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Climate neutral market opportunities and EU competitiveness

Final Report

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Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs

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Glossary

ACE – Architects Council of Europe

ACEA – European Automobile Manufacturers' Association

ACER – Agency for Cooperation of Energy Regulators

AE – Alkaline

AEM – Anion Exchange Membrane

AI – Artificial Intelligence

APAC – Asia-Pacific Region

APM – Advanced Porous Materials

AVERE – European Association for Electromobility

BEMS – Building Energy Management Systems

BEV – Battery Electric Vehicle

BIM – Building Information Modelling

BIPV – Building-Integrated Photovoltaics

CAF – Competitiveness Assessment Framework

CAGR – Compound Annual Growth Rate

CEF – Connecting Europe Facility

CESBA – Common European Sustainability Building Assessment

CfD – Contract for Difference

CHP – Combined Heat and Power

CLEPA – European Association of Automotive Suppliers

CO_2 – Carbon Dioxide

COMEXT – Eurostat’s statistical database on trade of goods

COMTRADE - International Trade Statistics Database

COVID-19 – Coronavirus disease 2019 caused by the coronavirus SARS-CoV-2

CPC – Cooperative Patent Classification

CRM – Critical Raw Material

CTG – Cleantech Group

DACH – Germany, Austria, Switzerland region

DEEP – De-risking Energy Efficiency Platform

DER – Distributed Energy Resource

DG CLIMA – European Commission’s Directorate General for Climate Action

DG ENER – European Commission’s Directorate General for Energy

DG GROW – European Commission's Directorate General for Internal Market, Industry, Entrepreneurship and SMEs

DIHK – Association of German Chambers of Commerce and Industry

DRC – Democratic Republic of Congo

E.DSO – European Distribution System Operators

EAFO – European Alternative Fuels Observatory

EARPA – European Automotive Research Partners Association

EASE – European Association for Storage of Energy

EC – European Commission

ECTP – European Construction Technology Platform

EeB PPP – Energy-efficient Buildings Public-Private Partnership

EED – Energy Efficiency Directive, Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on Energy Efficiency

EFV – European Federation of Premanufactured Buildings

EGD – European Green Deal Communication of 11 December 2019

EHPA – European Heat Pump Association

EIB – European Investment Bank

EIF – European Investment Fund

EL – Electrolysis

EMS – Energy Management System

ENTSO-E – European Network of Transmission System Operators for Electricity

ENTSO-G – European Network of Transmission System Operators for Gas

EoL – End-of-Life

EPBD – Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency

EPO – European Patent Office

ESCP – European Strategic Cluster Partnerships

ESPResSo – Efficient Structures and Processes for Reliable Perovskite Solar Modules

ETIP SNET - European Technology & Innovation Platform Smart Networks for Energy Transition

EU – European Union (synonymous with EU-27)

EU ETS – EU emissions trading system

EU-27 – European Union 27 Member States

EU-28 – European Union 27 Member States and the United Kingdom

EUBAC – European Building Automation and Controls Association

EUROBAT – Association of European Automotive and Industrial Battery Manufacturers

Europe – All countries that are part of the European single market (the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland)

EV – Electric Vehicle

FCH JU – Fuel Cells and Hydrogen Joint Undertaking

GDP – Gross Domestic Product

GHG – Greenhouse Gas

GW – Gigawatt

GWh – Gigawatt hour

H2020 – Horizon 2020

HFC – Hydrogen Fuel Cells

HVAC – High Voltage Alternating Current

HVDC – High Voltage Direct Current

ICC – International Code Council

ICE – Internal Combustion Engine

ICT – Information and Communications Technology

IEA – International Energy Agency

IoT – Internet of Things

IP – intellectual property

IPC – International Patent Classification

IPCEI – Important Project of Common European Interest

ITC – Investment Tax Credit

JRC – Joint Research Centre

KET – Key Enabling Technology

kW – Kilowatt

LCE – Low Carbon Energy

LOHC – Liquid organic hydrogen carrier

M&A – Mergers and Acquisitions

MFF – Multiannual Financial Framework

MS – Member State

MVOW – Mitsubishi Vestas Offshore Wind Joint Venture

MW – Megawatt

NACE – Statistical Classification of Economic Activities in the European Community (Nomenclature générale des Activités économiques dans les Communautés Européennes)

NECP – National Energy and Climate Plan

NIST – National Institute of Standards and Technology

O&M – Operation & Maintenance

OECD – Organisation for Economic Co-operation and Development

OEM – Original Equipment Manufacturer

PATSTAT – European Patent Office Worldwide Patent Statistical Database

PCI – European Projects of Common Interest

PEM – Proton-Exchange Membrane

PGM – Platinum Group Metals

PHEV – Plug-in Hybrid Electric Vehicle

PM – Permanent Magnet

PPA – Power Purchase Agreement

PRODCOM – Production Communautaire Database

PropTech – Property Technology

PV – Solar Photovoltaic

R&I – Research and Innovation

RD&D – Research, Design and Development

REDII – Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast)

RES – Renewable Energy Sources

RoW – Rest of the World

SAIDI – System Average Interruption Duration Index

SC – Steering Committee

SETIS – Strategic Energy Technologies Information System

SmartEn – Smart Energy Europe

SMEs – Small and Medium-sized Enterprises

SMR – Steam Methane Reformation

SO – Solid-Oxide

SWOT – Strengths, Weaknesses, Opportunities, Threats

T&E – Transport & Environment

TEN-E – Trans-European Networks in Energy (Regulation (EU) No 347/2013 on guidelines for trans-European energy infrastructure)

TEN-T – Trans-European Networks in Transport (Regulation (EU) No 1315/2013 on Union guidelines for the development of the trans-European transport network)

TRL – Technology Readiness Level

TS – Technical Specifications

TSO – Transmission System Operator

UK – United Kingdom of Great Britain and Northern Ireland

US – United States of America

VC – Value Chain

VIP – Vacuum Insulation Panels

VIPA – Vacuum Insulation Panel Association

WEF – World Economic Forum

WTO – World Trade Organisation

Executive Summary

This study has assessed the competitiveness of European[1] businesses within the global value chains of key strategic components of climate neutral solutions. Using 12 value chains as a basis for the assessment, it has identified where these can enable European companies to gain additional comparative advantage while helping the EU to achieve its climate neutrality ambitions.

The results of this study include: (i) a replicable Competitiveness Assessment Framework (CAF), as illustrated in Figure 0.1, that serves as a basis for assessing the competitiveness of the EU in global climate neutral value chains; (ii) a dataset and a strategic outlook for each of the 12 value chains analysed; and, (iii) key conclusions drawn from applying the CAF to all value chains, covering the main drivers and dynamics of climate neutral solutions in Europe. This includes a cross-comparison of the results for each value chain, together with key challenges and policy recommendations.

Figure 0.1 Competitiveness Assessment Framework (CAF)

Source: ICF, 2020

The CAF consists of three key elements:

- **Value Chain Analysis** – this entails a qualitative analysis of the strategic components which define the structure of the value chain. It identifies key market participants, looks into both historic and forward-looking market trends, maps investment flows and spots innovation trends within the value chain.
- **Data Collection** – this involves gathering quantitative data on key indicators from multiple sources (see Figure 0.2 below). These indicators inform both the current state of the market (e.g. imports, exports and production) and innovation aspects across the value chain (e.g. patent applications and RD&D investment).

[1] Throughout the report the "Europe" category includes all countries that are part of the European single market – which includes the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. Whenever data is limited to the EU-28 or EU-27 this is clearly indicated.

- **European Competitiveness Assessment** – this consists of using the results from the Value Chain Analysis and Data Collection to inform a strategic outlook and Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis of the value chain. It also entails mapping key challenges and opportunities for European businesses and suggesting actions which can bring about a positive impact for the competitiveness of the EU.

Figure 0.2 Key indicators and judgement criteria underpinning the CAF

	#	Quantitative indicator	Source	Judgement Criteria
Innovation and Future Market Trends	1	Public RD&D investment	IEA	Is the value chain benefiting from sustained and/or growing levels of RD&D investment from the public sector?
	2	Early stage private investment (Venture Capital)	CTG	Does the market recognise the potential for this value chain to invest in innovation and generate financial returns?
	3	Late stage private investment (Venture Capital)	CTG	
	4	Patent applications	PATSTAT	Is the value chain effectively translating investment into tangible IP?
	5	Companies	CTG	Do European value chains comprise of leading innovative firms in the global value chain? Are European firms achieving the market recognition to enable them to build market share?
Current Market Trends	6	Employment	EurObserver	Does the value chain have an established labour market or is it emerging? Is it expanding or contracting?
	7	Production	PRODCOM	Is there core EU28 production competence and capability in key parts of the value chain? Which Member States have the most significant production?
	8	Turnover	EurObserver	What is the significance of EU28 firm level turnover across the value chain? Which parts of the value chain demonstrate the largest sales?
	9	Imports & Exports	PRODCOM, COMTRADE	Is the EU28 generating strong exports into non-EU28 countries? What is the long-term trend in exports?
	10	Trade Balance	PRODCOM, COMEXT	Is the EU28 able to sustain a strong and positive trade balance?

Source: ICF, 2020

To develop a set of indicators that could be used to assess EU competitiveness within global climate neutral value chains, a thorough review of literature and available datasets was undertaken and findings were discussed with the European Commission (EC), who have conducted extensive research of their own in this area[2]. Although the indicator set presented in Figure 0.2 is not extensive, it does cover multiple aspects of competitiveness which, when consolidated, allows for a robust and meaningful overview of the EU competitive position within a specific climate neutral value chain, compared to other countries and regions. It is important to stress that this study does not include an assessment of barriers to deploy climate neutral solutions, nor does it deal with affordability of costs in scaling up technologies towards market uptake.

Since a key objective of this study was to explore a new methodology for assessing competitiveness, key recommendations for addressing the challenges and limitations associated with implementing the CAF are summarised in Table 0.1.

[2] Asensio Bermejo, J.M. and Georgakaki, A., 2020, *Competitiveness indicators for low-carbon energy industries*, EUR 30404 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-23345-9 (online), doi:10.2760/43258, JRC116838. Available at: https://op.europa.eu/en/publication-detail/-/publication/29158e35-1411-11eb-b57e-01aa75ed71a1/language-en

Table 0.1 Recommendations for addressing the limitations of the CAF

Limitation of the CAF		Recommendations to resolve issue
Technological Coverage	Technological coverage is not aligned across the different indicators within a given value chain. The specific coverage and product definitions do not necessarily match across the different sources.	This misalignment does not compromise either the overview provided by the datasets or the CAF. However, it is essential to give sufficient consideration to the technological coverage when applying the CAF to a given value chain and to adequately disclose these limitations.
Geographic Coverage	Geographic coverage is not aligned across the different indicators within a given value chain. For some indicators, the data is available for all countries - i.e. EU and the Rest of the World (RoW) - and in others for only a selection of countries (e.g. EU28 Member States, IEA members). Furthermore, some countries keep their data confidential in some databases for one or multiple years.	Due to these limitations, for some indicators, it is not possible to compare Europe with RoW. This misalignment does not compromise the overview provided by either the datasets or the CAF. However, it is essential to consider the geographic coverage when applying the CAF to a given value chain and to adequately disclose any limitations.
Data gaps	Some technologies are not covered by some of the databases used in this study. For example, there is very limited data coverage of employment and turnover in climate neutral value chains.	Where data is not available for specific indicators, additional literature review and expert judgment should be used to complete the SWOT analyses and to inform the strategic outlooks.

Source: ICF, 2020

In recent years, several studies on the EU competitiveness of what could be considered climate neutral value chains have been conducted. The selection of the value chains analysed in this study took account of prior analysis and was informed by discussions with the Steering Committee (SC), recognising the EC's priorities for this study, particularly in light of the European Green Deal. To help operationalise the CAF in the context of the EU climate neutral policy objectives, the selected value chains were grouped into four major thematic areas (Table 0.2).

Table 0.2 Overview of the value chains selected for detailed analysis

Thematic areas	Value Chains
Mobility	• Batteries • Hydrogen Fuel Cells • Electric Power Trains • Electric Vehicles Charging Infrastructure
Buildings	• Prefabricated Buildings • Superinsulation Materials • Heat Pumps
Clean Power	• Wind Rotors • Photovoltaic Solar Panels
Integrators	• Building Energy Management Systems • Grid Energy Management Systems • Hydrogen Production

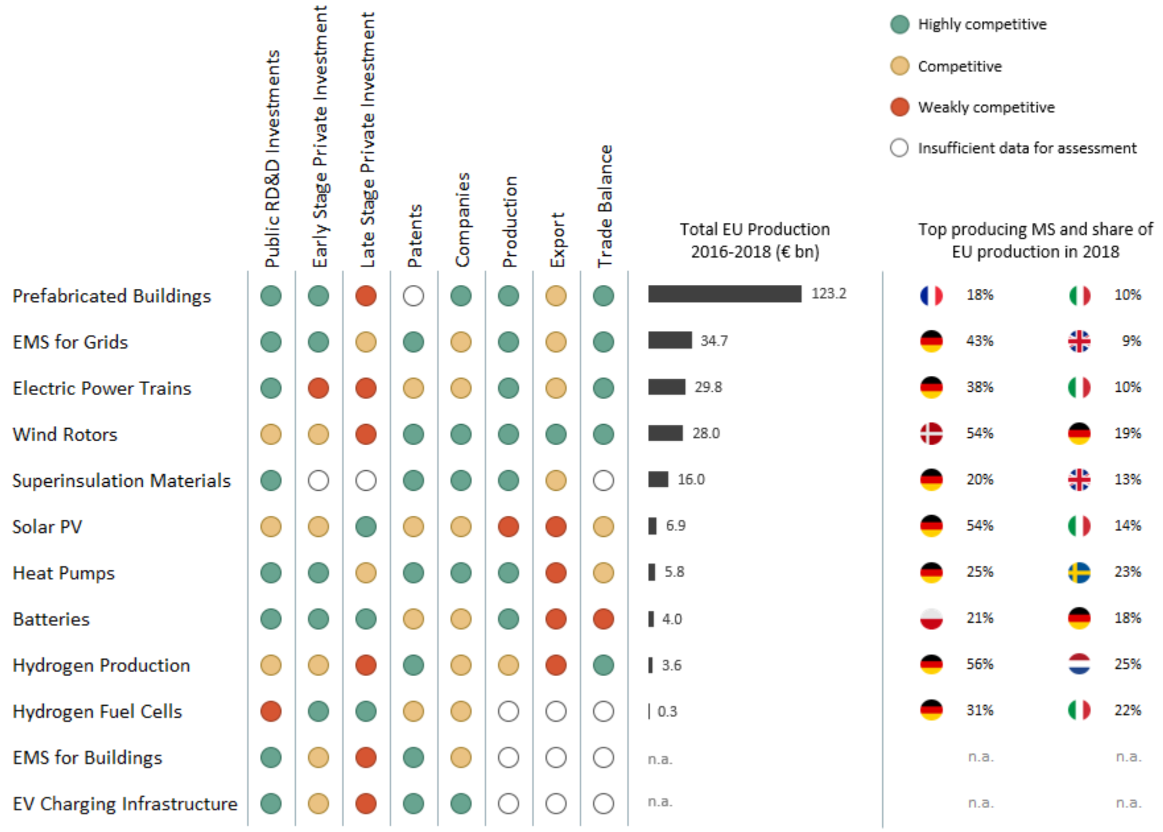
Source: ICF, 2020

Figure 0.3 below summarises the key conclusions drawn from applying the CAF to the 12 climate neutral value chains and comparing results across them. Based on this assessment, the main drivers, dynamics and trends regarding EU competitiveness were identified. This summary is based on the results of the data collection undertaken within Part 2 of the CAF. It illustrates: (i) how competitive a value chain is based on each of the indicators; (ii) the size of EU-28 production; and, (iii) the top producing Member States and their share of total EU-28 production in 2018.

For those indicators included in the summary, the judgement criteria for assessing competitiveness is based either on thresholds for the EU-28 or European share of global totals, or else on how the data has changed over the past years (i.e. increased, decreased or remained stable).

The summary does not include a cross-value chain assessment of employment and turnover, since the data on these indicators was only available for four out of the 12 value chains.

Figure 0.3 Summary findings across the 12 assessed value chains for selected indicators



Source: ICF, 2020

EU-28 production between 2016 and 2018 was aggregated to compare the order of magnitude across value chains. Although the Prefabricated Buildings value chain presents the highest production level, the data codes used in the analysis are not specific to low-carbon solutions, meaning that this total also includes traditional building products. This methodological issue also relates to Hydrogen Production, where the data codes do not differentiate between 'grey' and 'clean' hydrogen and therefore fail to illustrate that current clean hydrogen production in the EU-28 is still at a very small scale. Thus, the largest EU-28 climate neutral value chains of the 12 analysed are Grids Energy Management Systems, Electric Power Trains and Wind Rotors. The production of Photovoltaic Solar Panels (Solar PV) has decreased in the EU-28. Production in all other value chains for which data was available has grown over the period. Germany was the top producing EU-28 Member State in 7 out of the 10 value chains in 2018.

Public RD&D Investments have increased between 2009 and 2018 across most of the 12 value chains. The exceptions are Wind Rotors, Solar PV and Hydrogen Production – for which investments remained mostly stable – and Hydrogen Fuel Cells – where investments decreased. This may be due to the fact that these value chains are more established and public RD&D investments in them have already been at high levels.

The Private Investment data focuses on venture capital only and it covers mostly North America and Europe, since this is where there have traditionally been the largest venture capital investment flows. Across most value chains, the share of European investments is higher for early stage than for late stage (with Solar PV and Hydrogen Fuel Cells being the exceptions). This suggests that Series B+ investments[3] in European companies focused on low carbon technologies can potentially be expanded to strengthen EU competitiveness.

To put these trends in a wider perspective, European investments in seed, series A, series B, and growth equity rounds of energy and power companies grew at a rate of nearly 19% from 2015 to 2020, and totalled EUR 1.8 billion in 2019, comprising 44% of global investments into the sector, versus an average of 20% in the previous four years. Likewise, investments at the seed through growth equity stages in transportation and mobility in Europe grew in the same period at a rate of 28% to total nearly EUR 2.8 billion in 2019, 10% of global investments in the sector (and 11% through Q3 2020).[4]

With regards to patents, results indicate that Europe is highly competitive in more than half of the value chains analysed and weakly competitive in none, suggesting that Europe is a leading region for patent applications around climate neutral solutions globally. The European share of global high-value patent applications between 2014 and 2016 ranged between 15% for Hydrogen Fuel Cells and 63% for Wind Rotors.

Competitiveness in companies is based on the share of European companies included in the Cleantech Group database, which covers mostly innovative companies, but also, to a certain extent, more established market players. Based on this indicator, the results indicate that the EU competitiveness is average in more than half of the value chains and weak in none. The share of European companies ranges between 25% for Hydrogen Production and 59% for Heat Pumps.

With regards to exports, competitiveness is gauged by the share of EU-28 exports over total global exports between 2016 and 2018. The EU-28 is highly competitive only in the Wind Rotors value chain, where it dominates the global market with 39% of exports.

With respect to balance of trade, a value chain was classified as highly competitive where the EU-28 has a positive trade balance that has been improving between 2009 and 2018: a value chain was deemed to be weakly competitive where the converse was true. Five of the eight value chains were assessed as highly competitive, including Grids EMS, Electric Power Trains and Wind Rotors. The competitiveness of the Solar PV value chain was assessed as medium because the EU-28 trade balance is negative, although it has shown some improvement in the period. Likewise, the Heat Pumps value chain competitiveness was assessed as medium because the EU-28 trade balance is positive however it has been deteriorating over time.

Based on the assessment of the EU competitiveness across the 12 value, key market trends across climate neutral solutions were identified together with cross-cutting challenges, such as the lack of European-wide RD&D cooperative frameworks and limited end-of-life and

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[3] Series B financing is the second round of funding for a business through investment, including private equity investors and venture capitalists. The Series B round generally takes place when the company has accomplished certain milestones in developing its business and is past the initial startup stage. Source: Investopedia.

[4] Cleantech Group, 2020, i3 database. Conversion from USD to EUR based on https://xe.com.

recycling opportunities for some climate neutral solutions. Ten recommendations were identified to address the transversal challenges identified and contribute to enhancing the competitiveness position of the EU along the 12 analysed value chains.

Table 0.3 Policy Recommendations

R1	Use competitiveness assessments to identify VC segments of strategic importance for the EU economy and the transition to climate neutrality, to inform the design of strategic plans and calls for proposals; and, where necessary, create or enhance dedicated funding 'windows' within investment programmes and mechanisms to ensure sufficient support across the innovation cycle.
R2	Review the current European Strategic Cluster Partnerships, and overarching EU clustering strategy, to determine whether it remains fit-for-purpose and able to support VCs of key importance to achieve climate neutrality by 2050.
R3	Maximise the opportunities offered by public financial instruments deployed in recent years (e.g. EIF equity investments, InnovFin Energy Demo Projects facility, etc.) to increase the flow of private finance towards climate neutral solutions, at the scale-up and commercialisation stage (i.e. venture capital and private equity) as well as around main market deployment.
R4	Reduce the dependency of critical raw materials for innovative climate neutral solutions through increased focus on exploiting the EU own sources, developing the recycling sector and circular economy in line with the Action Plan on Critical Raw Materials.
R5	Build on the experience gained through establishment of the European Battery Alliance and the European Clean Hydrogen Alliance to adopt a more formal process to set-up coordinated sectoral strategies at EU level aimed at reinforcing the competitiveness of the EU in different industrial ecosystems. Adopting a stronger sectoral focus will require more intensive inter-service collaboration across the EC and the involvement of key stakeholders.
R6	Develop EU export strategies for key climate neutral solutions, building on existing initiatives and networks.
R7	Support standardisation of climate neutral solutions in the EU and beyond to ensure interoperability, facilitate the deployment of new technologies across the EU and simplify market adoption of leading innovations in the internal single market and across global markets.
R8	Exploit further the NECP progress reports, EU Semester process and Member State Recovery and Resilience Plans to coordinate: (1) public investments towards climate neutral solutions across Europe; (2) the development of appropriate infrastructure to support the transition towards climate neutrality; (3) the contribution of national innovation/industrial ecosystems to the building of European strategic and climate neutral VCs; and (4) the contribution of Member State policies to both the European RD&D and EU competitiveness objectives, while achieving the EU climate ambition.
R9	Reinforce the European low carbon energy market by: (1) further strengthening the transposition mechanisms at hand and ensuring that adopted European energy and climate legislation is correctly introduced on time into national laws; (2) coordinating large low-carbon infrastructure auctions (including RES) between Member States to enable a timely and scheduled connection of large projects and the respective enabling infrastructure to the grid; (3) increase interconnection between countries to at least 15% and ensure that barrier-free and easier trade of RES across Europe is possible and stimulated
R10	Develop strong demand-side policies to drive market developments in the EU and benefit from the first-mover advantage in innovative climate neutral VCs. Demand-side policies must complement the set of existing policies and measures in place to support the competitiveness of EU businesses developing climate neutral solutions. Creating demand and markets for clean, climate-neutral, energy-efficient and circular products is critical to ensure the EU can achieve its climate neutrality objectives.

Source: ICF, 2020

1 Introduction

This is the Final Report of the study entitled "*Climate neutral market opportunities and EU competitiveness*" which was commissioned by DG GROW and undertaken by ICF in association with the Cleantech Group. The study aimed to assess where the opportunities for sustainable growth in the market lie for European companies within the global value chains of climate neutral solutions.

The study had two specific objectives:

1. Develop a first-of-a-kind and replicable set of indicators on competitiveness to serve as a basis for in-depth competitiveness assessment, both under this study as well as in the future.

2. Assess the competitiveness of European businesses within the global value chain of key strategic components of climate neutral solutions, identifying where they can bring most added value to the EU-28, enabling the EU-28 to gain additional comparative advantage while achieving its climate neutrality ambitions;

This Final Report is structured as follow:

- **Section 2. Scoping and conceptual framework** presents the conceptual framework and process that led to the design of the Competitiveness Assessment Framework (CAF). It focusses on the work of the team and its interaction with the study SC and presents the reasoning behind the design of the framework;

- **Section 3. Competitiveness assessment framework** presents the CAF developed during the study. The section is written in such a way that it can be used as standalone guidance for the completion of future competitiveness assessments based on the developed framework;

- **Section 4. Strategic outlooks and policy recommendations** presents the results of the competitiveness assessments of European businesses within the global value chain of 12 strategic components of climate neutral solutions completed during the study; and,

- **Section 5. Conclusions and recommendations** presents the main conclusions of the study including a cross value chain analysis; the key methodological conclusions and the policy recommendations stemming from the study.

