competitors. Major plastic producers such as BASF (Germany), Dow Building Solutions (US), and Huntsman Corp. (US) are expanding their product manufacturing capabilities to enhance their presence in the Asia Pacific region (Grand View Research 2015).

However, while competition between mineral fiber and cellular plastics products manufacturers is international, competition regarding insulation works remains at a local level (also confirmed by an interviewed expert).

11.2.2 Relative competitive strengths

The pioneering task of the EU in buildings Thermal Insulation is also reflected in its technological competitiveness measured by transnational patent applications[157]. Figure 71 reveals that the EU has the far ahead strongest technological performance in Thermal Insulation[158]. This is underlined by the absolutely highest patent share in this field with 54.6% (Figure 71). It is furthermore much higher than the EU's total patent share (30.5%), proving its relative competitive technological strength in Thermal Insulation. Less pronounced, the same is true for China, that holds the second highest patent share (11%), and Canada (2.5%). On the other hand the US (8.4%) and particularly Japan (6.3%) show below average patent shares in this field.

Within the EU, the high and above average technological strength in Thermal Insulation of buildings is mainly attributed to Germany (with a patent share of 23.8%), France (8.8%), Austria (4.6%), Great Britain (3.8%), Belgium (3.8%) and the Netherlands (2.4%). Besides them, other smaller MS (Finland, Czech Republic, Slovenia, Greece, Croatia) also gain significantly above average patent shares in this field.

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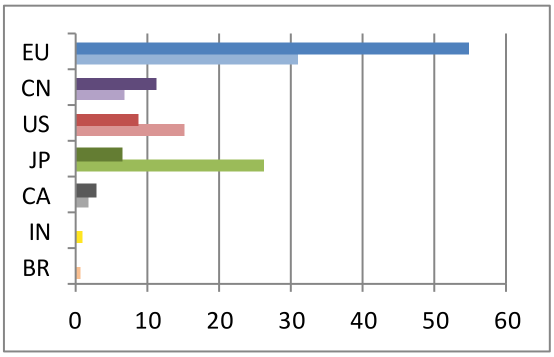
[157] The OECD Environment Directorate, in collaboration with the Directorate for Science, Technology and Innovation, has developed patent-based innovation indicators that are suitable for tracking developments in environment-related technologies. The patent statistics are constructed using data extracted from the Worldwide Patent Statistical Database (PATSTAT) of the European Patent Office (EPO). Patent data based on family size "two and greater" were used to count only the higher-value inventions that have been applied for protection in the home market and at least one foreign market. The relevant patent documents are identified using search strategies for environment-related technologies (Env-Tech: http://www.oecd.org/env/consumption-innovation/env-tech-search-strategies.pdf) which were developed specifically for this purpose. The data are available under http://stats.oecd.org/. The European Patent Office is also working with this definition, e.g. in the context of analysing the EU's patent performance in "Green Building" (http://www.epo.org/news-issues/technology/sustainable-technologies/green-construction.html).

[158] In the Env-Tech classification Thermal Insulation is covered by segment 7.3: Architectural or constructional elements improving the thermal performance of buildings.

However, compared to other CI sectors, the absolute number of patent applications in the field of Thermal Insulation is very small, supporting the statement of an interviewed expert, that the level of innovation in the conventional thermal insulation sector is rather low.

Figure 71: Patent share in the field of Thermal Insulation compared to total patent share 2010 to 2012



The upper bar shows the patent share (%) in Thermal Insulation, the lower bar the total patent share (with respect to all technologies).

Source: OECD.stat, Theme Environment, Dataset: Patents - Technology Development. - NIW calculation.

The IEA market assessment (IEA 2013, 21), differing between three levels of market saturation[159], clearly shows that the EU, the United States and Canada have made the most progress in deploying energy-efficient building envelopes. Japan also has made some progress. China and particularly India are still falling behind.

In the EU half of the defined building envelope markets are established to mature markets. This applies to double-glazed low-e glass, window attachments (e.g. shutters, shades, and storm panels), typical insulation, exterior insulation and air sealing. The markets for window films, highly insulated windows (e.g. triple glazed) and cool roofs are estimated as mature in the EU. Contrast to this, advanced roofs and super insulating materials (SIMs), such as vacuum insulation panels (VIPs), gas filled panels (GFP) and aerogel based products (in Figure 72 summarized as "advanced insulation"), are identified as initial markets. Today the cost of SIMs, that are originally developed for other purposes than buildings insulation (e.g. aerospace, machinery, container insulation) and achieve much higher resistance values than traditional insulation materials, is still considerably higher than that of traditional insulation materials, because they require complicated processing schemes. Thus, they only account for a small share of the actual European market for Thermal Insulation products and will not achieve the same

[159] Mature markets: greater than 50%, established markets (approximately 5 to 50%), initial markets (available but less than 5%). See IEA (2013, p. 18).

market value as conventional materials before production costs will sink significantly. Today, Switzerland and Germany are the front-runners in SIMs implementation (BPIE, 2016, p. 34).

The field of industrial insulation in the EU also reveals high competitive strength in technology and know-how, with the US being the other leading player, although the market for conventional insulation is basically characterized by pretty low innovation. Another advantage is that high insulation standards have been implemented in the EU for a long time. This favours European suppliers if other countries will raise their standards in the upcoming years, too.

Figure 72: An assessment of market saturation for high-priority building envelope components

Market maturity/ saturation	ASEAN	Brazil	China	European Union	India	Japan/ Korea	Mexico	Middle East	Australia/ New Zealand	Russia	South Africa	United States/ Canada
Double-glazed low-e glass	●	▲	▲	★	▲	●	●	▲	●	●	●	★
Window films	▲	▲	▲	●	▲	●	▲	▲	●	▲	▲	●
Window attachments (e.g. shutters, shades, storm panel)	●	▲	●	★	▲	●	▲	●	●	▲	●	●
Highly insulating windows (e.g. triple-glazed)		▲	▲	●		▲		▲	▲	▲	▲	▲
Typical insulation	★	●	★	★	●	★	●	★	★	★	●	★
Exterior insulation	●	▲	●	★	●	●	▲	●		▲	▲	★
Advanced insulation (e.g. aerogel, VIPs)				▲		▲				▲	▲	▲
Air sealing	●	▲	▲	★	▲	●		▲	▲	▲		●
Cool roofs	▲	▲	▲	●	▲	▲	▲	▲	▲			★
BIPV/ advanced roofs	▲	▲		▲	▲	▲			▲	▲	▲	▲

★ Mature market ● Established market ▲ Initial market

Notes: ASEAN = Association of Southeast Asian Nations. Blank cells indicate that there is currently not any market presence or it is so low that it is not known to domestic experts. Some technologies may not be recommended for all climates, such as cool roofs in Russia or highly insulated windows in hot climates. Typical insulation refers to widely available products such as fibreglass and various foams with thermal conductivities higher than 0.02 watts per meter Kelvin (W/mK). VIP = vacuum-insulated panel. See Annex A and Glossary for more detailed descriptions.

Source: IEA 2013, p. 21.

11.2.3 International trade performance

Box 15: International trade performance

This section investigates the EU-28's trade performance in the respective CI products with regard to the development in six competitive countries in America (USA, Canada, Brazil) and Asia (Japan, China incl. Hong Kong, India). Six trade indicators are analyzed to observe how the EU-28 and its Member States (MS) succeed in commercializing internationally competitive CI products. Those are significance (i.e. how important the specific CI products are in a country's total manufacturing exports), export market share (i.e. how important a country is for total global exports in the relevant CI), medium-term dynamics (i.e. how exports have changed within the pre-crisis years 2007/08 and 2013/14), trade balance (TB, comparing the absolute volumes of exports and imports), and two specialization indicators, namely export specialization (RXA, i.e. whether a country's global export share in a certain CI is higher/lower than its export share in total manufacturing products) and trade specialization (RCA, considering a country's relative export/import ratio of a certain CI compared to its total export/import ratio). Four of these indicators (export market share, significance, RXA and TB) are illustrated in the following chapter, the other two (medium-term dynamics, RCA) in the Annex 17/.

It is important to note that the analysis comparing the external trade performance of the EU-28 in a regional perspective only considers extra-EU trade flows. Otherwise, analysis that compares single Member States with non EU countries has to consider extra- and intra-trade. Hence, the calculated export market shares and export specialization figures (RXA) differ according to the respective perspective. Figures on the country level can be found in the Annex 17/.

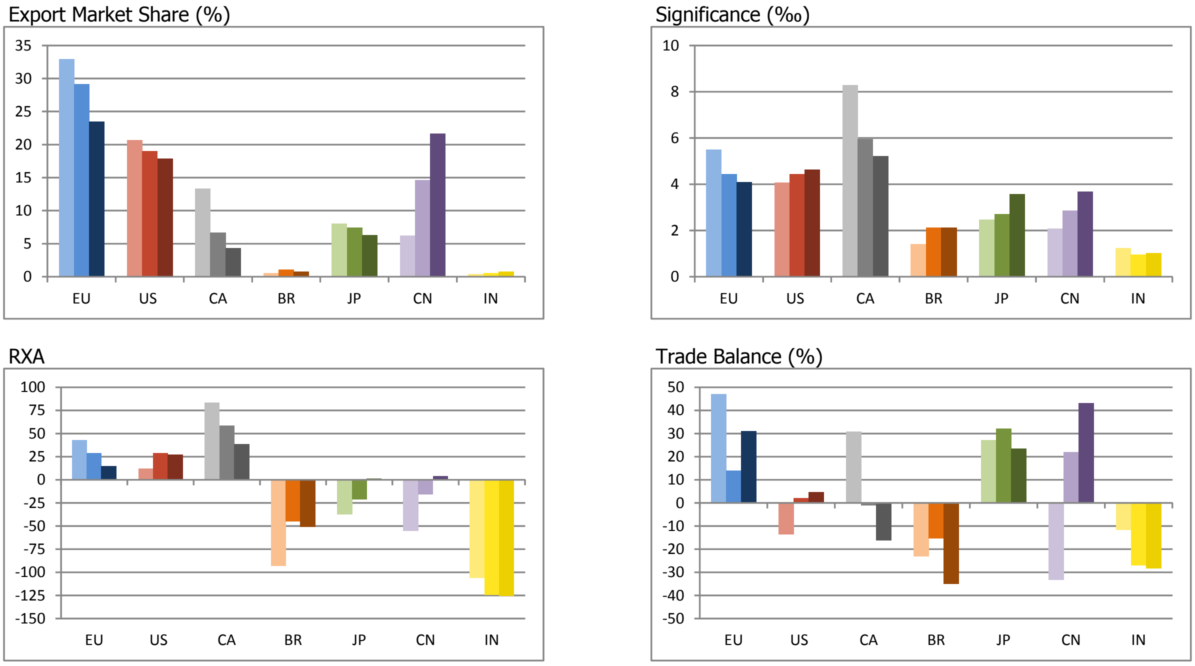
High but declining export performance of the EU-28 in global comparison

Regarding the EU-28 as a whole, trade analysis for Thermal Insulation (e.g. insulation products made of plastics,, wood, rock wool, glass fiber, nonwovens) reveals quite similar results than for products related to Heating and Cooling Systems 6/). Hence, the EU-28 shows a clear comparative advantage, realizing highly positive export specialization (RXA) and trade specialization (RCA) figures. Furthermore, the EU-28 has the highest export market share (23.5% of global exports in 2014). The strong export position of the EU in Thermal Insulation products is underlined by the positive trade balance. Despite this favorable status report for 2014, the EU's export performance (export market share, RXA) has declined over the last decade, because other countries (like the US and China) succeeded in realizing much higher export growth rates (Figure 73 and Figure 134 in Annex 17/). Yet, the EU's trade specialization (RCA) and TB has increased, because the import shares of non EU suppliers in the European market have declined even stronger than the EU's export shares. The only difference between products related to Heating and Cooling Systems and Thermal Insulation is attributed to the share of the particular exports in total manufacturing exports (significance): Whereas the EU holds the highest significance with respect to products related to Heating and Cooling Systems in 2014, Canada (5.1‰) and the US (4.6‰) reveal a slightly higher structural weight of Thermal Insulation exports within total exports than the EU (4.1‰).

Also in this field, China's export market share has strongly increased between 2002 (6.2%) and 2014 (21.6%). Now it holds the second highest share shortly behind the EU and prior to the US (17.9%; Figure 73). Japan traditionally holds a rather low export market share in this field (6.3%), whereas Canada reveals a very strong export position (4.3%; positive RXA) in Thermal Insulation products. Contrary to this, Brazil and India (with an export market share of only 0.8% each) still play a very minor role in the production and export of Thermal Insulation products, albeit India – starting from a very low level - achieved high export growth rates since 2007/08 (Figure 73 and Figure 134 in Annex 17/).

Within the important exporters, China reveals the highest medium-term export growth of more than 13% p.a., followed by the US (5%), Japan (3%) and the EU (2.2%). Canada even depicts an export decline (-3.3%, Figure 134 in Annex 17/), resulting in lower export market shares and deteriorating specialization (RXA, RCA) and TB figures. On the other hand, China meanwhile reveals a positive TB and balanced export specialization (RXA) in Thermal Insulation products (see Figure 73).

Figure 73: Trade indicators for the EU and selected other countries 2002, 2008 and 2014: Thermal Insulation products



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Belgium, Germany, Italy and Poland reveal high export market shares and comparative advantages

With respect to country comparison, e.g. considering EU-Extra-trade and EU-Intra-trade, Germany is the by far largest exporter of Thermal Insulation products, not only within the EU-28, but also in a global perspective. In 2014 the German export market share amounts to 15.1% (*Figure 134* in Annex 17/). Five MS (Poland, Belgium, Italy, France, and the Netherlands) hold shares between nearly 5% and more than 3.5%, three other MS (Great Britain, Spain, the Czech Republic) gain shares between less than 3% and more than 2%. Within these larger exporters, Belgium, Germany, Italy and Poland depict unambiguous comparative advantages (indicated by positive RXA and RCA figures) as well as a positive trade balance (TB) (*Figure 135* in Annex 17/). Besides, some smaller countries (Greece, Hungary, Portugal and Slovenia) also reveal comparative advantages and are net exporters of Thermal Insulation products. By contrast, other larger and/or highly developed MS (France, Great Britain, Sweden, and Austria) show a strong export position (RXA), but a clearly negative TB.

However, for most of the MS declining RXA values prove a mitigating export performance over time. This is related to comparably low medium-term export growth (*Figure 135* in Annex 17/). Except Poland all other larger EU exporters depict rather weak export dynamics, whereas some smaller countries, starting from a very low level, succeeded in realizing export growth rates higher than 10% p.a. (Romania, Bulgaria, and Malta).

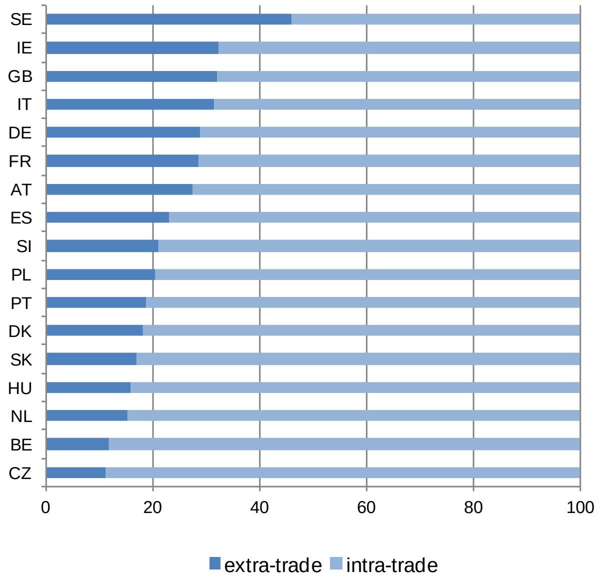
In Poland and some smaller countries (Luxembourg, Latvia, Lithuania, Slovenia, Croatia) Thermal Insulation exports account for more than 1% of all manufacturing exports. In the other MS, the structural weight of those products is comparably low (*Figure 136* in Annex 17/).

75% of EU exports are designated to the internal market, though the importance of extra-trade has increased over time

Figure 74 reveals the extraordinarily high importance of the EU's internal market for Thermal Insulation products with respect to MS with a global export market share of at least 0.5%. Although the importance of extra-trade has increased since 2008, 2014 still 75% of the Thermal Insulation exports refer to intra-trade (2008: 78%) and only 25% (2008: 22%) to extra-trade. The country perspective shows quite differing results.

Hence, particularly Swedish exports are comparably stronger designated towards non EU countries. Here, the share of extra-trade amounts to 46%, but also Ireland, Great Britain, Italy, Germany, France and Austria reveal an above average external orientation. The other diagramed MS (with a global export share >5%) sell higher amounts of their products on the internal market. This applies particularly to the Czech Republic and Belgium, depicting intra-trade shares of almost 90%.

Figure 74: Share of EU-Extra-trade and EU-Intra-trade (in %) in country exports: Thermal Insulation products



Including EU countries with an export market share in Thermal Insulation products higher than 0.5% in 2014. Source: UN COMTRADE-Database. – NIW calculation.

11.2.4 Market outlook

Following the 2°C Scenario (see chapter 11.1), the IEA (2013, p. 25) estimates a global investment of 3.7 trillion USD is needed in envelopes between 2015 and 2050 (new and retrofit). In OECD countries the largest share of additional investment will need to be made before 2030 as the existing building stock requires significant retrofitting. High operational costs due to increasing energy costs coupled with regulation policies and legislative support (e.g. tax benefits or rebates) - particularly in the EU and the US, but also with beginning efforts in other world regions - are expected to drive the overall demand for thermal insulation products. Other drivers are population growth and urbanization coupled with rising disposable income levels in emerging markets of Latin America and Asia Pacific that have driven demand for both commercial and residential buildings (Grand View Research 2015b, Harrod 2014). Furthermore, the construction of new buildings, suffering a lot during the global recession, is increasing in most regions, especially in the US, but also in Europe (FMI 2016).

According to Markets and Markets (2015) the global building Thermal Insulation market is projected to register a CAGR of 3.5% (between 2015 and 2020) with market size projected at €24.3 billion by 2020. The market is expected to grow on account of increasing wool insulation demand in North America and Europe and plastic foam demand in Asia Pacific (Grand View Research 2015b). North America and Europe are the major markets for Thermal Insulation products, but Asia Pacific is the fasted growing region mainly driven by growing commercial as well as residential constructions in China and India. On the other hand, the insulation market in Europe is mostly dependent upon re-insulation of old buildings.[160] Residential construction that was the largest application and accounted for over 50% of the total revenue of the global insulation industry in 2013 is expected to gain revenue share by 4.93% from 2014 to 2020.

The European Thermal Insulation market is estimated to grow at 2.8% CAGR from 2014-2019 up to € 13.2 billion (IAL Consultants 2015). The growth in Central and Eastern Europe (3.2% p.a.) is expected to surpass that of Western Europe (2.5%), where the market is more mature. However, in order to achieve the long-term EED target to reduce the CO_2-emission levels for the building sector by 80% in 2050, compared to 2010, the Eurima (2012) renovation track scenario analysis estimates about € 100-170 billion investments per year necessary for insulation and windows in the EU from 2015-2040. Based on the assumption of approximately 17 jobs created per million invested that would imply 170,000 to 290,000 jobs p.a. Increasing both depth and rate of energy renovations creates vast economic opportunities for the EU while increasing decarbonisation. A renovation scenario (BPIE 2011) indicates overall investments of €584 billion by 2050 and a net saving to consumers of €474 billion. Some examples of planned renovation strategies and expected economic effects are listed in Table 29 in Annex 16/.

Sustainability is the major force behind the development of new technologies, but there is no easy answer to this complex issue with respect to insulation materials (Harrod 2014). Product awareness is on the rise[161], but it is not correct to assume that natural fibres such as wool be automatically be more sustainable than plastic foams (see chapter 11.1). Advanced insulation technologies like SIMs have a high market potential in niche areas of the renovation market, such as refurbishments with weight or space limitations or to avoid thermal bridges. Process, product, service and marketing innovations in this field could slowly disrupt the conventional insulation market BPIE (2016). This might force the actors to adapt their products and services by lowering prices, increasing marketing efforts, delivering more systematic approaches or focussing on SIMs, too. With respect to new buildings (see also chapter 4/ on NZEBs), there is an increasing trend to develop factory-made durable high quality building envelope elements combining high insulation levels, high air-tightness and fast erection speed (Kotaji, Loebel 2011).

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[160] This is not only true for residential but also for industrial buildings. An interviewed expert stated that industrial insulation shows a market shift from new built projects to more specific and tailor made maintenance service, since many plants in Europe are aged.

[161] E.g. polyurethane spray foam (SPF) is an effective insulation and air sealant material, but there exist health concerns such as breathing problems, and asthma (FMI 2016).

11.3 Assessment of the competitiveness aspects

11.3.1 Export potential

Box 16: Export potential

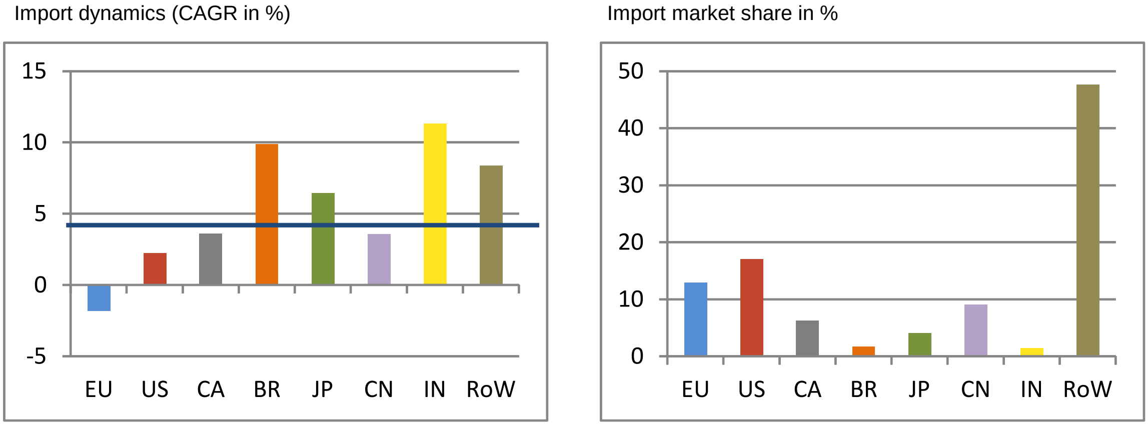
Export potentials emerge primarily in those goods and activities, in which the EU-28 already holds comparative advantages (measured in export specialization or trade specialization). In these goods and activities, trade volumes can be used as an initial indicator for market and growth potential. Hence, growing import rates of third countries may serve as a proxy for an increase in demand for CI goods in a specific country or world region that may subsequently translate into a growing export market for the EU and its Member States. At the same time, existing export advantages (indicated by RXA values) of the EU and its Member States in certain products may indicate promising preconditions for further growth and export potential.

Figure 75 reveals the global import market shares of the EU (excluding intra-trade) in comparison to other selected countries and the rest of the world (RoW) in Thermal Insulation (e.g. insulation products made of plastics, wood, rock wool, glass fiber, nonwovens), indicating that the US has been the largest single importer (17%) followed by the EU (13%) and China (9.5%), Canada (6%), Japan (4%), Brazil (2%) and India (1.5%). Contrary to the EU and the other represented countries, Canada constitutes considerably high demand for Thermal Insulation products compared to its structural weight in total manufacturing imports (3.9%). However, India (11.5%), Brazil (10% p.a.) and Japan (6.5%) yield the highest import dynamics since 2007/08, indicating an increasing appreciation of energy efficiency targets, linked with a growing demand for Thermal Insulation, also in these countries.

Otherwise, also lower growth rates connected with a high absolute import volume, as can be seen in the US (2.2%), can create growing export potential for EU manufacturers. The same is true for the EU itself, from whose perspective external imports could be substituted by internal production. As Table 27 in Annex 1/ depicts, the EU constitutes highly positive export specialization values (RXA) for Thermal Insulation products in China and India, indicating that it holds export market share higher than for total manufacturing exports. With respect to the US and Japan, low negative RXA values represent an almost balanced export performance. Only in Canada and Brazil, the EU reveals a negative export specialization in Thermal Insulation products. Considering the fact, that Thermal Insulation includes mainly low-tech products whose trade intensity is basically lower than for high-tech products[162], the EU's export performance in this field turns out rather satisfactory.

[162] With respect to the EU, this is proven by the high weight of intra-trade exports, accounting for 75% of all EU exports of Thermal Insulation products (see chapter 11.2.3).

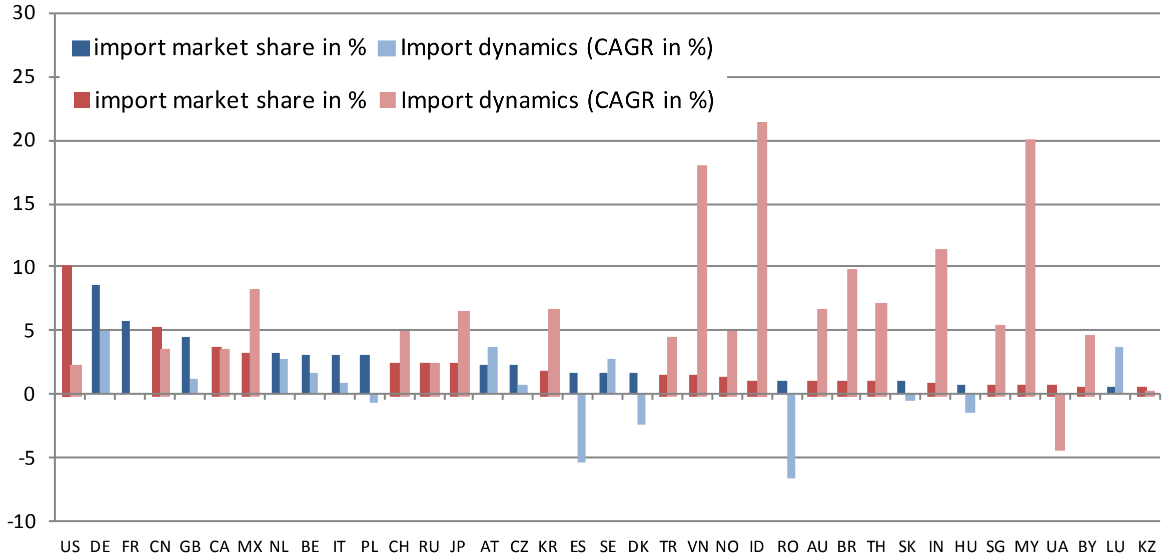
Figure 75: Import market share 2014 and import dynamics 2007/08 to 2013/14 in the EU-28 and selected non-EU countries: Thermal Insulation



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Moreover, Figure 75 above reveals also that almost 50% of the import demand for Thermal Insulation products in 2014 applies to other than the selected countries (RoW). On average, their import dynamics achieved 8.5% p.a., thus being significantly higher than the global average (less than 5%). Hence, Figure 76 illustrates import market shares and import dynamics for all countries with a global import market share higher than 0.5% in 2014. This points out that besides the above mentioned American and Asian countries several EU MS (e.g. Germany, France, Great Britain, the Netherlands, Belgium, Italy, Austria, Sweden), but also other European (e.g. Switzerland, Russia, Turkey, Norway) and overseas countries (e.g. Mexico, South Korea, Australia, Vietnam, Indonesia, Thailand, Malaysia), constitute considerable import market shares and/or remarkable growth rates, hence creating additional sales respective export potential for the EU's Thermal Insulation industry.

Figure 76: Import market share 2014 and import dynamics 2007/08 to 2013/14 in Thermal Insulation



Global imports including EU-intra-trade. - Regarding countries with a global import share higher than 0.5%. – EU MS: blue coloured; non EU countries: red coloured.
Source: UN COMTRADE-Database. – NIW calculation.

11.3.2 SWOT

Below the strength, weaknesses, opportunities and threats (SWOT) for the European buildings Thermal Insulation industry that could be identified by literature, own data analysis and based on expert interviews, are specified in bullet points.

Table 25: SWOT for the thermal insulation sector

Strengths	Weaknesses
▶ The EU has an absolute and relative technological strength in Thermal Insulation solution, indicated by the absolutely highest patent share (almost 55%) compared to competitive countries that is in addition much higher than the EU's total patent share (30.5%). ▶ Within the EU, the high and above average technological strength in Thermal Insulation is mainly attributed to Germany, France, Austria,	▶ The building sector involves a large number of actors and the general market is highly national. The large number of companies involved leads to a poor level of cooperation between them. ▶ Compared to others, the construction sector is characterized by a rather low level of innovation. Especially product innovation is scarce, while process innovation is applied more frequently. This can be explained by the

Great Britain, Belgium, and the Netherlands. But also some smaller MS (Finland, Czech Republic, Slovenia, Greece, Croatia) gain significantly above average patent shares in this field. - The EU shows a clear comparative advantage in international trade, realizing highly positive export specialization (RXA) and trade specialization (RCA) figures, although the market is generally less internationalized than others. - Within the larger exporters, Belgium, Germany, Italy and Poland depict unambiguous comparative advantages (RXA and RCA). Besides, some smaller countries (Greece, Hungary, Portugal and Slovenia) also reveal comparative advantages in this field. - The EU building sector is characterized by a high number of small enterprises, mostly operating at the local level. Value added by activities linked to Thermal Insulation of buildings (building envelope) was €166 billion in 2011, or 60% of total value added in the EU construction sector. In terms of employment, such activities represented 6.88 million jobs, 58% of total sectoral employment.	large number of SMEs, mainly providing services. - An expert indicated that the industry depicts a lack of understanding for marketing needs: firms are traditionally used to wait for jobs to come, instead of doing active marketing. - Much more work is needed globally to level up super insulating materials (SIMs) from the initial market stage to a market uptake. Most of them were not initially designed for the construction sector and have to be adapted for this purpose.
Opportunities - There is a clear increase in demand for high-energy-performing, flexible, smaller, easy-to-use, lifelong and multi-generational as well as affordable housing concepts, also pushing the demand for thermal building insulation. - The EU aims to have by 2050 a complete energy efficient building stock. With low demolition and new-built rates, Europe's challenge mainly relates to the energy-efficient renovation and investments in the existing	Threats - Lack of standardized certificates hamper the market development within the EU, but also globally, thus also restricting the export potential for European suppliers - Because of changing technological (building automation, smart meters…) and energy market conditions (decentralization, decarbonization), building processes are becoming more and more complex, which is why more interaction and collaboration

building stock (BPIE 2016). This requires a significant increase of the renovation rate and proposes additional jobs. Up to 2020, all in all nearly 2 million additional jobs could be created in the construction sector, including its extended value chain, most of them SMEs and at the regional and local level.

- Increasing both depth and rate of energy renovations creates vast economic opportunities for the EU while increasing decarbonisation. A renovation scenario (BPIE 2011) indicates overall investments of €584 billion by 2050 and a net saving to consumers of €474 billion.
- Current and future energy performance standards for renovations demand high insulation levels. However, traditional insulation materials cannot always satisfy these requirements. Thus innovations opportunities arise, e.g. product solutions to avoid thermal bridges, resource-efficient buildings or building components, smart-building envelope components such as self-regulating glazing phase change materials, super insulating glazing, super insulating materials (BPIE 2016, p. 15). Moreover, space or weight saving insulation solutions are necessary.
- Also outside the EU climate policy and energy saving targets push the demand for Thermal Insulation products for buildings, creating new export opportunities for European manufacturers. Although three third of the EU's Thermal Insulation exports in 2014 refer to intra-trade, the importance of extra-trade has increased over time (2008: 78%).
- The EU constitutes highly positive export specialization values (RXA) for Thermal Insulation products in China and India,

between actors is needed.

- New market players are emerging in the construction value chain, various types of loose or formal collaborations structures for achieving high energy-performing buildings are appearing and setting the scene for further development (BPIE 2016, p. 17)
- Successful small-scale developments and demonstration do not necessarily guarantee large-scale deployment of a given low-carbon technology or solution. Experience has shown that, even when low-carbon technologies prove to be cost-effective under prevailing market conditions, other non-financial barriers can stall their uptake and limit private-sector engagement.
- High share of private owners in buildings stocks blocks the investment in Thermal Insulation
- Important regulatory gaps refer to a lack of coherence in the implementation of the Energy Performance of Buildings Directive (EPBD) and the Energy Efficiency Directive (EED) at national level.
- The implementation of Energy Performance Certificates (EPC) schemes at MS level is still ongoing and struggles with challenges such as public acceptance and market uptake (DG RTG InnovREFIT Task Force, 2015, 138f.). Thus, the EPC schemes are not fully implemented in all MS nor sufficiently enforced.

indicating that it holds export market share higher than for total manufacturing exports. With respect to the US and Japan, low negative RXA values represent an almost balanced export performance. ▸ On the country level, several EU MS (e.g. Germany, France, Great Britain, the Netherlands, Belgium, Italy, Austria, Sweden), but also other European (e.g. Switzerland, Russia, Turkey, Norway) and overseas countries (e.g. Mexico, South Korea, Australia, Vietnam, Indonesia, Thailand, Malaysia), constitute considerable import market shares and/or remarkable growth rates for Thermal Insulation products, creating additional sales respective export potential for European suppliers. ▸ With respect to industrial insulation, an expert indicated that policies related to an increasing implementation of energy management systems are a key driver for market development. Furthermore he argues that there will be a change from providing services for newly build industry plants to providing maintenance services, since many industrial plants in Europe are aged.	

The EU aims to have a complete energy-efficient building stock by 2050. This requires significantly growing building renovation rates and proposes additional value added and jobs in the European construction sector and related services. Similar developments can be observed in other countries and world regions, pushing the global demand for Thermal Insulation of buildings. The EU has a strong technological (patent applications) and trade competitiveness in Thermal Insulation products, creating good preconditions to tackle with more complex technological solutions and to participate in the forecasted growing demand inside and outside the EU. However, although lot of national plans and targets exist on paper, the slow implementation of the required measures and the lack of unique standards and certificates hamper the market development within the EU and slows down its further globalization, thus also restricting the export potential for European suppliers.

11.4 Analysis of barriers

Buildings are long-term assets expected to remain useful for 50 or more years. Two thirds of the EU's buildings standing today were built when energy efficiency requirements were limited or non-existent and 75 to 90% are expected to remain in use until 2050. With low demolition rates (0.1% p.a.), low renovation rate (1.2% p.a.) and moves to highly energy-efficient new-builds (1% additions p.a.), Europe's challenge mainly relates to the energy-efficient renovation and investments in the existing building stock (BPIE 2016), because the existing market for building renovation is still small relative to the size of the opportunities.

Regulation affects every activity and aspect of the construction sector, being safety, energy or environment-related. Thus a number of regulations govern products and processes, other planning and environmental regulations govern finished products. Besides, innovation in the construction sector is characterized by the adoption of new practices and advances in both technological and business processes (DG RTG InnovREFIT Task Force, 2015, 35f.) Important regulatory gaps refer to a lack of coherence in the implementation of the Energy Performance of Buildings Directive (EPBD) and the Energy Efficiency Directive (EED) at national level. Furthermore, the implementation of Energy Performance Certificates (EPC) schemes at MS level is still ongoing and struggles with challenges such as public acceptance and market uptake (DG RTG InnovREFIT Task Force, 2015, 138f.). The EPC schemes are not fully implemented in all MS nor sufficiently enforced (BPIE 2014b). Moreover, although the national long-term renovation strategies, that had to be provided according to Article 4, EED, are in most cases "fully compliant" or "almost fully compliant" with the requirements of Article 4 (Castellazzi, Zangheri, Paci 2016), their transportation in higher energy renovation rates has not been implemented satisfactorily, yet (EuroACE, Press Release, 14th March 2016).

In general, the outcomes from energy efficiency improvements strongly depend on the country context. Several factors can play an important role in determining the level and type of outcomes that an energy efficiency measure will deliver, such as the geographic situation, the level of economic development, energy resource endowments and demographics. In some cases (e.g. Romania), regulated energy prices are below market prices, which currently discourages the adoption of energy-saving measures (BPIE 2014, p. 47). Thus, each MS has its own scheme, when it comes to calculating energy efficiency of buildings. Moreover, in the past energy efficiency was seen as a low consideration for buyers compared to factors such as location, amenities, design and layout.

Today, especially in more mature markets, most advanced building envelope alternatives are cost-effective over a long-term investment period but require greater initial capital financing (IEA 2013, 24). Reducing first costs and increasing annual savings that result in a greater overall improved return on investment will enable greater market uptake of advanced building envelope designs.

Another barrier is misalignment of financial incentives: Those investing in energy efficiency measures are not always the ones receiving the direct benefits. Around 70% of the EU population lives in privately owned residential buildings. Owners often do not undertake cost-efficient renovations because they lack awareness of the benefits, lack advice on the technical possibilities, face split incentives (e.g. in multi-apartment buildings) and have financing constraints (European Commission 2016, p. 4). This manifests itself as the usual "landlord/tenant" barrier, but also in the fact that the wider benefits of energy efficiency investment, such as improved security of supply and reduced carbon emissions, are not fully realised by those making the investment (BPIE 2014).

The long-term financial and wider benefits of improved energy efficiency are often regarded as less certain, partly because of the lack of relevant and trustworthy information in the market (BPIE 2014a). This is not only true for residential buildings, but also for industrial buildings. The responsible management often sees insulation rather as a necessary evil instead of a cost-saving technology or investment. He argues that it would be helpful if there were be some sort of top-down communication (supported by the EC) helping to create awareness on the benefits of insulation, e.g. emphasizing easy installation and short pay-back time. Furthermore, split responsibilities often make it difficult to fully leverage the potential of Thermal Insulation in industry, commercial and larger residential buildings. Mostly working as subcontractors, insulation firms only talk to the maintenance manager, who sets priority on the maintenance costs and is not responsible for the energy bill or incentivised to implement energy savings.

Another challenge is the difficulty of penetrating a market dominated by a small number of widely-used process technologies (BPIE 2016, p. 19). New technologies are generally unknown to potential users, as well as to building planners and installers that recommend their use to final consumers. Few professionals, particularly amongst the group of installers, have the required expertise in energy efficient construction. This represents a huge barrier to market diffusion (EPEC 2011, European Commission 2016, p. 5). This also applies to new super insulating materials (SIMs) that are superior to conventional insulation products, but have higher material costs and suffer from actor’s lack of knowledge and experience.

11.5 Suggested actions

Generally, the retrofit of the building envelope to more energy-efficient solutions can be leveraged via integrated business models combining energy consulting, selling of the actual equipment, installation and maintenance. Experiences made in single MS (Germany, Sweden, Great Britain) show that public policy[163] and public and private funding have pushed the development of thermal insulation for buildings and the way its use has been adopted (Kiss, González Manchón, Neij 2013). Building codes and standards play a highly significant role in promoting the development of technology (by, e.g. setting the direction of search, calling for the allocation of R&D resources, and testing), and in pushing high-performance products onto the market. The analysis proves that the EPBD and voluntary standards have forced market actors to find system solutions and to establish various forms of collaboration (learning-by-interacting). This is particularly important in the insulation industry, where platforms for interaction and feedback processes with potential intermediaries (such as architects, construction firms and installers) are still limited. Furthermore, the analysis reveals that financial incentives have

[163] In terms of “command-and-control regulation” (Hottenrott and Rexhäuser 2015, 395).

directly supported learning-by-using and indirectly facilitated learning-by-doing (Kiss, González Manchón, Neij 2013).

Thus, policy actions to foster thermal insulation and other aspects of improved energy efficiency in buildings should focus on the fast implementation of renovation rates and mandatory building codes within the national long-term national renovations strategies combined with public funding and financial incentives for private building owners as well as specific support for social rental properties and low income households. Conceivable are financing mechanisms such as utility programmes, revolving funds and energy-performance contracts (IEA 2013).[164] Moreover, clear targets and building energy codes that meet the latest insulation standards - including proper air sealing - provide guidance for building owners towards the required level of thermal insulation.

Analyses with respect to the effects of different policy measures prove that focussing on financial support is no satisfying alternative to stricter regulation in order to achieve the EU's ambitious energy efficiency targets. Furthermore, financial support measures always provoke windfall gains. Since energy efficient investments in thermal insulation require high investment costs, but long-term savings, combined approaches of the implementation of mandatory building codes and financial support show the greatest promise (Steinbach 2015).

Establishing targets, stricter legislation and support measures for deep energy renovations will also help to unlock the transition of new insulation technologies and materials (e.g. SIMs), stemming from manufacturers outside the construction market (BPIE 2016). To allow one type of insulation to be compared with another, it is vital to have accurate test protocols, ratings and performance declarations for the energy performance of different materials. Case studies and demonstrations of added-value high-performance insulation can show overall greater system energy efficiency and monetary effectiveness.

Trainings, guidelines and quality schemes shall be implemented to increase the competence level of the on-site workforce and building services (installers, designers and inspectors).

Lastly, to close information and knowledge gaps with respect to investments in thermal insulation, the co-benefits of low-energy buildings, such as comfort and health, need to be communicated in a better way to the public and to financial communities. A recent example is the German campaign "Deutschland macht's effizient", addressing all potential users (households, enterprises, communities) and serving information as well as public support measures to all sectors concerning energy-efficiency, thereby also TI in buildings.[165]

Split responsibilities often make it difficult to fully leverage the potential of Thermal Insulation. Here, programmes that support the broader implementation of energy managers would be helpful.

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164 For "best practice examples" within the EU see Table 29 in the **Error! Reference source not found.**.

165 http://www.deutschland-machts-effizient.de/KAENEF/Navigation/DE/Eigenheim/Sanieren/sanieren.html;jsessionid=D6EE343915F3567724F1B43D0C1B06C8

For improving Thermal Insulation in industry, whose contribution to energy savings due to insulation measures is often underestimated, but also considerably high, an interviewed industry expert suggests:

- Political measures to improve the implementation of energy management systems in European industry, because there is empirical evidence that if companies have such a system running (e.g. ISO 50001) they often choose to implement or improve insulation.
- To include an energy efficiency chapter in all BREFs, recommending the energy efficiency measures that can be taken, thereby also those concerning Thermal Insulation. This idea has already been proposed in the new heating and cooling strategy (EC 2016).
- To combine Article 8 of the EED with the request to implement identified savings potentials with short payback: see e.g. its transposition in Italy which stated that companies carrying out an energy audit have to implement at least one measure.

Furthermore, it should be made clear, that all policy measures taken in the Thermal Insulation context (residential and industrial buildings) will directly leverage investments, create jobs and pay back in Europe because of the local characteristic of the industry. E.g. input-output model analysis with respect to the German energy efficiency policy measures show that the budgetary funding volumes of some 9 billion € in the period 2015 to 2020 will not only have significant energy and climate impacts (e.g. primary energy savings and reduced GHG emissions), but also trigger tangible economic benefits in terms of additional investments, economic growth and new jobs even in this short term period (Ringel, Schlomann, Krail, Rohde 2016).

11.6 Bibliography thermal insulation

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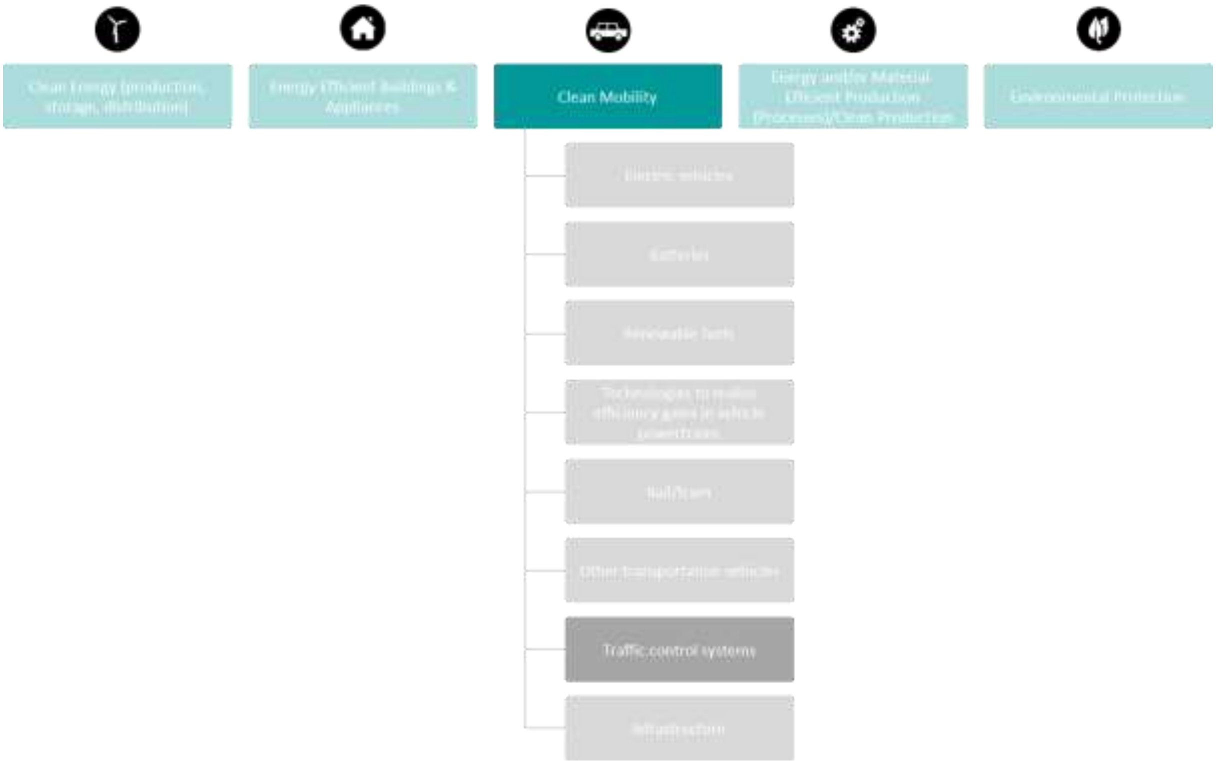
12/ Traffic control systems

Figure 77: Presentation of the selected priority sector within the Clean Industry taxonomy



12.1 Description and value chain

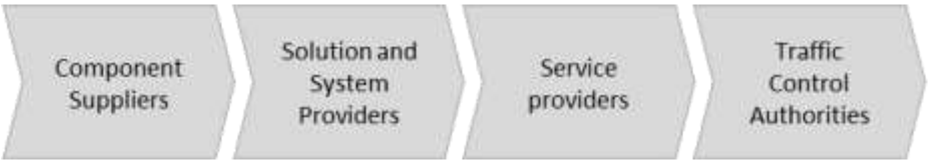
As of today, transport is still one of the major sources of greenhouse gas emissions in the EU, due to its large dependency on fossil fuels. Only since 2008, the greenhouse gas emissions from transport have started to decrease. However, despite this trend transport emissions were still 20.5 % above 1990 levels in 2012 and would need to fall by 67 % by 2050 in order to meet the 2011 Transport White Paper target reduction of 60% compared to 1990 (European Commission, 2016). Traffic control systems have been identified as one of the possible means to reach those ambitious target greenhouse gas emissions reduction targets.

Traffic control systems can be described as a variety of applications for planning, monitoring, and controlling or influencing various modes of transport (road, rail, aviation and waterborne). Traffic control systems are aimed at providing a wide variety of applications to help realise broader transport policy goals (e.g. maximising the effectiveness of the use of existing infrastructure; ensuring reliable and safe operation of transport; addressing environmental goals; and ensuring fair allocation of infrastructure space (road space, rail slots, etc.)) including decreasing emissions from transport (European Commission - Transport Research Knowledge Centre, 2009).

It is difficult to make a strict depiction of the value chain of traffic control systems due to the broad range of systems, components and applications involved, and the various modes of transport that they are destined for.

However, in Figure 78 an attempt is made to provide a simple value chain based on the suppliers of the different elements involved with traffic control systems. On the left side of the figure the components suppliers can be found. These players supply the wide range of components of the traffic control systems, such as sensors, telematics, and other communication technologies. Second in the value chain one can find companies providing traffic control solutions and systems. Services required by these systems, such as communication and telematics services are supplied by the service providers. The different components, solutions, systems and services are essentially often provided to the traffic control authorities, whose direct concern is to manage traffic at local, regional, national and even cross-border level. Those players are also generally responsible for formulating, publishing and enforcing traffic regulations, regulating the usage of traffic signals, closed-circuit television cameras, variable message signs et cetera, for implementing measures to enact key policy areas (Urban ITS Expert Group, 2013). Other players, not included in the figure, but also in ways involved in the traffic control systems industry are vehicle manufacturers, mobile network operators, and vehicle owners. When analysing the key players in the various markets for traffic control systems, we will not distinguish between the various segments of the value chain however, since the key players are generally involved in all of them.

Figure 78: Value Chain Traffic Control Systems



In order to be effective, traffic control systems need to be deployed systematically throughout a given transportation system and across countries. Furthermore, since traffic control systems are supported by a wide set of technologies and services supplied by a wide variety of public and private stakeholders, there is a great need for standardisation and harmonisation in this sector (UNECE, 2012).

As stated before, traffic control systems are of a very different nature in these various modes of transport, with different objectives regarding emission reductions, safety, or logistical efficiency. It follows that traffic control systems in these different modes of transport each follow very different principles and organisational and operational characteristics (European Commission - Transport Research Knowledge Centre, 2009). We will therefore describe the role of traffic control systems per mode of transport.

Road transport

Vreeswijk et al. (2010) estimate that 22% of all wasted fuel in road transport is due to inefficient deceleration and lack of anticipation, while congestion counts for another 15% (Urban ITS Expert Group, 2013), areas to which traffic control systems can contribute. In the field of road transport traffic control systems are often referred to as intelligent transportation systems (ITS). ITS's could be more specifically described as the application of information and communication technologies to the planning and operation of transport systems. When focussed on the road applications of traffic control systems, one can make a general distinction between traffic control systems (or ITS systems) within vehicles and infrastructure related traffic control systems. In-vehicle systems make use of data from the vehicle and its environment to either guide the driver or control the vehicle on some way that allows emission reductions. Infrastructure related systems can reduce the overall emission of traffic for example by influencing the routing or driving dynamics of that traffic (ERTICO, 2015). Traffic control systems in the form of tactical traffic management involve monitoring the actual traffic situation in real-time (including volumes, speeds, incidents, etc.) and then controlling or influencing the flow using that information in order to reduce congestion, deal with incidents and improve network efficiency, safety and environmental performance, or achieve other objectives. Other applications of traffic control systems in road transport include electronic tolling, real-time information and other driver-assistance systems such as electronic stability control and lane departure warning systems (Urban ITS Expert Group, 2013). Figure 137 and *Figure 138* in Annex 18/ provide an overview of the ITS applications with greatest potential for CO2 reduction (ERTICO, 2015).

In 2008, the European Commission specifically dedicated an action plan to the deployment of ITS in Europe (European Commission, 2008). The 2008 Action Plan and legal framework for the deployment of ITS In Europe by the European Commission was designed to overcome some of the barriers involving the traffic control system industry in Europe. The Action Plan had been aimed at ensuring the compatibility and interoperability of systems, facilitating the continuity of ITS services, and to do so through coordinated and concerted action at EU level, helping to speed up the deployment of ITS and to boost the EU's ITS industry. In 2010, the European Commission has launched the ITS Directive (European Commission, 2010), representing the first EU-wide legislative basis for the coordinated deployment of ITS's for the road. The Directive has been an important instrument for ITS implementation, backing up the measures foreseen in the 2008 ITS Action Plan. The European Commission also works to set the ground for the next generation of ITS solutions, through the deployment of Cooperative-ITS: systems that allow effective data exchange through wireless technologies so that vehicles can connect with each other, with the road infrastructure and with other road users (European Commission, 2015).

According to a market report from Grand View Research (2014), the global market for Intelligent Transportation Systems (ITS) was estimated at €12 billion in 2013, and expected to grow by 12% between 2014 and 2020. The market for intelligent traffic control systems is dominated by the US which generated in 2012 more than 42% of the total global turnover (about €5.16 billion). Following from another market report (Markets and Markets, 2012), Europe is estimated to have generated around €4.23 billion in 2012 (which would imply a share of 35%). Within Europe, Germany and France are the major contributors in the field of ITS (Markets and Markets, 2012). Dominating European players active in the traffic control systems industry include Thales Group (France), Kapsch TrafficCom AG (Austria), TomTom International BV (Netherlands), and Q-Free ASA (Norway), Siemens AG (Germany), Ricardo PLC (UK), EFKON AG (Austria), WS Atkins PLC (UK), Accenture (Ireland), Kapsch (Austria), LG CNS (Netherlands), Schneider Electric (French), and Siemens (Germany) (Markets and Markets, 2015; Grand View Research, 2014; Transparancy Market Research, 2015; Markets and Markets, 2016). A selection of other companies active in the different parts of the value chain can be found by visiting the ERTICO ITS-Europe website containing a list of partners (ERTICO - ITS Europe, n.d.).

Rail transport

The European Railway Traffic Management System is the European standard for the Automatic Train Protection (ATP) that allows an interoperable railway system in Europe. As an ATP, ERTMS is a safety system that enforces compliance by the train with speed restrictions and signalling status (European Commission, 2016). The ERTMS is project developed by eight UNIFE members - Alstom Transport, Ansaldo STS, AZD Praha, Bombardier Transportation, CAF, Mermec, Siemens Mobility and Thales - in close cooperation with the European Union, railway stakeholders and the GSM-R industry (ERTMS, 2013). One of the goals of the ERTMS project is to improve the competitiveness of the European rail transportation industry. Since rail transportation is the lowest CO2 emission mode of transport, improving the competitiveness of the rail transportation industry contributes to reducing CO2 emissions in transport (ERTMS, 2014). Statistics from UNIFE (December 2015) show that almost 76,100 km of railway tracks and nearly 9,500 vehicles are already running or contracted to be equipped with ERTMS worldwide. Europe’s share in trackside investment is 54%; but significant investments have also been on-going in Asia (29%) and in Africa and the Middle East (14%) (UNIFE, 2016).

The global railway management system market was valued at approximately 17.5 billion euro in 2014 and is expected to reach approximately 30.5 billion euro by 2020, growing at a CAGR of around 9.8% between 2015 and 2020 (Zion Research, 2016). Railway management systems include rail operations management systems, rail traffic management systems, rail asset management systems, rail control systems and rail maintenance management systems. The railway management systems market is mainly driven by increasing freight and passenger traffic. Furthermore, technological developments are expected to fuel the railway management system market in the near future. Europe dominated the railway management system market, accounting for 38.6% share in 2014 in terms of revenue. The dominance of the European market is mainly attributed to the increasing restructuring activities of railway sector coupled with advanced technology in this region. Some of the key players in railway management system market include ABB (Switzerland), Alstom (France), Ansaldo (Italy), Bombardier Transportation (Germany), GE Transportation (USA), Hitachi (Japan), IBM (USA), Indra Sistemas (Spain), and Siemens AG (Germany).

Waterborne transport

In the area of waterborne transportation there are several traffic control systems: River Information Services (RIS), The Union Maritime Information and Exchange System (SafeSeaNet), and The Long-Range Identification and Tracking (LRIT) system. Increasing the efficiency of waterborne transportation contributes to decreasing emissions.

River Information Services are information technology related services designed to optimise traffic and transport processes in inland navigation, i.e. to enhance a swift electronic data transfer between water and shore through in-advance and real-time exchange of information (RIS). RIS aims to streamline the exchange of information between waterway operators and users. Since 2005, an EU framework directive provides minimum requirements to enable cross border compatibility of national systems.

The Union Maritime Information and Exchange System (SafeSeaNet) is a vessel traffic monitoring and information system, established in order to enhance maritime safety, port and maritime security, marine environment protection, and efficiency of maritime traffic and maritime transport. SafeSeaNet has been set up as a network for maritime data exchange, linking together maritime authorities from across Europe. Automatic Identification System (AIS) are one of the main information elements in the SafeSeaNet system (EMSA, 2016)

The Long-Range Identification and Tracking (LRIT) system provides for the global identification and tracking of ships. The LRIT system consists of the shipborne LRIT information transmitting equipment, the Communication Service Provider(s), the Application Service Provider(s), the LRIT Data Centre(s), including any related Vessel Monitoring System(s), the LRIT Data Distribution Plan and the International LRIT Data Exchange (IMO, 2016)

The Automatic Identification System (AIS) is an automatic tracking system used on ships and by vessel traffic services (VTS) for identifying and locating vessels by electronically exchanging data with other nearby ships, AIS base stations, and satellites. According to a market report, the global market for Automatic Identification System (AIS) is estimated at 1155 million euro in 2014, and is expected to reach about 200 million euro by 2020, registering a CAGR of 4.33%. Key players in the AIS market include Furuno Electric Co. Ltd (Japan), Japan Radio Co. Ltd. (Japan), Saab Transponder Tech AB (Sweden), exactEarth (Canada), and ORBCOMM (USA).

Aviation transport

Globally, the aviation industry accounts for around 2% of all human-induced CO2 emissions. Aircrafts emit CO2 in direct proportion to the quantity of fuel burned and CO2 is also emitted at airports through various airport operations, such as ground support vehicles and passenger surface transport vehicles. According to the International Air Transport Association (IATA), Air Traffic Management (ATM) enhancements could improve airlines' fuel efficiency and CO2 emissions up to 12% (IATA, 2016). In 2014 the SESAR (Single European Sky ATM Research) was established, SESAR aims to improve ATM performance by modernising and harmonising ATM systems through the definition, development, validation and deployment of innovative technological and operational ATM solutions. The Single European Sky's high level 2020 environmental target sets out to decrease fuel burn by 10% per flight with respect to 2005 values. Of this 10%, 7% will be achieved by performance gains as a result of improved Air Traffic Management (SESAR, 2016).

According to market reports, the global market for air traffic control (ATC) equipment will witness steady growth at a moderate CAGR of close to 5% over the period 2016-2020, mainly driven by an increase in air traffic and the introduction of new aircrafts. Air traffic management can be segmented into three areas: navigation, communication, and surveillance. The communication segment is expected to reach USD 2 billion by 2020, growing at a CAGR of over 5%. Factors such as increasing investments in advanced technology communication equipment in airports and growing air traffic will propel the growth prospects for this market until the end of 2020. The global navigation equipment market is expected to reach USD 1.95 billion by 2020, growing at a CAGR of over 4%. The growing aircraft orders, backlogs, and deliveries, coupled with the advantages of navigational equipment, will drive the market. The global surveillance equipment market is predicted to reach USD 1.9 billion by 2020, growing at a CAGR of almost 5%. The major players in this market are Lockheed Martin Corporation (USA), Thales SA (France), Raytheon Company (USA), Northrop Grumman Corporation (USA), and Indra Sistemas, S.A. (Spain). In terms of geography, the Americas dominated the global ATC equipment market and accounted for more than 41% of the market share during 2015 (Markets and Markets, 2015; Technavio, 2016).

12.2 Assessment of the global environment

12.2.1 *Main competitors outside the EU*

The main competitors outside of the EU are the USA and the Asia-Pacific region, with the dominance of the regions differing per mode of transport for the application of traffic control systems.

In the field of traffic control systems for road transportation, the USA is dominating, having generated more than 42% of the total global turnover in the Intelligent Transportation Systems Market in 2012, compared to Europe's market share of about 35%.

In the field of traffic control systems for rail transportation, Europe dominates the market, accounting for 38.6% share in 2014 in terms of revenue. The Asia pacific region was second largest market and estimated to be the fastest-growing regional segment during the forecast period, led by dynamic growth in the long-term, highly influenced by new projects in China, India, and other countries in Asia Pacific.

In the field of waterborne transportation, the Asia-Pacific region, and China in specific, is expected to register higher CAGR and the total market in this region, and is projected to account higher market share as compared to other regions. It is reported that large scale terrestrial automatic identification system development program implemented by the concerned authorities in this specific region is the major factor that will drive the demand of automatic identification system, furthermore fuelling the growth of automatic identification system market.

In the field of aviation transportation, the USA had the major market share in 2015 due to the heavy air traffic in its region, followed by Europe. The air traffic control equipment market is expected to witness the highest growth in the Asia-Pacific. This growth can be attributed to the increase in government spending for infrastructure development, liberalization of regulations related to air transport, and growing GDP of the region.

The EU's transportation sectors are facing growing competition in fast developing world transport markets, as they are launching huge, ambitious transport modernisation and infrastructure investment programmes. The European Commission's White Paper: Roadmap to a Single European Transport Area therefore addressed the need for the European transport sectors to continue to develop and invest to maintain its competitive position. Delayed action and timid introduction of new technologies could condemn the EU transport industry to irreversible decline (European Commission, 2011).

12.2.2 *Relative competitive strengths*

A particular strength of Europe in the field of traffic control systems appears to be the cooperation between the European Commission and various transport industries in the development of coordinated initiatives for the implementation of European wide traffic control systems. Examples are the 2008 Action Plan and 2010 Directive for the implementation of Intelligent Transport Systems for the application of traffic control systems in road transportation, the European Railway Traffic Management System (ERTMS) for the application of traffic control systems in rail transportation, the Single European Sky ATM Research (SESAR) for the application of traffic control systems in aviation transportation, and the Union Maritime Information and Exchange System (SafeSeaNet) for the application of traffic control systems in waterborne transportation.

A second strength relates to the fact that Europe is generally well established in the various transportation industries. Traffic control systems are deployed both in infrastructure as well as the vehicles, and strong vehicle manufacturing industries are therefore beneficial to the traffic control systems industry. A similar reasoning applies for a sector that relates closely to the traffic control systems sector: the measuring and monitoring sector. It has not been possible to conduct an analysis regarding the global distribution of Research and Development (R&D) expenditures and patent applications in this field for the traffic control systems industry. However, this analysis has been conducted for the Measuring and Monitoring sector (see section 8.2.2). Given the fact that one of the application areas of measuring and monitoring technologies is the logistics and transportation sector, insights from this analysis could serve as an indication for the technological position of the EU in the field of traffic control systems.

12.2.3 International trade performance

Box 17: International trade performance

This section investigates the EU-28's trade performance in the respective Clean Industry products with regard to the development in six competitive countries in America (USA, Canada, Brazil) and Asia (Japan, China incl. Hong Kong, India). Six trade indicators are analysed to observe how the EU-28 and its Member States (MS) succeed in commercializing internationally competitive Clean Industry products. Those are significance (i.e. how important the specific Clean Industry products are in a country's total manufacturing exports), export market share (i.e. how important a country is for total global exports in the relevant Clean Industry), medium-term dynamics (i.e. how exports have changed within the pre-crisis years 2007/08 and 2013/14), trade balance (TB, comparing the absolute volumes of exports and imports), and two specialisation indicators, namely export specialisation (RXA, i.e. whether a country's global export share in a certain Clean Industry is higher/lower than its export share in total manufacturing products) and trade specialisation (RCA, considering a country's relative export/import ratio of a certain Clean Industry compared to its total export/import ratio). Four of these indicators (export market share, significance, RXA and TB) are illustrated in the following chapter, the other two (medium-term dynamics, RCA) in the Appendix.

It is important to note that the analysis comparing the external trade performance of the EU-28 in a regional perspective only considers extra-EU trade flows. Otherwise, analysis that compares single Member States with non EU countries has to consider extra- and intra-trade. Hence, the calculated export market shares and export specialisation figures (RXA) differ according to the respective perspective. Figures on the country level can be found in the Appendix.

Strong and growing comparative advantage of the EU-28 in Traffic Control Systems trade

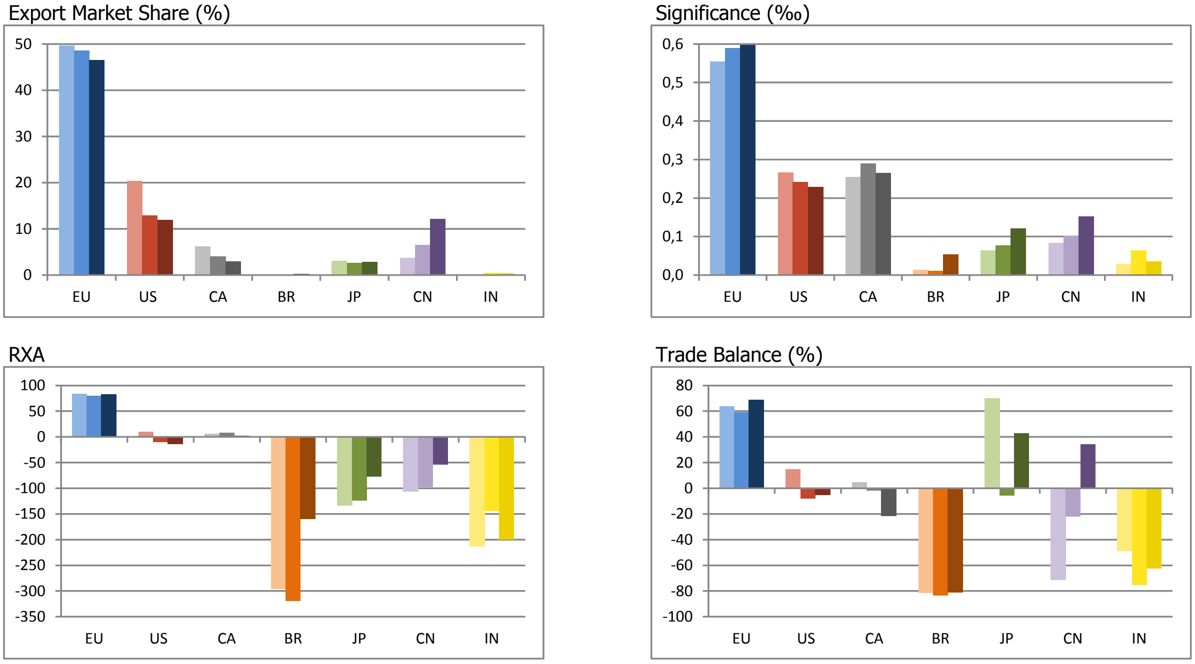
Trade analysis shows a clear comparative advantage of the EU-28 in Traffic Control Systems (e.g. products used for electrical signalling, safety, traffic control), realizing high export specialisation (RXA) and trade specialisation figures (RCA) that have further improved since 2008 (see Figure 79 and *Figure 139* in Annex 19/). Furthermore, the EU-28 depicts the by far highest export market share of about 46% of global exports in 2014. The strong comparative advantage of the EU in this field is underlined by the highly positive trade balance, that has increased by 10 percentage points since 2008 and positive medium-term export dynamics (5% p.a., see *Figure 139* in Annex 19/). Yet, the export volume of products representing this sector is comparably low: although the significance of Traffic Control Systems in total EU exports has increased over time, it only applies to 0.6‰ in 2014.