In addition, this Final Report contains a series of Annexes which underpin the analysis.

Table 1.1 Annexes to the Final Report

Annexes	
Datasets	12 excel datasets prepared for each value chain with the quantitative data collected from applying the CAF
Data Codes	Codes uses to extract quantitative data for each of the 12 value chains
Key indicators underpinning the SWOT	List of questions used to guide the SWOT analysis and their link to the quantitative indicators
References	References used in this study

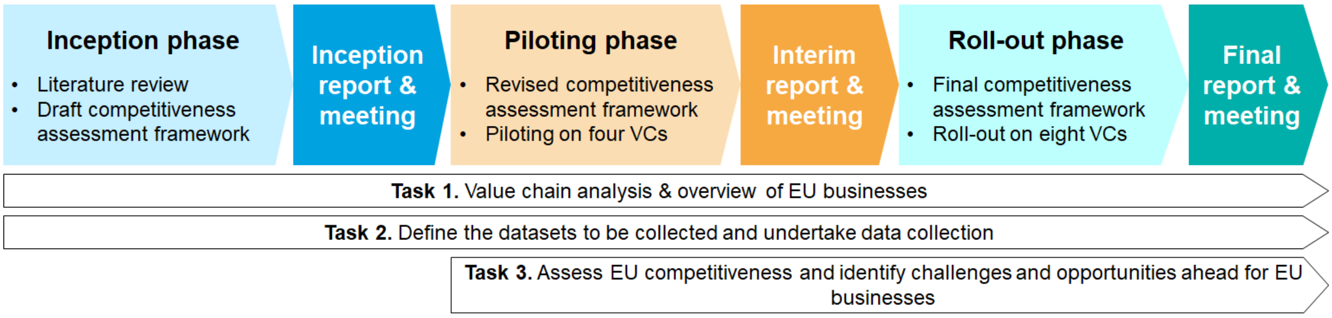
Source: ICF, 2020

2 Scoping and conceptual framework

This section presents the scope of the study and the conceptual framework underpinning its deployment. It also provides an overview of the process the study team went through and the approach followed to (1) develop the CAF presented under Section 3; and (2) select the 12 strategic components of the VCs that were analysed by the study team based on the CAF. This process, illustrated in Figure 2.1 below, shows the key milestones at which there was engagement with the study SC to gather feedback on the team's work. It also illustrates that the tasks of the study did not follow a sequential order, but were deployed throughout the study to contribute to the final outputs presented in Sections 3 and 4 of this report.

The remainder of this section is structured around the three tasks of the study. Each sub-section starts with an overview of how the different sub-tasks contributed to the development of the study and its outcomes. More details are then provided about the key findings from these different sub-tasks.

Figure 2.1 The study involved a comprehensive scoping and piloting phase before deploying the agreed methodology for remaining VCs



Source: ICF, 2020

2.1 Task 1. VC analysis & overview of European businesses

In terms of process and conceptual framework, the two main outcomes of Task 1 consisted of developing a lexicon of the key terms scoping the study and defining a standard approach to structuring VCs. These two elements are discussed below.

2.1.1 Lexicon of the key terms scoping the study

A first step for the successful deployment of the study was agreement on the definition of the key terms scoping the study to ensure clarity across the team, the study SC, and future readers.

Climate neutral solutions

In accordance with the study Technical Specifications (TS), climate neutral solutions are defined as technologies, products and services that have measurable environmental benefits in terms of their abilities to reduce greenhouse gas (GHG) emissions and to improve both energy and resource efficiency. Solutions include technologies, products or equipment that could be complemented by a service or a more integrated system.

It is important to stress that in this study, the term "*climate neutral solutions*" is considered to be a broad concept based on the above definition and is not intended as a group of solutions being effectively climate neutral based on comprehensive life-cycle assessments. In fact, this study is a separate stream of analysis to the ongoing work by the EC on the EU sustainable finance taxonomy and the technical screening criteria to determine under which conditions an economic activity qualifies as environmentally sustainable.

Strategic component

Each of the 12 VCs that have been analysed within the scope of this study relates to one strategic component, defined as a climate neutral solution deemed to play an important role for the EU climate neutral transition. The process the team went through to select these 12 strategic components is presented under section 2.2.2.

Thematic area

The strategic components are grouped within four major thematic areas, which are aligned to Technical Specifications (TS) requirements. Table 2.1 provides an overview of the four thematic areas - and the 12 strategic components within each of these - selected for detailed analysis.

Table 2.1 Overview of the strategic components selected for detailed analysis

Thematic areas	Strategic components
Mobility	■ Batteries ■ Hydrogen Fuel Cells ■ Electric Power Trains ■ Electric Vehicles Charging Infrastructure
Buildings	■ Prefabricated Buildings ■ Superinsulation Materials ■ Heat Pumps
Clean Power	■ Wind Rotors ■ Photovoltaic Solar Panels
Integrators	■ Building Energy Management System ■ Grid Energy Management Systems ■ Hydrogen Production

Source: ICF, 2020

Although there can be an overlap between the thematic areas (e.g. energy management systems for buildings also relate to the buildings thematic area, batteries also relate to the clean power thematic area), this categorisation was created to guide the scoping of the strategic components and the definition of the VCs. Also, because the strategic components are analysed from a VC perspective, there can be an overlap between two or more of them due to energy system integration liking various energy carriers with each other and with end-user sectors (e.g. electrification of transport, batteries and electric power trains).

Value chain

Since Michael Porter first introduced the concept of the VC in his seminal 1985 book "Competitive Advantage"[5] VCs have been defined in various ways to emphasise different characteristics[6]. The objective of this study is not to revisit this debate, but rather to build on the EC's previously commissioned work on VCs[7] to agree on a clear definition of this

[5] Porter, Michael E., 1985, *Competitive Advantage*, The Free Press, New York.

[6] University of Cambridge, *'Value Chain' Definitions and Characteristics*, Available at: https://www.cisl.cam.ac.uk/education/graduate-study/pgcerts/pdfs/Value%20Chain%20Definitions%20Rev%201%20-Updated%20links.pdf, [Accessed on: 24/11/2020]

[7] Some example of recent studies include: IDEA Consult, NIW and WIFO, 2016, *Identifying levers to unlock clean industry*, Summary Report prepared for DG for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW) by IDEA Consult, NIW and WIFO. ISBN: 978-92-79-60891-9,

term, that is able to both provide clarity to the readers and structure the study approach. In the scope of this study, a VC is to be understood as the full range of activities needed to create a product or service and manage its end-of-life, in the case of products.

Competitiveness

Competitiveness can be defined and measured at different levels of economic analysis: nations (macro level), sectors of economic activity at national and regional level (meso level) and firms (micro level). Research in the field has a variety of perspectives and as flagged in the recent EC report on competitiveness indicators for low-carbon energy industries[8], there is no agreement on a universal definition of 'competitiveness'. There are studies involving macroeconomic, microeconomic, business, geographical and sectoral factors which are all interrelated. A common feature of all these studies and approach is that competitiveness is always assessed in comparison to others.

The OECD has defined competitiveness in macroeconomics as the "*measure of a country's advantage or disadvantage in selling its products in international markets*"[9]. The World Economic Forum (WEF) adopts a wider definition of the concept and defines it as: "*the set of institutions, policies and factors that determine the level of productivity of a country*"[10]. The WEF makes a direct link between competitiveness, productivity and well-being.

Based on the TS and the above definitions, this study focusses on assessing the competitiveness of European suppliers of climate neutral solutions. This is done by analysing the comparative advantages and disadvantages of Europe compared to the rest of the world (RoW) and assuming that intra-EU competitiveness is benefiting Europe as a whole. It is important to stress that, in line with the TS, this study does not include an assessment of barriers to deploy climate neutral solutions, nor does it deal with affordability of costs in scaling up technologies towards market uptake

The "Europe" category includes all countries that are part of the European single market – which includes the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. This categorisation relates to the key objective of the study, which is to assess European competitiveness in climate neutral solutions. Within this context, the success of countries which are part of the single market is deemed to strengthen EU competitiveness and not weaken it.

Finally, given the study has forward-looking objectives, competitiveness has been assessed by combining those indicators which focus on the current market situation, with indicators covering innovation and future market trends to provide as a gauge of future competitiveness.

Available at: https://op.europa.eu/en/publication-detail/-/publication/539f2bd8-17c5-4f8e-bbae-514b5a9ceefd; European Commission, 2020, *KETs Observatory – Methodology*, Available at: https://ec.europa.eu/growth/tools-databases/kets-tools/kets-observatory/methodology, [Accessed on: 24/11/2020]; ICF International, 2014, *Study on the competitiveness of the EU Renewable Energy Industry (both products and services)*, Executive Summary of the Final Report to DG Enterprise & Industry prepared by ICF International in association with CE Delft. ISBN 978-92-79-39411-9, Available at: https://op.europa.eu/en/publication-detail/-/publication/874ad42f-f2c2-4813-8d4f-75b515307545

[8] Asensio Bermejo, J.M. and Georgakaki, A., 2020, *Competitiveness indicators for low-carbon energy industries*, EUR 30404 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-23345-9 (online), doi:10.2760/43258, JRC116838. Available at: https://op.europa.eu/en/publication-detail/-/publication/29158e35-1411-11eb-b57e-01aa75ed71a1/language-en

[9] OECD, 2014, *Glossary of Statistical Terms – Competitiveness*, Available at: https://stats.oecd.org/glossary/detail.asp?ID=399, [Accessed on: 24/11/2020]

[10] World Economic Forum, 2017, *What exactly is economic competitiveness?*, Available at: https://www.weforum.org/agenda/2017/09/what-is-economic-competitiveness/, [Accessed on: 24/11/2020]

2.1.2 Definition of a standard VC structure

A second key step of the study was defining a standard VC structure to be applied, not only in this study but also future VC assessments that use the CAF. The literature review conducted during the study inception phase showed that there are many ways to approach VC analysis. Given that the objective of this study is to consider the full VC of climate neutral solutions (i.e. strategic components), including consideration of the upstream clean industry VCs, a comprehensive approach to VC analysis has been adopted. This relies on performing an in-depth analysis for each VC, starting with the search for a unifying representation of the VCs' structure. Three main inputs were used to achieve this:

- Cleantech Group's understanding of the economic activities across the four thematic areas of interest to the EC (i.e. buildings, clean energy, mobility, and integrators);
- A review of the literature providing VC analyses in different sectors falling under these thematic areas. This included previous studies completed by the EC on this topic[11] and the approach adopted by the Key Enabling Technologies (KETs) Observatory[12]; and,
- A review of documentation on theory surrounding VC analysis (e.g. Smile Curve Analysis[13]) that was used to inform the development of the final VC structure.

Based on this review it was agreed to structure the standard VC structure around six main stages and to capture the value adding activities linked to each of these stages:

- **Design**: Activities that specify materials that go into components, it defines how components are assembled into final product and it also impacts how things are handled at end of life. All activities are directly related to the creation of the product.
- **Materials**: Activities for creating or discovering the raw materials use to create the product. Outputs from this stage are processed to make components or integrated directly into final goods.
- **Components**: Activities involved in processing primary materials into elements of the final product that will then be used in the assembly stage for production of the final good.
- **Assembly**: Activities involved in the conversion of materials and components into end products ready for market deployment.
- **Operations and maintenance**: Activities focused on the optimization, efficient management, and upkeep of manufactured products during their application.
- **End of Life Management**: Activities executed after the product can no longer be used for its intended purpose. Includes reuse, repair, refurbish, remanufacture, repurpose, recycle, recovery and disposal.

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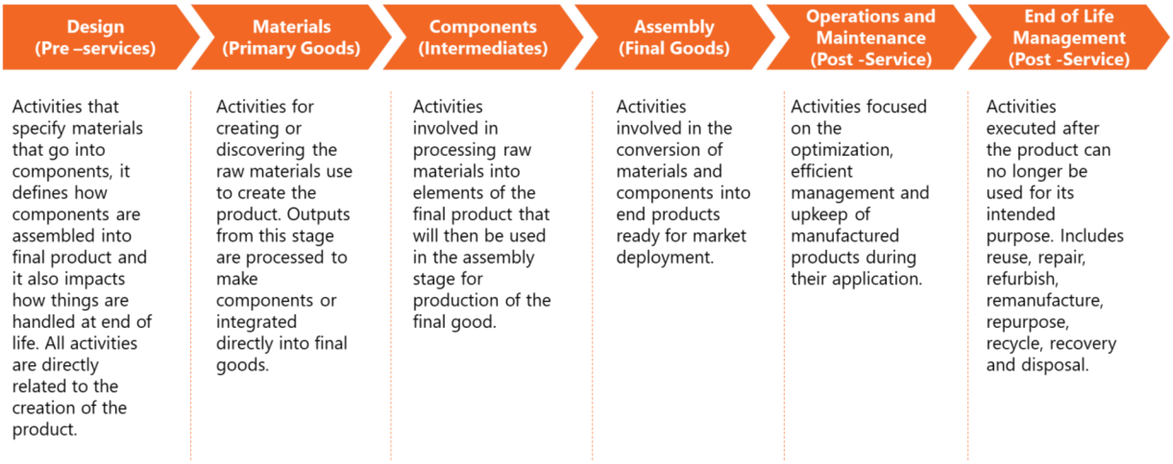
[11] IDEA Consult, NIW and WIFO, 2016, *Identifying levers to unlock clean industry*, Summary Report prepared for DG for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW) by IDEA Consult, NIW and WIFO. ISBN: 978-92-79-60891-9,
Available at: https://op.europa.eu/en/publication-detail/-/publication/539f2bd8-17c5-4f8e-bbae-514b5a9ceefd

[12] European Commission, 2020, *KETs Observatory – Methodology*, Available at: https://ec.europa.eu/growth/tools-databases/kets-tools/kets-observatory/methodology, [Accessed on: 24/11/2020]

[13] Rungi, Armando & Del Prete, Davide., 2018, The smile curve at the firm level: Where value is added along supply chains, Economics Letters 164, Available at: https://www.researchgate.net/publication/322296589_The_smile_curve_at_the_firm_level_Where_value_is_added_along_supply_chains

The resulting VC structure follows the technology development from design to end-of-life management, ensuring that each point of economic value creation is captured along the way (see Figure 2.2). This structure assumes that innovation and research and development (RD&D) activities happen along the whole VC and therefore do not require a specific stage in the established structure. In other words, RD&D can target one or more of the listed value adding activities (e.g. design, materials, components).

Figure 2.2 Standard VC structure to be used in this study



Source: Cleantech Group, 2020.

This structure can be applied therefore at different levels within a thematic area and has the advantage of capturing the full spectrum of economic activities linked to climate neutral solutions. Based on this standard VC structure, a specific VC was developed for each of the 12 strategic components analysed in this study.

As demonstrated by the literature on VCs, the above conceptual framework can be applied at almost any level within a sector depending on the research objectives, i.e. from high level sectoral VC analysis[14] to VC analysis at component level[15]. Each business activity could therefore benefit from its own VC analysis covering most standard value adding activities.

2.2 Task 2. Define the datasets to be collected and undertake data collection

The overall objective of Task 2 was to design a framework for the quantitative assessment of the competitiveness of European businesses in the global VCs of climate neutral solutions.

In terms of process and conceptual framework, the main elements of Task 2 consisted of:

- Designing an initial CAF;
- Revising it based on the feedback from the SC;

[14] Jäger-Waldau, A., 2018, *PV Status Report 2018*, EUR 29463 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-97465-6, doi:10.2760/826496, JRC113626. Available at: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC113626/pv_status_report_2018_online.pdf

[15] Lengton, M., Dervojeda, K., Koonstra, A., and Volosovych, V., 2017, *KETs Observatory Phase II: Methodology Report*, prepared for Executive Agency for Small and Mediumsized Enterprises (EASME) Contract nr EASME/COSME/2015/026, Available at: https://ec.europa.eu/growth/tools-databases/kets-tools/sites/default/files/documents/kets_observatory_phase_ii_methodology_report_ec.pdf

- Piloting the CAF on four initial VCs;
- Revising and finalising the CAF based on the pilot and the feedback of the SC;
- Roll-out of the CAF to eight additional VCs.

These elements are discussed below, starting with the design, revision and finalisation of the CAF, before focusing on the selection of the 12 VCs.

2.2.1 Initial design, revision and finalisation of the competitiveness assessment framework (CAF)

2.2.1.1 Design of the framework

Starting from the requirements of the TS, an initial long list of indicators that could be included in a robust and replicable CAF was established. Then, a review of recent competitiveness assessment studies were completed and the study team had a series of discussions with the EC to identify the set of questions that would need answering to construct a robust CAF. This process resulted in the following conclusions:

- **A limited set of indicators are typically used** by studies addressing multiple VCs for reasons of availability of data, relevance of indicators across VCs and comparability, in order to generate robust results;
- **Most competitiveness assessments combine quantitative indicators with qualitative information** to provide a more nuanced and meaningful analysis. This is the case for most recent competitiveness assessments[16]. Other studies[17] have employed for example Porters' Five Competitive Forces model as a basis for examining various renewable energy sectors, combining quantitative data analysis for a limited set of indicators with qualitative insights, including those derived from consultations with industry and trade bodies;
- **Most studies rely on the same established sources of information** to inform their quantitative assessment. These frequently include PRODCOM, COMTRADE and COMEXT (for production and trade), PATSTAT (for patents) and EurObserv'ER (for different indicators collated for the EU-28 renewables sector);
- **Few studies to date have undertaken very detailed analysis to generate more robust comparative data between Member States** (e.g. in their 2017 report on EU-28 manufacturing, Bruegel[18] looked for example at one specific trade code across four different VCs in order to generate conclusions);

[16] IDEA Consult, NIW and WIFO, 2016, *Identifying levers to unlock clean industry*, Summary Report prepared for DG for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW) by IDEA Consult, NIW and WIFO. ISBN: 978-92-79-60891-9,
Available at: https://op.europa.eu/en/publication-detail/-/publication/539f2bd8-17c5-4f8e-bbae-514b5a9ceefd

[17] ICF International, 2014, *Study on the competitiveness of the EU Renewable Energy Industry (both products and services)*, Executive Summary of the Final Report to DG Enterprise & Industry prepared by ICF International in association with CE Delft. ISBN 978-92-79-39411-9, Available at: https://op.europa.eu/en/publication-detail/-/publication/874ad42f-f2c2-4813-8d4f-75b515307545; Jespersen, M., Georgiev, I. and Jaganjacova, S., 2019, *Competitiveness of the heating and cooling industry and services*, prepared for DG Energy by COWI and CEPS, ISBN: 978-92-76-09233-9. Available at: https://op.europa.eu/en/publication-detail/-/publication/b23af898-c48e-11e9-9d01-01aa75ed71a1/language-en?WT.mc_id=Searchresult&WT.ria_c=37085&WT.ria_f=3608&WT.ria_ev=search

[18] Veugelers, R., 2017, *Remaking Europe: the new manufacturing as an engine for growth*, Bruegel. Available at: https://bruegel.org/wp-content/uploads/2017/09/Remaking_Europe_blueprint.pdf, [Accessed on: 24/11/2020]

- **Much of the comparative analysis is done on an intra-EU basis** (i.e. examining relative strengths and comparative advantages between EU-28 Member States) rather than between the EU-28 as a block compared with major non-EU countries.

Based on this review, and recognising the forward-looking nature of the study, the overall structure of the CAF was designed around two building blocks:

- The first block relates to both current EU competitiveness and competitiveness observed over past years (current competitiveness & market trends).
- The second block relates to innovation in Europe, which allows for an assessment of how EU competitiveness is expected to develop in the future (innovation & future market trends).

With these two blocks the intention was to cover the innovation cycle (i.e. from RD&D through to product development, through to initial sales and market diffusion) and assess EU competitiveness in the current context and how this is likely to evolve in the near future. Figure 2.3 illustrates this overall structure.

Figure 2.3 Structure of the CAF

Source: ICF, 2020.

In parallel, a shortlist of ten quantitative indicators was developed with the double objective to:

- Inform the competitiveness assessment of a particular VC when considered together; and,
- Construct a CAF that could be replicated across other VCs in the future, thereby enabling an EU wide system for tracking climate neutral competitiveness.

The study team has also sought to identify quantitative indicators to allow for comparison between regions, since the objective of the study is to assess the competitiveness of European businesses against businesses located in other regions in the world.

Table 2.2 below provides an overview of these ten indicators and the research questions they seek to inform.

Table 2.2 Key indicators underpinning the CAF

	#	Quantitative indicator	Source	Judgement Criteria
Innovation and Future Market Trends	1	Public RD&D investment	IEA	Is the value chain benefiting from sustained and/or growing levels of RD&D investment from the public sector?
	2	Early stage private investment (Venture Capital)	CTG	Does the market recognise the potential for this value chain to invest in innovation and generate financial returns?
	3	Late stage private investment (Venture Capital)	CTG	
	4	Patent applications	PATSTAT	Is the value chain effectively translating investment into tangible IP?
	5	Companies	CTG	Do European value chains comprise of leading innovative firms in the global value chain? Are European firms achieving the market recognition to enable them to build market share?
Current Market Trends	6	Employment	EurObserver	Does the value chain have an established labour market or is it emerging? Is it expanding or contracting?
	7	Production	PRODCOM	Is there core EU28 production competence and capability in key parts of the value chain? Which Member States have the most significant production?
	8	Turnover	EurObserver	What is the significance of EU28 firm level turnover across the value chain? Which parts of the value chain demonstrate the largest sales?
	9	Imports & Exports	PRODCOM, COMTRADE	Is the EU28 generating strong exports into non-EU28 countries? What is the long-term trend in exports?
	10	Trade Balance	PRODCOM, COMEXT	Is the EU28 able to sustain a strong and positive trade balance?

Source: ICF, 2020.

Box 2.1 European Geographic Definition

Whenever feasible country level data has been categorised between Europe or RoW. The "Europe" category includes all countries that are part of the European single market – which includes the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them.

This categorisation relates to the key objective of the study, which is to assess EU competitiveness in climate neutral solutions. Within this context, the success of countries which are part of the single market is deemed to strengthen EU competitiveness and not weaken it.

In some cases, the data is extracted at aggregated EU-28 level depending on how it is available from in the original source. For example, while production data is presented for the EU-28, patent data covers EEA members and Switzerland as well. Further details on this are presented in Section 3.2. Similarly, some market trends, policies and strategies might be EU-28 specific or also cover EEA countries.

Throughout the report, the following definitions were used:

EU-27 / EU: *European Union 27 Member States – mostly used in the context of the objectives of the study and future priorities or policies.*

EU-28: *European Union 27 Member States + United Kingdom – mostly used for production, exports, imports, trade balance, turnover and employment data, and of policies, trends or strategies that cover EU28.*

Europe/European: *EU-28 + EEA countries + Switzerland – mostly used for investment, patents and companies data and for policies, trends or strategies that cover EEA or the European single market.*

European countries considered part of the European trading block in this study			
Austria	Finland	Latvia	Portugal
Belgium	France	Liechtenstein	Romania
Bulgaria	Germany	Lithuania	Slovakia
Croatia	Greece	Luxembourg	Slovenia
Cyprus	Hungary	Malta	Spain
Czech Republic	Iceland	Netherlands	Sweden
Denmark	Ireland	Norway	Switzerland
Estonia	Italy	Poland	United Kingdom

Building on the experience gained through the piloting and roll-out of the framework (see more details on this under section 2.2.2), detailed guidance is provided in Section 3.2 on how to apply this framework to new VCs.

2.2.1.1 Key revisions and precisions following the feedback of the study SC and the piloting of the framework

Section 5.2 provides a detailed overview of the methodological conclusions drawn from applying the CAF across 12 VCs. This section therefore presents some key aspects of the CAF, including clarifying its scope and assessing the modifications undertaken during the study.

Scope of the CAF

As detailed in Figure 3.1, the CAF is composed of three main parts:

- Part 1: VC Analysis;
- Part 2: Data Collection; and,
- Part 3: European Competitiveness Assessment.