China (12.2%) and the US (11.9%) hold the second and third highest export market shares in Traffic Control Systems. Contrary to the EU, China was able to improve its comparative advantage in Traffic Control Systems since 2008; the US lost its positive trade specialisation over time (*Figure 139* in Annex 19/) and turned from a net exporter to a net importer of those products (Figure 79). This development was underlined by comparably low export dynamics (2.6% p.a.). China succeeded to triple its export share from 2002 to 2014. However, it is still rather low compared to other manufacturing goods (negative RXA), but the export/import ratio has considerably improved since 2008 (TB, RCA), indicating that the Chinese exports (16.3% p.a.) of Traffic Control Systems have grown faster than its imports.

Canada and Japan each account for 3% of global exports. While this share equals the general weight of Canada within global manufacturing exports, indicated by a balanced export specialisation (RXA), it is comparably low for Japan, indicated by highly negative RXA values (Figure 79). Yet, due to remarkable export dynamics (8.6% p.a.) since 2008 Japan actually depicts a positive trade specialisation (RCA) and trade balance (TB) in Traffic Control Systems (Figure 79, *Figure 139* in Annex 19/). In contrast, Canada only revealed low export growth (1% p.a.) and has lost his former comparative advantages (RCA) in this field.

India (0.4%) and Brazil (0.3%) still play a very minor role in the production and export of Traffic Control Systems and have no comparative advantages (RXA, RCA) in this field.

Figure 79: Trade indicators for the EU and selected other countries 2002, 2008 and 2014 and export dynamics 2007/08 to 2013/14: Traffic Control Systems



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Several highly industrialized MS depict high export shares and comparative advantages, but nearly all MS show considerable export growth

With respect to country comparison, e.g. considering EU-Extra-trade and EU-Intra-trade, Germany is the by far largest exporter of Traffic Control Systems followed by Italy (9%), China (8.9) and the US (8.7%), constituting very similar shares (*Figure 140* in Annex 19/). Within the EU-28, Austria (7.7%), France (5.2%), Great Britain (4.3%), Spain (4.2%) and Sweden (3.4%) also achieve considerable export market shares and reveal high comparative advantages in this rather small export segment, indicated by positive RXA, RCA as well as TB figures (*Figure 140* to Figure 142 in Annex 19/). Moreover, also Denmark and Croatia depict significant export market shares (>0.5%) and comparative advantages in Traffic Control Systems.

With the exception of Belgium, Slovakia and Luxemburg, all other MS show positive medium-term export growth in Traffic Control Systems. Thereby, some smaller countries (Bulgaria, Romania, Lithuania, Portugal) mostly starting from a very low level, achieved considerable annual growth rates of at least 40%. But also larger exporters as Italy and Denmark constitute growth rates higher than 10% (Figure 142 Annex 19/).

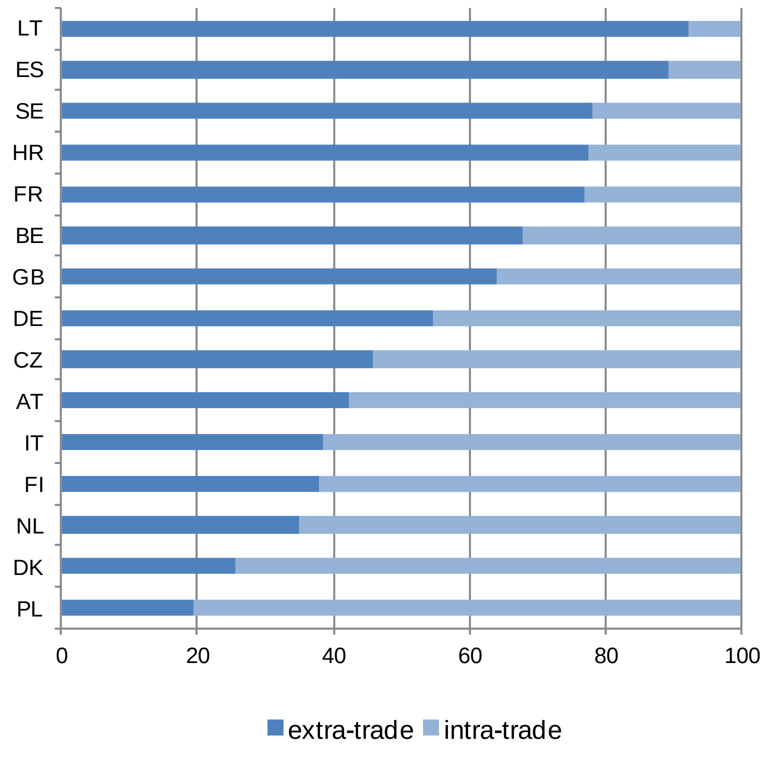
Only in Austria and Croatia, Traffic Control Systems account for more than 1.5‰ of all manufacturing exports. In the other MS, the structural weight of those products is comparably low (*Figure 141*in Annex 19/).

On average high and growing orientation of EU manufactures on the external market, but clear differences on the country level

Contrary to total manufacturing goods and most other Clean Industry products (except AMT and measuring and monitoring products), the intra-EU-exports share Traffic Control Systems is comparably low (45% in 2014). On average, 55% of EU exports are designated towards non EU countries, indicating that the export potential for those products in other world regions is particularly high. Moreover, the share of extra-trade exports has further increased over time (2008: 52% extra-trade, 48% intra-trade).

Figure 80 reveals the relation between extra-EU-exports and intra-EU-exports for MS that account for more than 0.5% of global exports in Traffic Control Systems. Thereby, considerable differences arise. Thus, Lithuania and Spain supply about 90% of their exports to non EU countries, Sweden, Croatia, and France almost 80%. Also Belgium and Great Britain still constitute extra-trade shares above the EU average that is determined by Germany. On the other hand, other larger exporters like Austria and Italy mainly export to the internal market. Denmark (74%) and Poland (81%) account for the highest intra-trade orientation.

Figure 80: Share of EU-Extra-trade and EU-Intra-trade (in %) in country exports: Traffic Control Systems



Including EU countries with an export market share in Traffic Control products higher than 0.5% in 2014.
Source: UN COMTRADE-Database. – NIW calculation.

12.2.4 *Market outlook*

As earlier addressed, traffic control systems are aimed at providing a wide variety of applications to help realise broader transport policy goals, such as maximising the effectiveness of the use of existing infrastructure, ensuring reliable and safe operation of transport, addressing environmental goals, and ensuring fair allocation of infrastructure space (road space, rail slots, etc.)). The need for improving the state of the various transportation systems is therefore the biggest driver for the traffic control systems industry. The major focus of regions where traffic control systems already are in a fairly good state of development is developing and deploying these systems to overcome issues such as traffic congestion, to enhance the safety and security of traffic, and to increase the efficiency of traffic. Developing countries like China, India, and countries in the Middle East, have significant plans for the development of expressways and highways, which increases the demand for traffic control systems such as electronic pricing systems (Markets and Markets, 2012). The Asia Pacific region is considered to be the fastest growing market in the field of traffic control systems as the region's emerging economics have high population growth, rapid urbanization, growth in vehicle sales, etcetera (PR Newshire, 2016).

The demand for traffic control systems in both the public and private sector are mainly driven by government initiatives and promotional activities (Transparancy Market Research, 2015). In Europe, the development of coordinated initiatives is driving the implementation of European wide traffic control systems. Examples are the 2008 Action Plan and 2010 Directive for the implementation of Intelligent Transport Systems for the application of traffic control systems in road transportation, the European Railway Traffic Management System (ERTMS) for the application of traffic control systems in rail transportation, the Single European Sky ATM Research (SESAR) for the application of traffic control systems in aviation transportation, and the Union Maritime Information and Exchange System (SafeSeaNet) for the application of traffic control systems in waterborne transportation. In countries such as India and Japan it is also regulatory initiatives and R&D activities that drive demand (Grand View Research, 2014). These governmental activities are supported by issues such as the increasing population, rapid growth in urbanization, increasing environmental concerns, parking problem, high pollution at cities borders, and the need for real time information and analytics (PR Newshire, 2016). Technological developments and economic growth further facilitate the uptake and deployment of traffic control systems.

Development in information and communication technologies are currently driving developments and innovation in the traffic control systems industry. Improvements in mobility through accurate positioning (GPS, Galileo, AIS), mobile communications and the possibilities of ubiquitous information processing, combined with the increasing demand for traffic information at all times and in all places, means that there is a huge potential for wealth creation to be harnessed (German Federal Ministry of Transport, Building and Urban Development, 2012). Vehicles are expected to become more and more connected to their vehicles, and developments in ICT will enhance the efficient use of road networks as vehicles will have the ability to dynamically plan and navigate routes taking into account real time changes in road network capacity and usage. Moreover, many governments are paving the way for the deployment of fully autonomous vehicles, which will have a large effect on the road transport. Not only in terms of efficiency, but also safety will be enhanced, given that almost three-quarters of all collisions are attributable to driver errors (AEA – Commissioned by European Commission, Joint Research Centre, Institute for Prospective Technological Studies, 2012). Developments in the field of sensors that can be integrated into handheld devices has spurred development activities in the field of traffic control systems (Grand View Research, 2014).

12.3 Assessment of the competitiveness aspects

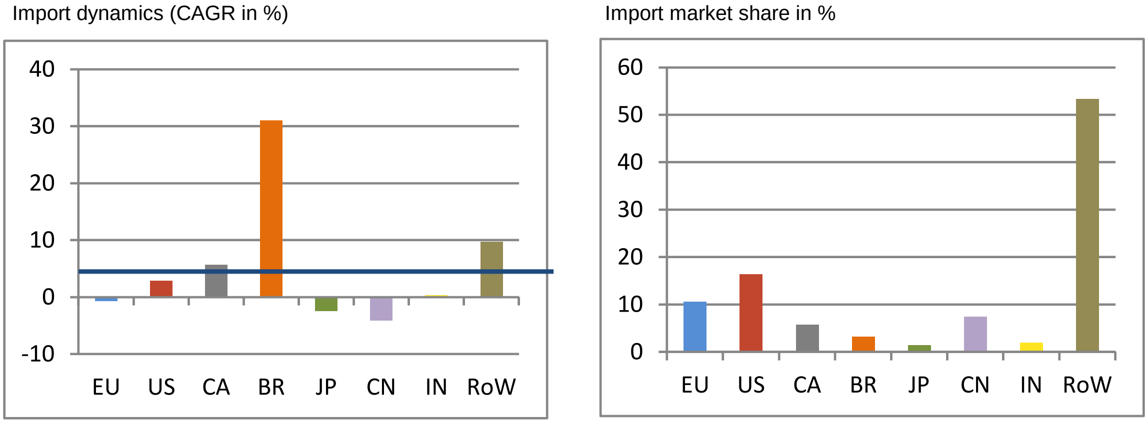
12.3.1 Export potential

Box 18: Export potential

Export potentials emerge primarily in those goods and activities, in which the EU-28 already holds comparative advantages (measured in export specialisation or trade specialisation). In these goods and activities, trade volumes can be used as an initial indicator for market and growth potential. Hence, growing import rates of third countries may serve as a proxy for an increase in demand for Clean Industry goods in a specific country or world region that may subsequently translate into a growing export market for the EU and its Member States. At the same time, existing export advantages (indicated by RXA values) of the EU and its Member States in certain products may indicate promising preconditions for further growth and export potential.

Figure 81 reveals the global import market shares of the EU (excluding intra-trade) in comparison to other selected countries and the rest of the world (RoW) in Traffic Control Systems (e.g. products used for electrical signalling, safety, traffic control), indicating that the US has been the largest single importer (20%) in 2014 followed by the EU (10%) and China (8%). Compared to its structural weight in total manufacturing imports, also Canada revealed a considerably high demand for traffic control systems (6%), whereas Brazil (3%), India (2%) and particularly Japan (1%) are still falling behind. However, Brazil (31% p.a.) yields the highest import dynamics since 2007/08, far ahead of Canada (5.6%) and the US (2.8%), indicating growing demand for traffic control systems in these countries. In contrast to this, the other represented countries/regions show very weak, partly even negative import dynamics in this field. Otherwise, also lower growth rates connected with a high absolute import volume, as can be seen in the US, can create growing export potential for EU manufacturers. The same is true for the EU itself, from whose perspective external imports could be substituted by internal production.

Figure 81: Import market share 2014 and import dynamics 2007/08 to 2013/14 of the EU-28 and selected non-EU countries: Traffic Control Systems

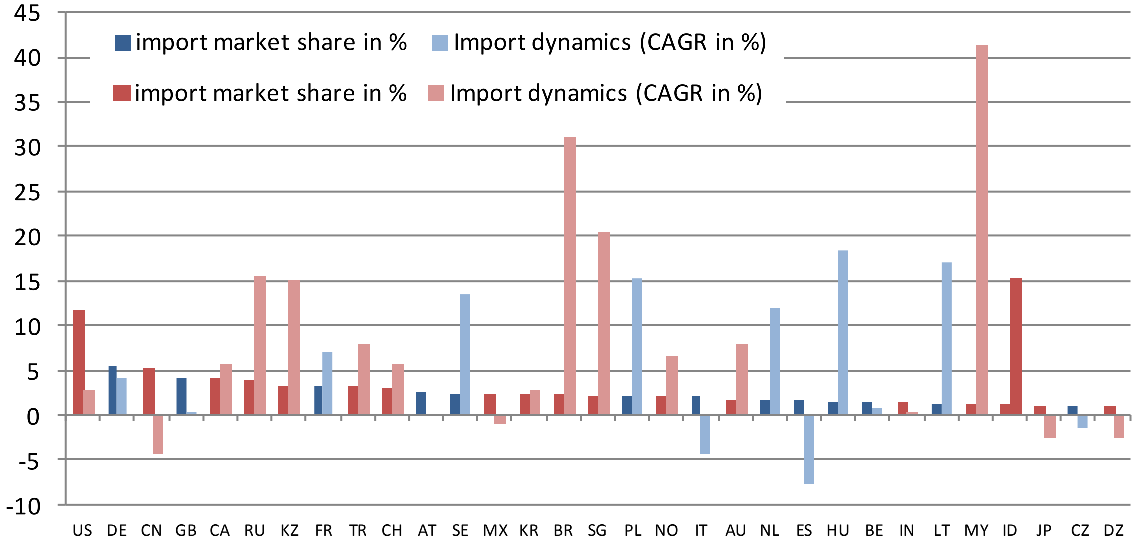


Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

As Table 27 in Annex 1/ depicts, the EU constitutes high export market shares and export specialisation values (RXA) for traffic control systems in each of the five selected foreign countries, especially in Brazil and the Asian countries. Thus, they basically all promise further export potential for EU Traffic Control Systems manufacturers as well as related service suppliers, although market volume and dynamics in China, Japan and India are actually falling behind.

Yet, Figure 81 above also reveals that more than half the import demand for Traffic Control Systems in 2014 applies to other than the selected countries (RoW). Furthermore, the import dynamics of RoW amounted to 10% p.a., thus being significantly higher than the global average (5.4%). Hence, Figure 82 illustrates import market shares and import dynamics for all countries with a global import market share of at least 1% in 2014. It becomes obvious, that besides the US, Canada, Brazil and several EU MS (Germany, Great Britain, France, Sweden, Poland, the Netherlands, Hungary, Latvia), also other European (e.g. Russia, Kazakhstan, Turkey, Switzerland) and overseas countries (e.g. Singapore, Malaysia, Indonesia), constitute considerable import market shares and/or remarkable growth rates, hence creating additional sales respective export potential for the EU Traffic Control Systems industry.

Figure 82: Import market share 2014 and import dynamics 2007/08 to 2013/14 in Traffic Control Systems on the country level



Global imports including EU-intra-trade. - Regarding countries with a global import share of at least 1%. – EU MS: blue coloured; non EU countries: red coloured.
Source: UN COMTRADE-Database. – NIW calculation.

12.3.2 SWOT

Table 26: SWOT for the traffic control systems sector

Strengths	Weaknesses
▶ Cooperation between the European Commission and various transport industries in the development of coordinated initiatives for the implementation of European wide traffic control systems. Examples are the 2008 Action Plan and 2010 Directive for the implementation of Intelligent Transport Systems for the application of traffic control systems in road transportation, the European Railway Traffic Management System (ERTMS) for the application of traffic control systems in rail transportation, the Single European Sky ATM Research (SESAR) for the application of traffic	▶ The market for traffic control systems for road transportation (intelligent transport systems) is dominated by the US which generated in 2012 more than 42% of the total global turnover in ITS. ▶ In the field of waterborne transportation, the Asia-Pacific region, and China in specific, is projected to account higher market share as compared to other regions. ▶ In the field of aviation transportation, the USA had the major market share in 2015 ▶ Cross border complexity: traffic control systems

control systems in aviation transportation, and the Union Maritime Information and Exchange System (SafeSeaNet) for the application of traffic control systems in waterborne transportation. ▸ Strong position in the various transportation industries. Traffic control systems are deployed both in infrastructure as well as the vehicles, and strong vehicle manufacturing industries are therefore beneficial to the traffic control systems industry. ▸ Relatively strong position in the field of measuring and monitoring technologies, an application area of which is the logistics and transportation sector ▸ Trade analysis shows a clear comparative advantage of the EU-28 in Traffic Control Systems, realizing high export specialisation (RXA) and trade specialisation figures (RCA) that have further improved since 2008. Furthermore, the EU-28 depicts the highest export market share of about 46% of global exports in 2014.	require close cooperation between the numerous stakeholders involved, and this might be more difficult in a region with many different Member States
Opportunities ▸ The global urge for a technological shift to more efficient, environmentally sound, and more intelligent transport to meet the mobility and the environmental challenges is seen as an opportunity to strengthen the leadership position of Europe in the field of transportation and therewith traffic control systems ▸ On average, 55% of EU exports are designated towards non EU countries, indicating that the export potential for those products in other world regions is particularly high. Developing	Threats ▸ Overall, the traffic control systems industry seems to witness the highest growth in the Asia-Pacific region: ▸ In the field of traffic control systems for rail transportation, the Asia pacific region is estimated to be the fastest-growing regional segment during the forecast period, led by dynamic growth in the long-term, highly influenced by new projects in China, India, and other countries in Asia Pacific. ▸ In the field of waterborne transportation, the

countries like China, India, and countries in the Middle East, have significant plans for the development of expressways and highways, which increases the demand for traffic control systems such as electronic pricing systems. In combination with the EU's comparative advantage in the trade analysis, this could be seen as an opportunity.	Asia-Pacific region, and China in specific, is expected to register higher CAGR and the total market in this region ▶ In the field of aviation transportation, the air traffic control equipment market is expected to witness the highest growth in the Asia-Pacific. ▶ This trend is also seen in the analysis on export potential: contrary to the EU, China was able to improve its comparative advantage in Traffic Control Systems since 2008. China succeeded to triple its export share from 2002 to 2014. ▶ Delayed action and timid introduction of new technologies could condemn the EU transport industry to irreversible decline, as these other world regions are launching huge, ambitious transport modernisation and infrastructure investment programmes

12.4 Analysis of barriers

The 2008 ITS Action Plan was aimed at overcoming the slow and fragmented uptake and deployment of ITS in road transportation. ITSs had at the time are already been applied across the EU, but in a fragmented manner, in mono-modal instances, in geographically isolated domains, and incompletely (European Commission, 2011). The action plan listed different measures to counter different barriers contributing to this slow and fragmented uptake and deployment of traffic control systems, including: differences between national policies and rules for cooperation on data exchange, content and service provision; interoperability issues; fragmented deployment of traffic control systems; lack of easy and efficient access to knowledge about the benefits and costs of ITS applications and services, and about experiences and evaluations of ITS implementation (European Commission, 2011). Besides the many successes the Action Plan has achieved in the past few years regarding the deployment of ITS's in Europe, there have also been some difficulties in the implementation of the Action Plan. Difficulties have been encountered in building consensus among Member States and stakeholders. As a consequence of the multitude and diversity of stakeholders and its various and sometimes diverging stakeholder interests, progress has been slow in some actions owing to the resistance of some players. In other cases, lack of involvement or real interest from some major stakeholders has caused delays. Finally, the wide range of very specific but quite different types of action set out in the Action Plan did not help to prioritise actions (European Commission, 2014). In a paper by Chatziathanasiou, Kortsari, and Tyrinopoulos (2015) on the barriers of ITS deployment, most of the earlier mentioned key barriers are found still to be in place. Additional barriers mentioned in the paper are: unbalanced deployment of ITS among EU member states, among transport modes and among major transport players and SMEs; lack of or limited funding that would facilitate investments; reluctance from some transport operators (especially SMEs) to adopt advanced technologies (either due to financial restrictions or due to lack of specific quantified benefits); bureaucratic obstacles and a lack of legislation in certain European countries; lack of or limited cooperation between the research/academia and industrial sectors; lack of quantified/tangible benefits from the use of mature ITS applications that would prompt other transport stakeholders to invest in similar solutions; and low visibility of outstanding ITS applications.

The wide variety of barriers mentioned with respect to the uptake and deployment of traffic control systems in road transportation in the form of ITSs appear to be a good illustration of the barriers related to traffic control systems in general. However, the main barriers mentioned with respect to traffic control systems in rail, aviation and waterborne transportation are related to interoperability issues. Interoperability in technological and regulatory terms, is seen as a key requirement for further development of sector, and also for potential export of European products to promising regions (SESAR, 2015; ERA, 2014). Traffic control systems require different components, technologies and actors to cooperate for the functioning of the system as a whole. Deploying traffic control systems requires a careful analysis of the specific institutional and regulatory frameworks that are in place with respect to the different stakeholders involved. Traffic control systems require the inter- and intra-system interoperability, within sector but also in connection with other sectors, such as the ICT sector and the energy sector. Effective deployment of traffic control systems also requires data sharing, and challenges regarding the privacy, availability and trustworthiness of data still need to be overcome (S3 Platform, 2014). Harmonised regulation, standardisation, legislation and policy could contribute to solving the some of the problems resulting from this complexity, and the lack of harmonisation and standardisation can therefore be considered as one of the major barriers related to traffic control systems.

One of the barriers for the further development of traffic control systems in Europe is derived from a platform for stakeholders from the various EU transport sectors aimed to discuss the implementation of the 2011 White Paper on Transport (TRANSFORuM, 2014). As one of the most important barrier the stakeholders identified a lack of commitment and a lack of goals and targets behind policy goals on traffic control systems. Currently, recommendations on EU policy level are too general. The different interpretations of the current policy framework on a European level represent a major barrier, which can only be overcome by multi-level and multi-actor policy coordination. Without a clear goal and purpose (e.g. to achieve a considerable increase in public transport) there is no incentive to invest in multimodal information systems and there will not be sufficient political driving power to overcome these implementation barriers.

Finally, traffic control systems require considerable investment and effort. Funding schemes are necessary to implement investments, at both regional, national and European level (S3 Platform, 2014). As a result of the economic downturn in 2008, followed by the financial crisis in 2011, receiving funding for the deployment of traffic control systems has become an increased issue, since there is competition against traditional hard infrastructures (European Commission, 2014).

12.5 Suggested actions

A review of the ITS Action Plan highlighted to its major successes. Identifying the successes is important in determining further policy actions. The main foundation for the success of the Action Plan was mainstreaming the notion of ITS in the design of transport policies and highlighting the value of deployment of ITS. Furthermore, the Action Plan has increased awareness about the need to tackle bottlenecks that hinder interoperable deployment and to address other technical or legal issues hampering a broader take-up of such systems. Finally, the Action Plan has been a catalyst for a greater and more focused involvement, cooperation and collaboration of the large stakeholder community. Demonstrating the benefits of traffic control systems has turned out to be crucial in securing funding (European Commission, 2014). It thus appears that increasing awareness and providing information about the benefits of traffic control systems is a policy suggestion that should be pursued among all areas of traffic control systems.

With respect to barriers related to interoperability issues there is a need for harmonisation and standardisation on a European level. European policy should support national and regional approaches by proposing specific quality measures for harmonizing services across Europe (TRANSFORuM, 2014). EU Cohesion Policy can provide support for research and innovation in this area.

However, besides regulatory harmonisation and standardisation it is necessary to organise commitment, cooperation and collaboration between the many stakeholders involved in traffic control systems. Examples of relevant platforms are iMobility Forum, the European Technology Platform ERTRAC, the European Innovation Partnership Smart Cities and Communities, the Smart Cities Stakeholder Platform, the Green Digital Charter, and the Covenant of Mayors (S3 Platform, 2014).

With respect to capital and financial barriers involved with traffic control systems, accessibility to funding is deemed highly necessary, and European structural and investment funds in combination with other financing opportunities remain key to further deployment of the traffic control systems industry and its deployment in Europe (European Commission, 2014).

A final interesting notion regards the disruption traffic control systems might impose on traditional business models in the transport industry. Traditionally governments provide infrastructure, and the industry provides vehicles. Traffic control systems however operate in the various areas that are interconnected. The traffic control systems industry therefore may create opportunities for many players ranging from different industries and different levels of authorities. In a paper on the challenges arising from this new situation (Maniak, 2014) it is concluded however that no single player can bear the costs needed to fund the investments in these traffic control systems projects. As a solution, joint investment pools and new contribution-remuneration systems are suggested. Examples can be found in the sharing economy, such as a consortium built around Autolib' in Paris, a form of joint investment and sharing of public and private benefits, or a partnership between General Motors and RelayRides, a peer-to-peer company that provides a service to rent your own vehicle to another person. Another example of an industry that might provide interesting business models are telecommunications, where cooperation between public and private players have succeed in bringing technological breakthroughs (2G-3G-4G, capacitive technology) into innovative offers based on new, shared and viable business models.

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ANNEXES

Annex 1/ Regional export potential of the EU-28

Table 27: Regional export market share and export specialisation of the EU-28 for selected Clean Industry products 2014

	US	CA	BR	CN	JP	IN	US	CA	BR	CN	JP	IN
	Export Market Share						RXA					
Wind Energy	31,0	14,3	45,1	45,5	14,8	45,6	43	36	63	103	9	112
Thermal Insulation	19,3	5,1	18,3	18,7	13,2	20,4	-5	-68	-27	14	-2	31
Prefabricated buildings of wood	25,1	2,1	28,1	16,5	49,3	22,7	22	-157	16	1	130	42
Heating and Cooling Systems	21,8	7,4	28,4	25,8	15,7	27,6	8	-30	17	46	16	62
ICE powered road vehicles	20,5	8,0	23,9	52,5	50,9	29,2	-6	-26	-4	129	121	60
Railway/Tramway (electrically driven)	25,7	0,5	46,6	66,7	80,5	9,4	24	-305	66	141	179	-46
Traffic Control Systems*	22,3	13,1	50,8	95,0	24,5	98,6	10	27	75	176	60	186
AMT	40,7	20,3	47,9	23,2	29,3	43,4	70	70	69	35	78	107
Measuring and Monitoring	38,8	11,9	33,4	27,3	28,3	34,8	65	17	33	52	74	85

Export market share: share of EU's exports in % of global exports to the specific country. - *India: 2013
Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Annex 2/ General figures and tables - Wind Energy

Figure 83: Connected wind power capacity in the European Union at the end of 2015 (MW)

Connected wind power capacity in the European Union at the end of 2015 (MW)

	Cumulative capacity at the end of 2014	Cumulative capacity at the end of 2015*	Capacity installed in 2015*	Decommissioned in 2015*
Germany	39 128.2	44 946.4	6 013.4	195.2
Spain	23 025.3	23 025.3	0.0	
United Kingdom	12 987.5	13 855.0	867.5	
France**	9 323.0	10 312.0	999.0	
Italy	8 638.0	8 933.0	295.0	
Sweden	5 425.0	6 029.1	614.5	10.4
Poland	3 836.0	5 100.0	1 264.0	
Portugal	4 947.0	5 079.0	132.0	
Denmark	4 887.0	5 013.0	160.0	34.0
Netherlands	2 865.0	3 390.0	535.0	10.0
Romania	2 952.9	2 975.9	23.0	
Ireland	2 262.3	2 486.3	224.0	
Austria	2 086.0	2 409.0	323.0	
Belgium	1 958.7	2 228.8	274.3	4.2
Greece	1 979.0	2 150.8	171.8	
Finland	632.0	1 005.0	379.0	6.0
Bulgaria	691.2	691.2	0.0	
Lithuania	282.0	424.3	142.3	
Croatia	339.5	420.5	81.1	
Estonia	334.0	334.0	0.0	
Hungary	329.0	329.0	0.0	
Czech Republic	278.1	282.1	4.0	
Cyprus	146.7	157.5	10.8	
Latvia	69.0	69.0	0.0	
Luxembourg	58.3	63.0	4.7	
Slovakia	5.0	5.0	0.0	
Slovenia	4.0	4.0	0.0	
Malta	0.0	0.0	0.0	
Total EU 28	129 459.6	141 718.2	12 518.3	259.8

* Estimate. **Overseas departments not included for France. Source: EurObserv'ER 2016.

Source: Eurobserv'Er 2016 p.6

Figure 84: Installed offshore wind power capacities in the EU at the end of 2015

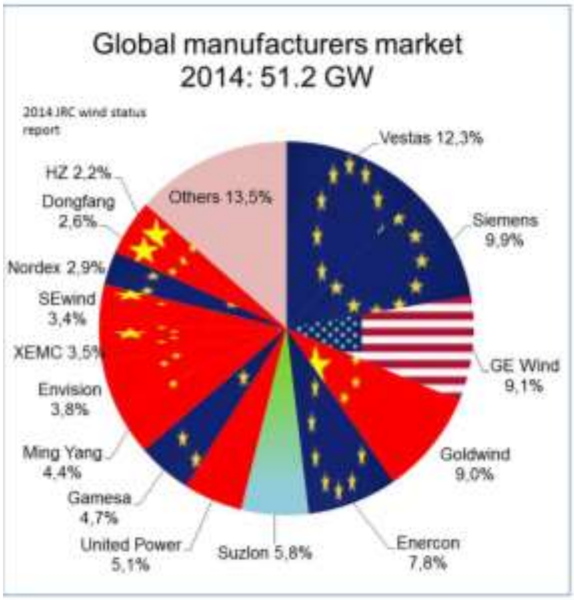
Installed offshore wind power capacities* in European Union at the end of 2015 (MW)

	2014	2015
United Kingdom	4 501.3	5 104.5
Germany	1 012.5	3 294.9
Denmark	1 271.1	1 271.1
Belgium	712.2	712.2
Netherlands	228.0	357.0
Sweden	211.7	201.7
Finland	28.0	28.0
Ireland	25.2	25.2
Spain	5.0	5.0
Portugal	2.0	2.0
Total EU 28	**7 997.0**	**11 001.6**

*and connected to the electric grid. **Source: EurObserv'ER 2016.**

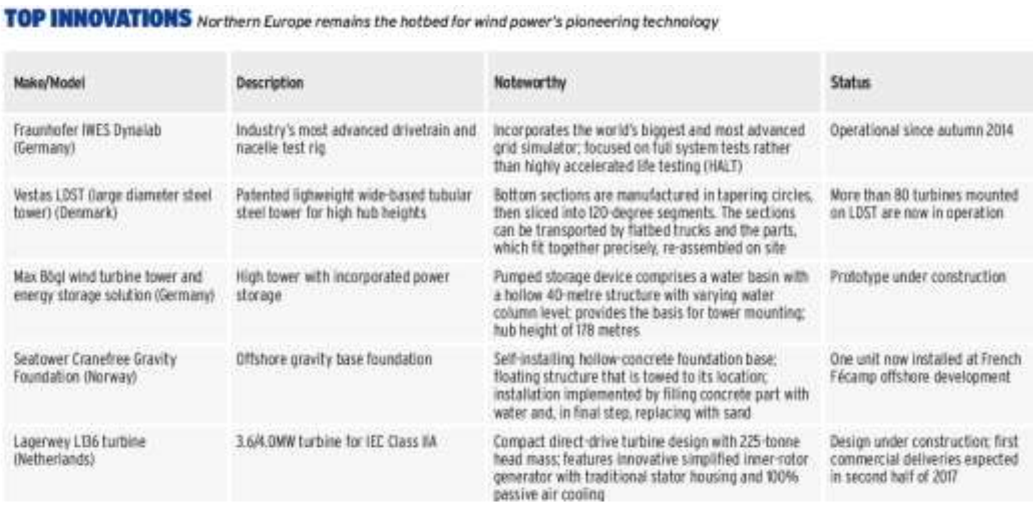
Source: Eurobserv'Er 2016 p.8

Figure 85: Market Shares of Top Ten Manufacturers 2014



Source: Lacal Arántegui 2016, p. 25.

Figure 86: Top Innovations rated by Windpower monthly

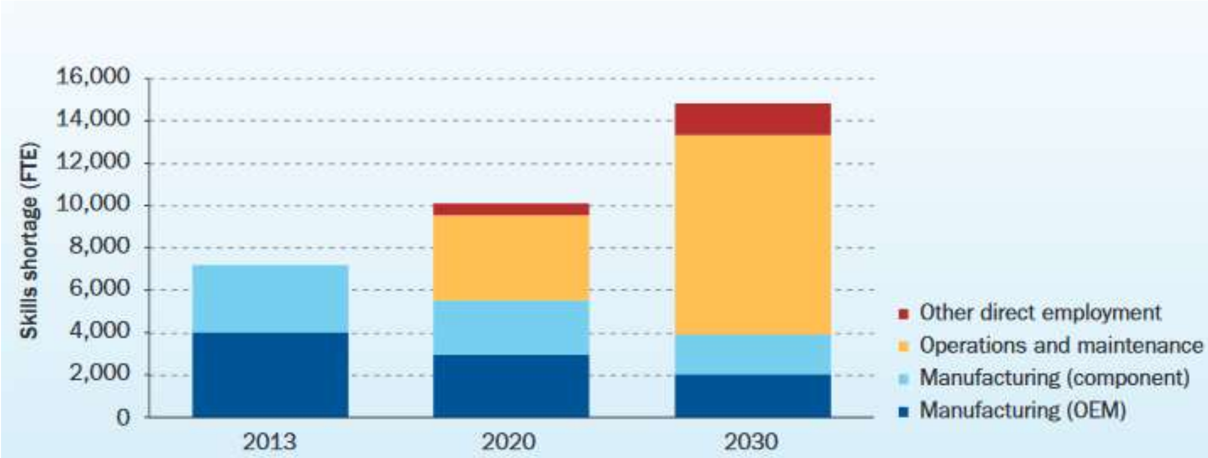


TOP INNOVATIONS *Northern Europe remains the hotbed for wind power's pioneering technology*

Make/Model	Description	Noteworthy	Status
Fraunhofer IWES Dynalab (Germany)	Industry's most advanced drivetrain and nacelle test rig	Incorporates the world's biggest and most advanced grid simulator; focused on full system tests rather than highly accelerated life testing (HALT)	Operational since autumn 2014
Vestas LDST (large diameter steel tower) (Denmark)	Patented lightweight wide-based tubular steel tower for high hub heights	Bottom sections are manufactured in tapering circles, then sliced into 120-degree segments. The sections can be transported by flatbed trucks and the parts, which fit together precisely, re-assembled on site	More than 80 turbines mounted on LDST are now in operation
Max Bögl wind turbine tower and energy storage solution (Germany)	High tower with incorporated power storage	Pumped storage device comprises a water basin with a hollow 40-metre structure with varying water column level; provides the basis for tower mounting; hub height of 178 metres	Prototype under construction
Seatower Cranefree Gravity Foundation (Norway)	Offshore gravity base foundation	Self-installing hollow-concrete foundation base; floating structure that is towed to its location; installation implemented by filling concrete part with water and, in final step, replacing with sand	One unit now installed at French Fécamp offshore development
Lagerwey L136 turbine (Netherlands)	3.6/4.0MW turbine for IEC Class IIA	Compact direct-drive turbine design with 225-tonne head mass; features innovative simplified inner-rotor generator with traditional stator housing and 100% passive air cooling	Design under construction; first commercial deliveries expected in second half of 2017

Source: Windpower monthly http://www.windpowermonthly.com/article/1377332/turbines-year-innovations

Figure 87: Skills Gap 2013-2030 by area

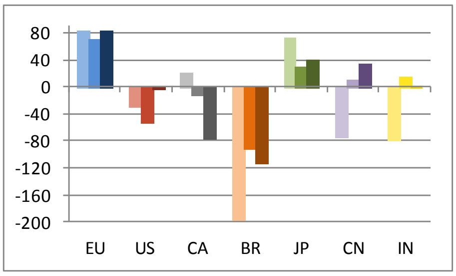


Source: TP Wind Survey

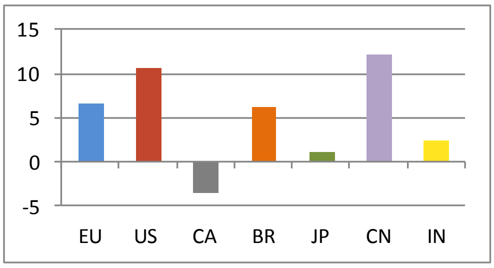
Annex 3/ Comparative advantage - Wind energy

Figure 88: RCA and medium term-export dynamics for the EU-28 and selected other countries: Wind related products

RCA



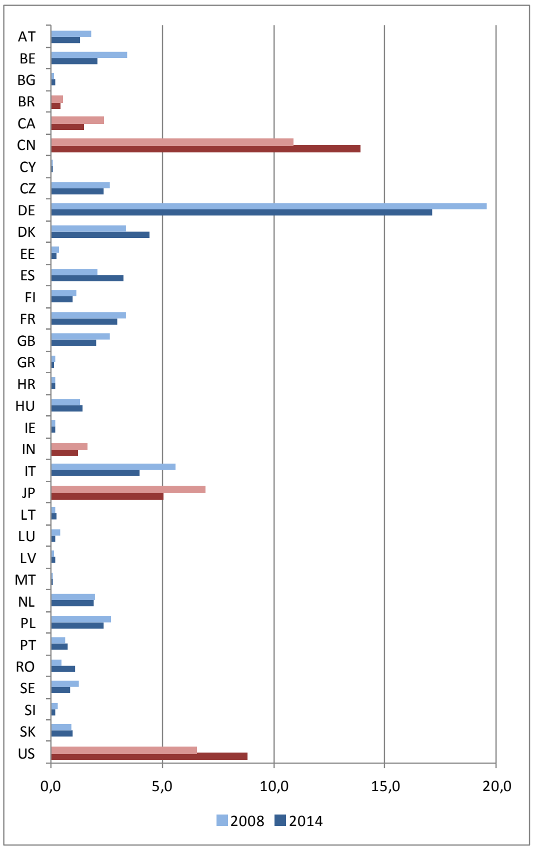
Medium-term export dynamics (CAGR %) in %



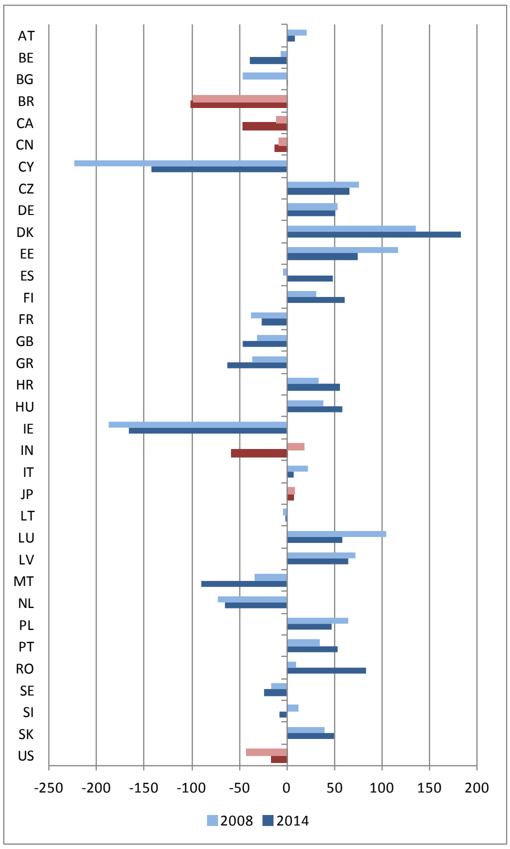
Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 89: Export market share (in %) and RXA for the EU Member States and selected other countries 2008 and 2014: Wind related products

Export market share (in %)



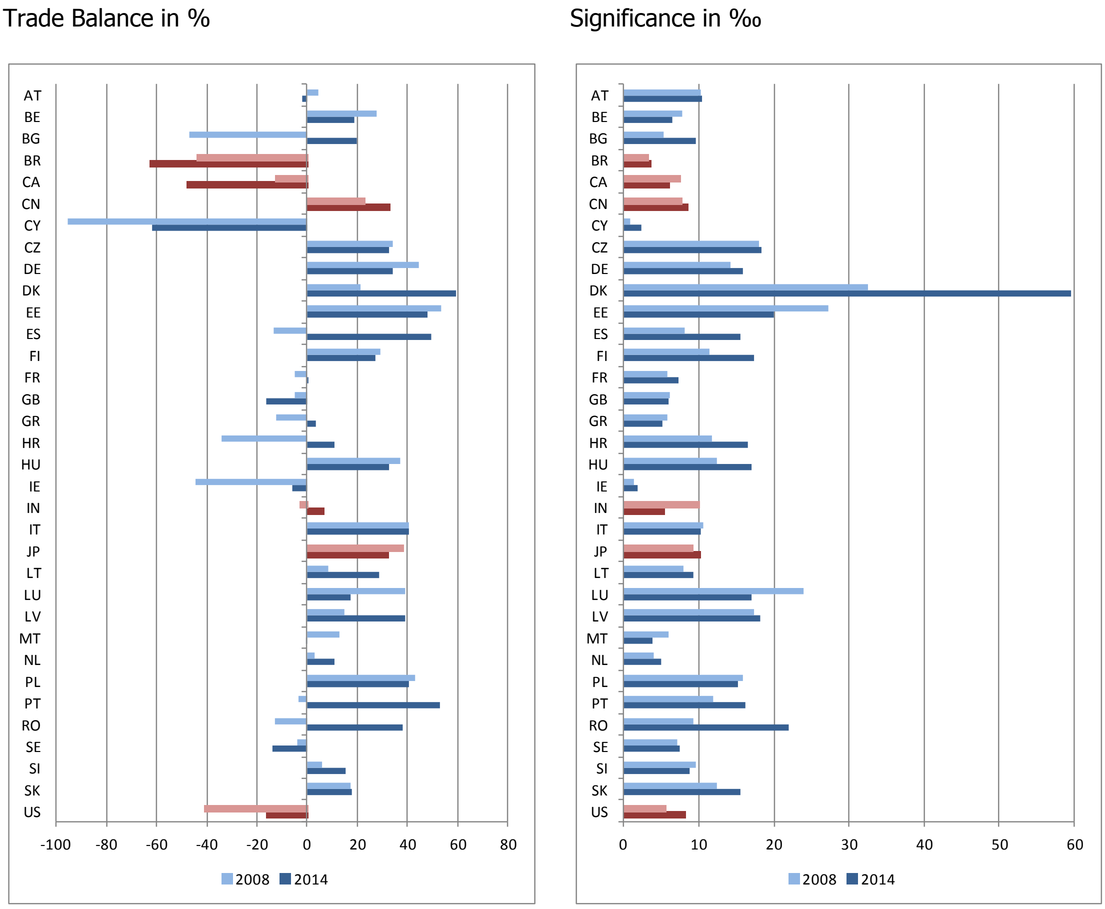
RXA



Including EU-Intra-Trade.

Source: UN COMTRADE-Database. – NIW calculation.

Figure 90: Trade Balance and Significance for the EU Member States and selected other countries 2008 and 2014: Wind related products

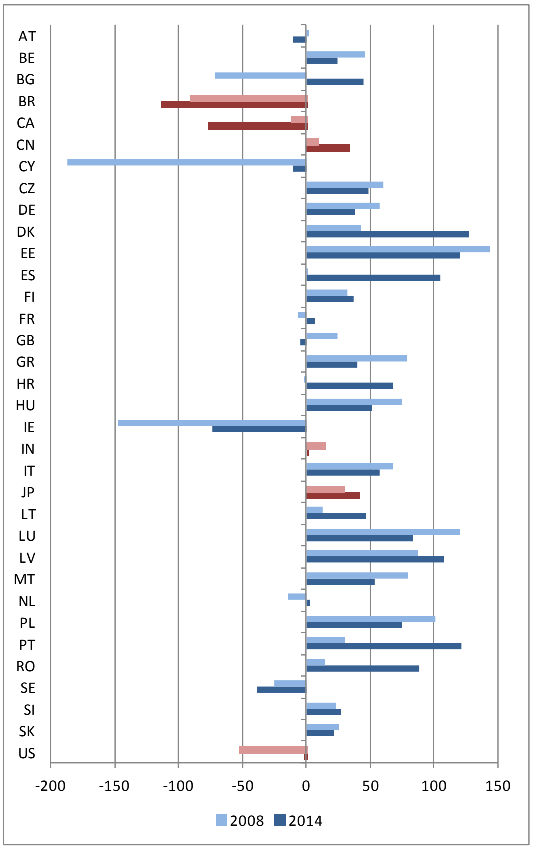


Including EU-Intra-Trade.

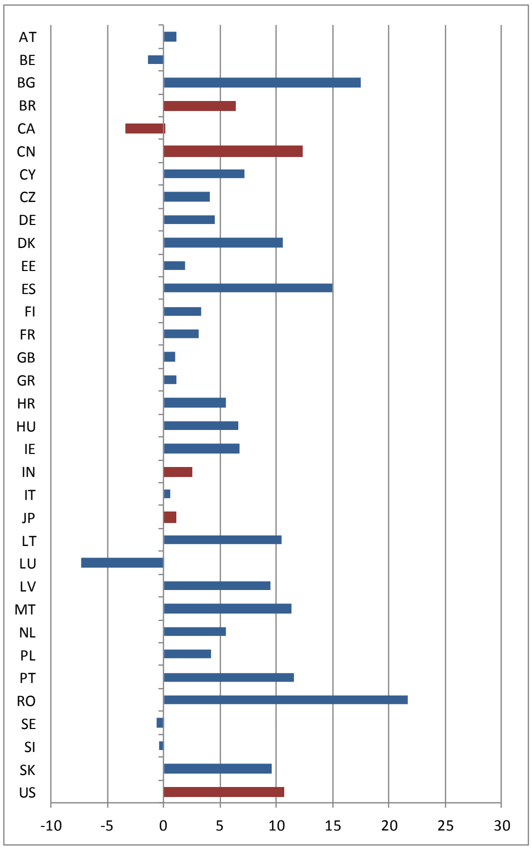
Source: UN COMTRADE-Database. – NIW calculation.

Figure 91: RCA 2008 and 2014 and Medium-term dynamics 2007/08 to 2013/14 for the EU Member States and selected other countries: Wind related products

RCA



Medium-term dynamics (CAGR in %)



Including EU-Intra-Trade.

Source: UN COMTRADE-Database. – NIW calculation.

Annex 4/ General figures and tables - Technologies to realise efficiency gains in ICE powered vehicles

Figure 92: Overview of key ICE optimisation technologies and their CO2 reduction potential (Roland Berger, 2009)

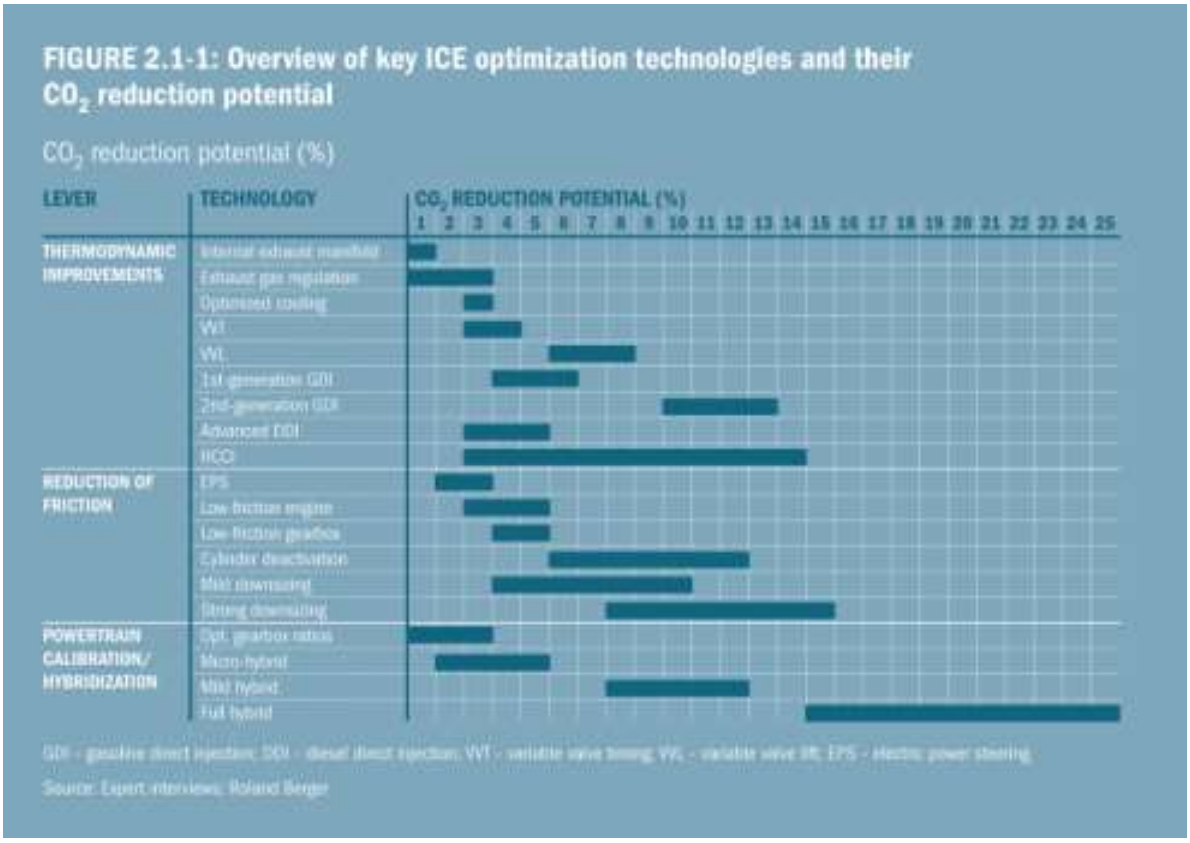


Table 28: GHG and efficiency technologies considered in the US, their efficiency benefits and costs (International Council on Clean Transportation, 2014)

Technology	CO_2 Reduction (% from baseline vehicle)[1]		2017 Total Cost for small car [2]	2025 Total Cost for small car
	SMALL CAR	LARGE CAR	2010$	2010$
ENGINE TECHNOLOGY				
Low-friction lubricants	0.6	0.8	4	4
Engine friction reduction level 1	2	2.7	44	43
Engine friction reduction level 2	3.5	4.8	97	93
Cylinder deactivation (includes imp. oil pump, if available)	n.a.	6.5	196	160
VVT - intake cam phasing	2.1	2.7	46	39
VVT - coupled cam phasing	4.1	5.5	46	39
VVT - dual cam phasing	4.1[3]	5.5[3]	95	78
Discrete VVLT	4.1[4]	5.6[4]	163	133
Continuous VVLT	5.1	7	244	200
Stoichiometric gasoline direct injection	1.5[5]	1.5[5]	277	226
Turbo+downsize (incremental to GDI-S) (18-27-bar)	11-17	14-21	427	337
Cooled exhaust gas recirculation (incremental to 24-bar TRBDS+SGDI)	3.6	3.6	305	249
Advanced diesel engine (T2B2 emissions level)	19.5	22.1	2965	2420
TRANSMISSION TECHNOLOGY				
Aggressive shift logic 1	2	2.7	33	27
Aggressive shift logic 2	5.2	7	34	27
Early torque converter lockup	0.4	0.4	30	25
High efficiency gearbox	4.8	5.3	251	202
6-speed automatic (from base 4AT)	3.1	3.9	-9	-8
8-speed dry DCT (from base 4AT)	11.1	13.1	80	66
Manual transmission (MT6)	0.5	0.5	260	218
HYBRID AND BATTERY ELECTRIC TECHNOLOGY				
12V start-stop	1.8	2.4	401	308
HV mild hybrid	7.4	7.2	3170	2273
Power split HEV	19	36	4483	3406
Two-mode hybrid drivetrain	23	28	7099	4722
Plug-in hybrid electric vehicle - 40-mile range	63	63	14401[6]	8626
Full electric vehicle (EV) - 100-mile range	100	100	17837[6]	9676
ACCESSORY TECHNOLOGY				
Improved high efficiency alternator and electrification of accessories (12 v)	1.7	1.3	89	75
Electric power steering	1.5	1.1	109	92
Improved high efficiency alternator and electrification of accessories (42 v)	3.3	2.5	143	120
Aero drag reduction (20% on cars, 10% on trucks)	4.7	4.7	74	71
Low-rolling-resistance tires (20% on cars, 10% on trucks)	3.9	3.9	73	44
Low-drag brakes	0.8	0.8	74	71
Secondary axle disconnect (unibody only)	1.3	1.3	98	82
MASS REDUCTION				
Mass reduction 10-20% [7]	5-10%	5-10%	149-668	120-526

Notes: [1] The benefits are incremental to base vehicle (2010 baseline). [2] The costs are total cost for small cars, consisting of direct (or material, manufacturing and labor costs) and indirect costs (R&D, learning, manufacturer markup, or costs related to corporation operation and selling); costs are normalized to 2010 dollars. [3] Reductions are relative to base vehicle; if based on ICP, will be 2.0-2.7% for small and large cars, respectively. [4] Reductions are relative to base vehicle; if based on VVT, will be 2.8-3.9% for small and large cars, respectively. [5] Reductions are referring to SGDI alone estimated by EPA. Others such as AAM estimates are higher (3-7%)—a 3% efficiency gain directly from SGDI and a 7% improvement in torque, which provides opportunity for engine downsizing and results in improved fuel economy. When SGDI is combined with other technologies, reduction potentials are much higher. [6] Costs do not include charger and charger labor cost, and only include battery and non-battery costs only. [7] Reductions did not count benefits from improved integrated design such as engine downsizing. For small amount of mass reduction (less than 5% for example), no engine downsizing is applied; therefore CO_2/fuel reduction is low (about a magnitude of 3%). But for greater mass reduction, it usually happens together with redesign; therefore, the overall benefits are much larger than the 5-10% estimates in the table. Source of benefit: EPA (2012). Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards (RIA). Source of cost: EPA (2012). Joint Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards (TSD).

Figure 93: Top 50 European OEM parts suppliers (Crain Communications, 2015)

Top 50 European OEM parts suppliers – Ranked by sales of original equipment parts in 2014

2014 Europe rank	2014 global rank	Company	Total Europe OEM automotive parts sales (dollars in millions) 2014	Total Europe OEM automotive parts sales (dollars in millions) 2013	2013 Europe rank	2013 global rank
1	1	**Robert Bosch GmbH** bosch.com	$22,120 e	$21,297 e	1	1
2	3	**Continental AG** conti-online.com	16,865 fe	16,415 fe	2	4
3	2	**Magna International Inc.** magna.com	14,167	14,094	3	3
4	7	**Faurecia** faurecia.com	14,024	12,033	4	7
5	9	**ZF Friedrichshafen AG** zf.com	12,428 f	11,852 f	5	9
6	8	**Johnson Controls Inc.** johnsoncontrols.com	9,200 f	9,845 f	6	8
7	11	**Valeo SA** valeo.com	8,278 e	6,833 e	8	14
8	16	**BASF SE** basf.com	7,229 f	7,164 f	7	16
9	10	**Lear Corp.** lear.com	7,091	6,169	10	10
10	12	**TRW Automotive Holdings Corp.** trwauto.com	6,983 e	6,820 e	9	11
11	18	**Mahle GmbH** mahle.com	6,538 f	3,998 f	17	22
12	13	**Delphi Automotive** delphi.com	6,081 e	6,051 e	11	13
13	30	**Magneti Marelli S.p.A.** magnetimarelli.com	5,372 f	4,911 f	12	28
14	28	**Gestamp Automocion SA** gestamp.com	5,234	4,755	13	27
15	23	**Schaeffler AG** schaeffler.com	4,312 e	4,572 e	14	24
16	4	**Denso Corp.** globaldenso.com	4,036 fe	4,212 fe	16	2
17	36	**Brose Fahrzeugteile GmbH** brose.com	3,738	3,429	20	38
18	29	**BorgWarner Inc.** borgwarner.com	3,737	3,570	18	32
19	35	**HELLA KGaA Hueck & Co.** hella.com	3,657 fe	3,551 fe	19	36
20	40	**Plastic Omnium Co.** plasticomnium.com	3,188	3,094	22	37
21	52	**Eberspaecher Gruppe GmbH** eberspaecher.com	3,128 e	2,560 e	27	55
22	22	**Autoliv Inc.** autoliv.com	3,049	2,905	24	19
23	6	**Hyundai Mobis** mobis.co.kr	2,886 f	2,640 f	25	6
24	41	**Samvardhana Motherson Group** motherson.com	2,885 f	2,544 f	26	40
25	34	**GKN** gkn.com	2,807	2,926	23	30
26	31	**Visteon Corp.** visteon.com	$2,703	$2,232	30	31
27	27	**Tenneco Inc.** tenneco.com	2,526 e	2,389 e	–	–
28	43	**IAC Group** iacgroup.com	2,301	2,184	32	42
29	5	**Aisin Seiki Co.** aisin.co.jp	2,246 fe	2,224 fe	31	5
30	59	**Leoni AG** leoni.com	2,244 f	2,560 f	29	56
31	19	**JTEKT Corp.** jtekt.co.jp	2,016 fe	1,476 f	38	17
32	39	**Dana Holding Corp.** dana.com	1,985	1,963	36	34
33	67	**Honeywell** honeywell.com	1,888	2,059	33	61
34	57	**Federal-Mogul Corp.** federalmogul.com	1,824 e	2,058 e	34	50
35	42	**Mitsubishi Electric Corp.** mitsubishielectric.com	1,800 fe	1,603 fe	–	41
36	66	**Grupo Antolin** grupoantolin.com	1,745	2,030	35	57
37	80	**KSPG AG** kspg.com	1,715 e	2,353 e	28	59
38	47	**Goodyear Tire & Rubber Co.** goodyear.com	1,700 e	1,400 e	41	52
39	63	**Webasto SE** webasto.com	1,512 f	1,414 f	37	58
40	75	**CIE Automotive SA** cieautomotive.com	1,465	1,147	47	75
41	51	**Nemak** nemak.com	1,446	1,455	40	48
42	76	**Leopold Kostal GmbH** kostal.com	1,434 fe	1,396 f	42	72
43	48	**Takata Corp.** takata.com	1,372 f	1,307 f	44	44
44	82	**TrelleborgVibracoustic** tbvc.com	1,364 e	1,318 e	45	81
45	61	**TI Automotive** tiautomotive.com	1,353 e	1,312 e	43	63
46	97	**Georg Fischer Automotive AG** gfau.com	1,345	1,406	39	93
47	65	**Infineon Technologies AG** infineon.com	1,301 e	1,133 e	48	78
48	21	**Panasonic Automotive Systems Co.** panasonic.net	1,157 fe	831 fe	–	23
49	62	**Cooper-Standard Automotive** cooperstandard.com	1,135 fe	1,082 fe	49	67
50	20	**CalsonicKansei Corp.** calsonickansei.co.jp	1,077 fe	858 fe	–	21

Figure 94: Top 100 global OEM parts suppliers (Crain Communications, 2015)

Top 100 global OEM parts suppliers – Ranked by sales of original equipment parts in 2014

2014 rank	Company	Address	Executive	Total global OEM automotive parts sales (dollars in millions) 2014	Total global OEM automotive parts sales (dollars in millions) 2013	Percent North America 2014	Percent Europe 2014	Percent Asia 2014	Percent rest of world 2014	Products	2013 rank
1	**Robert Bosch GmbH** (49) 711-811-0; bosch.com	Postfach 106050 Stuttgart D-70049, Germany	Volkmar Denner chairman	$44,240 e	$40,183 e	19	50	28	3	Gasoline systems, diesel systems, chassis system controls, electrical drives, starter motors & generators, car multimedia, electronics, steering systems, battery technology, exhaust gas turbochargers & treatment systems, service solutions	1
2	**Magna International Inc.*** (905) 726-2462; magna.com	337 Magna Drive Aurora, Ontario L4G7K1, Canada	Donald Walker CEO	36,325	34,375	54	39	5	2	Body, chassis, interior, exterior, seating, powertrain, electronic, vision, closure & roof systems & modules; vehicle engineering & contract manufacturing	3
3	**Continental AG** (49) 511-938-01; conti-online.com	Vahrenwalder Strasse 9 Hanover 30165, Germany	Elmar Degenhart CEO	34,418 e	33,500	23	49	25	3	Electronic brakes, stability management systems, tires, foundation brakes, chassis systems, safety system electronics, telematics, powertrain electronics, interior modules, instrumentation, technical elastomers	4
4	**Denso Corp.** (81) 566-25-5511; globaldenso.com	1-1 Showa-cho Kariya, Aichi 448-8661, Japan	Nobuaki Katoh chairman	32,365 fe	35,849 fe	22	12	64	2	Thermal, powertrain control, electronic & electric systems; small motors, telecommunications	2
5	**Aisin Seiki Co.** (81) 566-24-8441; aisin.co.jp	2-1 Asahi-Machi Kariya, Aichi 448-8650, Japan	Fumio Fujimori president	28,072 fe	27,125 fe	18	8	73	1	Body, brake & chassis systems, electronics, drivetrain, & engine components	5
6	**Hyundai Mobis** (82) 2-2018-5114; mobis.co.kr	679-4 SI Tower, Yeoksam1-dong, Gangnam-gu, Seoul 135-977, Korea	Myung-Chul Chung president & CEO	27,405 f	24,677 f	20	11	68	1	Chassis, cockpit & front-end modules; ABS, ESC, MDPS, airbags, LED lamps, ASV parts, sensors, electronic control systems, hybrid car powertrains, parts & power control units	6
7	**Faurecia** (33) 1-72-36-70-00; faurecia.com	2 Rue Hennape Nanterre 92735, France	Yann Delabriere chairman & CEO	25,043	23,958	25	56	14	5	Seating, emissions, control technologies, interior systems & exteriors	7
8	**Johnson Controls Inc.** (414) 524-1200; johnsoncontrols.com	5757 N. Green Bay Ave. Milwaukee, WI 53201, USA	Alex Molinaroli chairman & CEO	23,589 f	23,440 f	48	39	11	2	Complete automotive seats & seat components, lead acid & hybrid vehicle batteries	8
9	**ZF Friedrichshafen AG** (49) 7541-77-0; zf.com	Graf-von-Soden-Platz 1, Friedrichshafen, Baden-Wuerttemberg 88046, Germany	Stefan Sommer CEO	22,192 f	20,434 f	20	56	20	4	Transmissions, chassis components & systems, steering systems, clutches, dampers	9
10	**Lear Corp.** (248) 447-1500; lear.com	21557 Telegraph Road Southfield, MI 48033, USA	Matthew Simoncini president & CEO	17,727	16,234	38	40	17	5	Seating & electrical distribution systems	10
11	**Valeo SA** (33) 1-40-55-20-20; valeo.com	43 Rue Bayen Paris 75017, France	Jacques Aschenbroich CEO	16,878 e	13,886 e	20	49	28	3	Micro hybrid systems, electrical & electronic systems, thermal systems, transmissions, wiper systems, camera/sensor technology, security systems, interior controls	14
12	**TRW Automotive Holdings Corp.** (734) 855-2600; trwauto.com	12001 Tech Center Drive Livonia, MI 48150, USA	John Plant chairman, president & CEO	16,240 e	16,147	41	43	12	4	Steering, suspension, braking & engine components; fasteners, occupant-restraint systems, electronic safety & security systems	11
13	**Delphi Automotive** (248) 813-2000; delphi.com	5725 Delphi Drive Troy, MI 48098, USA	Kevin Clark president & CEO	16,002 e	15,475	35	38	23	4	Mobile electronics; powertrain, safety, thermal controls & security systems; electrical/electronic architecture, in-car entertainment technologies	13
14	**Yazaki Corp.** (81) 0559-65-3002; yazaki-group.com	1500 Mishuku, Susono City, Shizuoka Prefecture 410-1194, Japan	Yasuhiko Yazaki chairman	15,200 e	15,600 e	25	–	–	–	Wiring harnesses, connectors, junction boxes, power distribution boxes, instrumentation, high voltage systems	12
15	**ThyssenKrupp AG** (49) 201-8440; thyssenkrupp.com	ThyssenKrupp Allee 1 Essen 45143, Germany	Heinrich Hiesinger CEO	12,801 f	12,349 f	23	–	–	–	Steering, dampers, springs & stabilizers, camshafts, forged machined components, bearings, undercarriage systems & components, axle assembly, assembled camshafts, forged crankshafts & drivetrain components; high-strength, lightweight steel, electrical steel, tailored tempering, cell & battery production lines, valve control systems	–
16	**BASF SE** (49) 621-60-0; basf.com	Carl-Bosch-Strasse 38 Ludwigshafen 67056 Germany	Kurt Bock chairman	12,682 f	12,351 f	21	57	16	6	Coatings, catalysts, engineering plastics, polyurethanes, coolants, brake fluids, lubricants, battery materials	16
17	**Sumitomo Electric Industries** (81) 6-6220-4141; sei.co.jp	5-33 Kitahama, 4-chome, Chuo-ku Osaka City 541-0041, Japan	Masayoshi Matsumoto president & CEO	12,325 fe	13,127 f	26	–	–	–	Electrical distribution systems, electronics, connection systems	15
18	**Mahle GmbH** (49) 711-501-0; mahle.com	Pragstrasse 26-46 Stuttgart 70376, Germany	Wolf-Henning Scheider chairman	12,118 f	8,506 f	22	54	17	7	Piston systems, cylinder components, valvetrain systems, air & liquid management systems, powertrain engineering, vehicle climatization, climate compressors, engine & powertrain cooling, drives, starters & alternators, electrical driven auxiliaries	22
19	**JTEKT Corp.** (81) 52-527-1900; jtekt.co.jp	15th Floor, Midland Square, 4-7-1 Meieki Nakamura-ku, Nagoya 450-8515, Japan	Tetsuo Agata president	11,200 fe	11,351 f	23	18	58	1	Bearings, steering systems, driveline systems & machine tools	17
20	**CalsonicKansei Corp.** (81) 3-5385-0111; calsonickansei.co.jp	2-1917 Nisshin-cho, Kita-ku Saitama City, Saitama 331-8501, Japan	Hiroshi Moriya president, CEO & COO	9,789 fe	8,580 fe	32	11	21	36	Climate control, engine cooling & exhaust systems, instrument clusters, console boxes, instrument panels, cockpit & front-end modules	21