While the outcomes of Part 2 focus on analysis of a set of quantitative indicators and represent a central part of the CAF, the framework is complemented by qualitative elements derived from both Part 1 (i.e. description of the VC, list of European businesses, etc.), and Part 3 (i.e. strategic outlooks and SWOT analyses). Although the quantitative indicators form the basis for the CAF, these should not be considered in isolation; and the narrative, that has been built up from other parts of the framework, is as important for the deployment of robust and subtle competitiveness assessments. Furthermore, it is important that experts in strategic components of the VCs and the thematic areas are consulted on the results of the CAF, in order to bring insights and in-depth knowledge to enrich and validate the analysis.

Link between the framework and Technology Readiness Levels (TRLs)

During the Inception meeting, the question was raised as to whether the study should refer to TRLs to characterise the flow of investments into RD&D and innovation. After careful consideration it was decided not to refer to TRL terminology since this would add a level of complexity to the analysis with limited added value for the overall competitiveness assessment.

TRLs were developed as a means for measuring or indicating the maturity of a given technology on a scale of 1 (basic principles observed) to 9 (actual system proven in an operational environment and hence ready for market deployment). As such, TRLs can be considered as a vertical scale that can be applied to any type of innovation happening across the (horizontal) VC. While it is a useful concept, it does not necessarily drive funding rounds in innovative companies, which is one of the key indicators used in the approach to inform the competitiveness assessment. The CAF does however make a distinction between private venture capital investments made at early stage (i.e. seed, series A) and late stage (i.e. series B+) in companies producing innovative products and solutions. This information will be used as indicator to answer the following questions in the CAF: *Does the market recognise the potential for this component to invest in innovation and generate financial returns?*

Data sources on employment and turnover

In the original framework, sourcing turnover and employment data at company level to assess these indicators from a bottom-up perspective was considered. This information can potentially be sourced from either the D&B Hoovers or Moody's Orbis databases. However, when applying the methodology for the four pilot VCs, multiple limitations associated with that approach were identified. First, although the list of companies provided for the indicator "Number of companies" is comprehensive and relevant for an overview on EU competitiveness, it is not exhaustive. Furthermore, not necessarily 100% of a company's employment and turnover are associated with the specific VC in question. There are also significant challenges associated with the data collection as the company name and its location might not always be sufficient for identifying the company within the D&B Hoovers or Orbis databases. Finally, after testing the coverage of the D&B Hoovers database the study team noticed that for a significant number of companies, there is no information available on turnover and employment.

Taking the above into consideration, it was decided not to pursue this approach and to limit the data collection on employment and turnover to the VC level using the EurObserver database.

Correction of the approach to analyse patent application data

The number of patent applications was identified in the inception phase as a key indicator within the CAF. The method to analyse these data was completely revised following the feedback from the JRC to ensure it builds on the extensive work it has developed in this field and ensure a good level of comparability between the different studies analysed . The JRC compiles research and innovation statistics, including patent data from the PATSTAT European Patent Office (EPO) database[19] for SETIS[20]. For this analysis, the JRC collects patent data considering the country of the applicant, keeping the priority application date and grouping patents into families to apply a fractional approach. Further refining is applied to the data with a harmonisation algorithm and their own analysis, since the PATSTAT data contains inconsistencies. The JRC's analysis relies on the Cooperative Patent Classification (CPC), which groups patents across the International Patent Classification (IPC) according to their low carbon application[21]. As the JRC provides patent data under this method for multiple studies conducted by the EC, they have provided patent data for this study under the same method in order to preserve patent analysis consistency.

Difficulties in capturing some disruptive factors and trends to aid the analysis

Despite efforts to capture all the key elements underpinning competitiveness within the set of questions and indicators, some disruptive factors and trends might not be captured. That has proved the case, for example, with the digitalisation trend, and software development associated with it, that will impact most if not all climate neutral innovations. However, the study team has determined that this will not be captured by most quantitative indicators such as for example patent data as they are not frequently used in these fast-evolving sectors. These disruptive factors and trends are however systematically considered in the market trends analysis which informs Part 1 of the CAF and in the strategic outlooks and SWOT analyses under Part 3 of the CAF.

2.2.2 Piloting and roll-out of the CAF

As per the TS, the CAF was applied to 12 VCs, distributed across four thematic areas. This was organised in two phases: a pilot phase focusing on four VCs to test the framework and identify improvement opportunities; and a roll-out phase during which the final CAF was applied to eight additional VCs.

Selection of the VC & piloting

One of the key objectives of the inception phase was to select a short list of strategic components to be analysed by the study and used as basis for the development of the CAF.

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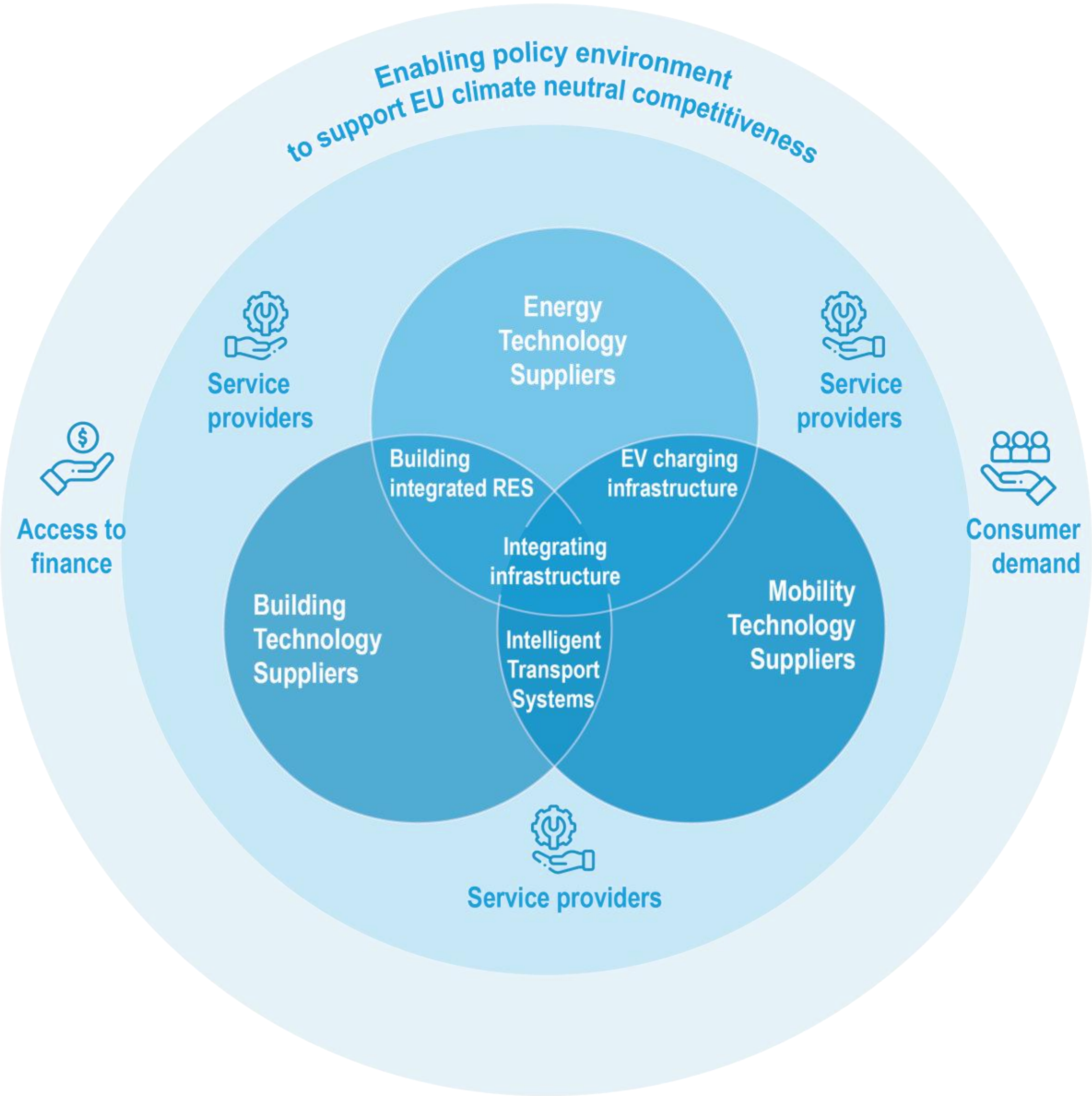
[19] European Patent Office, 2020, *PATSTAT,* Available at: https://www.epo.org/searching-for-patents/business/patstat.html#tab-1, [Accessed on: 24/11/2020]

[20] Fiorini, A., Georgagaki, A., Pasimeni, F. and Tzimas, E., 2017, *Monitoring R&I in Low-Carbon Energy Technologies,* EUR 28446 EN, ISBN 978-92-79-65592-0, doi: 10.2760/447418, JRC105642, Available at: https://setis.ec.europa.eu/publications/relevant-reports/monitoring-ri-low-carbon-energy-technologies

[21] European Patent Office, 2020, *Cooperative Patent Classification,* Available at: https://www.cooperativepatentclassification.org/cpcSchemeAndDefinitions/table, [Accessed on: 24/11/2020]

To do so, the study team started with the study TS requirements and key guidance provided by the SC during the kick-off meeting. These elements are summarised in the Venn diagram presented in Figure 2.4 that illustrates the inter-relationship between the four thematic areas of interest, built on a common integrating infrastructure in which key interdependencies and business opportunities for climate neutral solutions are now emerging such as building integrated energy systems , EV charging infrastructure (at homes and around city streets) and intelligent transport systems. It also illustrates that to be competitive, climate neutral solutions require not only new business models and reliable supply chains, but also consumer demand, access to finance and an enabling policy environment.

Figure 2.4 Framework that guided the scoping and inception phase



Source: ICF, 2020.

The next step was then to define clear criteria to select the 12 VCs to be analysed by the study team. Two groups of selection criteria were used: market relevance criteria; and methodological criteria.

Market relevance criteria

The following selection criteria were used to guide the short-listing process:

- **Global and European market size and expected growth rate**: as an indicator of the importance of Europe in different global climate neutral VCs, as well as the expected growth of the European market compared to other global markets.
- **Investment trends globally and within the European at early stage and growth rate**: as an indicator of the level of innovation within different VCs. The study team focussed on innovation to ensure the relevance of the study for the future, given the increased EU climate ambition by 2030 and the net-zero trajectory by 2050. The approach adopted by the study team has been to follow capital flows to identify the most relevant innovations.
- **European leadership in the sector**: in addition to the share of the European market size compared to the global market size, this indicator was used to select VCs where Europe plays different roles, e.g. from a market leader actively looking for new export countries in the offshore wind sector to a new player aiming to build competitive advantages in the EV battery sector. The study team has also looked into the leading Member States within Europe and the key competitors in the global market to inform the selection process.

Methodological criteria

Given the study objective to develop a first-of-a-kind set of indicators on competitiveness to serve as a basis for additional in-depth competitiveness assessments, two methodological criteria were considered for the selection of the VCs:

- The need to have a **heterogenous group** of strategic components to test the applicability of the set of indicators on competitiveness at different levels (i.e. both at a high sectoral level, e.g. batteries, and at a more specific component level, e.g. wind rotors) and across the four thematic areas in scope (i.e. ensuring a good coverage of the chosen thematic areas); and
- The need to select strategic components for which **sufficient data** will be available across most of the indicators included in the CAF. This requirement means ideally focusing on the VCs of strategic components where there is an existing market from which to derive data (including production and trade codes) coupled with the presence of prominent European companies, backed where possible by strong innovators, in order to understand the positioning of European companies versus non-European.

In addition to the above two criteria, a third criterion guiding the selection process was the desire to focus the study on solutions supporting **deep decarbonisation** and enabling the integration of the energy sector (related to the “integrators” VC of the study), going beyond electrification and gas networks and considering a stronger link of components of the energy system.

The final element that informed the selection of VCs was the discussion with the SC and recognising the EC’s priorities for the study which have also considered the other studies on EU competitiveness being conducted at the same time as this study. In this context Figure 2.5 provides an initial overview of the EC’s approach for selection of VCs within the four thematic areas of the study.

Figure 2.5 Approach for selecting climate neutral strategic components – internal document DG GROW

Thematic Areas	MOBILITY	BUILDINGS	CLEAN POWER	INTEGRATORS
Materials	Materials (aluminium)	Building materials (insulation, glass)	Materials (steel, copper, composite)	Materials, components and equipment for energy networks (grid, pipelines, storage)
Components	Batteries/Fuel cells/Electric engine (power train)	Heat pumps Heat/cooling systems	Rotors/blades/solar PV cells/inverters	
Equipment	EV/FC vehicles	Low carbon buildings	Wind mill/Solar PV system or farm	Hydrogen/other energy carriers and large-scale batteries

Source: Adapted from EC, 2020.

Based on the above elements the study team developed a short list of 14 VC. Of these, four VCs were selected for piloting of the CAF, i.e.:

- Wind rotors;
- Heat pumps;
- Batteries; and,
- Hydrogen fuel cells.

Results of the pilot exercise and selection of the eight remaining VCs

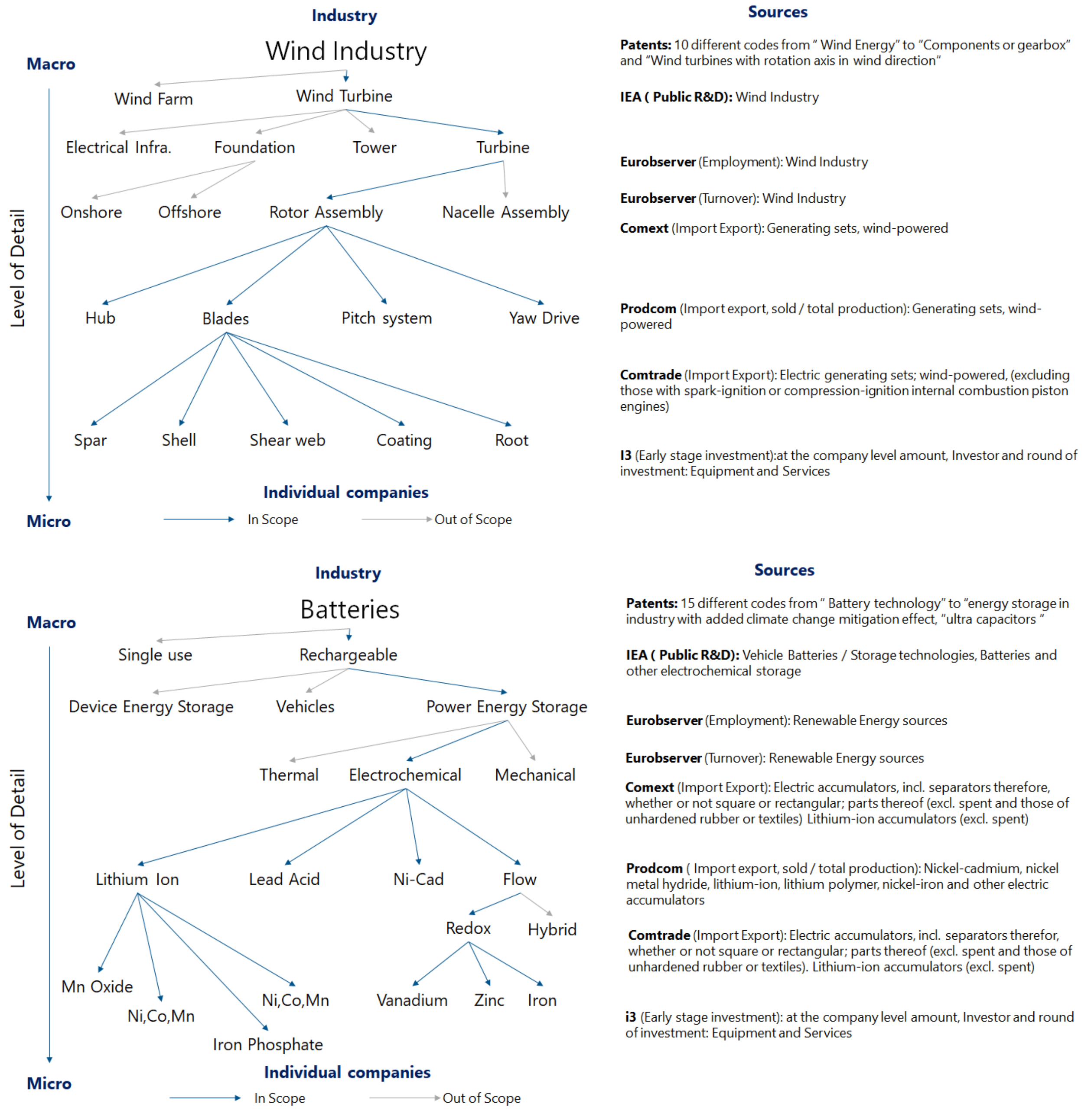
Box 2.2 provides an overview of the key limitations of the CAF, as identified during the pilot phase.

Box 2.2 While there are limitations to the CAF, it still has clear advantages

- Data coverage is limited and there are data gaps within the analysis. For some VCs there can be more or less data available from an innovation or current market perspective. However, the framework is designed to use qualitative data and expert insight to undertake VC analysis whenever quantitative data is not available.
- The granularity of data availability is different for the different indicators within a VC. For the wind VC for example, employment and turnover data is only available at the broad wind sector level, while production and trade are available specifically for generating sets. It is not always possible to analyse a VC at the same level from the different indicators' perspective.
- Furthermore, while each indicator on its own provides only a limited assessment of a given VC, the group of indicators does allow a relevant assessment of European competitiveness within each global VC.
- These limitations are inherent to the framework and do not compromise its key objective of being a first-of-a-kind and replicable framework to assess EU competitiveness in global climate neutral VCs.

Some of these limitations were taken into account in the selection of the eight remaining VCs and to help with their precise scoping. The pilot exercise demonstrated that, although the CAF can be used to analyse the VCs of strategic components at different level of detail within an industry, the availability of data varies considerably depending on the level one looks at. One might therefore have to rely on data available at different levels of detail when completing a competitiveness assessment, while providing full transparency on the exact coverage of different sources. The two diagrams below (Figure 2.6) illustrate this point for the wind rotors and batteries VCs. The first diagram shows, for example, that if one wishes to assess the competitiveness of European businesses within the wind blades value, it will be possible to access data at the level of wind blades for certain indicators of the framework, e.g. patents. For other indicators, however, it will only be possible to access information at a higher level within the VC. For example, RD&D data are available at the level of the wind industry as a whole, whereas import-export data are available only at the level of the generating set.

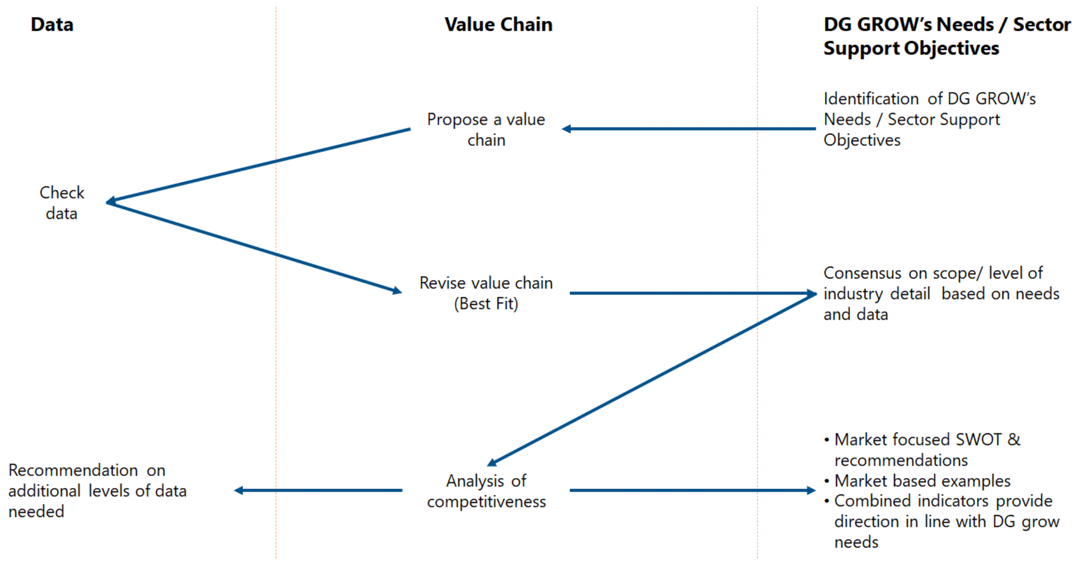
Figure 2.6 Data coverage at different level of details within the wind and battery VCs



Source: ICF & Cleantech Group, 2020.

Based on the above observations the process presented in Figure 2.7 was established to select the eight remaining VCs and define their scope.

Figure 2.7 Process established to select the eight remaining VCs and define their scope



Source: ICF & Cleantech Group, 2020.

Table 2.3 below provides an overview of the final list of VCs that were selected following this process and defines their respective scope.

Table 2.3 Overview of the value chain selected for detailed analysis together with strategic components which have been assessed

	Value chain	Scope	Example of areas of innovation with scale up potential in EU
Mobility	VC1 - Batteries	Grid-connected electrochemical batteries used for energy storage and digital control systems.	Battery chemistry, electrolytes, battery management systems.
Mobility	VC2 - Hydrogen Fuel Cells	Stationary fuels cells are electro-chemical cells including: electrolyte membrane, catalyst layers (anode, cathode), diffusion media, supporting hardware (plates, gaskets), interconnectors and digital technologies enabling fuel cell optimisation.	Membrane type, catalyst materials, operating temperature requirements.
Mobility	VC3 - Electric Power Trains	Electric components responsible for propulsion of road vehicles, fuelled solely or partially by electric power.	Electric motors, power electronics, integration with the grid.
Mobility	VC4 - Electric Vehicles Charging Infrastructure	Equipment and services used to deliver power to electric vehicles and the accompanying software.	Fast charging systems, predictive maintenance, smart charging, peer to peer energy trading.
Buildings	VC5 - Prefabricated Buildings	Technologies enabling the offsite construction of residential and commercial and industrial buildings resulting in lower carbon footprint (e.g. efficiency gains).	Design for easier and faster assembly; design for end-of-life processing; smart, low-carbon, and recycled materials and components.
Buildings	VC6 - Superinsulation Materials	Materials which can contribute to the achievement of ultra-low energy usage during building operations, achieving lower carbon footprints.	Improvements to existing insulation materials and further development of novel materials such as aerogels and Vacuum Insulation Panels.

	Value chain	Scope	Example of areas of innovation with scale up potential in EU
	VC7 - Heat Pumps	Air-, ground- and water- source heat pumps including piping, valves, heat exchanger, oil separator, compressors, evaporators, condensers, accumulators, electronic expansion valve, pumps, refrigerant, controllers and fan motors.	Analytics for optimised system performance (weather compensation, advanced controls), dual-source heat pumps (i.e. air and ground source).
Clean Power	VC8 - Wind Rotors	Onshore and offshore blades and hub – including all systems inside the hub (e.g. pitch control) and where the system is a direct drive turbine includes the annular generator (rotor & stator).	Blade manufacturing and materials, O&M (operational improvement – digital control & maintenance), End-of-life (recycling of blades)
Clean Power	VC9 - Photovoltaic Solar Panels	Photovoltaic panels for converting solar energy into direct current electricity.	Materials and chemistry, assembly process, O&M
Integrators	VC10 - Building Energy Management Systems (BEMS)	Digital integrated systems (hardware and software) to manage energy in commercial and residential buildings and the interaction with the energy grid. Covers BEMS and smart homes, covering all buildings (commercial, domestic, public) and their grid interaction.	Software and hardware to monitor and automate control of energy usage in buildings
Integrators	VC11 - Grid Energy Management Systems	Digital integrated systems to manage, coordinate, monitor and control utility-connected grids for efficient transmission and distribution of electricity.	Largely software-based approaches to managing energy flow on grids, O&M solutions, technologies to enable power electronic communication
Integrators	VC12 - Hydrogen Production	Sustainable production of hydrogen focused on innovations to produce clean hydrogen (i.e. based on RES), as well as hardware and processes for non-carbon-based production across the VC.	Components and processes for clean hydrogen production including emerging novel solutions such as Photo Electrochemical, Biogas/Biomass (microbial, bio gasification), Plasmalysis, Plasmolysis, Non-membrane Electrolysis and Pressurised Electrolysis.

Source: ICF, 2020.

2.3 Task 3. Assess EU competitiveness and identify challenges and opportunities ahead for European businesses

The overall aim of Task 3 was to identify (possible) future actions with regards to enhancing the competitiveness position of European businesses along the 12 defined VCs. To achieve this goal required a two-stage process, comprising firstly the analysis of individual VCs and interpretation of the datasets collected in order to develop VC-specific SWOT analyses. These then enabled a strategic outlook and conclusions to be developed.

In terms of the process and conceptual framework the main elements of Task 3 consisted of:

- Defining a structure for the development of comparable strategic outlooks for the VC of climate neutral solutions;
- Identifying a list of key questions that are required to complete a robust SWOT analysis of climate neutral solutions;

- Defining a framework for the identification of policy recommendations to strengthen EU competitiveness against the global VC of climate neutral solutions; and,
- Piloting the above elements with four VCs in order to refine them, before rolling the approach out across all 12 VCs.

These elements are discussed below, starting with the design, revision and finalisation of the CAF and then focusing on the selection of the VCs.

2.3.1 Strategic outlooks and SWOT analyses

This sub-task required a stock-take of all the outputs previously generated in the study, and then taking a step back from these findings and re-interpret them in an integrated manner in order to generate the strategic outlooks. This process also enabled the team to identify possible future actions to strengthen the competitiveness of European businesses in the global VCs of climate neutral solutions by:

- Reinforcing the core strengths of European climate neutral VCs;
- Mitigating identified weaknesses;
- Taking advantage of key future opportunities; and,
- Mitigating foreseen threats.

This sub-task was structured in two steps.

Step 1: Framing the conclusions by developing strategic outlooks for each VC

The objective of the strategic outlooks is to bring together the key insights generated by the study and answer the "So what?" question. The strategic outlooks are structured around the following questions:

- **How does the global and European landscape for each climate neutral value chain currently look like?**

  [*Answered based on literature review and high-level CAF summary*]

- **What are the current market sizes and dynamics?**

  [*Answered based on high-level CAF summary & the market analysis*]

- **Which key features and trends, including EU policy initiatives, will shape these emerging markets until 2030?**

  [*List key policy initiatives within EU and top competitors likely to impact the VC*]

- **Which stakeholders (private/public) will play a key role in these emerging markets until 2030?**

  [Answered based on high level CAF summary & market analysis]

Once drafted, each industry outlook was reviewed by an industry specialist from ICF, in order to ensure its accuracy and relevance to the most pressing challenges faced by each VC. When considering the strategic outlooks, it is important to bear in mind that these documents are not meant to provide a detailed review of the technologies, but rather an assessment of the competitiveness of European businesses within specific VCs compared to businesses operating in other regions.

Step 2: Undertaking SWOT analyses for each VC

Building on the insights from Task 1 and 2, detailed SWOT analyses were completed for each VC. As per the inception report, the SWOTs do not assess either the barriers to deploy climate neutral solutions or the affordability of costs in scaling-up technologies towards market uptake, since these two aspects were outside the scope of this study.

To inform the SWOTs and ensure their comparability across VCs, a list of key questions which the study team used to guide their assessments was compiled. These questions, which are organised by key areas typically considered in SWOT analyses (e.g. innovation potential, policy, economic and social environment), were complemented by elements from Porter's Five Competitive Forces Model, as applied to climate neutral VCs, and explained in more detail in Box 2.3. Importantly, a clear link was made between these questions and the indicators derived from Task 2. Table 2.4 presents the final list of questions which were agreed with the study SC. It includes analysis around the implications of the Covid-19 pandemic, which arose during the study.

Table 2.4 Overview of the SWOT analysis framework

Criteria	Key areas	Key questions *The questions in italics are those informed by the shortlisted quantitative indicators under Task 2*
Strengths & weaknesses: *Internal attributes, characteristics and factors that give competitive advantage to the EU or on the contrary weaken its competitiveness in the global VC.*	Innovation potential	■ Does the VC (or key components within it) benefit from sustained and/or growing levels of RD&D investment from the public sector? ■ Does the European VC have access to internal financing and what is the significance of European firm turnover across the VC? ■ Does the market recognise the potential for this VC (component) to invest in innovation and generate financial returns? ■ Does the VC effectively translate investment into tangible Intellectual Property? ■ Does the public / private sector already recognise the VC through specific clustering initiatives? ■ Does the European VC comprise of leading innovative firms in the global VC?
	Key characteristics of the VC	■ Does the VC have an established and skilled labour market on which it can build or is it still emerging? ■ Does the VC have core production competence and capability within Europe? ■ Are actors in the VC well organised and able to advocate for their interests? ■ Is Europe perceived as a leading actor in the VC and able to export to other non-European countries? ■ Is Europe able to sustain a strong and positive trade balance?
Opportunities & threats: *External situations and factors that can strengthen the competitive advantage of the EU or provide the EU with new sources of competitive advantage or on the contrary create problems for the EU compromising its competitive advantage to a certain extent.*	Policy environment	■ Is the policy environment favourable for the development of the VC in Europe?
	Economic environment	■ Is the economic environment favourable for the development of the VC in Europe?
	Social environment	■ Is the VC operating in a favourable social environment?
	Market conditions*	■ Level of competition?* ■ Risk of entry by non-European competitors?* ■ Level of technology lock-in to existing VCs?* ■ Level of threat of vertical integration by buyers or suppliers?* ■ Level of substitutability of an industries' value propositions?*

Criteria	Key areas	Key questions *The questions in italics are those informed by the shortlisted quantitative indicators under Task 2*
	Other considerations: Covid-19	■ How strongly are European and global VCs expected to be disrupted by the Covid-19 crisis? ■ Does this create new threats or opportunities for European actors?
	Other considerations: digitalisation	■ How strongly are European and global VCs expected to be disrupted by further digitalisation? ■ How prepared are European actors prepared for these disruptions compared to the actors in the RoW?

** Based on Porter's Five Forces competitiveness model, see Box 2.3 Porter's 5 Competitive Forces Model applied to Climate Neutral VCs.*

Box 2.3 Porter's 5 Competitive Forces Model applied to Climate Neutral VCs

Changes in the strength of the five forces shown below, as applied to climate neutral VCs, will indicate changes in the competitive landscape which are essential to understanding what potential policy actions could improve competitiveness:

Competitive Rivalry – What is the strength of competition in the European VCs? How many rivals are present? Who are they, and how does the quality of their products and services compare? Intense rivalry can lead to limits on price and profitability, as well as increased spending on innovation and improvements to products/service.

Supplier power - The power of suppliers is determined by analysing how easy it may be for them to develop the technology and charge higher prices (Porter, 2008). What is the ability of suppliers to drive up prices of inputs into the VC (taking account of price controls where relevant for regulated sectors)? This will depend on the number of potential suppliers and uniqueness of their product or service, as well as how expensive it would be to switch to from one supplier to another?

Buyer power – The power of buyers is determined by analysing how easy it may be for buyers to drive down costs (Porter, 2008). What is the strength of customers to drive down prices in the VC? This will depend on the number of buyers and scale of their procurement (including whether they are supplying intermediary products which may have an essential role in an overall product offer), as well as how expensive it would be to switch to buying an alternative product and service.

Market Entry – New entrants to an industry bring new capacity, have an impact on prices, costs and the amount of investment required to compete (Porter, 2008). The extent to which non-European suppliers can access the European market and displace European firms is an important consideration; it is also relevant in global VCs as European firms increasingly look outwards for new markets (for example, are non-European rivals benefiting from government support in the form of hidden subsidies). Is there a level-playing field in Europe compared to other regions?

Threat of Substitution – To what extent can different products and services be substituted within the VC to achieve the same or similar function? How likely might this happen within the VC? Effective substitution (i.e. a reliable product that is cheap to manufacture) could weaken EU competitiveness, impacting profitability.

2.3.2 Assessment of challenges and opportunities ahead for European businesses including identification of possible actions

This subtask built on the strategic outlooks and SWOTs to identify which actions should be taken to enhance the competitiveness of European businesses active in the VCs of climate neutral solutions and of the European economy. A focus was put on identifying actions with the highest positive impact on respective VCs. This subtask was organised around three steps.

Step 1: Identification of potential actions at VC level

Building on the results of the SWOT analyses, the study team identified what actions should be taken by different players in each VC to further improve the EU competitiveness. To ensure the relevance of this exercise, these suggested actions were framed according to different levels of technology and business maturity and organised actions according to the specific market needs they aim to address, such as the need to:

1. Accelerate the lab-to-market process;
2. Make support programmes more efficient and better targeted;
3. Increase flows of private sector capital into company formation and infrastructure;
4. Increase the effectiveness of trade support into non-European countries/regions within the limits of the WTO rules and other trade agreements.

Particular attention was put on those stakeholders expected to lead on each suggested action, with attention directed at:

- European level decision-makers;
- Member State level decision-makers; and,
- Public-private partnerships & other initiatives supporting innovation, e.g. accelerators, incubators, etc.

Step 2: Prioritising actions with the highest positive impact across VCs

Following the identification of a long list of actions across the VC, the study team took stock of the 12 strategic outlooks to identify the actions with the highest benefits for Europe across these VCs. This prioritisation exercise helped identifying a set of 10 policy recommendations.

3 Outcome 1 – Competitiveness assessment framework

This section presents the detailed methodology and the analytical framework developed in this study. The framework – which is summarised in Figure 3.1 and presented in this chapter – can be used to inform European competitiveness in climate neutral strategic components.

The framework consists of three key components:

- **VC Analysis** entails of a qualitative analysis of the strategic component which covers defining the structure of the VC, identifying key market participants, looking into historic and forward looking market trends, mapping investment flows and spotting innovation trends within the VC.
- **Data Collection** involves gathering quantitative data on key indicators from multiple sources. These indicators inform on both the current market (e.g. imports, exports and production) and innovation aspects (e.g. patent applications and RD&D investment).
- **EU Competitiveness Assessment** consists of using the results from the VC Analysis and the Data Collection to inform a strategic outlook and SWOT analysis of the VC. It also entails mapping key challenges and opportunities for European businesses and suggesting actions which can bring a positive impact for EU competitiveness.

Figure 3.1 Summary of the Competitiveness Assessment Framework (CAF)

Source: ICF, 2020

3.1 Part 1. Value Chain Analysis

3.1.1 Value chain structure

The first step of the framework consists of defining the structure and scope of the value chain. This implies:

- Clearly defining the scope of the strategic component that will be analysed;
- Identifying and mapping the **value adding activities** along the six main stages of the VC based on the standard framework (Figure 2.2) that is tailored to the reality of each thematic area/VC. The resulting VC follows the technology development from design to end-of-life management, ensuring that each point of economic value creation is captured along the way; and,
- Identify key areas of innovation within the VC.

The following section presents the approach to ensure the CAF is carried out in line with the study methodology. This guidance therefore contains instructions for future users.

3.1.2 Key Market Participants

Within each stage of the VC, companies should be identified. When applying this framework, Cleantech Group’s database has been used as a starting point for mapping key market participants.

A representative sample of European companies should be included in each VC in order to display innovative business activities within each of the stages. Three procedures are required, as described below:

- **Identification, mapping and clustering of companies** along each VC is done to identify both established incumbents and innovators and to distinguish between European and non-European companies. The initial identification of companies draws on Cleantech Group’s in-house i3 database that tracks approximately 35,000 companies across the global cleantech landscape. The approach to mapping clusters is a bottom review of companies’ business activities as defined by their products, services, and business models. For example, battery management systems for electrochemical batteries may employ various technologies (e.g. machine learning, artificial intelligence, blockchain, physical interfaces, etc.), platforms and business models, but the intended outcome, and therefore business activity, is the efficient operation of the battery system. These activities may apply to one section of the VC or span multiple sections. After the initial landscape is completed, the scope of secondary research should be expanded to identify additional companies and their activities.
- **Location:** The location of the tracked companies is based on the primary addresses of their headquarter.
- **Expansion of geographic scope** is required to include a global view for comparison between Europe and other geographies. Development stage, geographic reach, level of vertical/horizontal integration, market share consolidation and supply chain position should be considered in order to understand the potential for European companies to extend their businesses beyond Europe.

3.1.3 Market Trends

Finally, for each VC, an analysis of key market trends should be undertaken, focusing on:

- Historic market trends;
- Forward-looking market trends; and,
- Private investment and innovation trends.

Identification of both historical and forward-looking trends should be built on the findings from the literature review and the VC development. These should reveal past activities of most market participants and provided insights into upcoming activities that will impact the VC.

As part of the VC research, private venture capital investment data from Cleantech Group's i3 platform was used as a source to understand the changing innovation landscape of each of the sectors. Additional secondary research should be conducted as required to uncover further insights.

The backward-looking view should focus on identifying how European companies have responded to changes in comparison to the rest of the world. The forward-looking view, by contrast, aims to provide insights into how European companies within the sectors and the markets themselves will continue to evolve.

Trends can be based around "inflection points", i.e. key events that have contributed to the current status, as well as those to watch for in the future that may indicate a 'tipping point'. These include regulation, product/service introduction, investment, mergers, acquisitions or other market-related trends (e.g. health or economic crisis).

3.1.4 Outputs

The outputs resulting from implementing the methodology are presented for each VC in its slide deck (Annex 2) and cover:

- An overview of each VC covered within the study;
- An assessment of the positioning of European businesses within these VCs; and,
- An overview of the key features and trends shaping these markets.

3.2 Part 2. Data Collection on Key Competitiveness Indicators

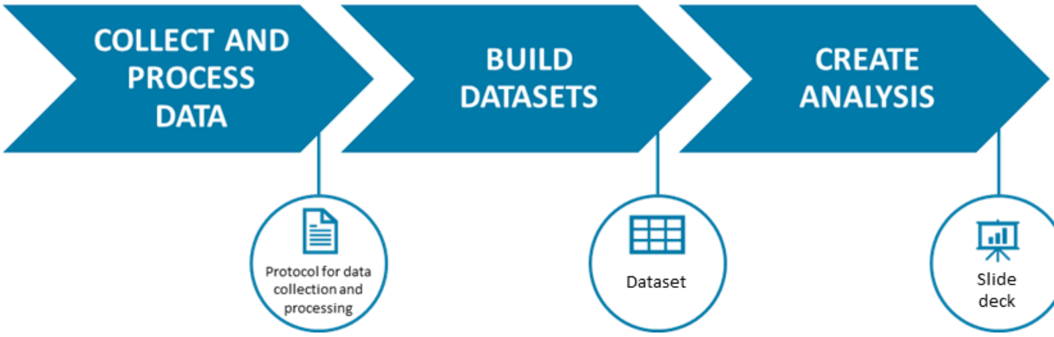
Figure 3.2 presents the key activities and deliverables for the data collection process, which are also detailed here:

- **Collect and Process Data.** This activity consists of following the methodology in this Section for data collection for each of the competitiveness indicators listed in Table 2.2. A key step to inform this process is to precisely define the scope of the VC one wants to analyse. For most databases, this implies selecting a series of codes which are used to filter the relevant data. Box 3.1 below provides an overview of this framework's approach for code selection.
- **Build Datasets**. The preparation of datasets follows the data collection and initial processing. For each strategic component, the database includes raw figures (e.g. number of high-value patent applications per country, EU-28 production, EU-28 trade per year, private investment), as well as calculated indicators (e.g. leading countries in Europe in trade and patents, share of European investment over global)

and graphs summarising key information. An inventory of European companies at the cutting edge of solutions for each strategic component should also be included in the dataset.

- **Create Analysis.** The data collected and the calculated indicators should be used to assess European competitiveness. Graphs and key findings related to each of the indicators should be summarised in a slide deck. The slide deck should include the outputs from the VC Analysis as well as those from the Data Collection to inform the SWOT analyses and strategic outlooks created to assess EU competitiveness.

Figure 3.2 Key activities and deliverables for Task 2



Source: ICF, 2020

Box 3.1 Which approach should be adopted to select relevant codes within the production and trade database?

A key step in the data extraction process is defining which codes are linked to the VCs under investigation to get a representative and robust analysis of the VC. The process to be followed for this selection in set out in the steps below:

1. Identify VC codes across the IEA, PATSTAT, COMEXT, COMTRADE and PRODCOM databases for products at the end of the VC. Identify equivalences between products codes across these data sources.
2. Use a source of HS codes identified in previous JRC studies which can be used.[22]
3. Assess which codes are discreet and specifically focused on the VCs of interest and which codes are generic. In some cases, more than one code is assigned per VC.
4. Assess to what extent the codes are well defined and equivalent across databases to support the robustness and comparability of the analysis across indicators.

The above being set out, it is also important to stress that for some VCs, it is likely that there will be very limited flexibility in terms of code selection, especially for the most innovative VCs, since they are unlikely to have been integrated yet into databases.

This section details the methodology that should be followed for collecting, processing and analysing data for applying the competitiveness assessment framework designed in this

[22] Pasimeni F., 2017, *EU energy technology trade: Import and export*, EUR 28652 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-69670-1, doi:10.2760/607980. Available at: http://publications.jrc.ec.europa.eu/repository/handle/JRC107048

study. It also provides guidance on how to replicate the assessment for other VCs. For each key indicator (Table 2.2), the protocol contains:

- The key data sources and where to access them; and,
- A step-by-step process for extracting and processing the data.

The processed data and results should be included in the VC's excel dataset, and the key graphs should also be included in a slide deck that summarises key findings from applying the framework.

3.2.1 Public Investment in RD&D

Source of information

The International Energy Agency (IEA) tracks yearly public investments in RD&D in its member countries. The database is available at http://wds.iea.org/wds/default.aspx and the documentation supporting the database is available at http://wds.iea.org/wds/pdf/RDD_Documentation.pdf.

Step-by-step process for extracting and processing the data

- Analyse the supporting documentation and select the **flow definitions** relevant for a given VC
- Access the database using the guest credentials (Username: GUEST / Password: GUEST)
- Select the **Energy Technology RD&D** folder
- Select the **Detailed Country RD&D Budgets** datasets
- Define the data parameters
  - **TIME**: Select the appropriate time range. Data is available since the 1970's. For the purpose of this study, the data was extracted for the 10 most recent years for which data is available (i.e. **2009 – 2018**).
  - **COUNTRY**: Select all countries. IEA RD&D Budget data covers: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, South Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.
  - **PRODUCT**: Select the Total RD&D Million **Euro (2018 prices and exch. Rates)** product.
  - **FLOW**: Select the relevant flows for the VC.
- Extract the dataset by clicking in Actions and Download report data in excel.
- Use the data extracted to create a table with the countries as rows and the years as columns.
- Calculate the total investments over the past 3 years (i.e. 2016-2018).
- Sort the table using the total investments over the past 3 years to assess which countries have been investing the most lately.

- Sum yearly budgets for European countries to assess the volume of investments within Europe. Because IEA data coverage is limited, a RoW total is not calculated as it would not allow for an unbiased comparison.
- Present total investments over the past 3 years in a table and a graph for the Top 10 countries. For some VCs, there are fewer than 10 countries in the Top list. This happens if there has been investment in less countries.
- Present European investments over time in a graph.

Shortcomings and Limitations

- The geographic coverage of the data is limited as only countries that are members of the IEA are included. For most flows data is available for up to 30 countries and key players such as Brazil, Russia, India and China are not covered. There are gaps in the database and some countries choose to keep their data confidential.
- Some flows are broad and include more specific flows within it. For example, 32 Wind Energy covers: 321 Onshore wind technologies, 322 Offshore wind technologies (excluding low wind speed), 323 Wind energy systems and other technologies, and 329 Unallocated wind energy. Caution is advised when selecting the flows to avoid double counting.
- In some cases, the codes are not specific enough to allow for a thorough assessment. For example, there are no codes within 122 Building Operations and Efficient Building Equipment that specifically relate to Superinsulation Materials or with Prefabricated Buildings. Caution is advised when drawing conclusions bases on broader flows as there might be overlap between the information reported for different VCs.

3.2.2 Early Stage Private Investment (Venture Capital)

Source of information

Cleantech Group's database has information on over 35,000 companies (and growing daily). Each company's investments, partnerships and relationships are tracked from their first funding round until they are no longer a private operating entity. The database was developed systematically since 2002 based on the following approach:

- The database provides comprehensive profiles of European and non-European companies and investors (Europe represents approximately 1/3 of the companies) as well as sector, innovation and investment data on five sectors: Agriculture & Food, Energy & Power, Materials & Chemicals, Resources & Environment and Transportation & Logistics. An additional category of Enabling technologies – those technologies that cut across the five sectors are actively tracked. Innovators within these sectors/themes that enable resource efficiency (doing more with less) or contribute to reduction in climate impact of existing processes are recorded in the database.
- The Cleantech Group's team of analysts focused on each of the sectors searches for private company activity daily through a review of industry-trusted sources globally. Furthermore, through the process of ongoing research, the team is continuously adding new companies and updating existing profiles as they engage directly with the companies.

- Companies are added through recommendations from the Cleantech Group network of investors, corporates, economic development agencies, and entrepreneurial support organisations (incubators, accelerators, challenge programs, etc.). Finally, the innovators themselves have the ability create and suggest edits to profiles within the database.

Some key characteristics of the database include:

- 60,000 investment deals have been catalogued since the creation of the database. On average (2013-2019), 2,100 new companies are added annually.
- 35,000 companies and private investors have been added to the database since creation. On average (2013-2019), 2,200 new investment events are added annually.
- Counts of new investments and new companies added to the database and associated with each VC varies significantly based on the definition of the VC in question.
- European companies represents approximately 1/3 of the database, North-America accounts for approximately 1/2 of the database and the rest of the world is responsible for the remainder.

Data is tracked at company level with location based on primary address of the headquarter. Each organisation is tagged, by the analysts, with relevant groupings based on the organisation's activities. Using the tags associated with each company and correlating them to the VCs of interest, the Cleantech Group can determine the relevant private investment activity going into each VC for the last 5 years. Once a company has received private investment during that period, they will be represented within that dataset. Grants, public funding, private investment into public entities and other non-venture capital investment are not reflected in the investment data. Early stage private investment is defined as seed or Series A. Late stage private investment is defined as Series B and beyond.

Data are extracted from the Cleantech Group's database for each strategic component. This initial dataset is then expanded through desk-based research to ensure recent market developments are taken into account and key market players are included. It is important to recognised that the data are not comprehensive they do, however, provide a reasonable starting point to understand market dynamics in Europe compared the rest of the world for this indicator.

Step-by-step process for extracting and processing the data

- Use the data extracted to create a table with the countries as rows and the years as columns. The table should present the number of investments (i.e. count of investments) and the total amount of investments (i.e. sum of investments) per country per year
- The Cleantech Group database presents investment values in USD. These have been converted to EUR using the annual average exchange rate of the year when the investment happened. These rates are available at https://www.statista.com/statistics/412794/euro-to-u-s-dollar-annual-average-exchange-rate/ and presented in Table 3.1.

Table 3.1 Annual average EUR to USD exchange rates (Source: Statista)

Year	Exchange Rate
2009	1.39
2010	1.33
2011	1.39
2012	1.28
2013	1.33
2014	1.33
2015	1.11
2016	1.11
2017	1.13
2018	1.18

- Calculate the total investments over the past 6 years (i.e. 2014-2018). The period for the analysis is longer for private investments (versus public RD&D investments) as these present a high year-on-year variation.
- Sum total amount of investments and number of investments for Europe and RoW investments and present results in two pie charts.
- Present Europe and RoW investments over time in a graph.
- Present country totals sorted from largest to smallest and present Top 10.

Shortcomings and Limitations

- In some cases, an investment is registered in the database but there is no information on the amount invested. This happens because sometimes the value of an investment round is kept confidential.
- The Cleantech Group investment database is global. While the database is the most extensive for private investment into low carbon companies, it is not comprehensive since these transactions are private by definition. Also, while there is confidence regarding the coverage of venture capital investments in the US and Europe, data from emerging markets can be underestimated due to this information not being made public in some cases.
- Because the database is built based on tracking and monitoring venture capital investments, it does not provide a precise figure on investments per country per year. For some strategic components, the database presents only a small number of investments in specific countries. This does not necessarily mean that there were zero investments in the countries not presented in the results.
- An investment may be related to companies that are active in multiple VCs which may create an overlap between the results produced for each VC (e.g. an investment being included in the dataset of more than one VC).
- When disclosed, the database tracks which investors contributed to specific investment rounds and can therefore associate a region to these investors. However, the amount of investment provided by each investor is however rarely communicated and the database can therefore not be used to attribute specific investment amounts to a particular region. Due to this limitation, in this framework, the study team has looked into the countries that received these investments but not where they came from.
- The Cleantech Group investment database is not an open data source that users can get access to when applying this framework. The data has been extracted for the 12 VCs covered in this study.
- The regional concentrations of investment data in the North American and European markets that has been captured in the Cleantech Group's i3 database reflect the historical realities of cleantech venture capital investments over the past 15 plus years; and these two regions continue to be home to the largest and most well established venture capital firms. Venture capital investments in the RoW are starting to catch up – rapidly in some countries – but it is an important feature that should be borne in mind when considering the investment data.