Figure 95: Ranking of the world's leading car manufacturers as of August 31, 2014, based on revenue (Statista, 2016)

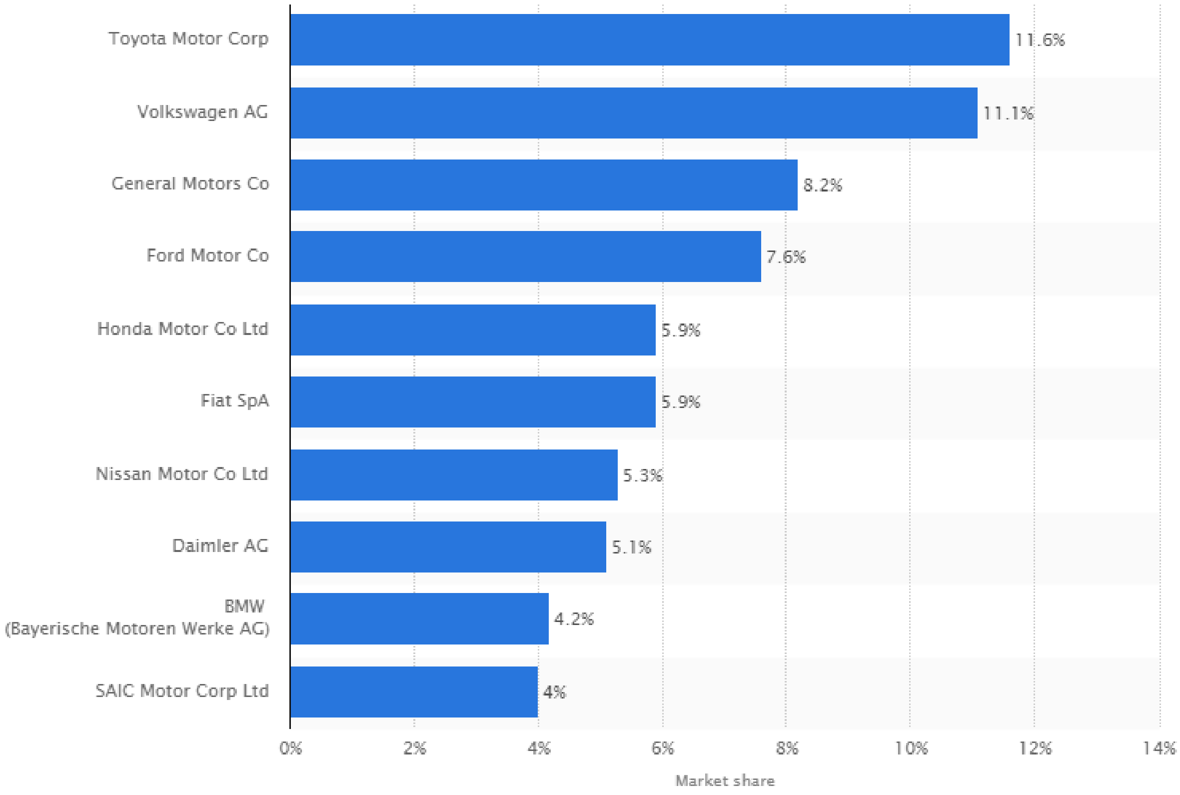
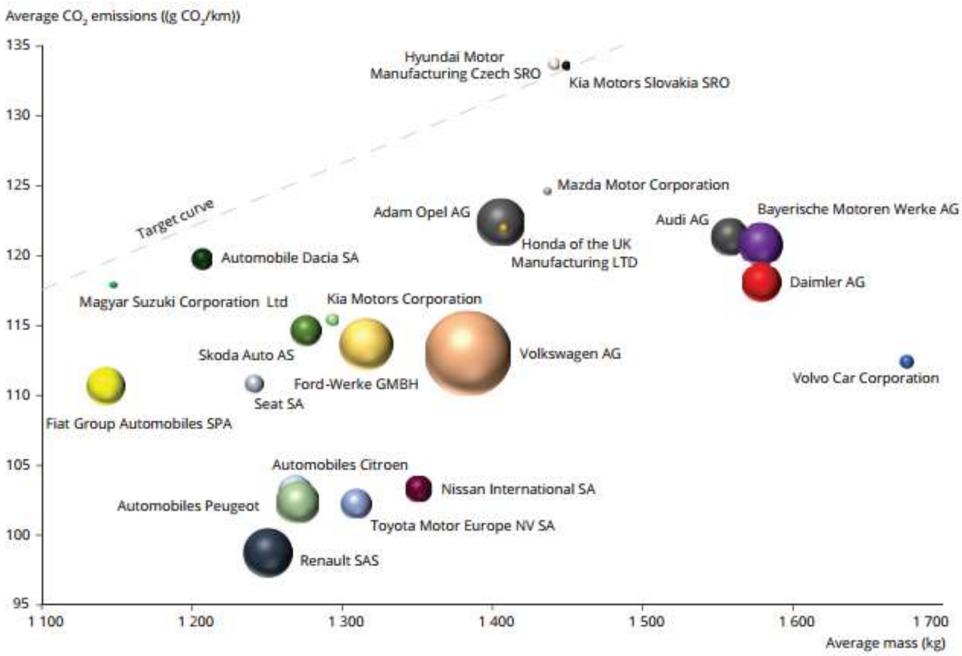
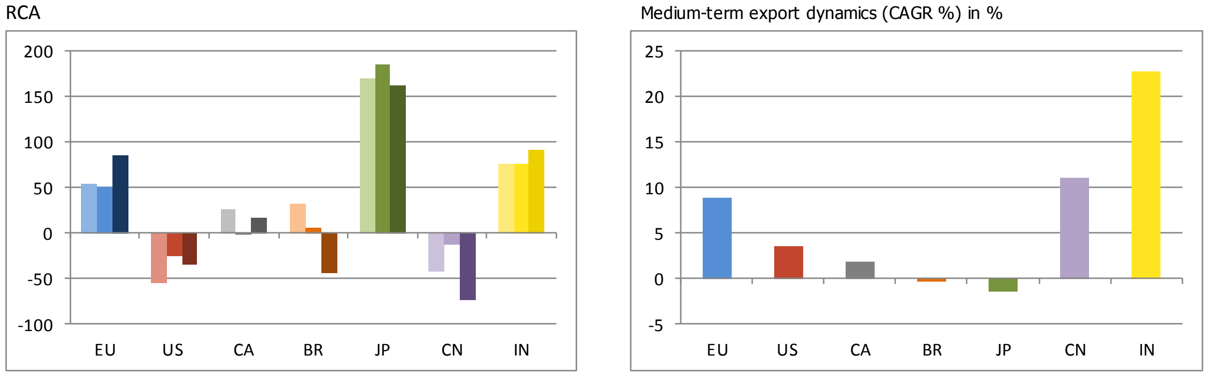


Figure 96: Distance to 2014 target by individual manufacturer (European Environment Agency, 2015)



Annex 5/ Comparative advantage - Technologies to realise efficiency gains in ICE powered vehicles

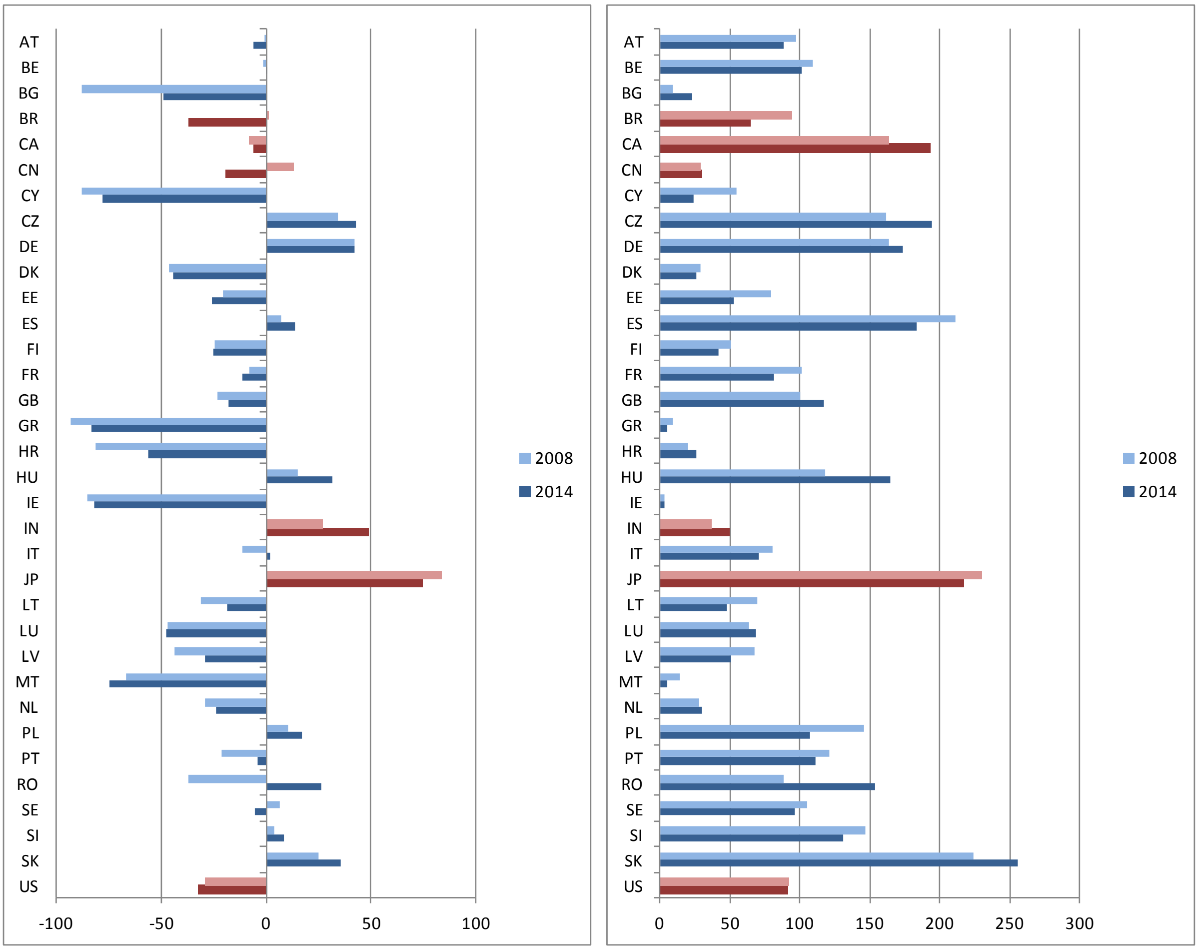
Figure 97: RCA and medium term-export dynamics for the EU-28 and selected other countries: Vehicles



EU-Extra-trade only. -

Source: UN COMTRADE-Database. – NIW calculation.

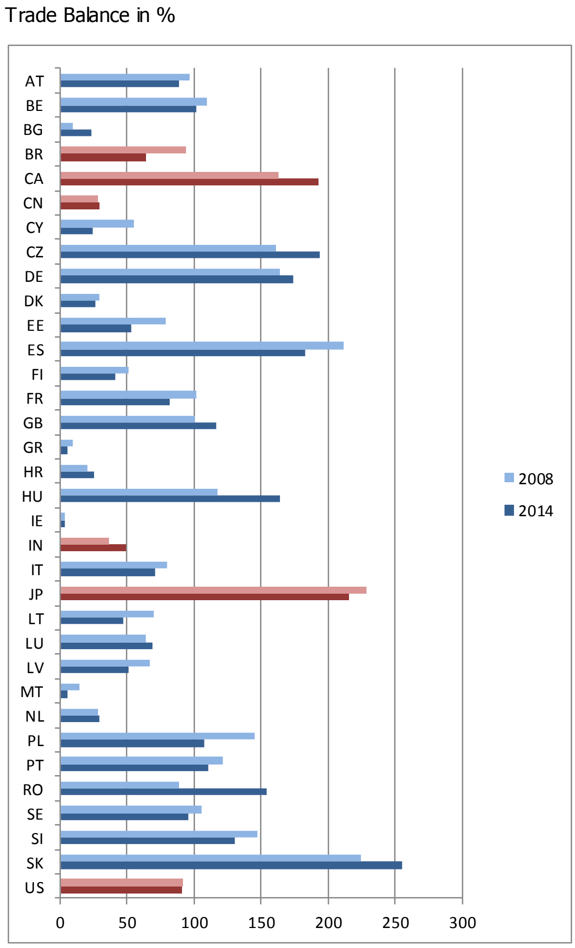
Figure 98: Export market share (in %) and RXA for the EU Member States and selected other countries 2008 and 2014: Vehicles

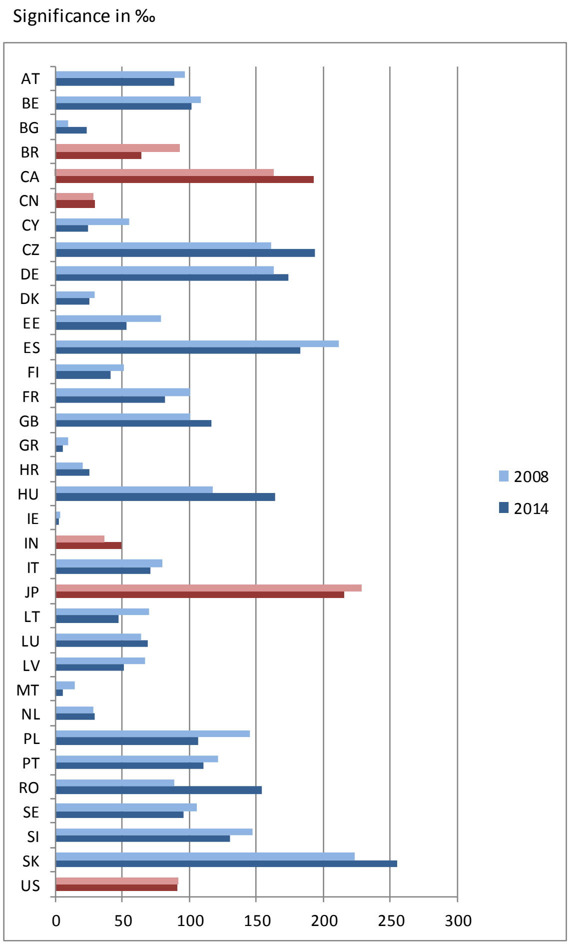


Including EU-Intra-trade.

Source: UN COMTRADE-Database. – NIW calculation.

Figure 99: Trade Balance and Significance for the EU Member States and selected other countries 2008 and 2014: Vehicles



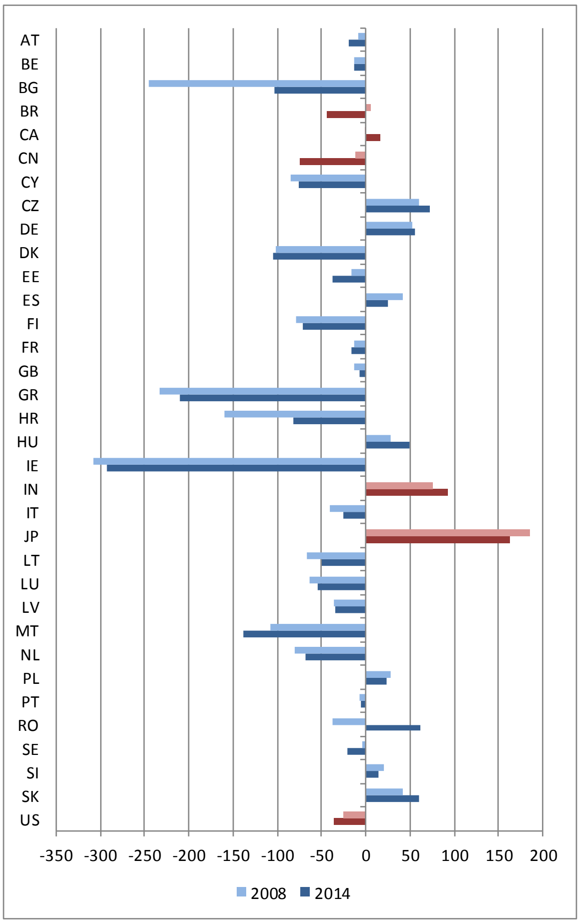


Including EU-Intra-trade.

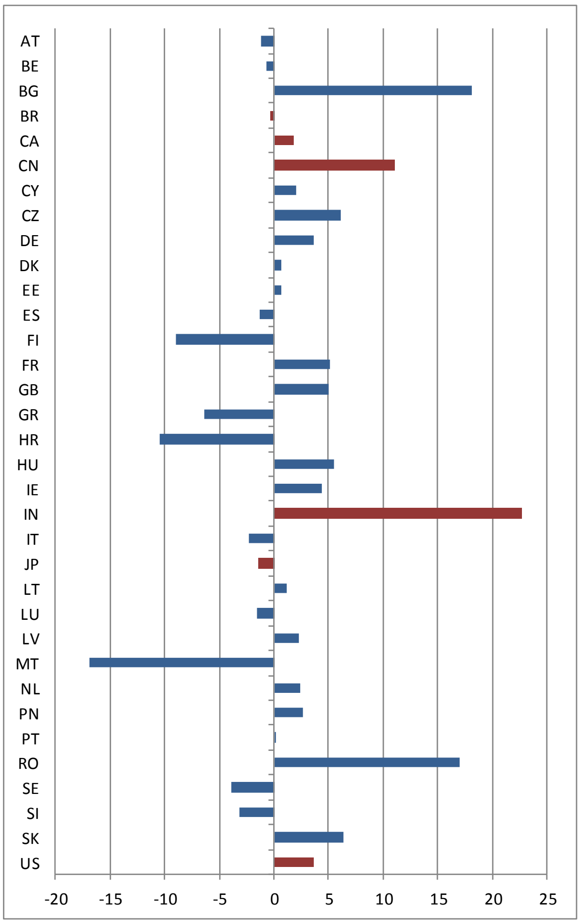
Source: UN COMTRADE-Database. – NIW calculation.

Figure 100: RCA 2008 and 2014 and Medium-term dynamics 2007/08 to 2013/14 for the EU Member States and selected other countries: Vehicles

RCA



Medium-term dynamics (CAGR in %)

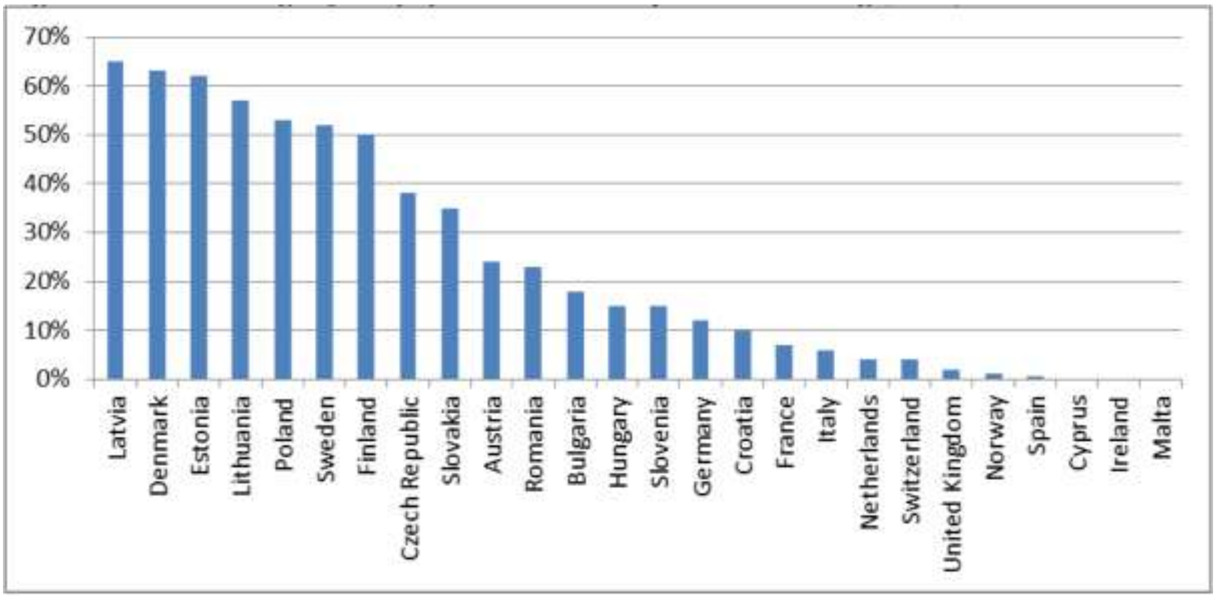


Including EU-Intra-trade.

Source: UN COMTRADE-Database. – NIW calculation.

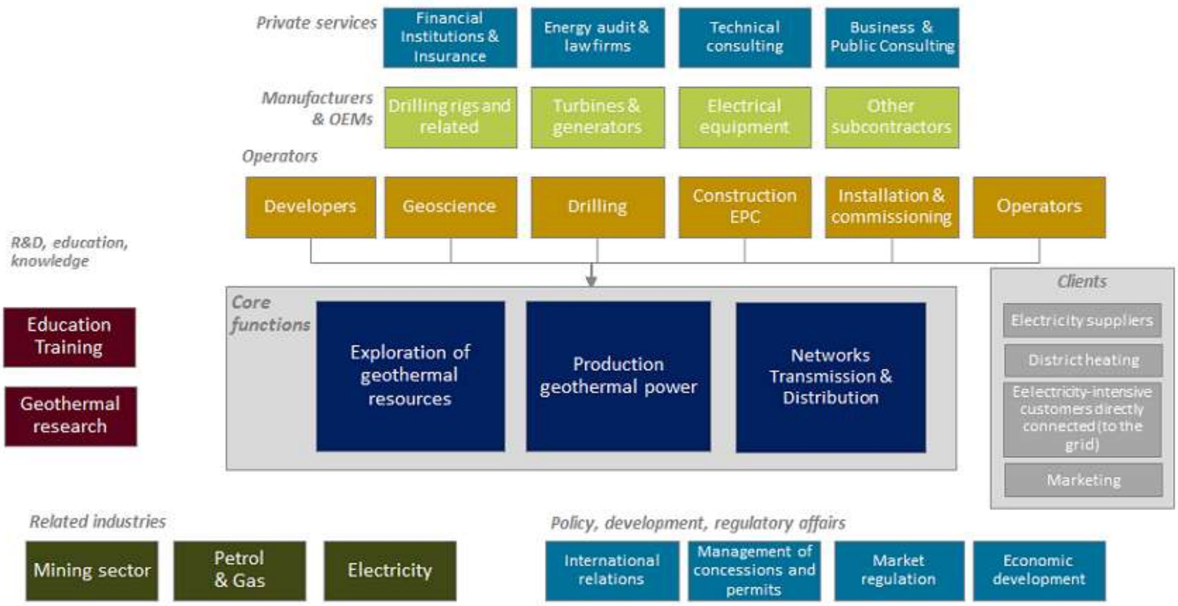
Annex 6/ General figures and tables - District Heating and Cooling

Figure 101 Percentage of the Population Served by District Heating (2013)



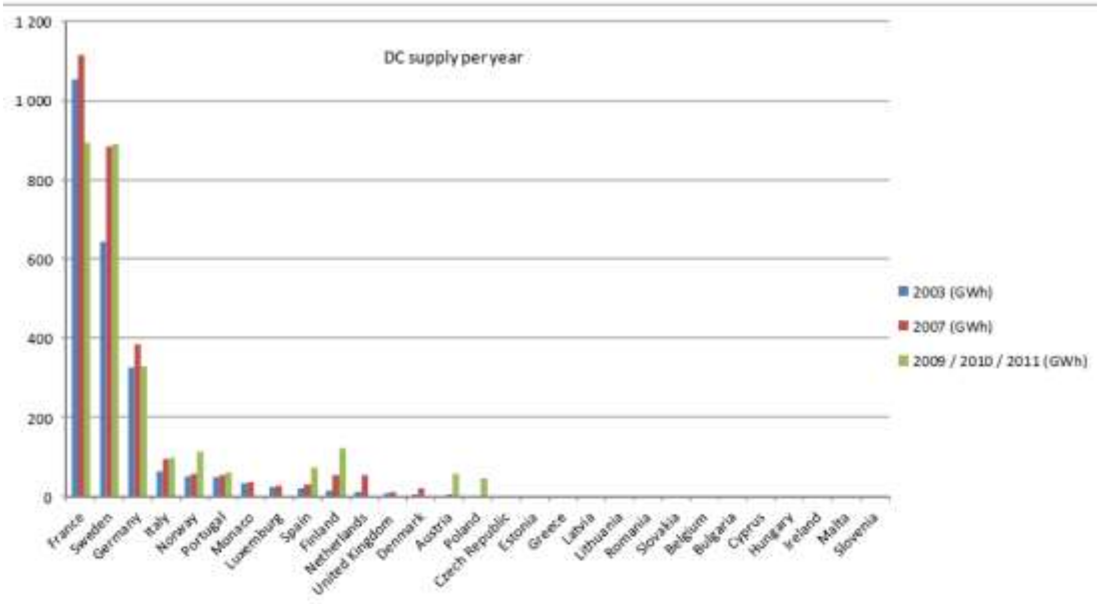
Source: EU Commission (2016), Strategy on Heating and Cooling, Commission Staff Working Document Part 1, p. 88, Figure 5-1.

Figure 102: Industry Overview of Geothermal District Heating



Source: GeoElec (2013), p. 7, figure 1.

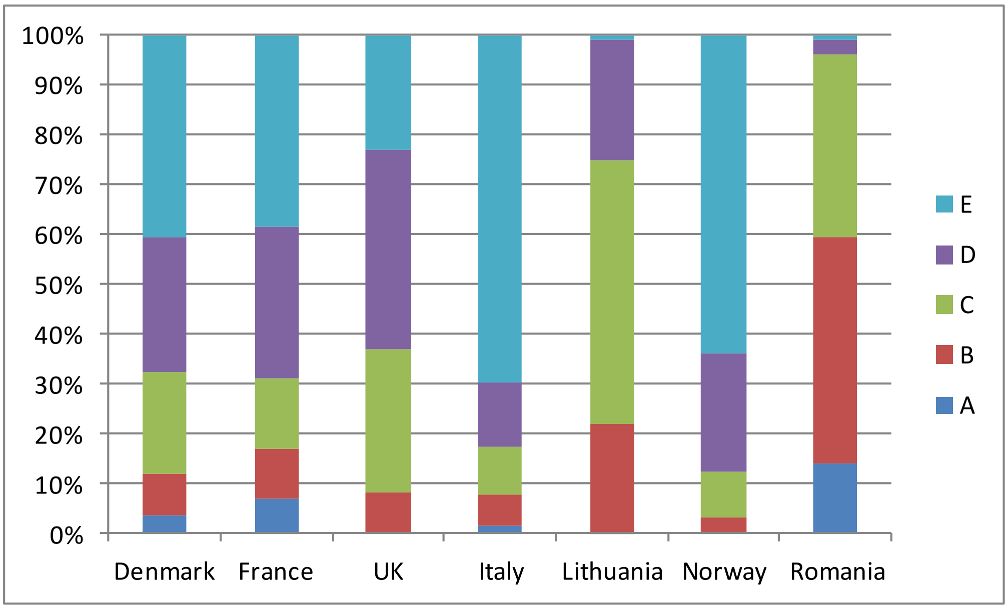
Figure 103: DC Supply in the EU



Source: RESCUE (2013), p.20.

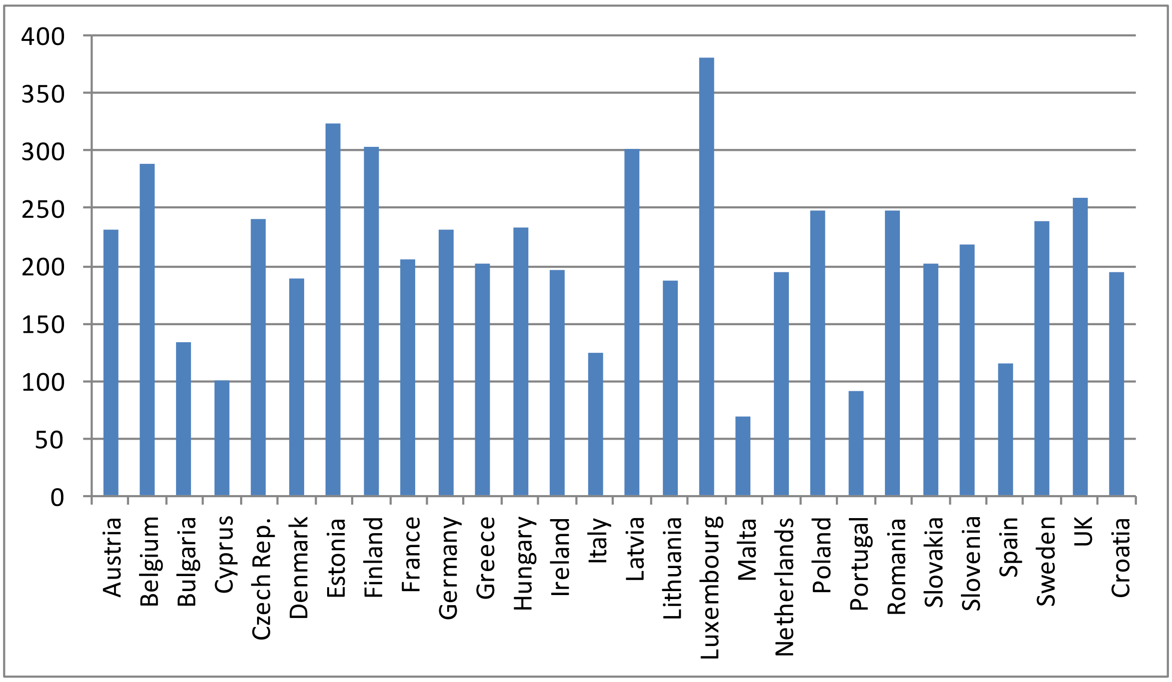
Annex 7/ General figures and tables - NZEBs

Figure 104: Distribution of EPC in existing registered dwellings by label in selected MS in 2013



Source: Zebra2020 Data Tool.

Figure 105: Total unit consumption (all end uses) per m² in residential buildings (at normal climate) in kWh, 2008

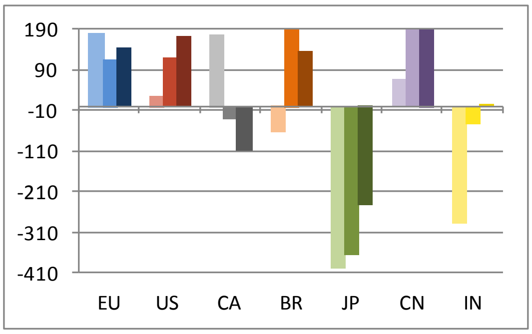


Source: Entranze data

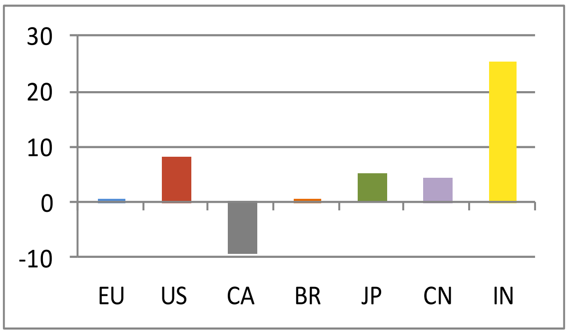
Annex 8/ Comparative advantage - NZEBs

Figure 106: RCA and medium term-export dynamics 2007/08 to 2013/14 for the EU-28 and selected other countries: Prefabricated buildings of wood

RCA



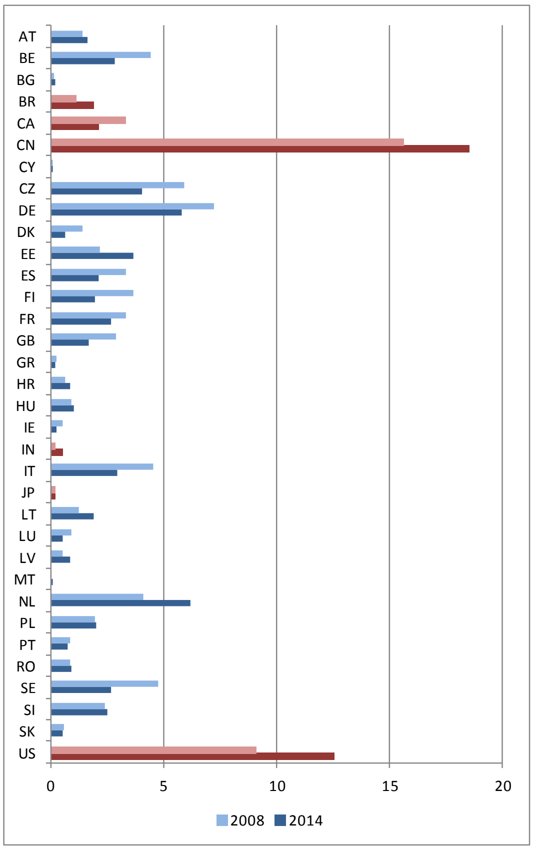
Medium-term export dynamics (CAGR %) in %



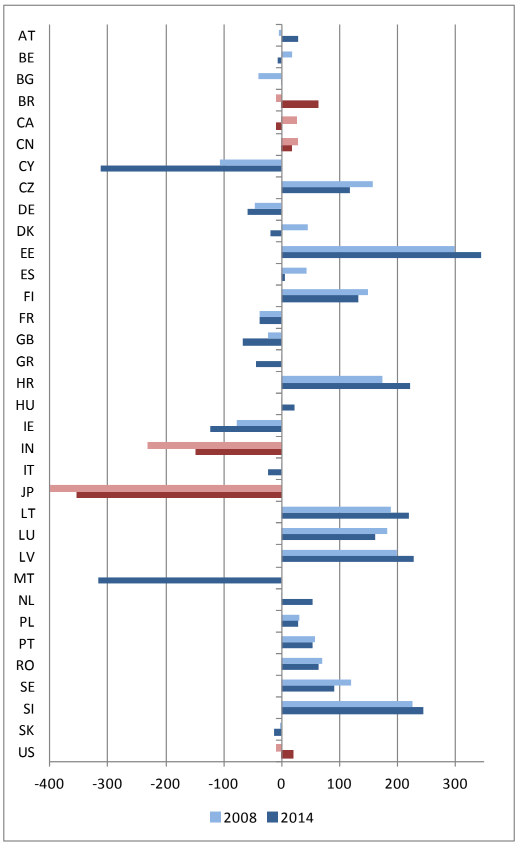
Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 107: Export market share (in %) and RXA for the EU Member States and selected other countries 2008 and 2014: Prefabricated buildings of wood

Export market share (in %)



RXA

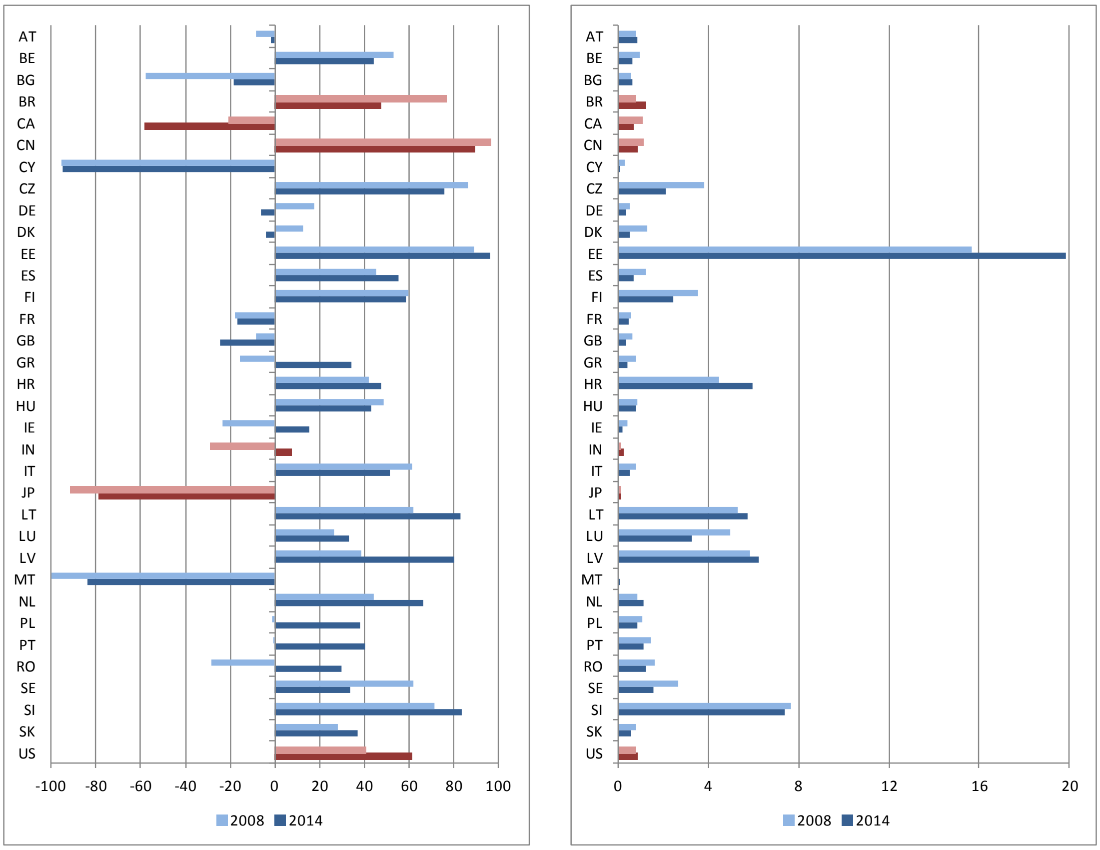


Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 108: Trade Balance and Significance for the EU Member States and selected other countries 2008 and 2014: Prefabricated buildings of wood

Trade Balance in %

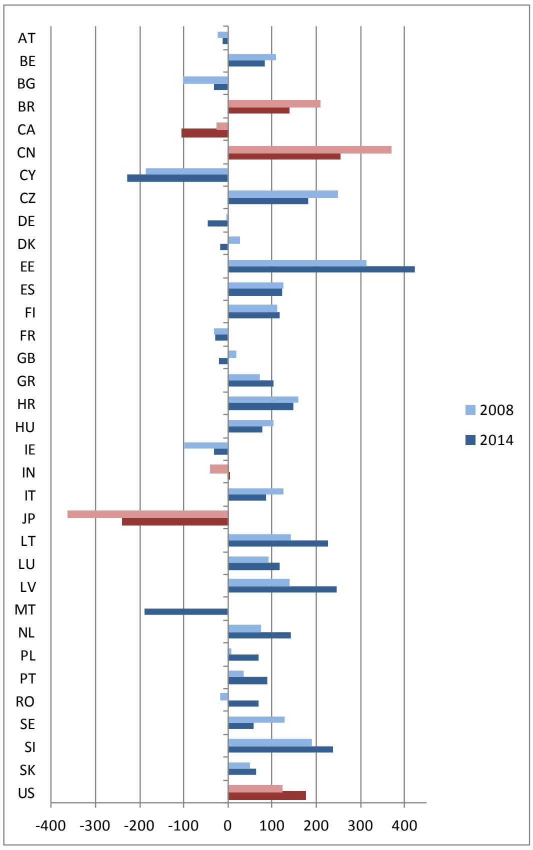
Significance in ‰



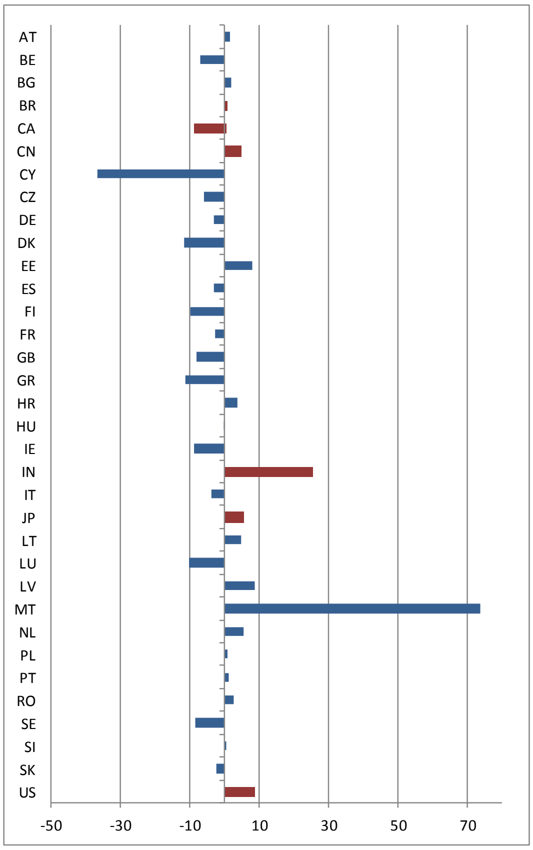
Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 109: RCA 2008 and 2014 and Medium-term dynamics 2007/08 to 2013/14 for the EU Member States and selected other countries: Prefabricated buildings of wood

RCA



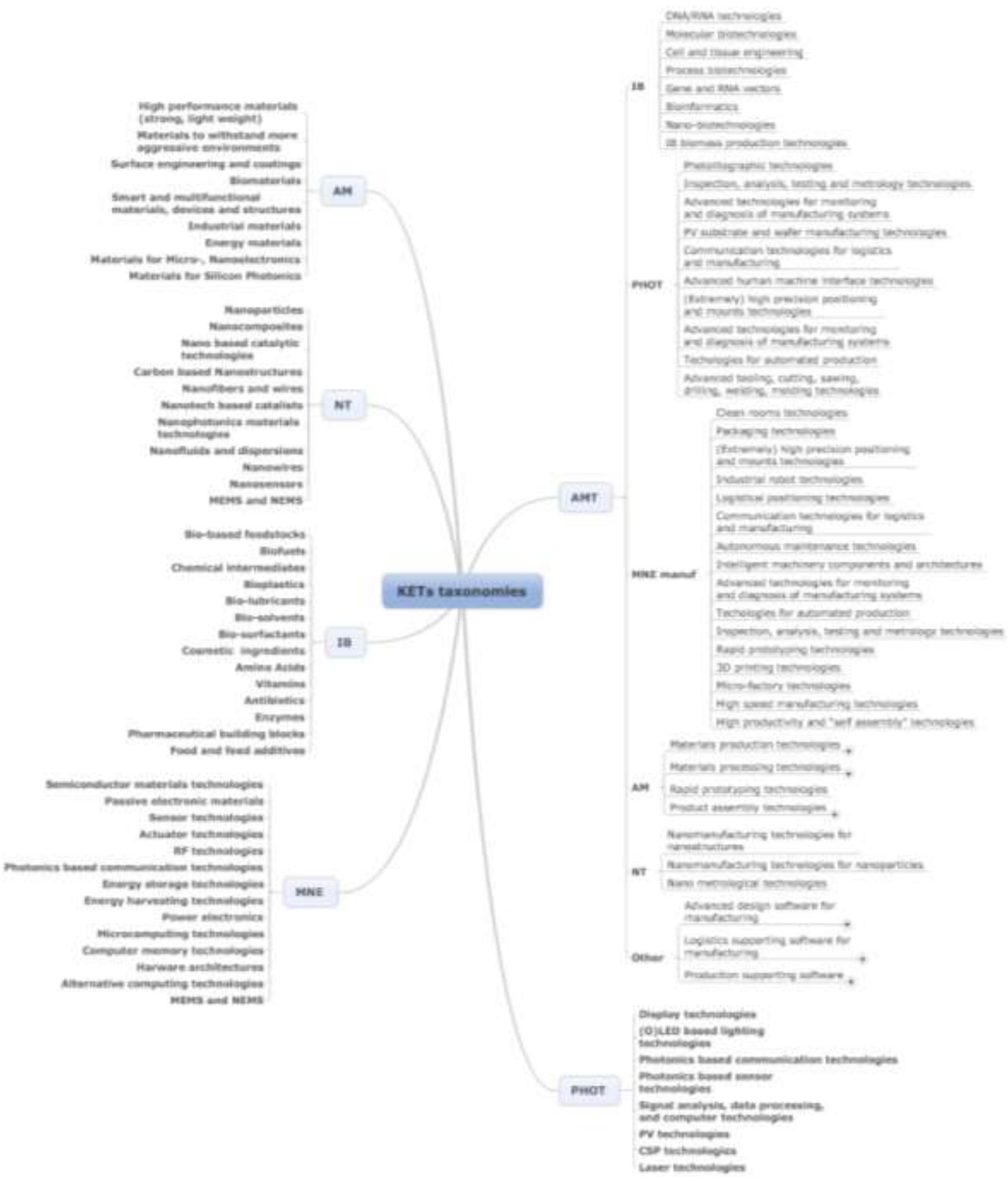
Medium-term dynamics (CAGR in %)



Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

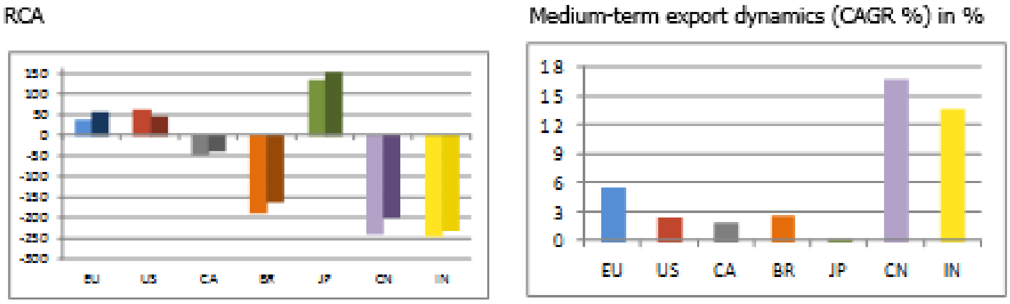
Annex 9/ KETs taxonomy – Advanced Manufacturing Technologies

Figure 110: KETs Taxonomy



Annex 10/ Comparative advantage - Advanced Manufacturing Technologies

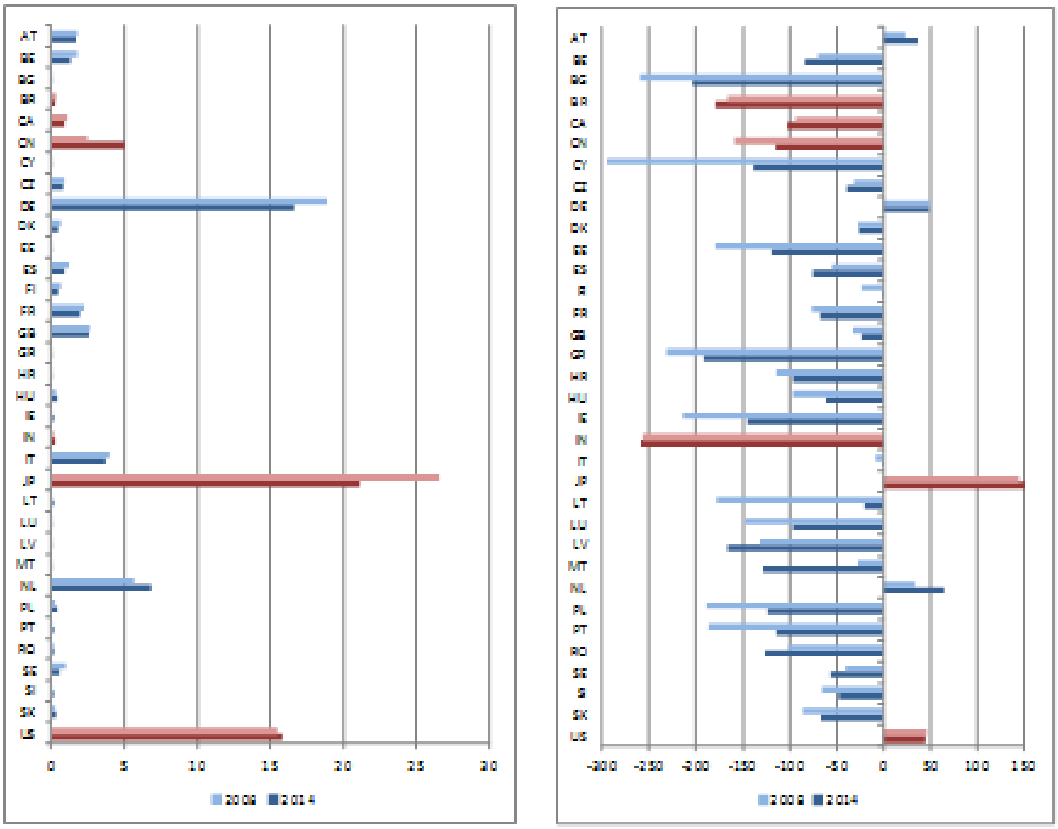
Figure 111: RCA and medium term-export dynamics 2007/08 to 2013/14 for the EU-28 and selected other countries: AMT



Regarding EU-Extra-trade only. Source: UN COMTRADE-Database – NIW calculation.

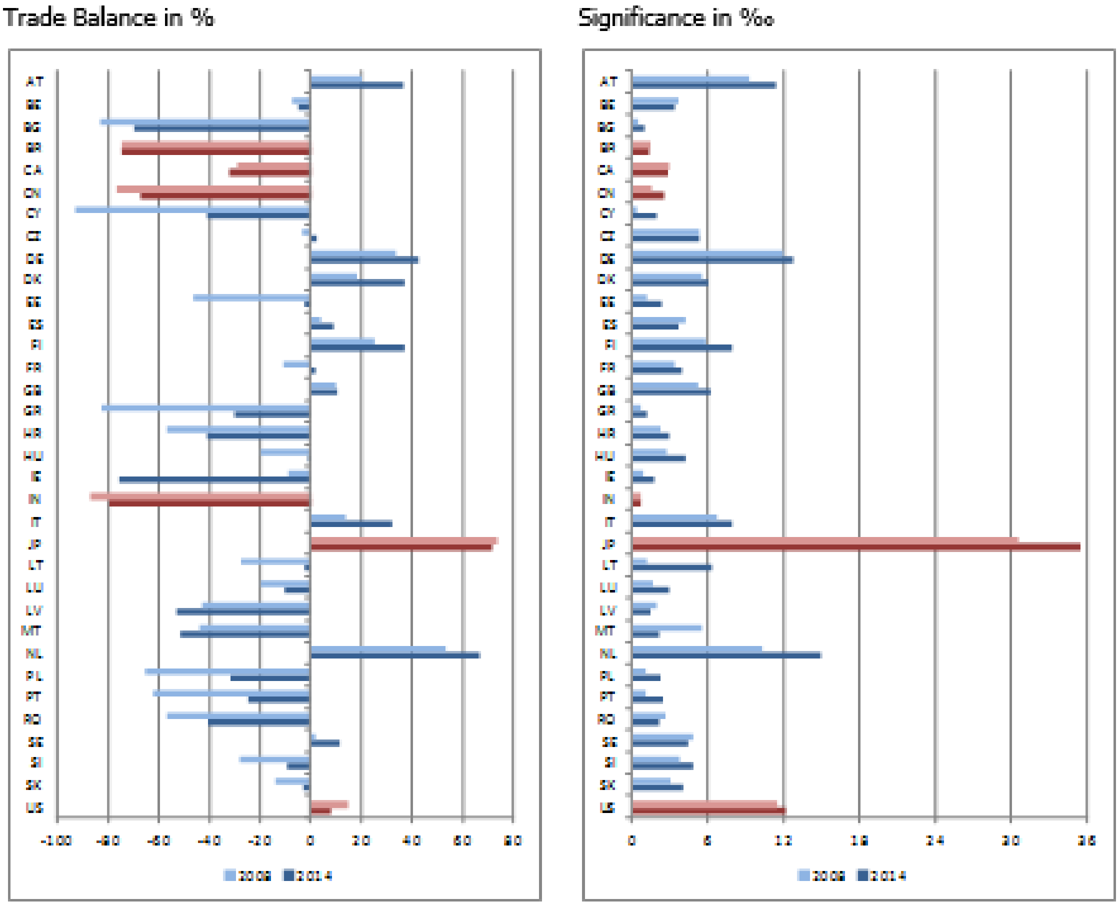
Figure 112: Export market share (in %) and RXA for the EU Member States and selected other countries 2008 and 2014: AMT

Export market share (in %) RXA



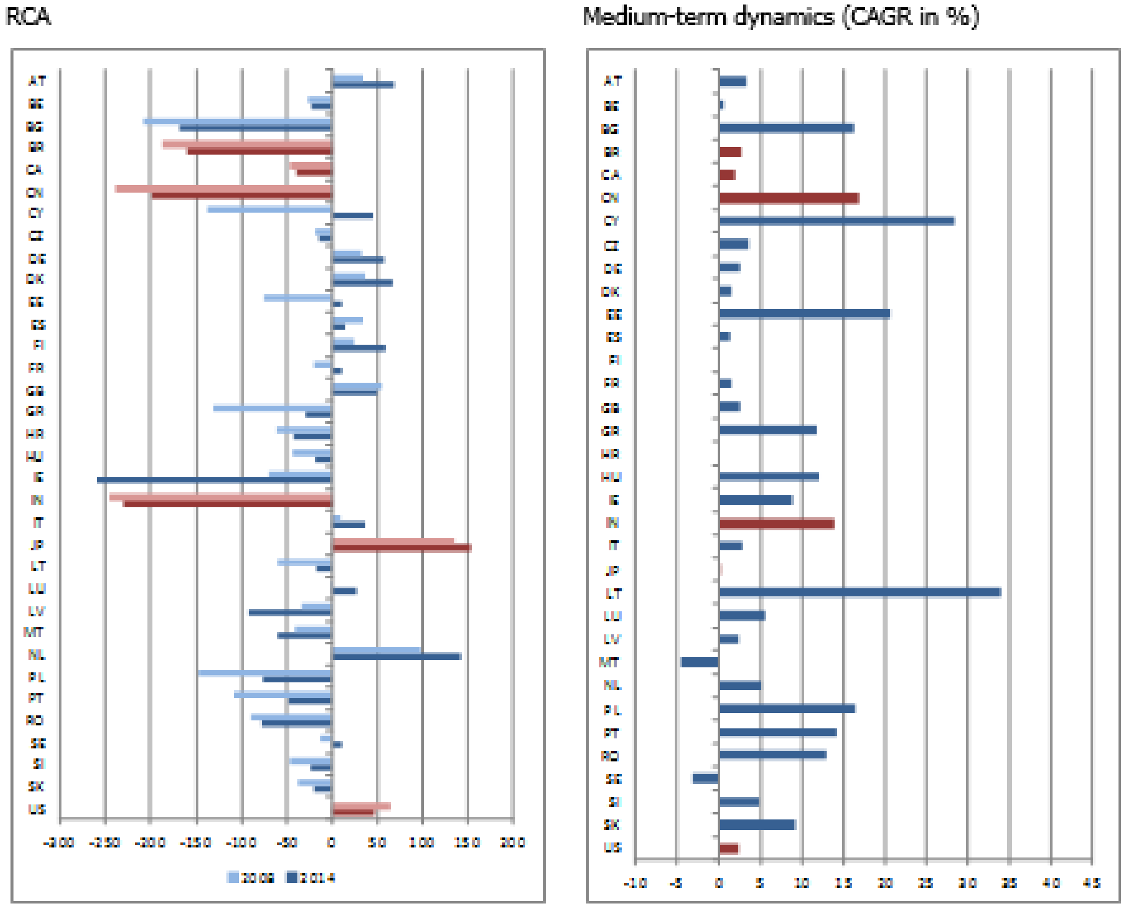
Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 113: Trade Balance and Significance for the EU Member States and selected other countries 2008 and 2014: AMT



Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 114: RCA 2008 and 2014 and Medium-term dynamics 2007/08 to 2013/14 for the EU Member States and selected other countries: AMT



Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

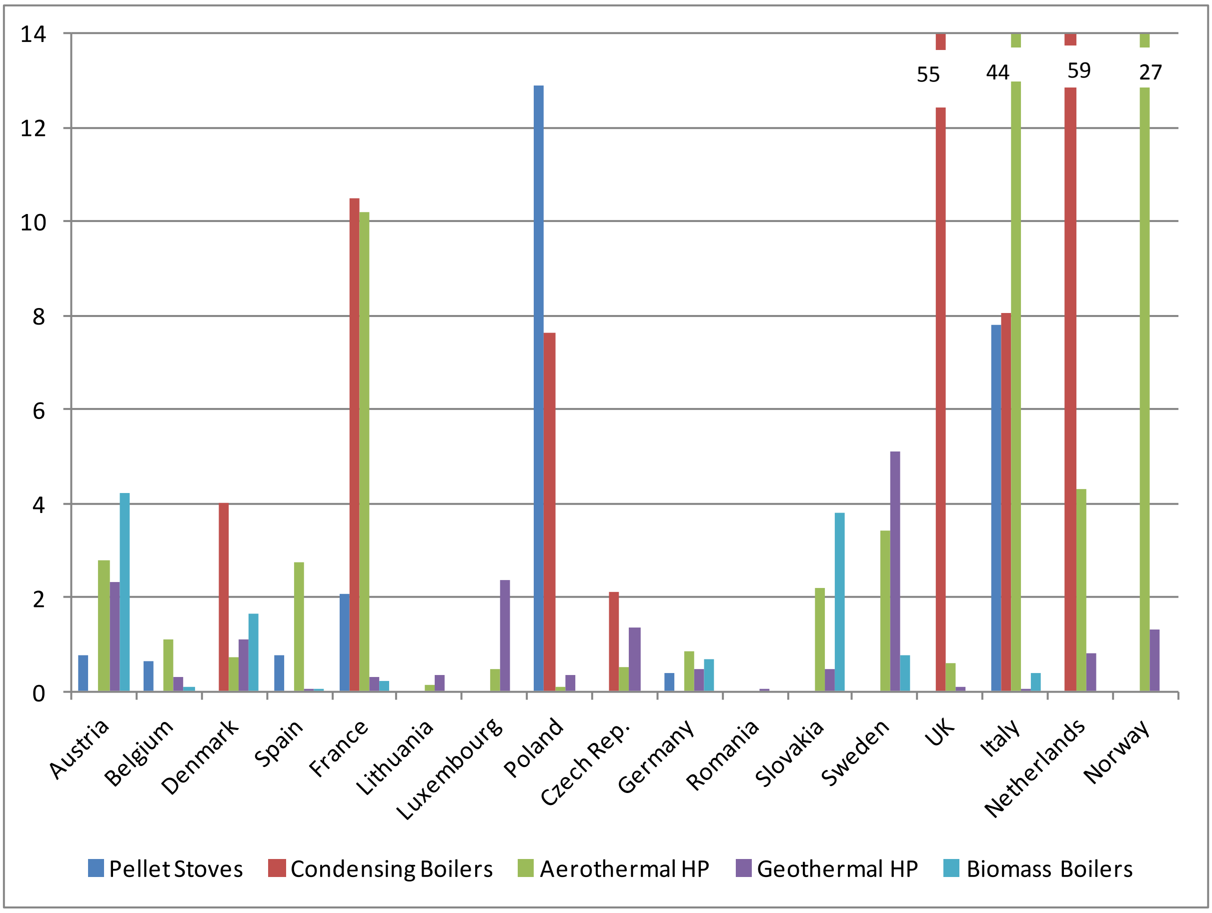
Annex 11/ General figures and tables – Heating and Cooling Systems

Figure 115: Technologies used for Space Heating (EU-25, 2012)

	EU25 (Thousands)	Italy	UK	Germany	France[46]	Sweden
Non-condensing boilers	(75.784) 64%	87%	44%	71%	80%	12%
Condensing boilers	(31.092) 26%	12%	56%	22%	12%	1%
Biomass boilers	(7.030) 6%	1%	<1%	4%	3%	18%
Heat pumps	(2.712) 2%	<1%	<1%	3%	5%	46%
Other	(1.083) 2%	<1%	<1%	1%	1%	22%

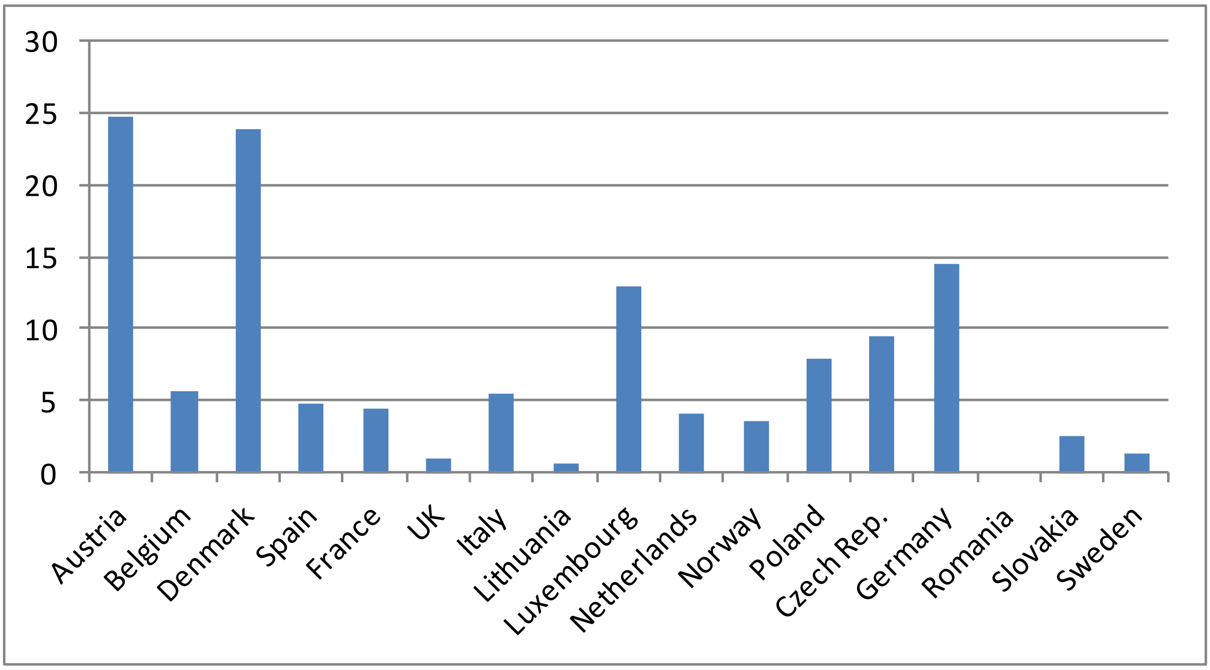
Source: EU Commission (2016) Commission Staff Working Document, Review of available information accompanying the document "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on an EU Strategy for Heating and Cooling", Table 4.1, p. 35.

Figure 116: Share of Heating Equipment Sales per 1000 Dwellings



Source: ZEBRA2020 Data Tool.

Figure 117: Annual Installations of Solar Thermal Systems per Capita (2012)



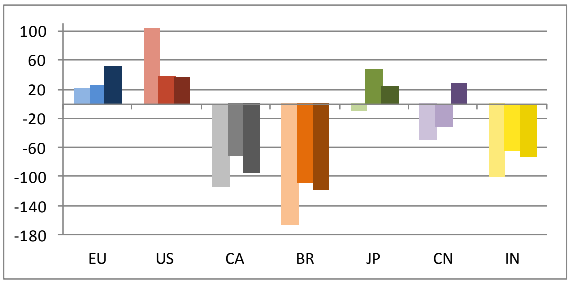
Source: ZEBRA2020 Data Tool.