3.2.3 Late Stage Private Investment (Venture Capital)

The exact same approach described in Section 3.2.2 is followed to extract and process data on late stage private investment. Also, the same shortcomings and limitations apply.

3.2.4 Patent Applications

Source of information

Part of this analysis is a review of Patent statistics as a measure of innovation in Europe in the targeted sectors. The JRC has been involved in the development of this study. Patent data is gathered within PATSTAT, managed by the EPO, which accumulates globally submissions from patenting agencies. The JRC are experienced in extracting information from PATSTAT, as set out in the methodological paper underpinning the JRC work for the SETIS Research & Innovation dashboard[23]. The patent data is collected under an approach considering the country of the applicant, keeping the priority application date and grouping patents into families to apply a fractional approach. It is furthermore refined using a harmonization algorithm and analysis to clarify data inconsistencies.

The data used in this study has been sourced from JRC. Key steps followed by JRC for data extraction include:

- Accessing the PATSTAT database to download the dataset.
- Cleaning the data of inconsistencies such as typos or missed entries.
- Identifying "high-value" patent families. These are patent families for which an application has been filed in more than one country. This is deemed to be an indicator of "high value" because applying for multiple patent protections implies the value the patent has for export.
- The analysis also includes a fractional approach to the results. For this reason, some of the entries may not have an integer value. Indeed, if a patent was applied for in a country but with multiple countries of origin, it is assumed the research was undertaken in these multiple countries, hence a fraction of the patent application is assigned to each country involved.
- This first analysis consists first of cleaning the data of inconsistencies such as typos or missed entries.

Step-by-step process for processing the data

- Categorise countries in Europe (as defined in Box 2.1) and RoW.
- Creating a table with high value patent applications per country (RoW) and per year (column). Include grouped results in the table (Europe and RoW).
- Present the total of patent applications for the 3 more recent years for which data is available (2014 to 2016) per country for the top 10 countries in a table and in a graph.
- Present the yearly total of patent applications for Europe and RoW in a graph.

[23] Fiorini, A., Georgagaki, A., Pasimeni, F. and Tzimas, E., 2017, *Monitoring R&I in Low-Carbon Energy Technologies,* EUR 28446 EN, ISBN 978-92-79-65592-0, doi: 10.2760/447418, JRC105642, Available at: https://setis.ec.europa.eu/publications/relevant-reports/monitoring-ri-low-carbon-energy-technologies

Shortcomings and Limitations

- The data for recent years is not available at a high-quality from PATSTAT. There is a lag of 3 years associated with the data on patent applications.
- There are several shortcomings associated with the quality of the data extracted directly from PATSTAT that are addressed through JRC's methodology. This is covered in further detail in JRC's 2017 report *Monitoring R&I in Low-Carbon Energy Technologies*[24].
- To assess patent applications in climate neutral solutions, the Y codes system which was designed to improve identification of patents relevant to climate change mitigation was used. While some strategic components are ranked as clean technologies due to the renewable energy source used (e.g. wind rotors, solar panels) others are not. For example, prefabricated buildings are not necessarily climate neutral solutions and the Y code system does not cover this strategic component.
- The use of patent varies considerably across industries and sectors. As flagged by the Bruegel report, "*in some low-carbon technology areas such as batteries and photovoltaics, the number of patents is high, because they are types of technology for which there is more patenting, commercial interest in the technologies is high and the categories are broadly defined. Much less patenting occurs in relation to electric vehicles and wind turbines, though EU member states have embarked more on specialisation in the latter two fields. Patenting data is no perfect measure for innovative activity.*"[25] In addition, patent data will not capture strengths in software development and digitalisation as they are not frequently used in these fast-evolving sectors.

3.2.5 Companies

Source of information

Cleantech Group's database has information on over 35,000 companies (and growing daily). Each company's investments, partnerships and relationships are tracked from their first funding round until they are no longer a private operating entity.

The Cleantech Group's team of analysts, focused on each of the sectors, searches for private company activity daily through a review of industry-trusted sources globally. Furthermore, through the process of ongoing research the team is continuously adding new companies and updating existing profiles as they engage directly with the companies. The Cleantech Group Events also provide a rich source of company information.

Companies are added through recommendations from Cleantech Group's network of investors, corporates, economic development agencies and entrepreneurial support organisations (incubators, accelerators, challenge programmes, etc.). Finally, the

[24] Fiorini, A., Georgagaki, A., Pasimeni, F. and Tzimas, E., 2017, *Monitoring R&I in Low-Carbon Energy Technologies,* EUR 28446 EN, ISBN 978-92-79-65592-0, doi: 10.2760/447418, JRC105642, Available at: https://setis.ec.europa.eu/publications/relevant-reports/monitoring-ri-low-carbon-energy-technologies

[25] Veugelers, R., 2017, *Remaking Europe: the new manufacturing as an engine for growth*, Bruegel. Available at: https://bruegel.org/wp-content/uploads/2017/09/Remaking_Europe_blueprint.pdf, [Accessed on: 24/11/2020]

innovators themselves have the ability to create and suggest edits to profiles within the database.

Data is tracked at company level with location based on primary address of the headquarter. Each organisation is tagged, by the analysts, with relevant groupings based on the organisation's activities. Using the tags associated with each company and correlating them to the VCs of interest, the Cleantech Group can determine the relevant private investment activity going into each VC for the last five years. Once a company has received private investment during that period, they will be represented within that dataset.

Companies that have not received investment, but were identified through additional research, will not be reflected in the investment data. However, they will be captured in the list of companies. Those organisations are tagged with one of the following statuses:

- Private – a for-profit organisation that is private and still operational; or,
- Acquired – an organisation that has been purchased wholly by another entity; or,
- Public – an organisation which trades on a public stock exchange; or,
- Other – a not-for-profit organisation that includes social enterprises, public bodies, government organisations; or,
- Bankrupt / Out of Business – an organisation that is no longer operational.

The data provides the following information on each company: year founded, status, short description, website URL, country, and region.

Step-by-step process for extracting and processing the data

- Create a column which identifies whether the company is headquartered in Europe (as defined in Box 2.1) or elsewhere (RoW).
- Create a column which identifies whether the company is active or not. Companies are considered active unless their status is *Bankrupt* or *Out of Business*.
- Present total number of active companies per country in a table. The table of Top countries should include all countries where there is more than 1 active company.
- Present total number of active companies per country in a bar chart for the Top 10 countries.
- Sum total Europe and RoW active companies and present results in a pie chart.

Shortcomings and Limitations

- The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of companies headquartered in the US and in Europe, data from emerging markets can be underreported.
- The Cleantech Group company database is not an open data source that users can get access to when applying this framework. The data has been extracted for the 12 VCs covered in this study.
- Companies included in the database may be active in multiple VCs which can create an overlap between the results produced for each VC (e.g. a company being included in the dataset of more than one VC).

3.2.6 Employment

Source of information

Employment data is sourced from the EurObserver database available at https://www.eurobserv-er.org/online-database/. The data is limited to EU-28 countries and only available for a selected period of time. It covers both direct and indirect jobs.

Step-by-step process for extracting and processing the data

- Select the source for data extraction and download the data.
- Present the table with total employment per year (column) per country (row) and EU-28 total.
- Present employment in the latest year for which data is available for the top 10 countries in a bar chart.
- Present total EU-28 employment over time in a graph.
- Calculate growth trend over time in the EU-28.

Shortcomings and Limitations

- Employment data from EurObserver is only available for renewable energy technologies and not for climate neutral solutions in other sectors.
- The data is limited to EU-28 countries.
- Data is only available for a selected time period. When piloting the framework for the first four VCs, for example, data was available for the 2015-2017 period. However, when replicating the methodology for the remaining eight VCs, the only available data was for the 2017-2018 period.

3.2.7 Production

Source of information

The PRODCOM database link can be found on the Eurostat website at:

https://ec.europa.eu/eurostat/web/PRODCOM/data/database

It can be downloaded as a full excel sheet published for each year under:

https://ec.europa.eu/eurostat/web/PRODCOM/data/excel-files-nace-rev.2

or navigated through a database interactive tool:

https://ec.europa.eu/eurostat/web/PRODCOM/data/database

which can then be manipulated on the server or downloaded as a csv. To allow for processing the data in the context of this framework, the data should be collected through the database portal.

PRODCOM is operated by Eurostat and provides import, export, sold production and total production of products data as reported by European countries, and countries in European area of influence (Norway, Iceland, Turkey, Bosnia and Herzegovina, Macedonia, Montenegro, Serbia). The information is also reported under EU blocks: 15, 25, 28 and 27 (without UK).

Step-by-step process for extracting and processing the data

- Access the database using the link. Click on the logo next to the "Sold production, exports and imports by PRODCOM list (NACE Rev. 2) - annual data (DS-066341)".
- Define the data parameters
  - **PERIOD**: Select the appropriate time range. Data is available since the 1995. For the purpose of this study, the data was extracted for the 10 most recent years for which data is available (i.e. **2009 – 2018**).
  - **DECL**: defines the declaring country. Select all countries. PRODCOM covers all the EU-28 countries along with EU aggregates: France, Netherlands, Germany, Italy, United Kingdom, Ireland, Denmark, Greece, Portugal, Spain, Belgium, Luxemburg, Sweden, Finland, Austria, Malta, Estonia, Latvia, Lithuania, Poland, the Czech Republic, Slovakia, Hungary, Romania, Bulgaria, Slovenia, Croatia, Cyprus, EU15Totals, EU25Totals, EU27Totals_2017 and EU27Totals_2020.
  - **Production**: Select the relevant code for the **product** to be extracted (e.g. wind powered generating sets is coded by 28112400).
  - **Indicators**: for the purpose of this framework all indicators should be selected for download (i.e. export quantity, export value, import quantity, import value, production quantity, production value, and quantity unit).
- After the data parameters have been defined, press "download" on the top right of the interface. An Excel or csv of the data isolated can be downloaded through this link.
- Use the data extracted to create a table with the production value (in EUR) per country and EU-28 total.
- Present production per year over time for the EU-28 in a graph and include top producing countries shares.

Shortcomings and Limitations

- Data is only available for European countries.
- Although the EU-28 production values as a block are reported, the Member States may choose to keep production values confidential at a national level, which limits the analysis.

3.2.8 Turnover

Source of information

Turnover data is sourced from the EurObserver database available at https://www.eurobserv-er.org/online-database/. The data is limited to EU28 and only available for a selected period of time.

Step-by-step process for extracting and processing the data

- Select the chosen strategic component of the VC for data extraction and download the data.

- Present the table with total turnover per year (column) per country (row) and EU-28 total.
- Present turnover in the latest year for which data is available for the top 10 countries in a bar chart.
- Present total EU-28 turnover over time in a graph.
- Calculate growth trend over time in the EU-28.

Shortcomings and Limitations

- Data is only available for European countries.
- Although the EU-28 production values as a block are reported, the Member States may choose to keep production values confidential at a national level, which limits the analysis.

3.2.9 Imports & Exports

Source of information

For this indicator, data is sourced from PRODCOM and UN COMTRADE. The procedure described in Section 3.2.73.2.7 for PRODCOM is used to extract import/export data. UN COMTRADE data is found at: https://comtrade.un.org/data/.

Step-by-step process for extracting UN COMTRADE data and processing PRODCOM and UN COMTRADE data

- Access the database using the link.
- Define the download parameters as:
- **PERIODS**: Select the appropriate download years. These can only be downloaded to a maximum of 5. Hence 3 downloads will be completed: 2005 to 2009, 2010 to 2014 and 2015 to 2019.
- **Reporters**: are the countries making the declaration of import and export of goods. For a world analysis, please mark this section as "All"
- **Partners**: defines the countries to whom the reporters are exporting/importing to/from. In order to establish the total world market, please mark this section as "World".
- **Trade flows**: defines the type o trade to report, import/ export / re-export. For this study, this is marked as "All".
- **HS (as reported) commodity codes**: defines the product HS codes of interest. Enter the relevant codes selected for the analysis.
- Once the parameters have been set, click the "download CSV" link to extract the raw data. Use the data extracted from PRODCOM to create two tables with the imports and exports value (in EUR) per country and EU totals.
- Present top 5 EU-28 importers and exporters 3 year total (2016-2018) in a table and a graph.
- Present total EU-28 imports and exports over time in a graph.

- Use COMTRADE data to assess total global exports over the past 3 years (2016-2018) and compare it to EU-28 totals in a table and graphically.
- Identify top 10 global exporters and importers using COMTRADE data and present 2016-2018 total for these countries in a table and a graph.

Shortcomings and Limitations

- To look at Imports & Exports, this framework uses PRODCOM and COMTRADE data as complementary sources of data. While PRODCOM data covers only European countries in EUR, COMTRADE covers global flows in USD. The data codes do not always match exactly between the two databases.
- In some cases, the total exports/imports figures do not match between the databases for selected countries. While this can be caused by an imperfect alignment between the codes covered in each database or a lack of precision in converting COMTRADE data from USD to EUR, in some cases it is not possible to clearly understand what drives this difference.
- On PRODCOM, although European production values as a block are reported, the Member States may choose to keep production values confidential at a national level, which limits the sample for the analysis.

3.2.10 Trade Balance

Source of information

For this indicator, data is sourced from PRODCOM and COMEXT. The procedure described in Section 3.2.7 for PRODCOM is used to extract import/export data. The COMEXT databases can be found at: http://epp.eurostat.ec.europa.eu/newxtweb/setupdimselection.do.

Step-by-step process for extracting COMEXT data and processing PRODCOM and COMEXT data

- Select the appropriate download dataset by opening "available datasets", then "International Trade" and finally "EU Trade Since 1988 by HS2, 4, 6 and CN8".
- As the data to be extracted is large, one must first register to the Eurostat on the top right of the portal. The registration process is free. Once registered, continue the query process by login in.
- Create a new query process. In the first step, define the parameters of the query:
  - **Declarant**: defines the declaring country. Select all countries 28 declarant countries (the EU-28 Member States on file).
  - **Partners**: defines the countries to whom the reporters are exporting/importing to/from. In this study, the main trading partners of the EU-28 countries have been analysed. For each VC, data is extracted by selecting the EU-28 Member States and the top 10 global importers and exporters identified from the COMTRADE data.

  - **Product**: defines the product HS codes of interest. Enter the relevant codes[26].
  - **Flows**: defines the type o trade to report, import/ export. For this study, select both import and export.
  - **Stat_regime**: For data consistency, the "normal" stat regime is selected.
  - **Period**: Select the appropriate time range. For the purpose of this study, the data range is from Jan 2007 to Nov 2019.
  - **Indicators**: for the purpose of this study please select all for download. This indicator export quantity, export value, import quantity, import value, production quantity, production value, quantity unit (e.g. kg)
- Once these indicators have been selected, the data can be "compressed" using the button on the bottom right of the screen.
- The next step of the data extraction is to determine layout for the data. On the columns, select "Period" and in the rows select "Partner". This will keep a consistent format to the data.
- The last step requires to justify the output selection. One can select the format (Excel for this study) and the extraction name.
- Once "finish" is pressed, the Eurostat system will email the user once the data has been prepared. The user can then log back on to Eurostat website to download the data.
- Calculate the trade balance using the formula below and the PRODCOM data as presented for indicator 9 on imports and exports. This should be presented in a table per country (row) per year (column).

  Trade Balance = Exports - Imports

- Present total EU-28 trade balance over time in a graph.
- Identify and present graphically the trade balance over time for countries that have presented:
- Top positive trade balances (latest 3 years)
- Top negative trade balances (latest 3 years)
- Top improving trade balances (latest 10 years)
- Use COMEXT data to identify and present top 10 trading partners for the key countries identified in the previous step.

[26] The codes used for the VCs analysed in the study are presented in Annex 2.

Shortcomings and Limitations

- To look at Imports & Exports, this framework uses PRODCOM and COMEXT data. In some cases, the export/import figures do not match between the databases for selected countries.
- COMEXT data can only be extracted for each declarant country to a selection of partners. This means that the database does not allow for extraction of all trade flows from a declarant country to all of its partners. In this framework, the study team proposes selecting the top 10 exporters and top 10 importers identified through COMTRADE, as well as the European countries for each strategic component. However, this approach can potentially exclude key trading partners of specific countries.

3.2.11 Outputs

The outputs resulting from implementing the Data Collection on Key Competitiveness Indicators methodology are:

- An Excel dataset (see Annex 1) with data on the 10 relevant indicators (Table 2.2) and key results for each VC covered within the study, including a representative inventory of European companies at the cutting edge of each VC.

3.3 Part 3. Assess EU competitiveness and identify challenges and opportunities ahead for European businesses

3.3.1 Strategic outlook

The objective of the strategic outlooks is to bring together the key insights generated under Part 1 and 2 of the framework and answer the “So what?” question. The approach adopted to draft the strategic outlook is presented in section 2.3.1 of this report.

Validation of key findings from experts and stakeholders

Once the strategic outlooks are drafted, it is advised to consult with industry specialist(s) - or even better industry stakeholders – in order to validate findings and ensure accuracy and relevance to the most pressing challenges faced by each VC. When considering the strategic outlooks, it is however important to bear in mind that these documents are not meant to provide a detailed review of the technologies but rather to provide an assessment of the competitiveness of European businesses within specific VCs compared to businesses operating in other regions.

3.3.2 SWOT analysis

The approach adopted to draft the SWOT is presented in section 2.3.1 of this report. The list of key questions that one should consider when completing the SWOT analysis of European businesses within the global VCs of climate neutral solutions has been included in Annex 3 of this report. These questions are organised by key areas typically considered in SWOT analysis (e.g. innovation potential, policy, economic and social environment) and are complemented by elements from Porter’s Five Competitive Forces Model applied to climate neutral VCs, as explained in more details in Box 2.3. It is important to stress that this list of questions can be tailored depending on the specific objectives of the assessment.

3.3.3 Outputs

The outputs resulting from implementing the methodology for assessing EU competitiveness and identifying challenges and opportunities ahead for European businesses are:

- A strategic outlook document for each VC, providing conclusions on European business competitiveness, as well as an assessment of the challenges and opportunities ahead for European businesses; and,
- An in-depth SWOT analysis for each VC.

4 Outcome 2 – Strategic Outlooks

In this section, the results from applying the framework to a selection of 12 value chains are presented. For each VC, a strategic outlook is presented which summarises key findings from Parts 1, 2 and 3 of the CAF.

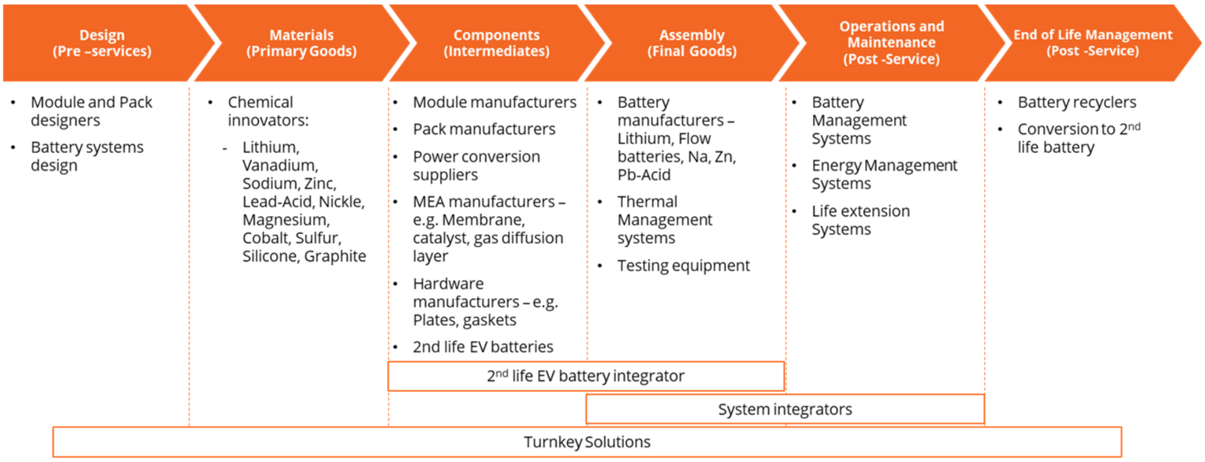
4.1 Batteries

4.1.1 Scope of the VC – Batteries

The scope of the Batteries VC covers grid-connected electrochemical batteries used for energy storage and digital control systems. However, this VC does not include activities linked to material extraction (e.g. sourcing and excavating), batteries for small-scale electronics (<160 Wh), hydrogen-related energy storage, flywheels, ultracapacitors, thermal storage, and mechanical storage (e.g. compressed air energy storage).

The structure of the Batteries VC split by segment of activity is elaborated in Figure 4.1.

Figure 4.1 Batteries VC Structure



Source: Cleantech Group, 2020.

4.1.2 European market overview[27] – Batteries

Historically, the European battery segment has a large chemical industry cluster and a large ecosystem around batteries as well as a few associations that represent the industry – Association of European Automotive and Industrial Battery Manufacturers (EUROBAT), European Association for Storage of Energy (EASE).

However, when it comes to modern applications it is a relatively new and growing economic sector. The battery VC is characterised by a few large players in the European market. According to some estimates, Europe's electrochemical battery market potential could reach €250 billion annually by 2025[28].

The EU Strategic Action Plan on Batteries provides the framework for the EC's actions to support the whole VC and increases its global competitiveness. In particular, the

[27] Note: When this document refers to "Europe" it includes all countries that are part of the European single market – this covers the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. In some cases, the data is extracted at aggregated EU-28 or EU-27 level. Datasets, reports and information that was extracted for the period before 2018, refers to the EU-28 and includes the UK in the analysis.

[28] European Battery Alliance, 2020, Available at: https://www.eba250.com/, [Accessed on: 24/11/2020]

forthcoming legislative proposal on batteries, due to be adopted by the EC before the end of 2020, coupled with the actions of the European Battery Alliance will be key drivers also for growth of this market.

Horizon 2020 funding has supported battery RD&D over the last MFF and from April 2020 it is deploying €90 million for next generation battery projects which is expected to spur innovation efforts. Additionally, from September 2020, the EC is providing €40.5 million of support into key research projects over 3 years as part of the large-scale European research initiative BATTERY 2030+. This aims to make Europe a world-leader in the development and production of batteries[29].

Some of the trends that are expected to have a wide-ranging impact on this VC include the expected six-fold increase of the EU-28 electric vehicle (EV) production value up to 2025, which would in turn increase the activity across the Batteries VC. Technological innovations (e.g. graphene, silicon anodes) are expected to pave the way for further efficiency increases and are considered one of Europe's major competitive advantages against lower cost Asian battery manufacturers. Anode, cathode, separator, and electrolyte improvements are expected to enable forecast cost reductions of 450% by 2028[30], while manufacturing improvements could enable new designs and lead to cost reductions. Software enabling performance improvements and individual battery lifetime extension are also expected to influence this VC.[31]

Furthermore, lithium-ion batteries are viable in short-duration applications where services can be stacked and adapted to market pricing (e.g. hourly balancing, peak shaving and ancillary services) but are less cost effective for longer duration storage (above 4-6 hours). However, globally, demand for new batteries has outpaced supply, creating an opportunity for new entrants as incumbents struggle to meet demand. EV demand is the main driver of technology cost reduction in lithium-ion batteries. Both manufacturing scale and production efficiency, as EV demand has tripled global manufacturing capacity for lithium-ion since 2013, has helped to decrease costs by 73%.[32]

Europe's lack of its own local production capacity for EV cells has created uncertainty, prompting warnings that Europe could leave the car industry exposed and too reliant on foreign manufacturers. This is mainly due to the external dependence on some components and more importantly raw materials (such as cobalt, lithium, manganese oxide, electrodes amongst others), which are almost entirely imported. However, in 2019, through their manufacturers' associations, European automotive firms signed long-term trade agreements with Chinese manufacturers.[33] One of the three key strategic areas of collaboration is 'new energy' vehicles.

[29] European Battery Alliance, 2020, *About us*, Available at: https://battery2030.eu/about-us/, [Accessed on: 24/11/2020]

[30] Louis Brasington, Energy and Power Lead, Cleantech Group – "Cleantech insights Electrochemical Batteries: Chemistry and Software" (13 June 2019) – Report is behind a paywall and there is no public link to it.

[31] Louis Brasington, Energy and Power Lead, Cleantech Group – "Cleantech insights Electrochemical Batteries: Chemistry and Software" (13 June 2019) – Report is behind a paywall and there is no public link to it.

[32] Louis Brasington, Energy and Power Lead, Cleantech Group – "Cleantech insights Electrochemical Batteries: Chemistry and Software" (13 June 2019) – Report is behind a paywall and there is no public link to it.

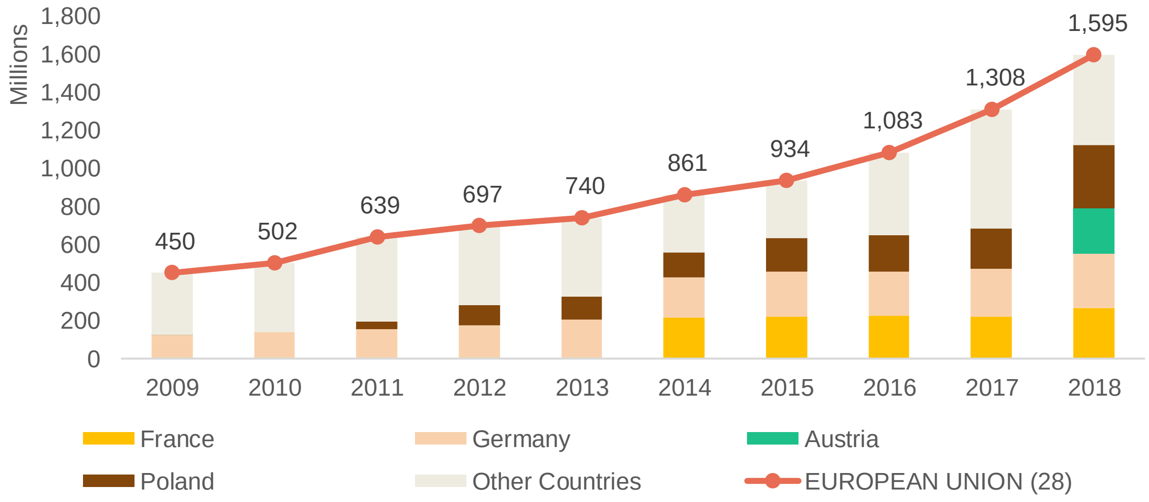
[33] European Automobile Manufacturers Association, 2019, *European and Chinese auto makers commit to working more closely together*, Available at: https://www.acea.be/press-releases/article/european-and-chinese-auto-makers-commit-to-working-more-closely-together, [Accessed on: 24/11/2020]

4.1.3 European industry size and VC – Batteries

Based on the data from the Cleantech Group database, compared to the RoW, 28% of the active companies and innovators in the sector are headquartered in Europe.[34]

Between 2009 and 2018, the annual total production of batteries in the EU-28 has been steadily increasing at a rate of 39% per year and as a result tripled from €450 million (in 2009) to €1,595 million (in 2018). In 2018, Poland was the largest producer, accounting for 21% of EU-28 production, followed by Germany (18%), France (16%) and, since 2018, Austria as the fourth largest manufacturer (15%).

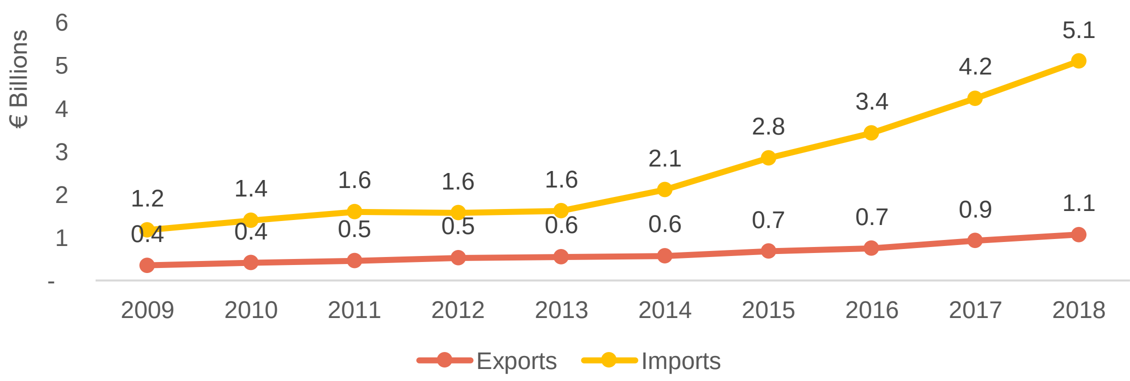
Figure 4.2 Total Production Value in the EU-28 and Top Producer Countries – Batteries[35]



Source: ICF, 2020

Between 2009 and 2018, EU-28 exports to the RoW have been steadily increasing from €0.4 billion (2009) to €1.1 billion (2018). On the other hand, imports more than tripled from €1.6 in 2013 to €5.1 billion in 2018.

Figure 4.3 Total EU-28 Imports & Exports – Batteries[36]



Source: ICF, 2020

[34] According to analysed data from Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the USA and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

[35] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

[36] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

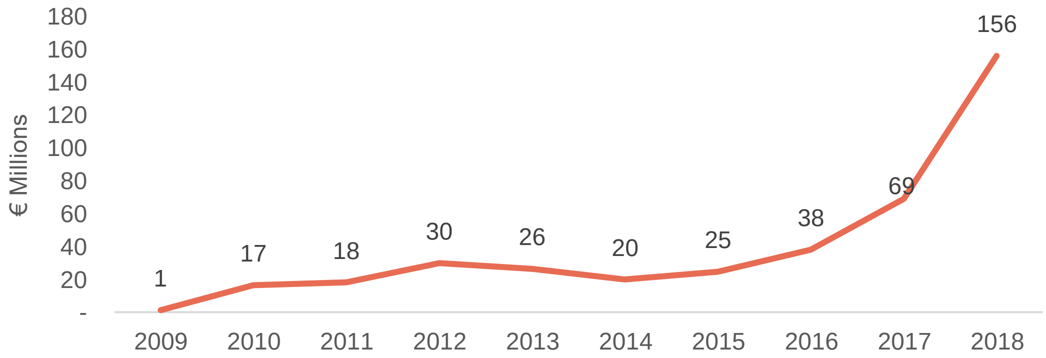
For the 2016-2018 period, the EU-28 share of global exports (EU-28 to RoW) was stable at roughly 2%. The top three exporters globally were China, South Korea, and Japan while out of the EU-28 countries the top exporters for this period were Germany, Poland, and the Czech Republic. In addition, the top five importers in this VC were the US, China, Germany, Hong Kong, and France.

Between 2009 and 2018, the EU-28 trade balance has experienced a decreasing trend, remaining negative during the whole period. The countries with the highest negative trends were Germany, France and the Netherlands. Germany and France's export partners by value are mainly outside of the EU-28, with South Korea and China being the largest ones. The Netherlands has been importing mainly from the US and China.

4.1.4 Innovation and investment in RD&D – Batteries

Over the 2009-2018 period, Europe is increasing the investments in research and innovation in the battery sector. As shown in the figure below, European public investments have been increasing since 2009, growing from an average annual investment of €20 million between 2010 and 2015 period, all the way to €156 million in 2018. Out of the countries for which the IEA has data, the UK was by far the largest investor, followed by France, Norway and Canada.

Figure 4.4 EU-28 Public RD&D Investments in the Batteries VC[37]



Source: ICF, 2020

In recent years, the share of investments in European companies has been increasing.

Over the 2014-2019 period, 40% of the total value of global private venture capital investments in early and late stage companies on the battery VC was in European companies.[38] When looking at the share of the number of investments, this number decreases to 33% for early- and 28% for late-stage companies, which translates into a higher average size of investments in Europe compared to the RoW. France and the UK stand out in terms of total size of investments into early stage companies, while Sweden and Germany are the Europe's leading countries in late-stage private venture capital investments.

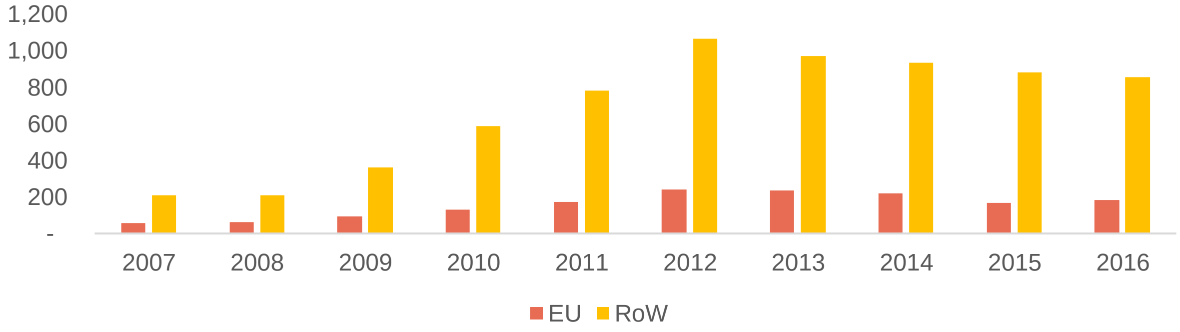
Furthermore, for the 2007-2016 period, more patent applications have been filed in the RoW than in Europe. Specifically, for the 2014-2016 period, 18.5% of high value patent

[37] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

[38] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the USA and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

applications were filed in Europe. More specifically, Germany and France stand out in terms of the number of high-value patent applications over the 2014-2016 period.

Figure 4.5 Patent applications EU-28 vs rest of the world – Batteries[39]

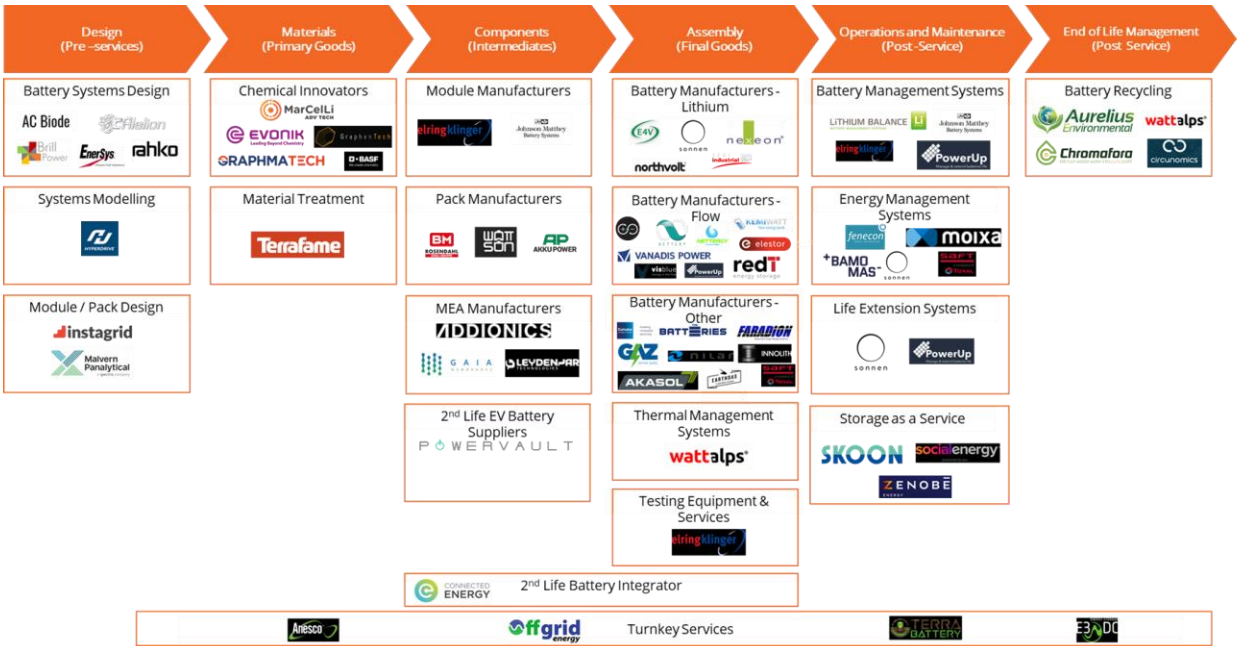


Source: ICF, 2020

Some of the important developments in this VC include Northvolt's creation of Europe's biggest battery plant, due to be online in 2021. This may be largely for EV capacity, given Northvolt's automotive investors, but will likely also have an impact on grid storage. In addition, there were a number of automotive and start-up partnerships driving EV-focused battery innovations aimed at optimising vehicle range.

Some of the areas of technical innovation include solid state electrolytes, room-temperature polymer electrolytes, big-data-driven component recycling and repurposing (e.g. Circunomics). In addition, battery management system innovators are leveraging analytics and artificial intelligence (AI) to improve battery performance. There were also business model innovations around turnkey (integrated) solutions and storage as a service. Furthermore, Figure 4.6 provides an overview of some of the key European market players, divided by segment of the Batteries VC.

Figure 4.6 European Key Market Participants – Batteries



Source: Cleantech Group, 2020

[39] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

However, compared to the rest of the world, when it comes to assembly and production, Europe is largely playing catch-up to Asian rivals such as CATL, Samsung and LG Chem.

This VC is characterised as an active investment space and growing market potential. Recent investments in late stage European companies are increasing, led by large rounds in a few companies (e.g. Northvolt, Sonnen, Rimac). Early stage investment peaked across the board in recent years as new technology developments emerged.[40]

There were numerous acquisitions involving vendors, integrators and developers both up and downstream (e.g. Shell's acquisition of Sonnen), to capture additional value and hedge risk across new technology segments.

Across Europe, North America and Asia, countries are launching programmes and targets to increase investments for battery market to help encourage EV adoption and address technology bankability.

4.1.5 Threats and challenges – Batteries

Cost

There is a need for cost reduction leading to innovation around four parameters - energy, power, lifespan and safety. In addition, the cost of long-duration storage mechanisms is considered to be hindering growth in the wider uptake of such solutions.

Foreign competition

As illustrated above, between 2009 and 2018, the EU-28 trade balance for batteries has remained negative and with a decreasing trend and imports more than tripled from 2013 to 2018. Europe's position in the market is more and more at risk of becoming a highly dependent importer, primarily from Asian countries, which are characterised by very competitive players in this VC.

Asian participation in the market is very strong in the small portable electronics batteries sector and is growing rapidly in the domain of electrochemical batteries for automotive use. In addition, Asian companies are beginning to invest heavily in battery production in the EU-28 (e.g. LG Chem in Poland, SK Innovation & Samsung in Hungary and CATL in Germany). While this provides support for European VCs and employment, it is considered as a threat to the emerging European battery industry.

The capacity of Asian manufacturers to ramp up production enables them to produce lithium-ion batteries at lower cost than other market participants; this also allows them to enter more aggressively the grid-scale energy markets. In addition, the ability of aforementioned companies to manufacture large quantities of lithium-ion cells gives them a competitive advantage to then be able to assemble these into automotive and grid-scale batteries. This in turn, could exacerbate the Europe's dependency on third countries supplying raw materials, as well as manufactured units and equipment.

External dependencies

European manufacturers and battery developers are largely dependent on raw materials from countries outside Europe. Lithium, nickel, manganese, cobalt and graphite are core materials in the manufacturing of lithium-ion batteries. China is the biggest supplier of

[40] Based on analysis of data from Cleantech Group i3 Database, which is not public domain (see section 3.2.2)

Critical Raw Materials (CRMs) to Europe, with a share of ~40%, followed by South Africa, Russia, the Democratic Republic of Congo (DRC) and Brazil.[41]

Furthermore, car batteries for EVs are a crucial component for Europe's sustainable future and currently they account for approximately 40% of the cost of an EV[42]. However, 96% of them are produced outside Europe.[43]

Thus, the European battery sector is threatened with becoming increasingly dependent for both raw materials and components on third countries. However, there are some measures to counteract this and Europe has boosted its "*planned lithium-ion battery production capacity, with its global share set to reach 14.7 percent by 2024*"[44].

One of the crucial recent measures in remedying these external dependencies on CRMs is the European Action Plan on Critical Raw Materials. As well as the launch of a European Raw Materials Alliance, which is largely expected to strengthen this VC.

Brexit

Brexit has created a challenge in the short to medium term for the Batteries VC, mainly because the UK market is well developed and active when it comes to investments in this sector, particularly around R&I. For example, the Faraday battery challenge (part of the UK's Industrial Strategy Challenge Fund) has a government investment of up to €346.68[45] million (£317.75 million), which seeks to strengthen the whole Batteries VC to capitalise on the growing automotive battery technology market. Clearly there are opportunities for EU and the UK cooperation in this area, which is estimated to be worth €5.5 billion in the UK and €55 billion across Europe by 2025.[46] Given the right legal framework, political will and investors' interest there are future possibilities for greater EU and UK cooperation across the Batteries VC.

Covid-19

Despite the current pandemic, the European Battery Alliance has remained on track and the initiative has even been reinforced.[47] In December 2019, the EC adopted its decision on the provision of State aid to establish Europe's first major battery consortium involving 17 companies across seven Member States[48]. This decision concerns the use of an EU

[41] European Commission, 2019, *Actions needed to ensure the supply of materials for emerging dual use technologies*, JRC, Available at: https://ec.europa.eu/jrc/en/news/actions-needed-ensure-supply-materials-emerging-dual-use-technologies, [Accessed on: 24/11/2020]

[42] Drabik, E. and Rizos, V., 2018, *Prospects for electric vehicle batteries in a circular economy,* CEPS Research Report, Available at: https://circulareconomy.europa.eu/platform/sites/default/files/circular_economy_impacts_batteries_for_evs.pdf, [Accessed on: 24/11/2020]

[43] European Economic and Social Committee, 2020, Europe's sustainable future depends on accessibility of raw materials for batteries, Available at: https://www.eesc.europa.eu/en/news-media/news/europes-sustainable-future-depends-accessibility-raw-materials-batteries, [Accessed on: 24/11/2020]

[44] European Commission, 2020, *Statement by Vice-President Maroš Šefčovič following the meeting with high-level industrial actors under the European Battery Alliance*, Available at: https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_20_914, [Accessed on: 24/11/2020]

[45] Exchange rate of £1:€1.09, based on XE.com (9.11.20)

[46] UK Research and Innovation, 2020, *Future of Mobility,* Available at: https://www.ukri.org/our-work/delivering-economic-impact/industrial-strategy-challenge-fund/future-of-mobility/, [Accessed on: 24/11/2020]

[47] European Commission, 2020, *Statement by Vice-President Maroš Šefčovič following the meeting with high-level industrial actors under the European Battery Alliance*, Available at: https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_20_914, [Accessed on: 24/11/2020]

[48] European Commission, 2019, *State aid: Commission approves €3.2 billion public support by seven Member States for a pan-European research and innovation project in all segments of the battery value chain*, Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_19_6705, [Accessed on: 24/11/2020]

instrument, Important Projects of Common European Interest (IPCEI), which allows above normal use of State aid for highly innovative investments in sectors of strategic importance to the EU. This IPCEI decision will allow up €3.2 billion in State aid, unlocking a further €5 billion in private sector investment. A second, and potentially even larger IPCEI, is currently being assessed with a decision expected by the end of 2020. Finally, the European Investment Bank announced in May 2020 that it will "*increase its backing of battery-related projects to more than €1 billion of financing in 2020*". Thus, preliminary trend analysis indicates that the crisis has pushed Europe further towards securing its own battery supply chain and to reduce its dependence from exporters such as China.

4.1.6 Future EU potential – Batteries

Policy support

The Batteries VC is regarded as a highly strategic technology sector both by business and policy-makers, as evidenced from the pan-European research and innovation projects in all segments of the Batteries VC, as well as a few giga-factory projects under way (e.g. Northvolt in Sweden and Tesla in Germany).

The sector's EU policy framework, namely the EU Strategic Action Plan on Batteries, aims to make Europe a global leader in sustainable battery production and use, in the context of the circular economy. In addition, the Batteries Directive 2006/66/EC has set the rules for Europe-based manufacturers and importers, waste operators and end-users for the sustainable treatment of batteries in Europe.

This Directive will be updated and strengthened through a proposed revision to be adopted by the EC before the end of 2020. This new legislation is expected to reinforce the increasing role of batteries in the decarbonisation of the EU, to support the circular economy and to help deliver the objectives of the European Green Deal. The legislative proposal are expected to update the EU legal framework to ensure that all batteries are produced sustainably and can be easily recycled[49]. The proposal is also expected to cover the full life battery cycle, from design & production to reuse & recycling with the goal to minimise harmful effects on the environment.

Furthermore, this legislative proposal will be consistent with other related initiatives including the New Industrial Strategy for Europe[50], adopted in March 2020, and the upcoming revisions of the Alternative Fuels Infrastructure Directive, the Trans-European Networks in Transport and Energy Regulations (TEN-T and TEN-E) and policy actions on raw materials - the Raw Materials Initiative, the European Innovation Partnership on Raw Materials, the European Action Plan on Critical Raw Materials, and the European Raw Materials Alliance.

Growth potential

[49] European Commission, 2020, *Batteries – modernising EU rules*, Available at: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12399-Modernising-the-EU-s-batteries-legislation, [Accessed on: 24/11/2020]

[50] European Commission, 2020, *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions – A New Industrial Strategy For Europe*, 10 March 2020, COM(2020) 102 final, Available at: https://ec.europa.eu/info/sites/info/files/communication-eu-industrial-strategy-march-2020_en.pdf, [Accessed on: 24/11/2020]

In recent years, cost reduction of lithium-ion batteries increased the competitiveness of applications such as EVs and energy storage at grid level, which are expected to be main drivers for European battery market expansion.

When it comes to the sourcing of raw materials, there are a number of Member States that aim to achieve more cost-efficient processes for extraction of materials needed for the production of battery packs. For instance, Finland has raw material deposits of cobalt, lithium, graphite, and nickel and copper, an active mining and metallurgical industry as well as a growing manufacturing sector.[51] Currently, in Finland there are "*ten active mines and exploration projects, at various stages of development, three of which […] produce nickel, copper and cobalt concentrates, which are mostly refined locally to supply the EU market*"[52].

There are many and diverse private European investors whose investment focus overlaps with the Batteries VC. Despite only 3% of global production capacity currently being located within Europe, the sector is a very active investment space.

The European Batteries VC is characterised by many actors, which represent a mix of corporates and innovators. However, similar to other new technology VCs there is a high potential for non-energy storage focused investors to enter the space.

4.1.7 SWOT – Batteries

Strengths *Internal attributes, characteristics and factors that give competitive advantage to the EU in the global VC.*	**Weaknesses** *Internal attributes, characteristics and factors that weaken the competitiveness of the EU in the global VC.*
• Large ecosystem around batteries in a growing economic sector. • Europe is increasing RD&D investments and the share of investments in EU companies. • Batteries VC is characterised by higher average size of investments in Europe vs RoW for the studied period. • Annual total production of batteries in the EU-28 has been growing. • Some Member States (e.g. FR & DE) have offered a number of incentives to encourage the move to zero emission mobility and, especially, electric vehicles. • Stable EU-28 share of global exports and 28% of active companies in sector are headquartered in the EU. • For 2012-2018 period, EU-28 exports more than doubled and are on an upwards trend.	• EU-28's trade balance has remained negative and with a decreasing trend, due to higher imports than exports. • Although EU-28 exports are increasing, imports more than tripled in 2012-2018 period. • For the 2007-2016 period, more patent applications were filed in the RoW, which could have impacts in the longer term. • Car batteries are a crucial component for Europe's growing EV needs, but 96% of them are produced outside Europe, creating an external dependence for components. This figure is expected to decrease as European and foreign investment in Europe takes effect. • Europe is highly dependent on third countries for sourcing raw materials.