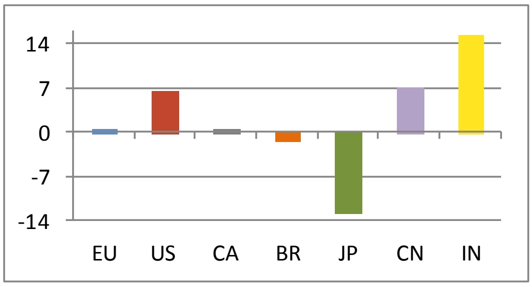
Annex 12/ Comparative advantage – Heating and Cooling Systems

Figure 118: RCA and medium term-export dynamics 2007/08 to 2013/14 for the EU-28 and selected other countries: Heating and Cooling Systems

RCA

Medium-term export dynamics (CAGR %) in %



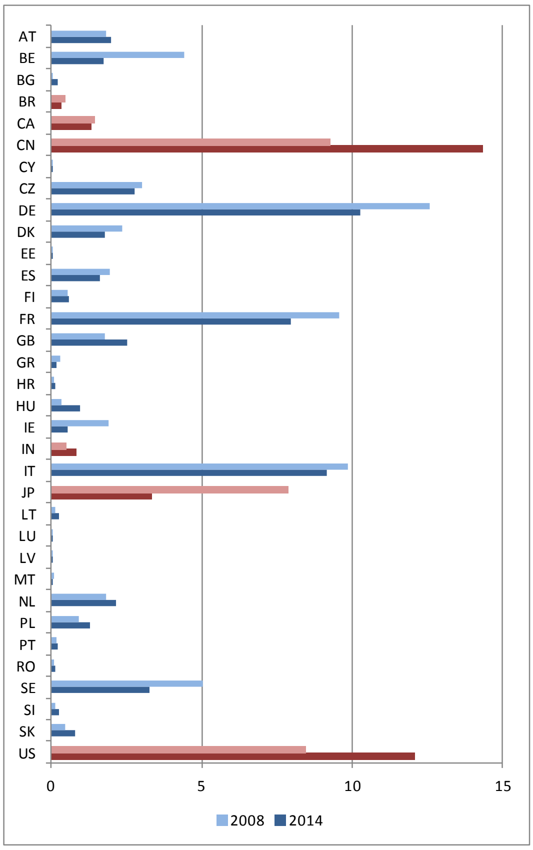


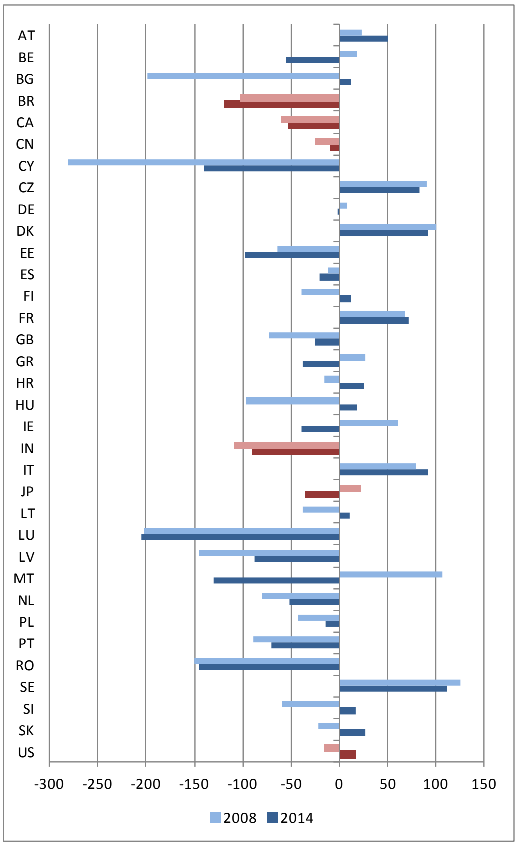
Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 119: Export market share (in %) and RXA for the EU Member States and selected other countries 2008 and 2014: Heating and Cooling Systems

Export market share (in %)

RXA

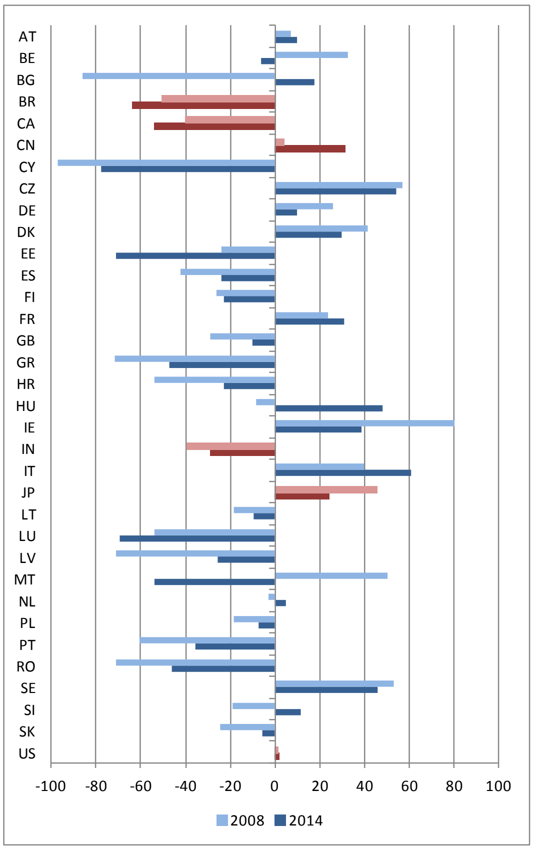




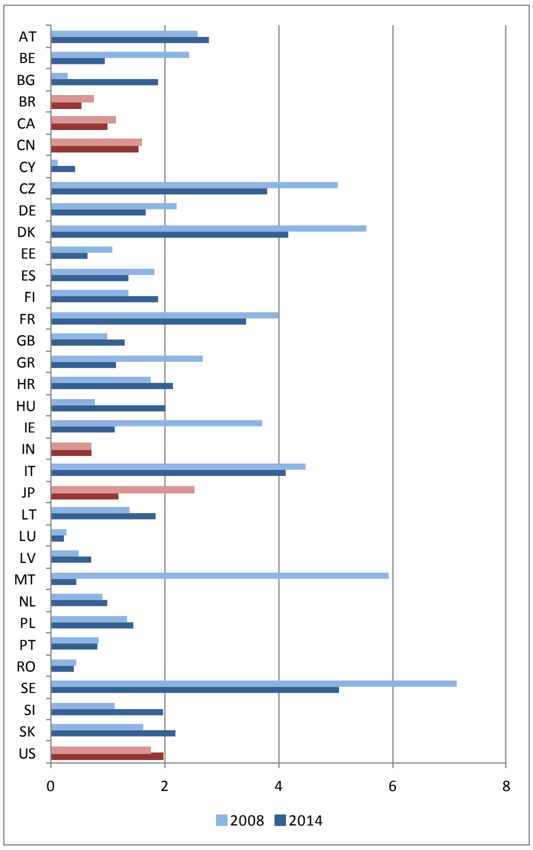
Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 120: Trade Balance and Significance for the EU Member States and selected other countries 2008 and 2014: Heating and Cooling Systems

Trade Balance in %



Significance in ‰

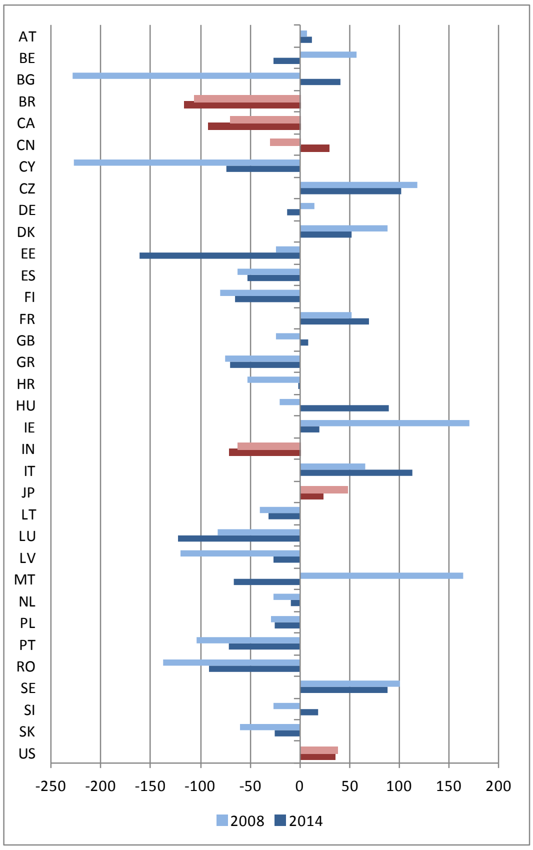


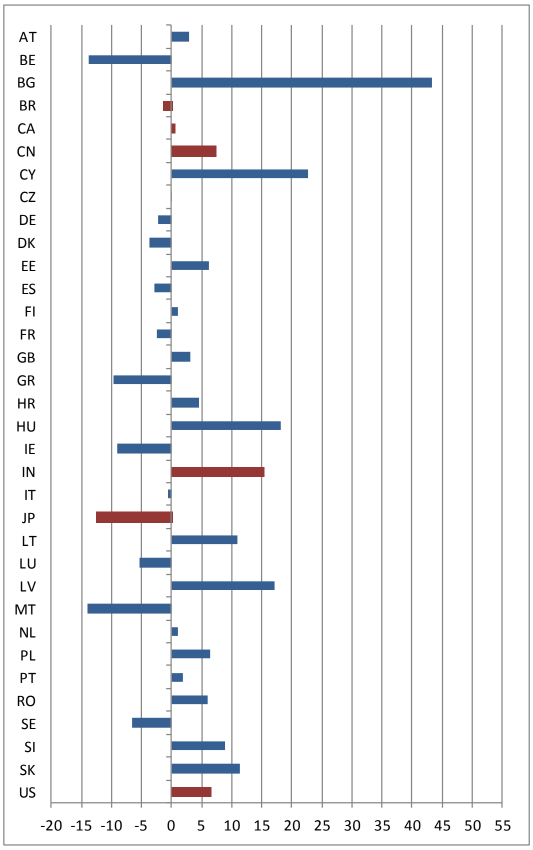
Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 121: RCA 2008 and 2014 and Medium-term dynamics 2007/08 to 2013/14 for the EU Member States and selected other countries: Heating and Cooling Systems

RCA

Medium-term dynamics (CAGR in %)



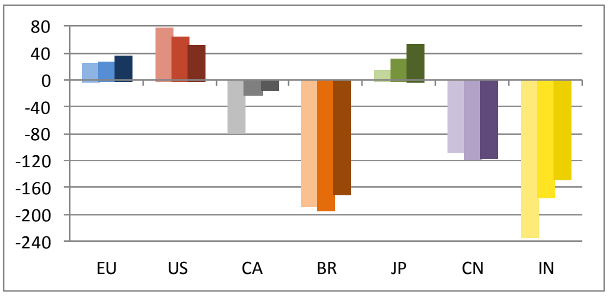


Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

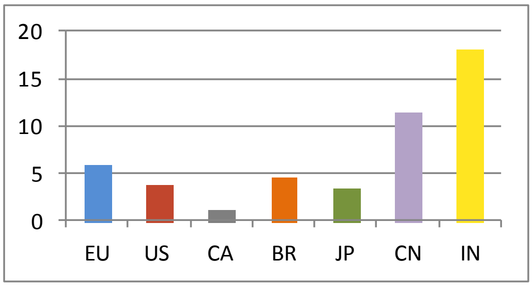
Annex 13/ Comparative advantage – Measuring and Monitoring

Figure 122: RCA and medium term-export dynamics 2007/08 to 2013/14 for the EU-28 and selected other countries: Measuring and Monitoring

RCA



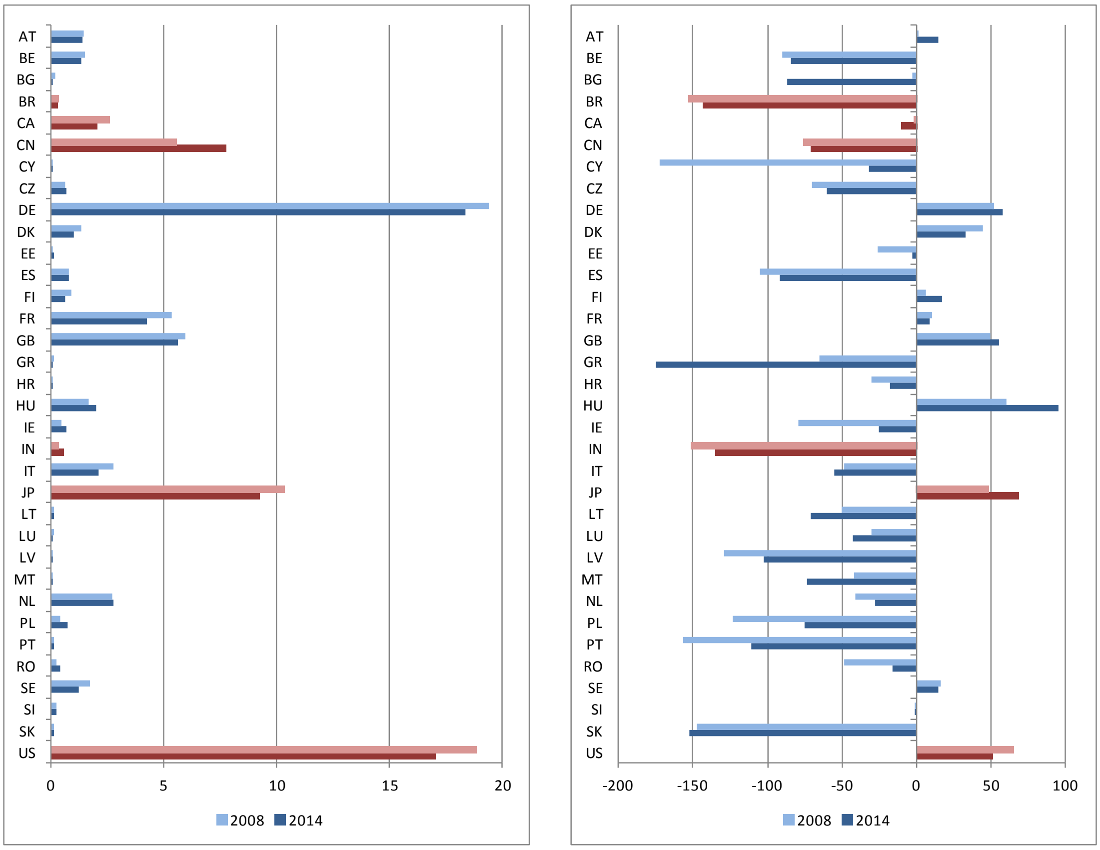
Medium-term export dynamics (CAGR %) in %



Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 123: Export market share (in %) and RXA for the EU Member States and selected other countries 2008 and 2014: Measuring and Monitoring

Export market share (in %) RXA

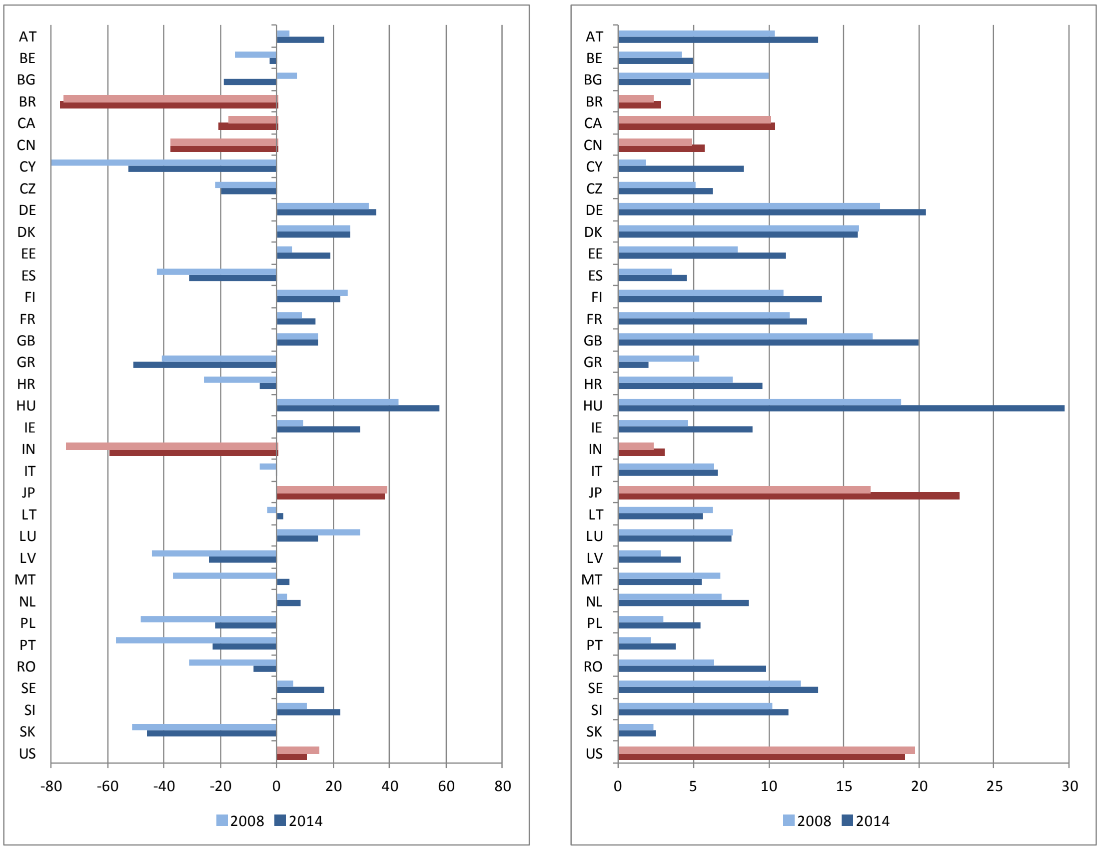


Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 124: Trade Balance and Significance for the EU Member States and selected other countries 2008 and 2014: Measuring and Monitoring

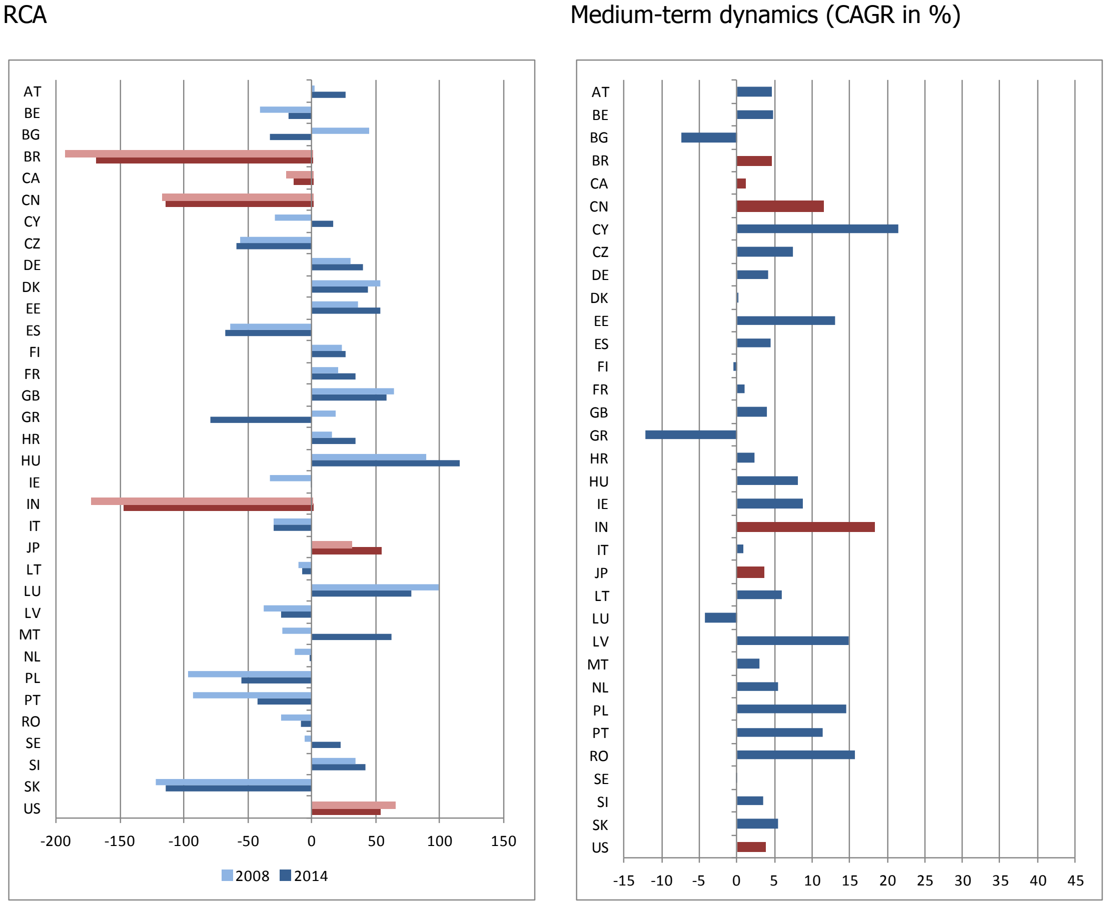
Trade Balance in %

Significance in ‰



Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 125: RCA 2008 and 2014 and Medium-term dynamics 2007/08 to 2013/14 for the EU Member States and selected other countries: Measuring and Monitoring



Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

Annex 14/ General figures and tables – Rail/Tram

Figure 126: *Illustration by* (UNIFE, 2015)

Figure 127: *Value chain (freight and passenger) rolling stock and locomotives (Ecorys, 2012)*

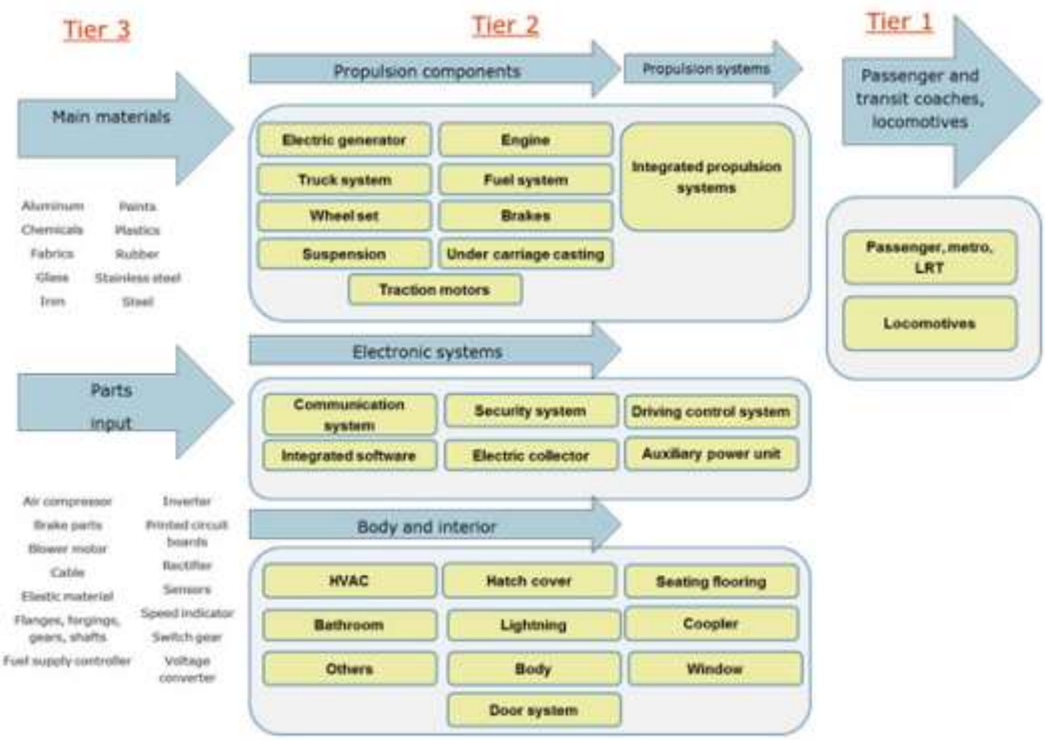


Figure 128: Value chain railway infrastructure

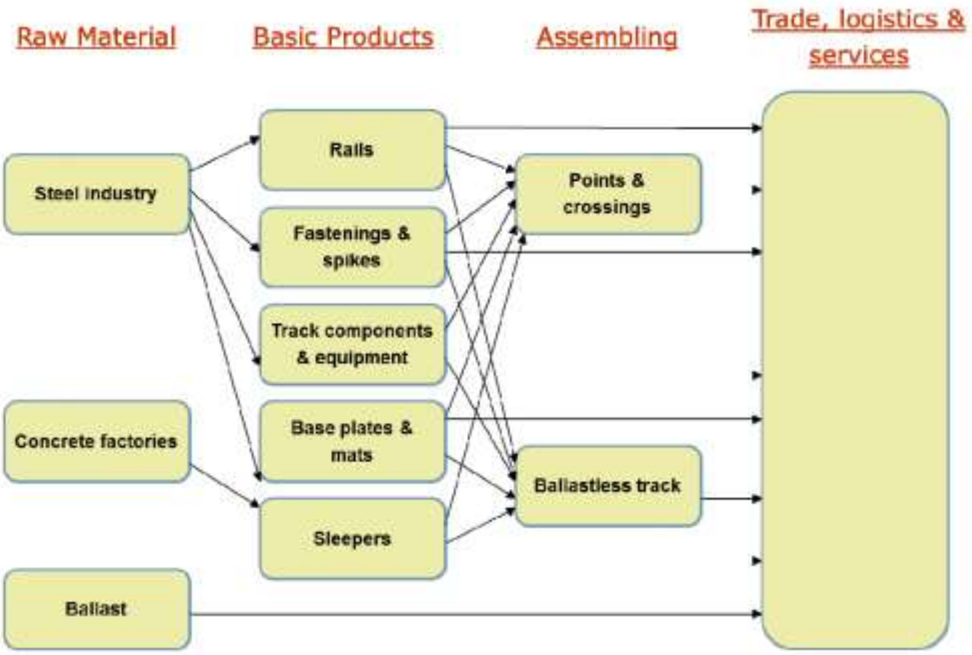
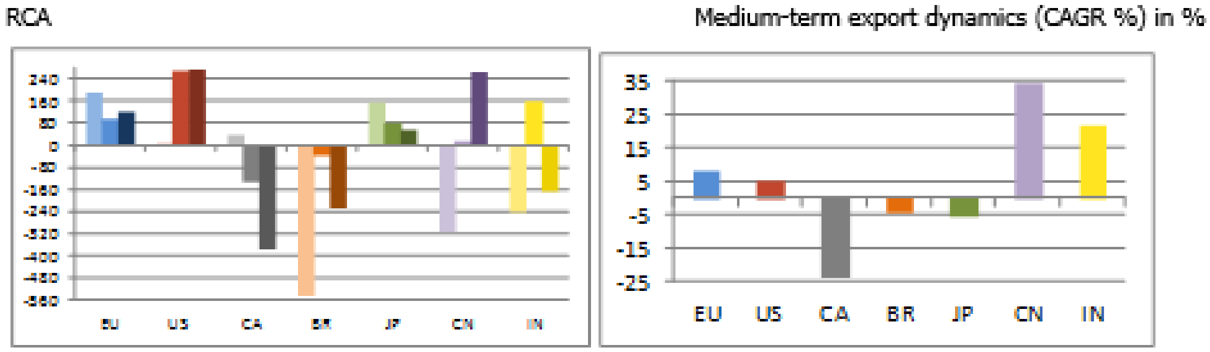


Figure 129: Overview of UNIFE members (UNIFE, 2014)

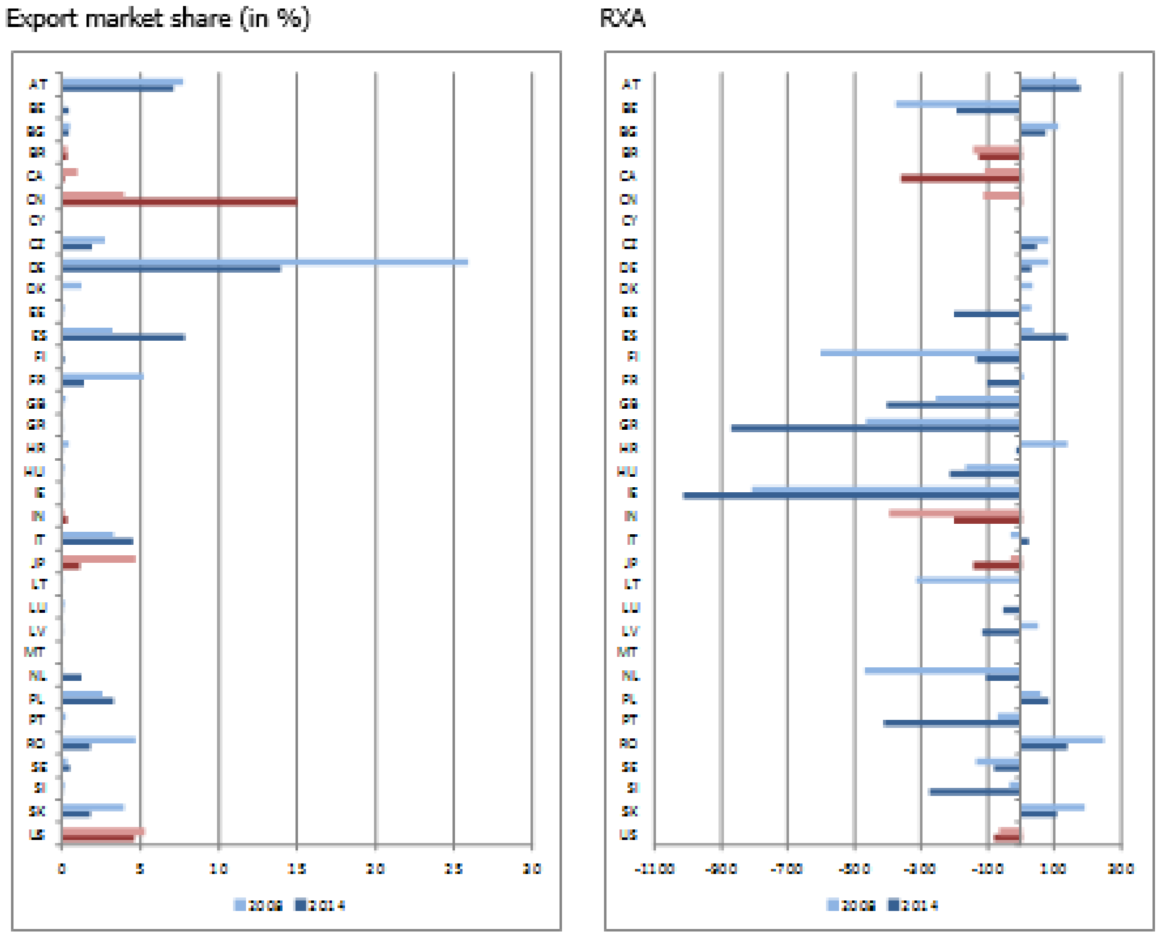
Annex 15/ Comparative advantage – Rail/Tram

Figure 130: RCA and medium term-export dynamics 2007/08 to 2013/14 for the EU-28 and selected other countries: Rail/Tram



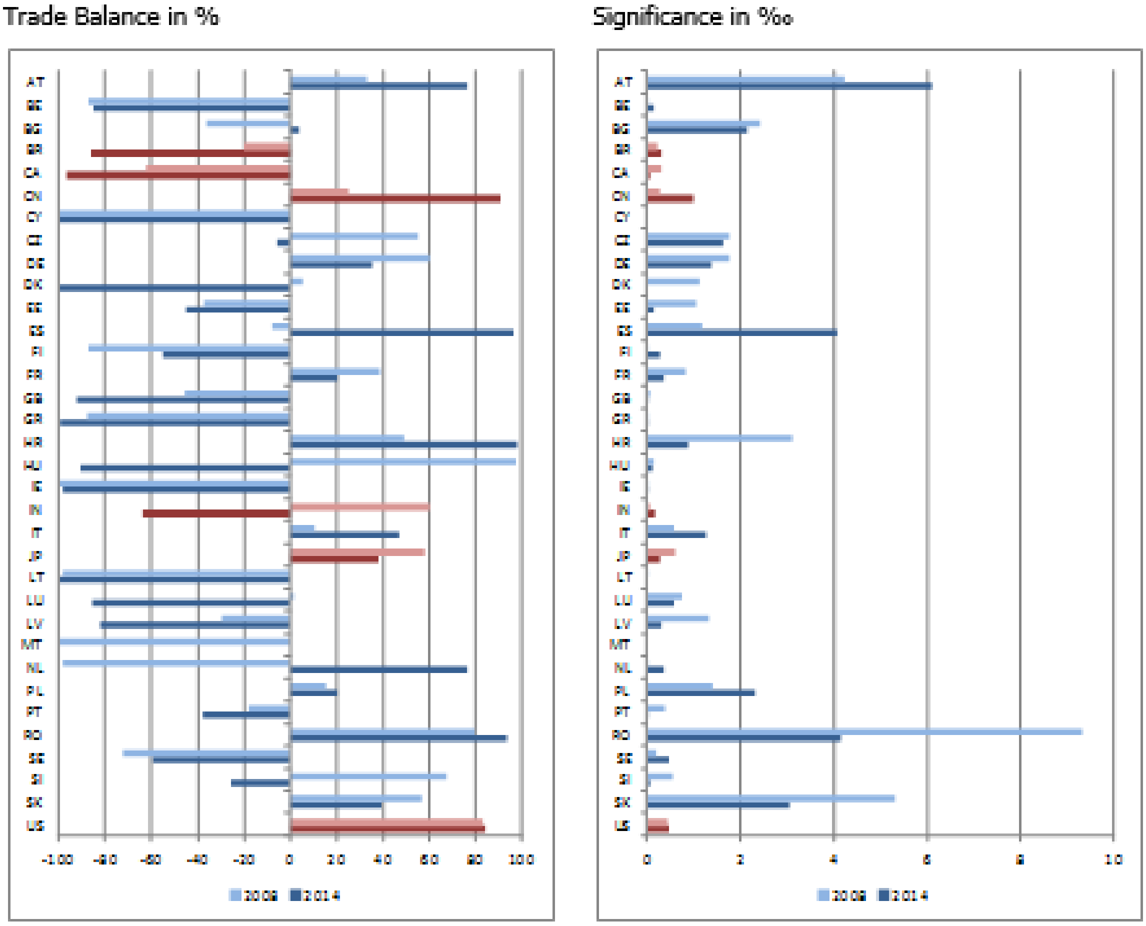
Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 131: Export market share (in %) and RXA for the EU Member States and selected other countries 2008 and 2014: Rail/Tram