[51] Dehaine, Q., Michaux, S., Pokki, J., Kivinen, M. and Butcher, A., 2020, *Battery minerals from Finland: Improving the supply chain for the EU battery industry using a geometallurgical approach,* Available at: https://eurogeologists.eu/dehaine-battery-minerals-from-finland-improving-the-supply-chain-for-the-eu-battery-industry-using-a-geometallurgical-approach/, [Accessed on: 24/11/2020]

[52] Dehaine, Q., Michaux, S., Pokki, J., Kivinen, M. and Butcher, A., 2020, *Battery minerals from Finland: Improving the supply chain for the EU battery industry using a geometallurgical approach,* Available at: https://eurogeologists.eu/dehaine-battery-minerals-from-finland-improving-the-supply-chain-for-the-eu-battery-industry-using-a-geometallurgical-approach/, [Accessed on: 24/11/2020]

Strengths *Internal attributes, characteristics and factors that give competitive advantage to the EU in the global VC.*	**Weaknesses** *Internal attributes, characteristics and factors that weaken the competitiveness of the EU in the global VC.*
Opportunities *External situations and factors that can strengthen the competitive advantage of the EU or provide the EU with new sources of competitive advantage.*	**Threats** *External situations and factors that can create problems for the EU compromising its competitive advantage to a certain extent.*
• Batteries are a high potential technology sector with further opportunities for cost reduction, efficiency gains, lifespan improvements and safety gains. • Batteries VC is characterised by many and diverse private European investors. • Potential for non-energy storage investors to enter the space and invest in this VC. • Future EU battery legislation provides a firm foundation for further investment in innovation and production in the EU battery VC. • Although Brexit is considered a threat to the strength of this VC in the short to mid-term, there are a number of important opportunities for EU and UK cooperation. • European Battery Alliance represents a major opportunity for public/private cooperation and strengthening of the European battery sector through innovation and investments, as well as new BATTERIES 2030+ research initiative.	• Currently, there are only a few large players in the European market. • Very strong external competition that currently develops at a faster pace than its European competitors. • Europe is increasingly dependent for both raw materials and components on third countries. This represents one of the main threats to the successful increase in competitive advantage of this VC in Europe. • There is technological competition with other energy storage technologies.

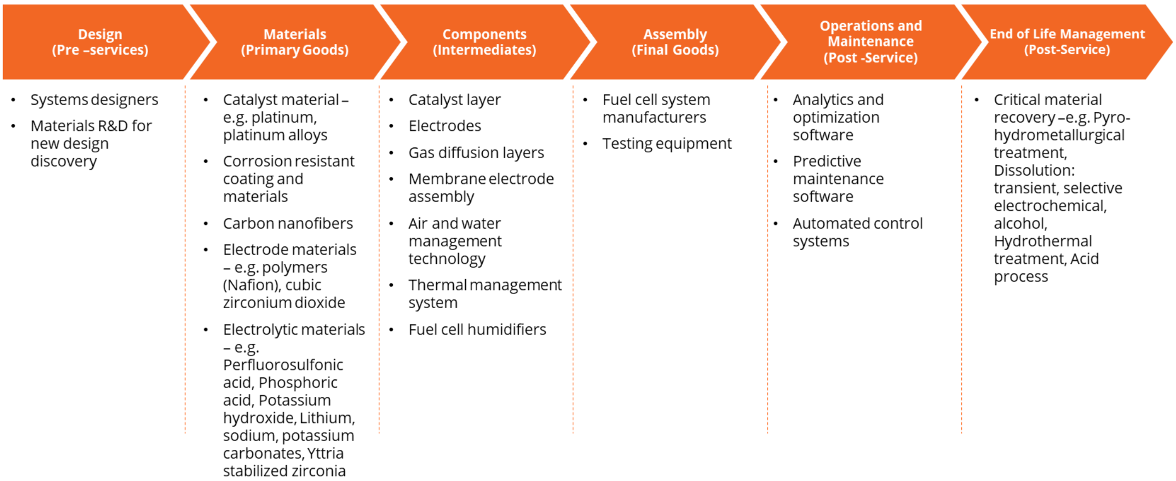
4.2 Hydrogen Fuel Cells

4.2.1 Scope of the VC – Hydrogen Fuel Cells

The scope of the Hydrogen Fuel Cells VC is stationary fuels cells, which covers electro-chemical cells including electrolyte membrane, catalyst layers (anode, cathode), diffusion media, supporting hardware (plates, gaskets), interconnectors and digital technologies enabling fuel cell optimisation. This VC does not cover non-hydrogen fuel cells (e.g. methane), electrolysis-focused technology (this is covered in the Hydrogen Production VC), hydrogen infrastructure for storage, processing or distribution, vehicle-based fuel cells.

The structure of the Hydrogen Fuel Cells VC split by segment of activity is elaborated in Figure 4.7.

Figure 4.7 Hydrogen Fuel Cells VC Structure



Source: Cleantech Group, 2020.

4.2.2 European market overview[53] – Hydrogen Fuel Cells

Europe has an active, moderately developed, ecosystem of corporations and innovators in the hydrogen VC. There are many hydrogen gas projects, as well as strong policy and advocacy support by several fuel cell and hydrogen focused industry groups across Europe. The two main organisations are the association Hydrogen Europe and the public-private partnership Fuel Cells and Hydrogen Joint Undertaking (FCH JU).

Hydrogen and its many applications are not new to many industries. It can be used as a chemical feedstock (e.g. for producing ammonia) but also as an energy storage or as a green transport fuel, since the burning of hydrogen does not generate CO_2. However, currently over 95% of the world's hydrogen is produced from fossil fuels through: the steam reforming of natural gas, partial oxidation of methane, or gasification of coal[54]. According to the International Energy Agency (IEA), the production of this hydrogen derived from fossil fuels (also known as "grey hydrogen") is responsible for around 830 million tonnes of CO_2

[53] Note: When this document refers to "Europe" it includes all countries that are part of the European single market – this covers the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. In some cases, the data is extracted at aggregated EU-28 or EU-27 level. Datasets, reports and information that was extracted for the period before 2018, refers to the EU-28 and includes the UK in the analysis.

[54] Rapier, R., 2020, *Life cycle emissions of hydrogen*, Fourth Generation, Available at: https://4thgeneration.energy/life-cycles-emissions-of-hydrogen/, [Accessed on: 24/11/2020]

emissions per year[55]. The IEA also states that, not only does hydrogen production need to shift to renewable energy sources, it must also "*be adopted in sectors where it is almost completely absent, such as transport, buildings and power generation*" in order to make a significant contribution to the clean energy transition.[56]

To this end, there are two main ways to make clean hydrogen: production through hydrolysis directly from water by using power from renewable energy sources (known as "clean" or "green hydrogen") or made from natural gas in combination with carbon capture and storage or utilisation technologies for the CO_2 emissions (known as "low carbon hydrogen"[57]). However, in order for "clean hydrogen" to become competitive, lower electricity prices and high electrolyser utilisation rates will be needed.[58] According to Hydrogen Europe, "*the clean hydrogen sector has finally reached the pre-commercialisation phase and is ready to play its essential role in decarbonising*"[59] the EU economy.

The EU aims to be climate neutral by 2050[60] and hydrogen is likely to play an important role in reducing carbon in energy-intensive sectors like heavy industry and freight. This would require significant investments in hydrogen infrastructure and production across the whole VC. While the production of "low carbon hydrogen" could be done at scale already, the technology today for the development of "green hydrogen" is substantially more costly and energy consuming[61]. This creates the possibility that in the very short term future "low carbon" hydrogen could be the faster deployed technology, while later on "clean" hydrogen could take over once the needed cost-efficient technology for the required volumes is in place.

According to Hydrogen Europe, the economic crisis following the Covid-19 pandemic may cause a significant delay in the adoption and commercial roll-out of "green hydrogen".[62] However, if some of the recovery instruments in response to the crisis cover measures that will stimulate growth in the hydrogen VC, this could accelerate "green hydrogen" penetration

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[55] International Energy Agency, 2019, *The Future of Hydrogen – Technology Report*, Available at: https://www.iea.org/reports/the-future-of-hydrogen, [Accessed on: 24/11/2020]

[56] International Energy Agency, 2019, *The Future of Hydrogen – Technology Report*, Available at: https://www.iea.org/reports/the-future-of-hydrogen, [Accessed on: 24/11/2020]

[57] Defined as "low carbon" hydrogen in the EU Hydrogen Strategy 2020 (European Commission, 2020, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - A hydrogen strategy for a climate-neutral Europe,* 08 July 2020, COM(2020) 301 final, Available at: https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf) although widely referred to in the sector as "blue" hydrogen (e.g. see Čeković, I., Conti, I., Jones, C. and Piebalgs, A., 2020, *Hydrogen Technology - Workshop Summary Technical Report*, Available at: https://cadmus.eui.eu/bitstream/handle/1814/67676/Hydrogen_technology_report.pdf?sequence=4, [Accessed on: 24/11/2020])

[58] Wood Mackenzie, 2019, *The future for green hydrogen*, Available at: https://www.woodmac.com/news/editorial/the-future-for-green-hydrogen/, [Accessed on: 24/11/2020]

[59] Hydrogen Europe, 2020, Post COVID-19 and the Hydrogen Sector - A Hydrogen Europe Analysis, Available at: https://hydrogeneurope.eu/sites/default/files/Hydrogen%20Europe%20Analysis_Post%20COVID-19%20and%20the%20Hydrogen%20Sector_final.pdf, [Accessed on:24/11/2020]

[60] European Commission, 2020, *Proposal for a Regulation of the European Parliament and of the Council establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999 (European Climate Law)*, 04 March 2020, COM(2020) 80 final, 2020/0036 (COD), Available at: https://ec.europa.eu/info/sites/info/files/commission-proposal-regulation-european-climate-law-march-2020_en.pdf

[61] Čeković, I., Conti, I., Jones, C. and Piebalgs, A., 2020, *Hydrogen Technology - Workshop Summary Technical Report*, Available at: https://cadmus.eui.eu/bitstream/handle/1814/67676/Hydrogen_technology_report.pdf?sequence=4, [Accessed on: 24/11/2020]

[62] Hydrogen Europe, 2020, Post COVID-19 and the Hydrogen Sector - A Hydrogen Europe Analysis, Available at: https://hydrogeneurope.eu/sites/default/files/Hydrogen%20Europe%20Analysis_Post%20COVID-19%20and%20the%20Hydrogen%20Sector_final.pdf, [Accessed on: 24/11/2020]

in the European economy in the long run[63]. Such measures include amongst others scaling up of the capacity of electrolysers, conversion and adaptation of gas networks for hydrogen transportation and increase in hydrogen storage capacity.

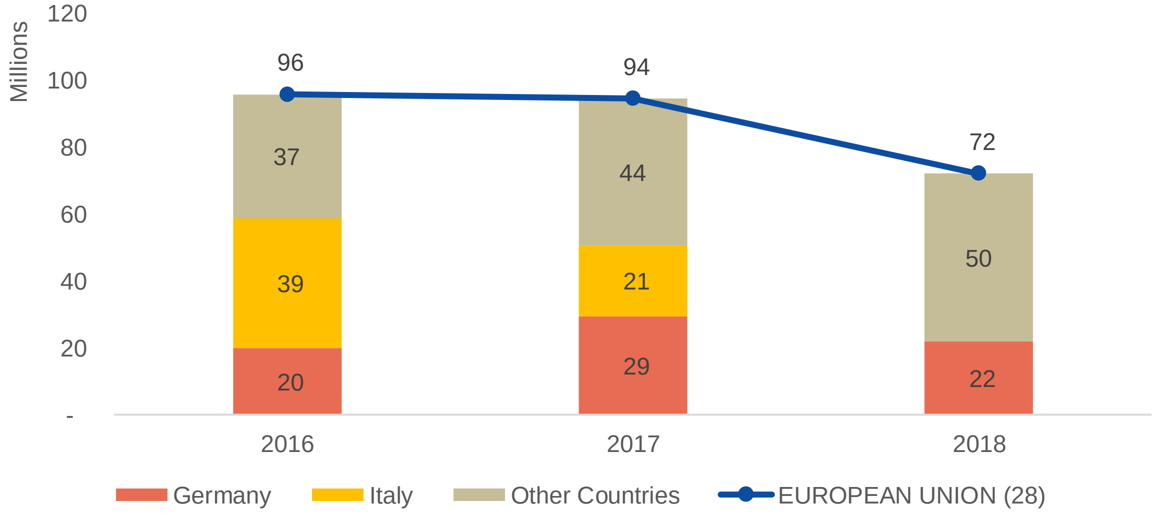
When compared to the RoW, the US is the world leader in this VC – its market has been supported by federal RD&D programmes and tax incentives. Furthermore, rising energy demand and need to decarbonise is expected to boost demand in the Asia Pacific region. China is driving hydrogen and fuel cell development and is on track to outpace development in both Europe and the US, with a focus on hydrogen buses and trucks. In the first seven months of 2019, the Chinese installed capacity of hydrogen fuel cells increased six-fold to reach 45,876.9 kilowatts.[64]

4.2.3 European industry size and VC – Hydrogen Fuel Cells

Currently, 34% of the active companies of the world fuel cell industry are headquartered in Europe.[65] Out of the top ten countries in the world where fuel cell companies have headquarters, six are in Europe. The European headquarters are mainly centred in the UK, comprising 32% of them, Germany - 14%, and Denmark - 11.5%.

Between 2016 and 2018, the annual production value of fuel cells in the EU-28 experienced relatively small changes, with a modest drop in production value represented by the lack of information obtained from Italy. Nevertheless, production remained roughly steady at around €95 million. Germany and Italy account for around half of the EU-28 production of fuel cells.

Figure 4.8 Total Production Value in the EU-28 and Top Producer Countries – Hydrogen Fuel Cells[66]



Source: ICF, 2020

[63] Čeković, I., Conti, I., Jones, C. and Piebalgs, A., 2020, *Hydrogen Technology - Workshop Summary Technical Report*, Available at: https://cadmus.eui.eu/bitstream/handle/1814/67676/Hydrogen_technology_report.pdf?sequence=4, [Accessed on: 24/11/2020]

[64] ChinaDaily, 2019. China's installed capacity of hydrogen fuel cells soars sixfold in first seven months. Available at: http://www.chinadaily.com.cn/a/201909/02/WS5d6cd8b6a310cf3e355693f0.html [Consulted on 11/12/2020]

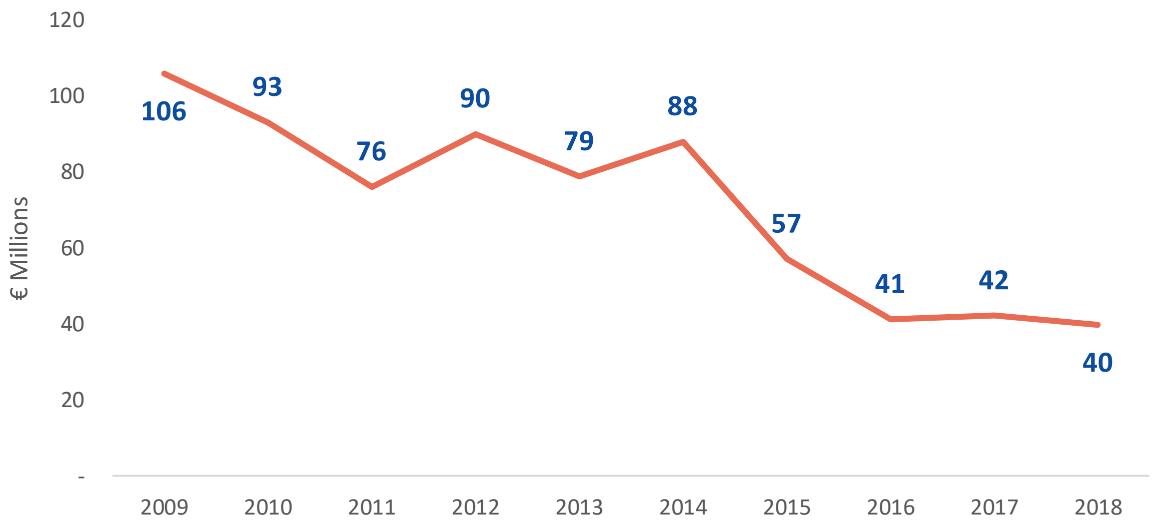
[65] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details).

[66] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

4.2.4 Innovation and investment in RD&D – Hydrogen Fuel Cells

The data on public investment in RD&D is available for a limited group of countries covered by the IEA. Although seven of the top ten RD&D investor countries are European, EU-28 public investment has been decreasing ever since 2009 at an average of €7-9 million per year (as shown in Figure 4.9).

Figure 4.9 EU-28 Public RD&D Investments in the Hydrogen Fuel Cells VC[67]



Source: ICF, 2020

Out of the countries for which the IEA has data, Japan is by far the largest investor, followed by South Korea, France and Canada. In addition, historically, the US has lead hydrogen development in the last 20 years, aiming to find an alternative fuel to oil that can support their economic growth. China on the other hand, besides being the largest hydrogen manufacturer by means of coal gasification, indicated its goal of becoming a global leader in fuel cell vehicles in upcoming years.[68]

However, individual European countries have enacted own initiatives such as: France's Hydrogen Deployment Plan for Energy Transition; Germany's National Innovation Programme Hydrogen and Fuel Cell Technology; UK's H2Mobility coalition; and Spain's National Policy Framework to support the deployment of hydrogen in transport. Additionally, industrial clusters exist for hydrogen more broadly (e.g. Port of Rotterdam, Leeds HyNet/H21) which ultimately support the development of hydrogen fuel cells.

Albeit the larger size per private investment in early stage companies compared to the RoW, the overall share of investments in early stage European companies has experienced a large downfall in recent years.[69] Especially after 2015, where private venture capital investments in early stage companies dropped from €11.9 million to €1.6 million over a 3 year period; an 86% reduction that contrasts with the RoW, which increased investment by 3400%, from €0.2 million (2015) to €6.8 million (2019). In addition, two out of the top five countries where these investments occurred are in Europe, with France and Germany

[67] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

[68] China Hydrogen Alliance, 2020, Available at: http://www.h2cn.org/en/dynamics.html, [Accessed on: 24/11/2020]

[69] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the USA and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

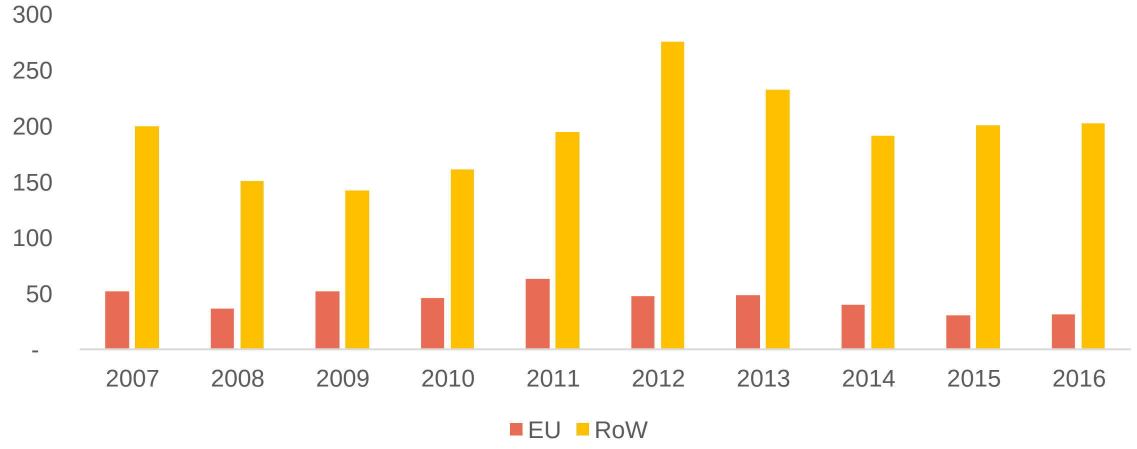
standing out in terms of total size of private investments in early stage companies over the 2014-2019 period.

Over the 2014-2019 period, 46% of the total value of global private investments in early stage hydrogen companies and 50% in late stage hydrogen companies was in European companies.[70] When assessing the number of investments, the percentages decrease to 27% and 45% respectively, suggesting that the average size of investments was larger in Europe than in the RoW. The UK and Germany stand out in terms of total size of investments in late stage companies.

Both in Europe and in the RoW, late stage private investments in hydrogen technology have experienced growth for the 2014-2019 period. This growth has been led by Europe, with an average yearly growth of 75%, which contrasts with the 28% growth experienced in the RoW.

Historically, over the 2007-2016 period, more patent applications have been filed in the RoW than in the EU-28. Over the 2012-2016 period, the EU-28 accounted only for 15% of the overall high value patent applications. In addition, five out of the top ten countries where these patent applications occurred are in Europe, where France and Germany stand out in terms of number of high-value patent applications over the 2014-2016 period. This is to show that, although being represented amongst the top countries for patent applications, EU-28 countries are far behind the top performers Japan, South Korea and the US.

Figure 4.10 Patent applications EU-28 vs rest of the world – Hydrogen Fuel Cells[71]



Source: ICF, 2020

Areas of technical innovation in this VC include carbon nanomaterials, platinum-free catalysers, electrically-conductive polymer materials, corrosion resistant coatings. There is some innovation around stand-alone power solutions, but overall less energy management and software integration activity than in other VCs.

FCH JU has funded projects to address the lack of competitive European stack suppliers, while the European Project HyTechCycling aims to develop end-of-life strategies for fuel cells and hydrogen technologies, which at present have no commercialised offer in Europe.

Innovation activity in this VC is dominated by start-ups and university spin-offs, small number of incumbents producing components. In addition, industrial incumbents such as

[70] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details).

[71] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

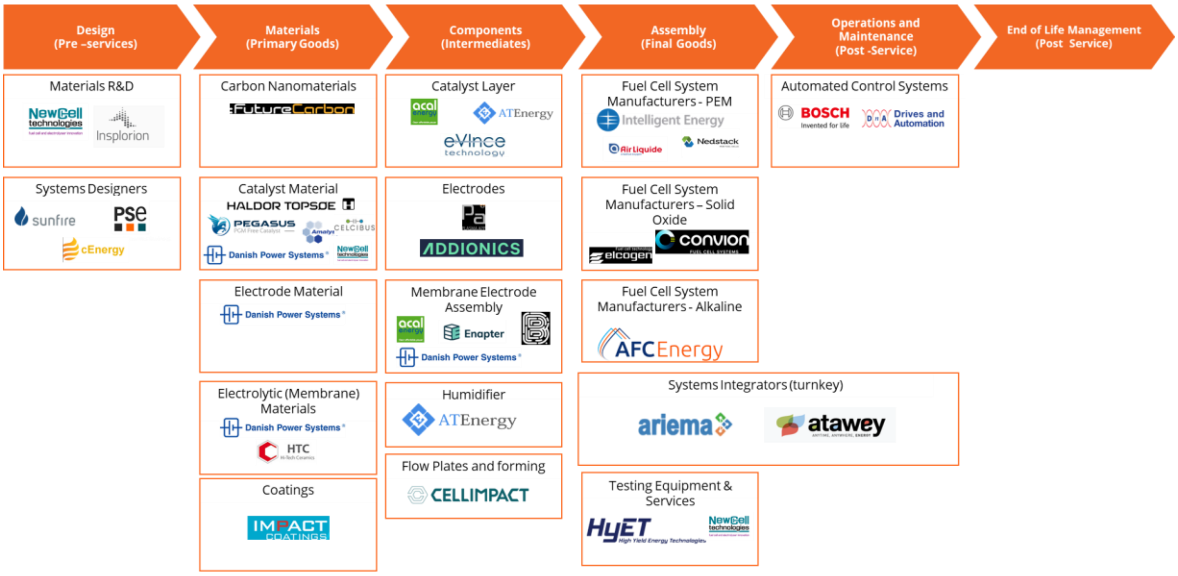
Shell, Toyota are sponsoring innovative start-ups, as a way to find potential solutions to expand their portfolio and minimise the risk of stranded assets when it comes to fossil fuel infrastructure in the future.

Activity so far has been predominantly with grants and other public funding mechanisms rather than private investment, resulting in low private investment overall. Solid Oxide Fuel Cell innovators, such as Sunfire, are responsible for most late stage financing in Europe.

Some other examples of innovators include the early stage European financing led by Germany-based Elcore to develop their CHP products based on High Temperature Proton-Exchange Membrane (PEM) technology. As well as the H2 Refuel Accelerator, run by Greentown Labs and Urban Future Lab, which promotes hydrogen technologies.

Furthermore, in Figure 4.11 are exemplified some of the key European market players, divided by segment of the Hydrogen Fuel Cells (HFC) VC.

Figure 4.11 European Key Market Participants – Hydrogen Fuel Cells



Source: Cleantech Group, 2020

4.2.5 Threats and challenges – Hydrogen Fuel Cells

External dependencies

Hydrogen storage technologies and fuel cells requires around 30 raw materials, of which 13 materials, according to a recent EC study[72], are regarded as critical for the European economy, with Platinum Group Metals (PGM), being the most important. The EC concluded in its 2020 report on 'CRM for Strategic Technologies and Sectors in the EU' that active dematerialisation effort has enabled PGM intensities in PEM fuel cells to be reduced by 80% since 2005. However, despite a diversified supply base for many raw materials, there is still a European dependency on the import of CRMs including PGMs. The largest suppliers of PGMs include China, South Africa, Russia and Zimbabwe which over time could impact European production of key technologies in this value chain.