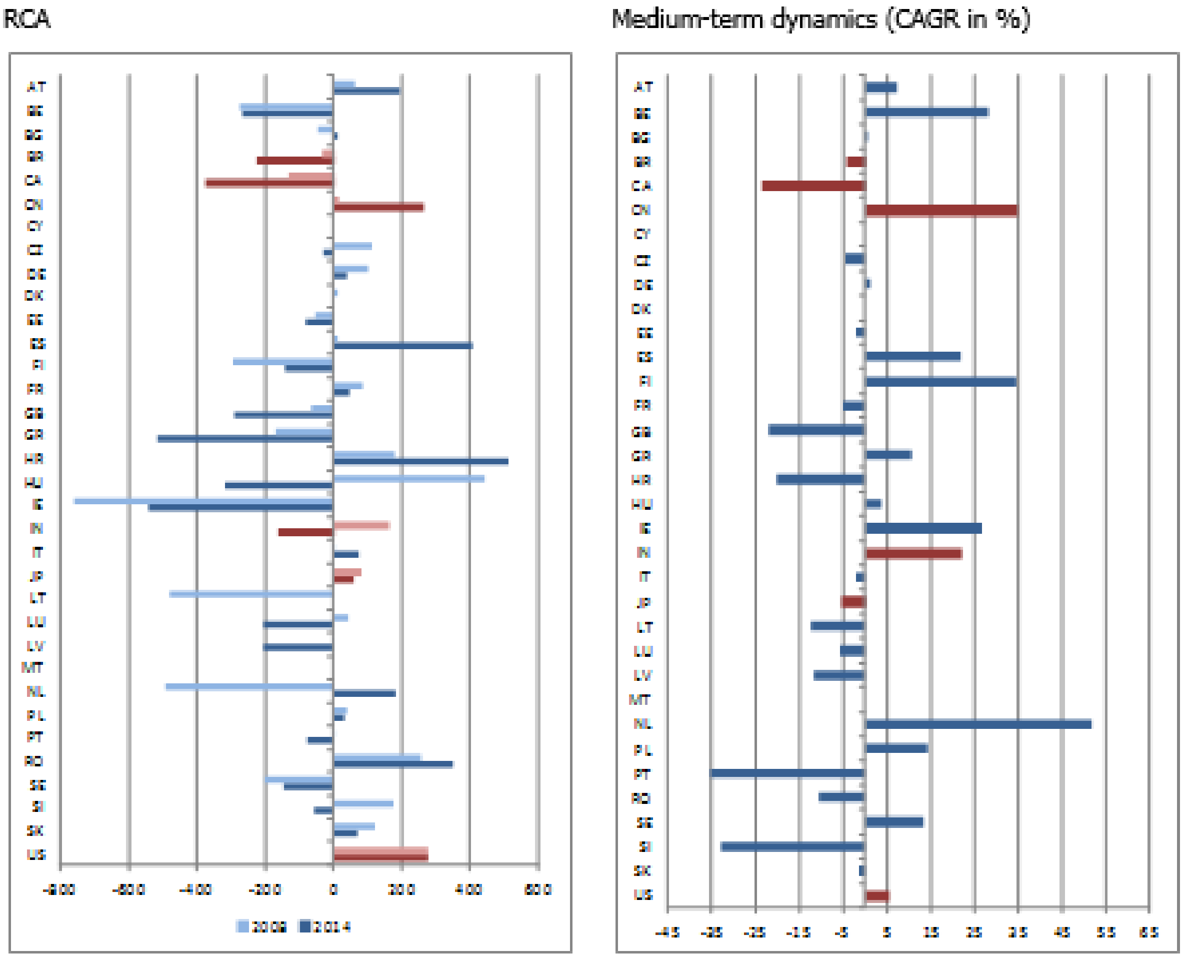
Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 132: Trade Balance and Significance for the EU Member States and selected other countries 2008 and 2014: Rail/Tram



Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 133: RCA 2008 and 2014 and Medium-term dynamics 2007/08 to 2013/14 for the EU Member States and selected other countries: Rail/Tram



Including EU-Intra-trade. - Source: UN COMTRADE-Database. – NIW calculation.

Annex 16/ General figures and tables – Thermal Insulation

Table 29: Renovation Strategies of selected Member States

Country	**Horizon**	**Target**	**Planned Investment**	**Economic Impact**
Belgium (Brussels Capital Region)	2030		€ 179-211 million totalling € 3 billion	a
Czech Republic	2050		€125-145 million per year	Ca. 35,000 new jobs; GDP increase by 1%
France	2017/2030	500,000 dwellings shall be renovated annually in order to meet the energy savings target of -38% by 2030. Additionally 120,000 social housing units shall be renovated by 2017 via the introduction of a renovation obligation.		100,000 jobs in the short term (75,000 in the energy renovation sector and nearly 30,000 in the renewable energy sector), in addition to more than 200,000 jobs by 2030; increase of GDP by 0.8% in 2020 and by 1.5% in 2030.
Germany	2019		€ 518 million to support modernisation of social housing	Since 2006, the KfW-programme has led to efficient renovation or construction of 4.1 million homes with total investments of about € 226 billion.[166] For every €1 of public funds, €12 of private investment has been leveraged
The Netherlands	2020/2030	improve 300,000 existing homes and other buildings a year by at least 2 energy label steps; reach an average label B for social rental property in 2020 while 80% of private		

[166] http://www.bmwi.de/DE/Themen/Energie/Energieeffizienz/nape,did=671876.html

		rental should achieve minimum label C and to achieve at least an average label A for buildings in 2030		
Romania	2020-2050			estimation of generated employment p.a. from energy saving differs between 15,854 (modest scenario: energy saving of 30.4% compared to 2010) to 39,736 jobs (ambitions scenario associated with energy saving of 61.8%); total social benefit (including also economic stimulus, health benefits, environmental benefits and energy system benefits) could be approaching five times the value of the energy cost savings
United Kingdom	2050	Green Deal (providing grants for smaller consumers who invest in energy-saving improvements for their home[167]), the Smart Metering Programme (requiring energy companies to replace conventional electricity and gas meters by smart meters in all domestic and smaller non-domestic properties by 2020[168]) and the Energy Company Obligation (ECO)[169] (focussing on providing energy efficiency		reduced energy costs for consumers, reduced fuel poverty, increased energy security, expanding global markets for energy saving technologies, developing skills and supply chains

[167] https://www.gov.uk/green-deal-energy-saving-measures/overview

[168] https://www.gov.uk/guidance/smart-meters-how-they-work

[169] https://www.gov.uk/government/publications/2010-to-2015-government-policy-household-energy/2010-to-2015-government-policy-household-energy

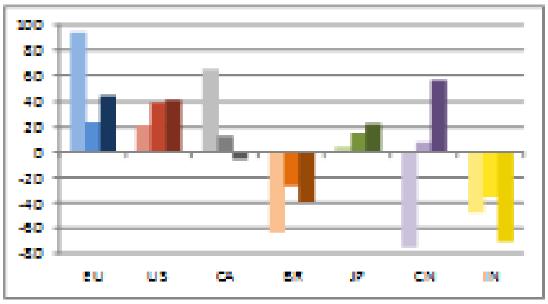
		measures to low income and vulnerable consumers and those living in "hard-to-treat" properties).		

Source: BPIE (2014), own display.

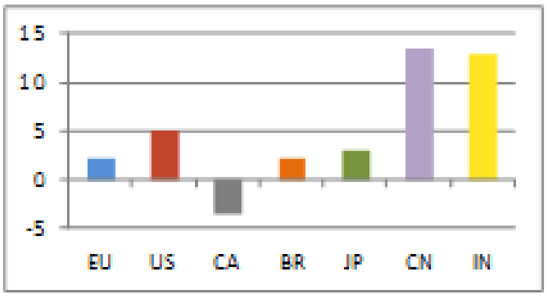
Annex 17/ Comparative advantage – Thermal Insulation

Figure 134: RCA and medium term-export dynamics for the EU-28 and selected other countries: Thermal Insulation products

RCA



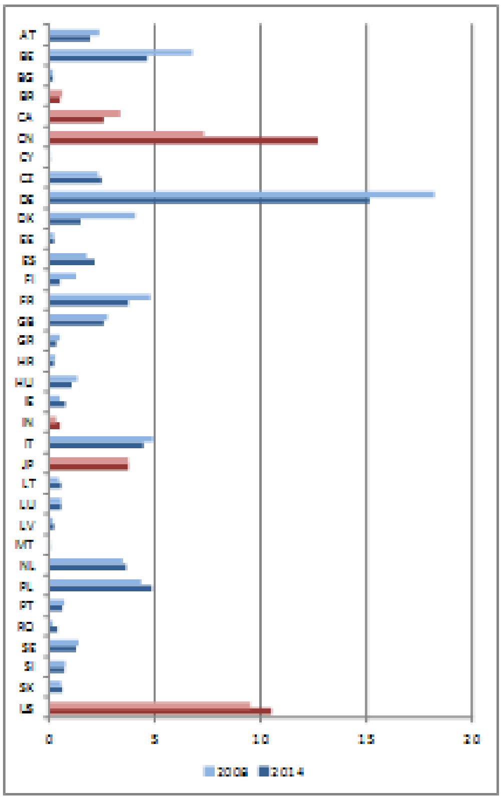
Medium-term export dynamics (CAGR %) in %



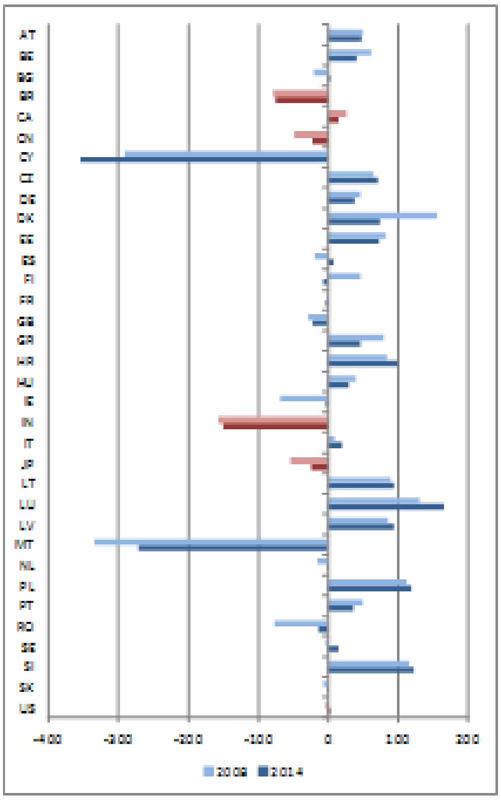
Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 135: Export market share (in %) and RXA for the EU Member States and selected other countries 2008 and 2014: Thermal Insulation products

Export market share (in %)

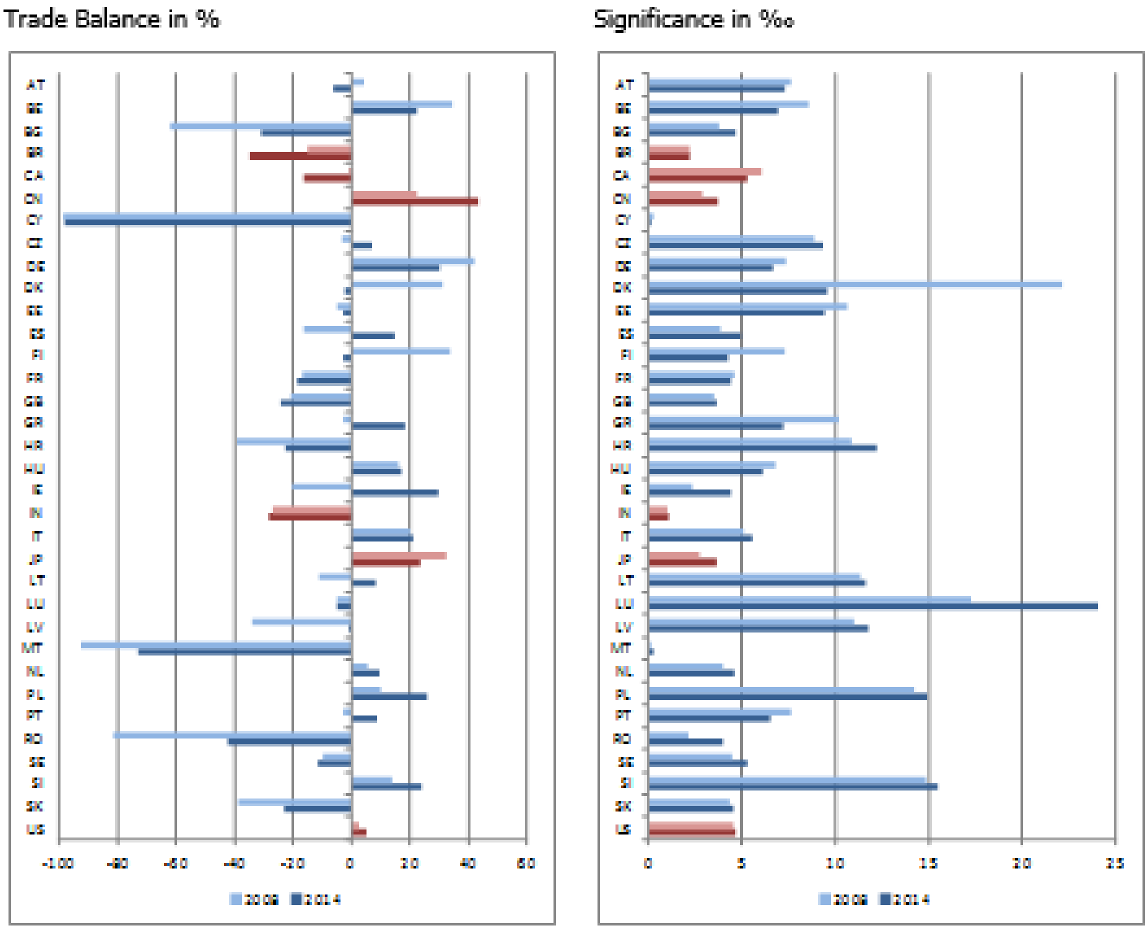


RXA



Including EU-Intra-trade.
Source: UN COMTRADE-Database. – NIW calculation.

Figure 136: Trade Balance and Significance for the EU Member States and selected other countries 2008 and 2014: Thermal Insulation products



Including EU-Intra-trade.
Source: UN COMTRADE-Database. – NIW calculation.

Annex 18/ General figures and tables – Traffic Control Systems

Figure 137: CO2 reduction potential of application studied (ERTICO, 2015)

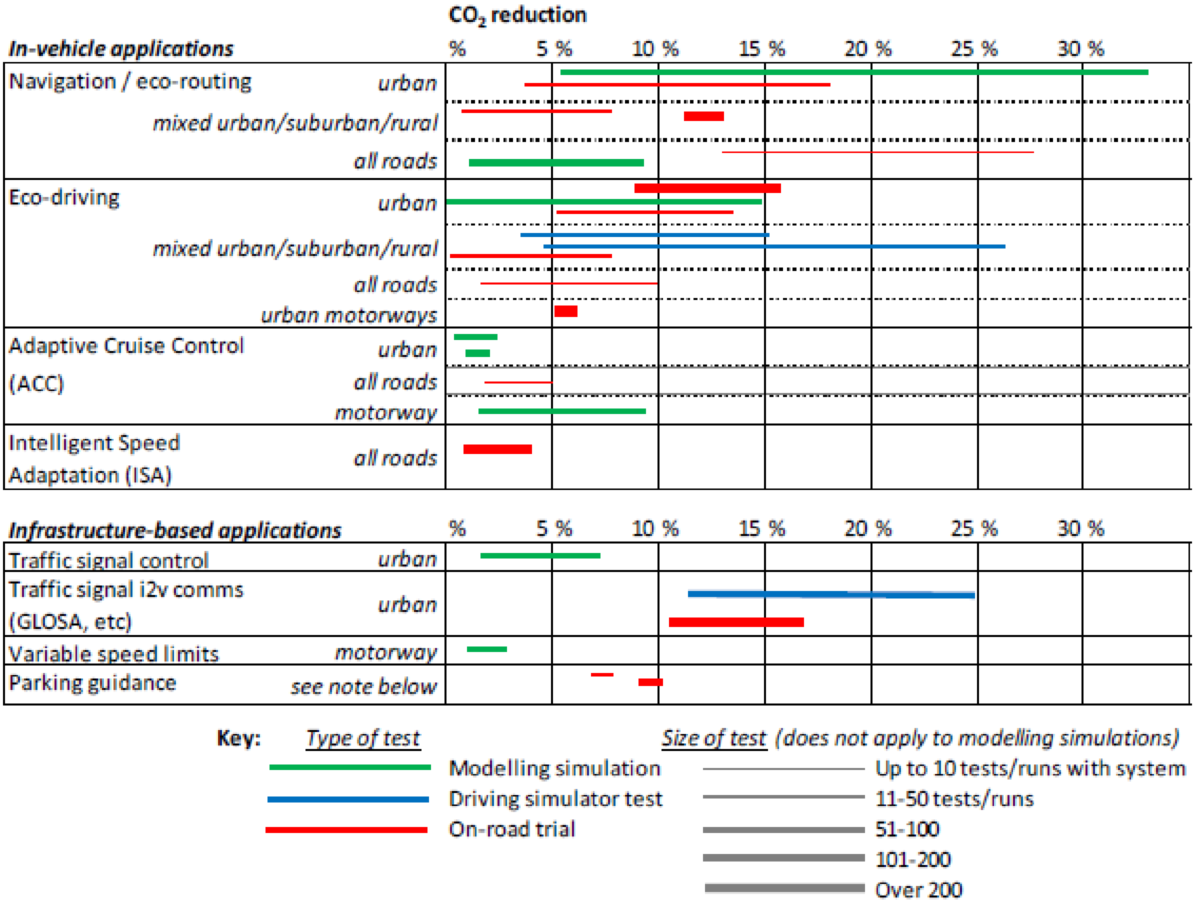


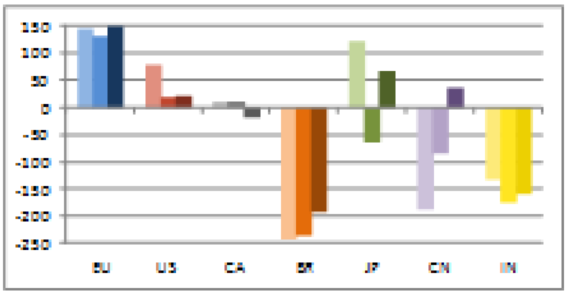
Figure 138: Summary of WG4CEM results: ITS applications with greatest potential for CO2 reduction (ERTICO, 2015)

High level category (ECOSTAND/ Amitran classification)	ITS measure	Estimated possible CO_2 reduction (percentage reduction from current levels)	Implementation timeframe
Navigation and travel Information	Navigation and eco-routing	5-10%	Today
	Connected eco-routing (taking into account real-time information)	5-10%	Until 2020
	Personalised multi-modal navigation tools.	5-10%	Today
Traffic management and control	Traffic signal control and signal coordination (UTC – Urban Traffic Control)	5-10% reduction until 2020, >10% reduction after 2020	Today, but much improved by 2020
	Cooperative traffic signals (i2v / GLOSA - green light optimal speed advisory and green priority)	>10%	Until 2020
	Dynamic lane allocation	0-5%	Today
	Variable Speed Limits (VSL)	0-5%	Today
	Coordinated ramp metering (motorway access control)	0-5%	Today
	Parking guidance	0-5%	Today
	Cooperative parking guidance (i2v routing)	0-5%	Until 2020
Demand and access management	Variable road pricing – Distance-based	>10%	Today
	Variable road pricing – Congestion -based	5-10%	Today
	Pay-as-you-drive insurance	5-10%	Today
Driver behaviour and eco-driving	Eco-driving support	5-10% with mobile or aftermarket solution >10% with integrated (embedded) solution	Today (mobile) Beyond 2020 (integrated)
	Mandatory ISA (Intelligent Speed Adaptation)	5-10% (0-5% potential with voluntary ISA)	Beyond 2020 (Voluntary ISA possible today)
	Cooperative Adaptive Cruise Control (C-ACC)/ Automation (autonomous platooning)	5-10%	Beyond 2020

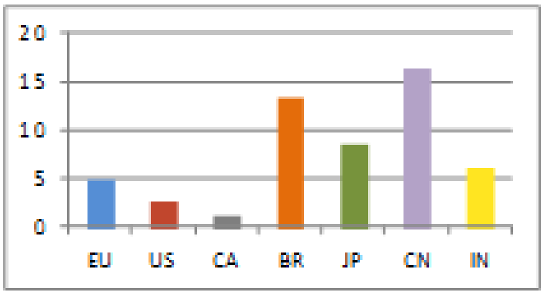
Annex 19/ Comparative advantage – Traffic Control Systems

Figure 139: RCA and medium term-export dynamics for the EU-28 and selected other countries: Traffic Control Systems

RCA



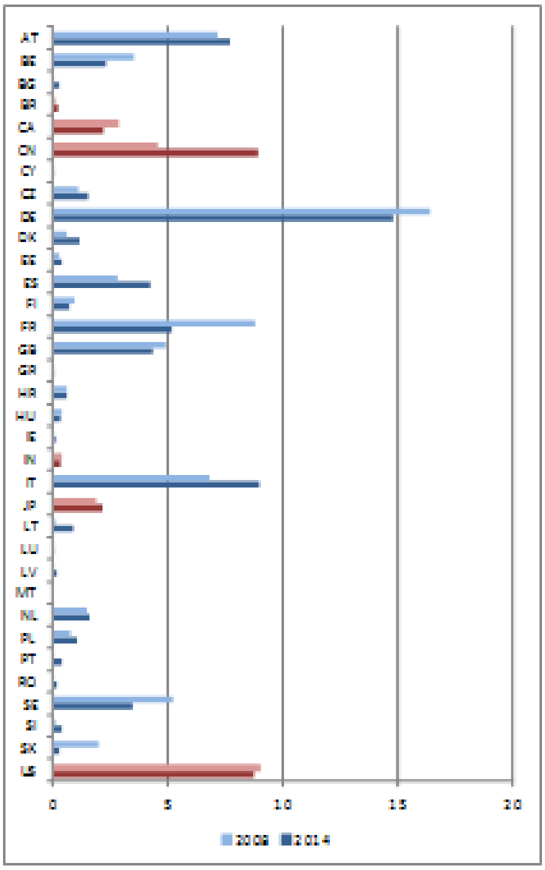
Medium-term export dynamics (CAGR %) in %



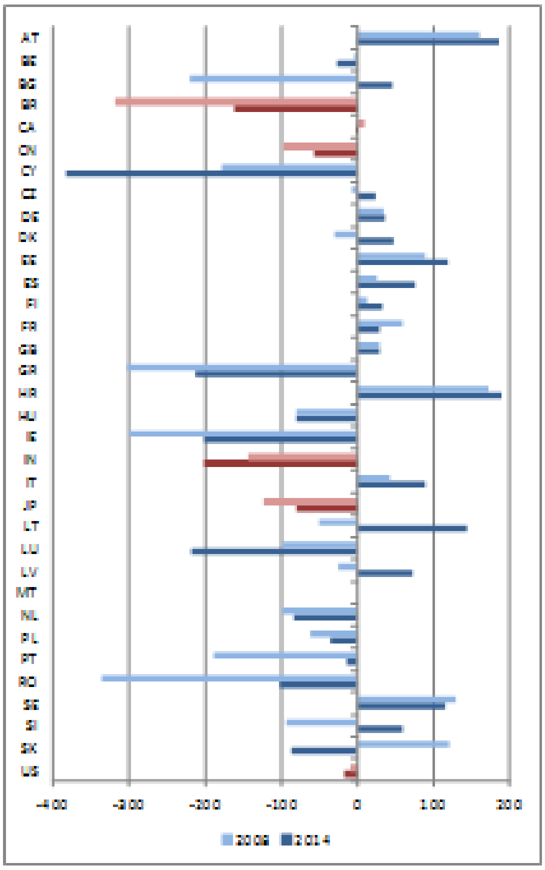
Regarding EU-Extra-trade only. - Source: UN COMTRADE-Database. – NIW calculation.

Figure 140: Export market share (in %) and RXA for the EU Member States and selected other countries 2008 and 2014: Traffic Control Systems

Export market share (in %)

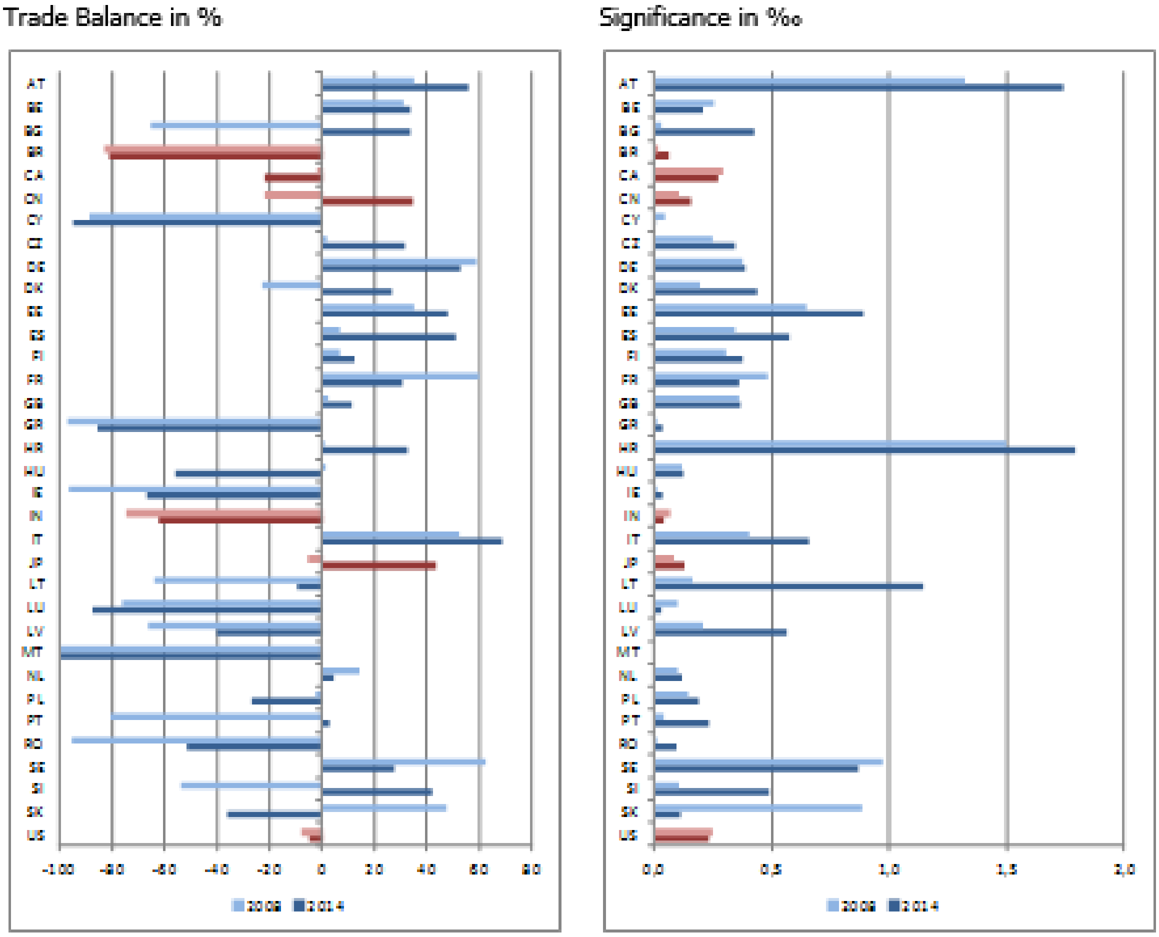


RXA



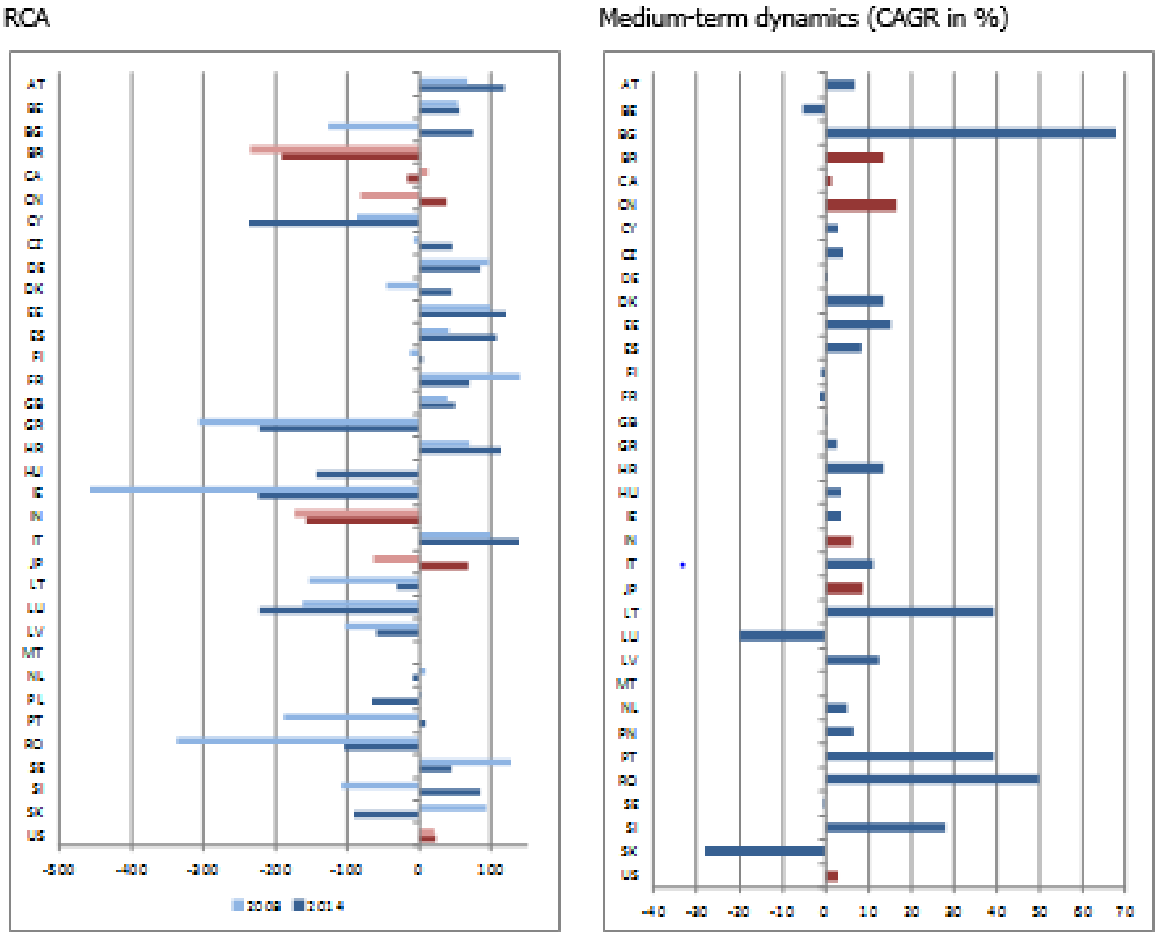
Including EU-Intra-trade.
Source: UN COMTRADE-Database. – NIW calculation.

Figure 141: Trade Balance and Significance for the EU Member States and selected other countries 2008 and 2014: Traffic Control Systems



Including EU-Intra-trade.
Source: UN COMTRADE-Database. – NIW calculation.

Figure 142: RCA 2008 and 2014 and Medium-term dynamics 2007/08 to 2013/14 for the EU Member States and selected other countries: Traffic Control Systems



Including EU-Intra-trade.

Source: UN COMTRADE-Database. – NIW calculation.