[72] Carrara, S., Alves Dias, P., Plazzotta, B. and Pavel, C., 2020, *Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system*, EUR 30095 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16225-4 (online), doi:10.2760/160859 (online), JRC119941, Available at: https://ec.europa.eu/jrc/en/publication/raw-materials-demand-wind-and-solar-pv-technologies-transition-towards-decarbonised-energy-system

Cost

Performance, weight, size and cost issues have posed barriers to the commercial adoption of fuel cell technology within the EU. In addition, current membrane materials made from high-cost rare earth metals make some of the technologies less competitive. In addition, ‘clean’ hydrogen infrastructure development needs to be significantly scaled up in order to meet the set climate neutrality target. Thus, there is a need for balance of infrastructure investment and timing of demand for electrolysers, storage, and transport.

Complex multilevel system

The European HFC VC is characterised by a large heterogenous mix of companies and smaller scale innovators co-existing in a moderately developed ecosystem that needs further development and investments.

Although there is a healthy corporate participation from energy corporations (e.g. Total, Shell, E.ON) and industrial groups (e.g. Paul Wurth, Michelin, Anglo Platinum), which invest in different applications of hydrogen technologies as a way to minimise stranded assets from fossil fuels, there is not a developed active ecosystem of European private investors focused primarily on stationary HFCs, yet. Investments into the VC are led by general clean technology investors, those active in the renewable energy space or those interested in fuel cells for mobility.

Additionally, the EU still has internal cross-border regulatory barriers (on production, storage, distribution etc), which hamper more efficient multilateral developments. This makes it difficult for a standalone supplier to compete in the existing market.

Foreign competition

New capacity being built in China is mostly focused on vehicles, but higher production volume of HFCs results in lower system costs. These cost benefits are expected to expand to stationary systems and create potential for a strong export market from Asia, which will impact Europe’s position.

Covid-19

Although, some developers do not see large implications from the Covid-19 pandemic for the hydrogen VC and long-term projects, there is a general threat that the ongoing situation might delay green ambitions and investments in sustainable transition technologies.

According to Hydrogen Europe, the pandemic may even permanently endanger the capacity of the clean hydrogen sector to assume its role as the “missing link” in the energy transition.[73] Furthermore, the association recognises three major risks for the “clean hydrogen” sector. In the short term, small “*companies which form the backbone of the technology providers are likely to suffer a major shortage of liquidity due to a steep drop in revenues which will result in staff cuts or even bankruptcy*”[74]. For the mid to long term consequences, the association points out that if climate and environmental policy commitments take a backseat in economic recovery plans in Europe and elsewhere, large

[73] Hydrogen Europe, 2020, Post COVID-19 and the Hydrogen Sector - A Hydrogen Europe Analysis, Available at: https://hydrogeneurope.eu/sites/default/files/Hydrogen%20Europe%20Analysis_Post%20COVID-19%20and%20the%20Hydrogen%20Sector_final.pdf, [Accessed on: 24/11/2020]

[74] Hydrogen Europe, 2020, Post COVID-19 and the Hydrogen Sector - A Hydrogen Europe Analysis, Available at: https://hydrogeneurope.eu/sites/default/files/Hydrogen%20Europe%20Analysis_Post%20COVID-19%20and%20the%20Hydrogen%20Sector_final.pdf, [Accessed on: 24/11/2020]

companies which were planning major investments in clean technology could abandon or scale-down these plans. Finally, the pandemic situation may make investors "*less inclined to finance the planned growth of the [hydrogen] sector*".[75]

4.2.6 Future EU potential – Hydrogen Fuel Cells

Policy support

In 2019, the Fuel Cells and Hydrogen Joint Undertaking published the "*Hydrogen Roadmap Europe: A sustainable pathway for the European Energy Transition*"[76], which lays out a pathway for the large-scale deployment of hydrogen and fuel cells until 2050.

The European Green Deal has also outlined hydrogen as a priority area for climate neutral, affordable, secure energy. With the new EU Industrial Strategy, published in March 2020, the EC launched the European Clean Hydrogen Alliance. The Alliance is expected to encompass all segments of the hydrogen VC from production, supply, distribution to the industrial end-use for energy-intensive industries or as a transport fuel. Furthermore, projects that are able to be classified as an Important Project of Common European Interest (IPCEI) would benefit from a relaxed State Aid regime, which in turn will also be reviewed in the coming years in order to allow for European companies to consolidate, grow and be able to compete with international competition outside of the EU.

Additionally, in July 2020, the EC released its hydrogen strategy called "*Building a hydrogen economy for a climate neutral Europe*"[77]. According to the strategy "*renewable hydrogen is the most compatible option with the EU's climate neutrality goal in the long term and is the priority focus*". Furthermore, as part of the measures the EC is proposing the creation of "*dedicated gigawatt-scale green hydrogen factories*" with 4 GW of electrolysers by 2024 and at least 40 GW by 2030, which will strengthen the HFC VC as well as the EU hydrogen sector in general.

When it comes to future legislation, the hydrogen VC most likely will be impacted by the upcoming revisions in 2020 of the Regulation on Trans-European Networks – Energy (TEN-E) and Transport (TEN-T), as well as the Alternative Fuels Infrastructure Directive (the latter two scheduled for 2021) – all proposed under the European Green Deal. While, currently large infrastructure hydrogen projects are not specifically included as a cluster in TEN-E, Hydrogen Europe[78] is calling for their recognition as a new thematic area under the TEN-E Regulation, which would allow them to apply for Connecting Europe Facility (CEF) funding.

Growth potential

Europe has globally leading companies and research institutes across many hydrogen and fuel cell technologies and applications with strengths in key components of fuel cell stacks and electrolysers. Pioneering stakeholders might earn global leadership in underlying

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[75] Hydrogen Europe, 2020, Post COVID-19 and the Hydrogen Sector - A Hydrogen Europe Analysis, Available at: https://hydrogeneurope.eu/sites/default/files/Hydrogen%20Europe%20Analysis_Post%20COVID-19%20and%20the%20Hydrogen%20Sector_final.pdf, [Accessed on: 24/11/2020]

[76] Fuel Cells and Hydrogen Joint Undertaking, 2019, *Hydrogen Roadmap Europe: A sustainable pathway for the European Energy Transition*, ISBN 978-92-9246-331-1 Available at: https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf

[77] European Commission, 2020, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - A hydrogen strategy for a climate-neutral Europe,* 08 July 2020, COM(2020) 301 final, Available at: https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

[78] Chatzimarkakis, J. 2020. Clean hydrogen needs its own infrastructure. In: New Europe. Available at: https://www.neweurope.eu/article/clean-hydrogen-needs-its-own-infrastructure/ [Accessed on: 10/12/2020]

technologies (e.g. scaling of electrolysers). Based on its extensive chemical industry, Europe may leverage its existing knowledge base and infrastructure.

Together with other energy system integrators, Europe has the potential to create markets and value along the full VC, from hydrogen generation, storage and distribution through to utilisation.

4.2.7 SWOT – Hydrogen Fuel Cells

Strengths *Internal attributes, characteristics and factors that give competitive advantage to the EU in the global VC.*	**Weaknesses** *Internal attributes, characteristics and factors that weaken the competitiveness of the EU in the global VC.*
• The HFC VC is characterised by an active, moderately developed ecosystem of corporations and innovators with strong policy and advocacy support. • Average size of investments is larger in Europe than the RoW with growing late stage private investments. • Individual Member States enacted own initiatives and industrial clusters. • More than 1/3 of active fuel cell companies are headquartered in Europe. These companies have a track record for producing innovative products.	• Over the 2007-16 period, more patent applications were filed in the RoW than in the EU-28, which could have long-term implications for innovation. • EU-28 public investment has been decreasing even though investments in hydrogen need to be significantly raised if the EU is to achieve its hydrogen goals and climate targets. • The overall share of private investments in early stage European companies has experienced a large fall, which could impact this VC’s future development and strength. • Currently, there are no strongly active European private investors focused on HFCs. • Performance, weight, size and cost issues have posed barriers to the commercial adoption of fuel cell technology within Europe.
Opportunities *External situations and factors that can strengthen the competitive advantage of the EU or provide the EU with new sources of competitive advantage.*	**Threats** *External situations and factors that can create problems for the EU compromising its competitive advantage to a certain extent.*
• The EU aims to be climate neutral by 2050 and hydrogen is likely to play an important role in reducing carbon in energy-intensive sectors like heavy industry and freight. • European companies and hydrogen research institutes are well placed and might earn global leadership in underlying technologies. • There is a potential to create and develop markets and value along the full hydrogen VC all over Europe. • Initiatives such as the European Clean Hydrogen Alliance present a strong opportunity for cooperation, consolidation and innovation on a large scale in Europe. • The European Green Deal and the Communication on “*A hydrogen strategy for a climate-neutral Europe*” are essential guidance for the strengthened policy development of this VC.	• The HFC VC in Europe is characterised by a large heterogenous mix of companies and smaller scale innovators that need further development to successfully compete with foreign competitors. This could be aided by initiatives such as the European Clean Hydrogen Alliance. • High likelihood that Asia (e.g. China and Japan) will become a large exporter of fuel cells. • Covid-19 is considered a threat to the development of this VC in the short to medium term as resources could shift towards other priority areas. • Dependency of Europe on the import of critical raw materials, particularly Platinum Group Metals from inter alia China, South Africa, Russia and Zimbabwe, could affect European production of key hydrogen production and storage technologies.

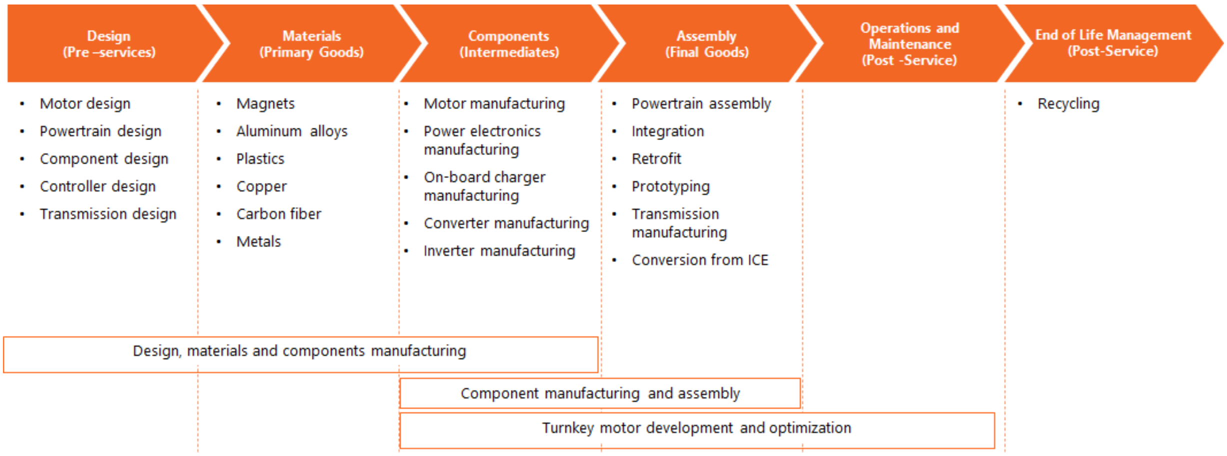
4.3 Electric Power Trains

4.3.1 Scope of the VC – Electric Power Trains

The scope of the Electric Power Trains VC is focused on electric components responsible for propulsion of road vehicles fuelled solely or partially by electric power. It includes electric traction motors, power electronics (motor controllers, internal chargers and converters), for four-wheeled road vehicles (buses, cars) in battery electric vehicles (EVs) but excludes activities associated with the axles and the batteries themselves as these are addressed in another VC. The areas of innovation covered by this VC include electric motors, power electronics and technologies integrating these different components. From a methodological perspective, it is important to stress that it is difficult to separate investment into powertrains from other activities in EV companies or Tier 1 providers supplying the space.

The structure of the Electric Power Trains VC, split by segment of activity, is elaborated in Figure 4.12.

Figure 4.12 Electric Power Trains VC Structure



Source: Cleantech Group, 2020.

4.3.2 European market overview[79] – Electric Power Trains

The automotive supply chain is well established in Europe, but the electric power trains VC remains relatively small with a large growth potential. The industry is represented by various organisations such as the European Association for Electromobility (AVERE), the European Automobile Manufacturers' Association (ACEA), the European Association of Automotive Suppliers (CLEPA), and the European Automotive Research Partners Association (EARPA).

The adoption of EVs in Europe has largely been driven by each country and its local policies. More specifically, those initiatives that address EV affordability, convenience and awareness, and plans and regulations regarding target EV sales volume or share, which have served as the underlying framework.

[79] Note: When this document refers to "Europe" it includes all countries that are part of the European single market – this covers the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. In some cases, the data is extracted at aggregated EU-28 or EU-27 level. Datasets, reports and information that was extracted for the period before 2018, refers to the EU-28 and includes the UK in the analysis.

Thus, although the European market for EVs has seen rapid growth in recent years, it remains small and dependent on support policies and adoption is highly fragmented across countries. The majority of the deployed EVs are concentrated in the Nordic region and western Member States.

One of the drivers that enhanced this VC is the 2016 European strategy for low-emission mobility[80]. It established the 2050 target of 60% reduction in transport emissions compared to 1990 levels, introduced key levers for improving transport system efficiency, low-emission alternative energy and low- and zero-emission vehicles.

Furthermore, the 2017 Resolution on a European Strategy for Low-Emission Mobility[81] set the ambition to adopt a plan for the market uptake of EVs and to issue Member States with guiding recommendations to encourage them to implement fiscal incentives for zero- and low-emission vehicles. In addition, in 2017 the EC launched 'Europe on the Move'[82] – a wide-ranging set of initiatives that proposed the use of improved emission standards, smart road charging and scale up of low-emission alternative energy for transport, such as renewables, biofuels and hydrogen.

Finally, the EC indicated plans for a post-2020 CO_2 standards for cars and vans. The assessment is expected to cover costs and benefits, competitiveness impacts and industrial policy developments across the EU and different ways to incentivise low- and zero-emission vehicles in a technology neutral way. These are expected to be introduced in proposals implementing the European Green Deal. Additionally, the EC has adopted the 2030 climate target plan in September 2020, proposing an increased EU GHG emissions reduction target of “at least 55%” by 2030 compared to 1990 levels.

4.3.3 European industry size and VC – Electric Power Trains

When it comes to the currently active companies in the electric power trains VC, the analysis of the Cleantech data showed that 28% of them are headquartered in the EU-28. In addition, six out of the top ten countries where these companies are located are in Europe. Electric power trains companies headquartered in Europe, are concentrated in Germany (25%) and the UK (42.5%).[83]

Over the period 2009 – 2015, the annual production value of electric power trains in the EU-28 remained in the range of €4 billion to €5.5 billion. Post 2015, the production value sharply increased to reach €10.23 billion in 2018. Italy and Germany jointly accounted for about half of the EU-28 production value.

As illustrated in Figure 4.13 between 2009 and 2018, EU-28 exports to the RoW increased from €1.14 billion to €4.86 billion in 2018. On the other hand, imports have seen a similar trend – increasing from €0.43 billion to €3.30 billion. The EU-28 share of global exports

[80] European Commission, 2016, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A European Strategy for Low-Emission Mobility*, 20 July 2016, COM/2016/0501, Available at: https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52016DC0501

[81] European Parliament, 2017, *European Parliament resolution of 14 December 2017 on a European Strategy for Low-Emission Mobility (2016/2327(INI))*, P8_TA(2017)0503, Available at: https://www.europarl.europa.eu/doceo/document/TA-8-2017-0503_EN.pdf

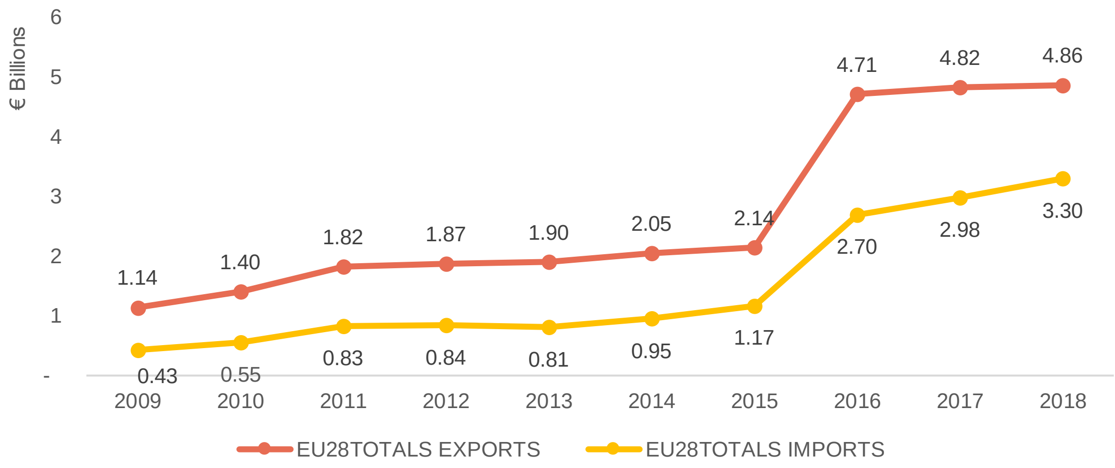
[82] European Commission, 2017, *Europe on the Move: Commission takes action for clean, competitive and connected mobility*, Available at: https://ec.europa.eu/transport/modes/road/news/2017-05-31-europe-on-the-move_en, [Accessed on: 24/11/2020]

[83] According to the analysed data from the Cleantech Group’s database (see section 3.2.2 for more details).

remained around 15% from 2016 to 2018. Top EU-28 exporters were Germany, Italy, and the Czech Republic.

Between 2016 and 2018, five out of the top ten global exporters were EU-28 countries. Key competitors were China and the US. For the same period, three out of the top ten global importers were EU-28 countries. Germany was the largest importer followed by the US, China and Mexico.

Figure 4.13 Total Production Value in the EU-28 and Top Producer Countries – Electric Power Trains[84]



Source: ICF, 2020

Between 2009 and 2015, the EU-28 trade balance remained positive in the range of €0.7 billion to €1 billion. In 2016, it increased to €2 billion and then decreased to €1.56 billion in 2018. The countries with the higher positive trends were Germany, Finland and Italy, and that with the lowest negative trends were France, the UK, and Denmark. Portugal and Slovenia were top performers when it comes to improvement in trade balance. Germany exported both to the rest of the EU-28 Member States as well as outside the EU-28 and France has imported mostly from within the EU-28.

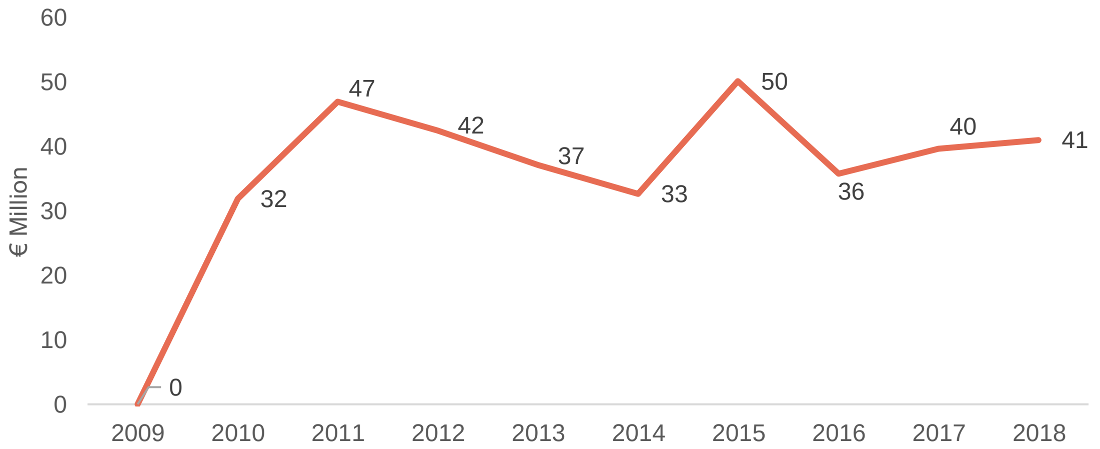
To put the European market in perspective with other trading blocks, in 2019, Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) held a 5% market share in China, a 3% market share in Europe and a 2% market share in the US. China's dominance has been driven by strong national and local industrial policies supporting domestic EV manufacturing (e.g. 'Made in China 2025' programme) and consumer uptake. In 2017, China secured €21.7 billion of investment from European car makers in EV manufacturing, while Europe itself secured €3.2 billion.

4.3.4 Innovation and investment in RD&D – Electric Power Trains

The data on public investment in RD&D is available for a limited group of countries covered by the IEA. Starting from 2009, EU-28 public investment has increased to €41 million in 2018. Out of the countries for which the IEA has data, France was by far the largest investor, followed by the UK. In addition, seven out of the top ten countries where these investments are in Europe.

[84] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

Figure 4.14 EU-28 Public RD&D Investments in the Electric Power Trains VC[85]



Source: ICF, 2020

Over the 2015-2019 period, only 2% of the total value of global private venture capital investments in early stage companies active in the electric power train VC was in European companies.[86] Investments level decreased during this period to reach €5 million in 2019. When assessing the number of investments, this percentage grows to 30%, suggesting that the average size of investments was higher outside of Europe. China and the US largely outperformed Europe in terms of attractiveness for early stage investors, as they respectively secured investment in the range of €3 billion and €1 billion.

The situation is similar in terms of late stage private investment as 2% of the total value of global private investments was in European companies.[87] While the share of investments in European companies has increased fivefold in recent years to reach €150 million (2019), it is still dwarfed by the China and the US that both secured over €6.5 billion of late stage private investment during the 2015-2019 period.

Over the period 2007-2012, the number of patent applications in the EU[88] and RoW increased. Since 2012, the number of patent applications in the EU-28 has been declining, whereas in RoW, for the 2013-2016 period they remained relatively stable. For the studied period, the EU-28 accounted for roughly for one third of the overall high value patent applications. In addition, five out of the top ten countries where these patent applications happened are in the EU-28, with France and Germany standing out in terms of number of high-value patent applications over the 2014-2016 period. Germany, as the EU-28 patent leader, has evenly spread patents across electric, hybrid, hydrogen and internal combustion engine (ICE) vehicles (similar to Japan and South Korea), while US patents (Tesla notwithstanding) are focused on ICE technology and the few patents held by India and China are mostly in new energy technologies.

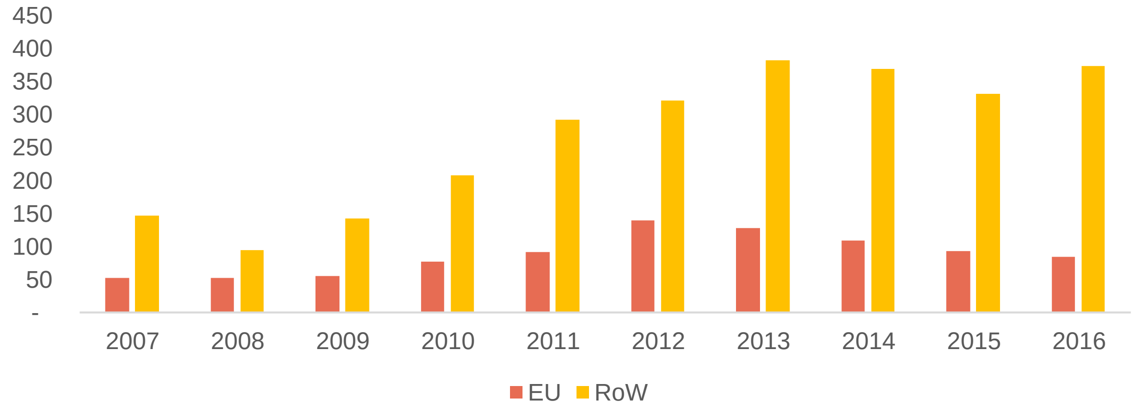
[85] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

[86] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the US and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

[87] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details).

[88] Croatia joined the EU in 2013, so in this case the historical EU-27 data refers to the EU Member States including the UK and excluding Croatia.

Figure 4.15 Patent applications EU-28 vs rest of the world– Electric Power Trains[89]



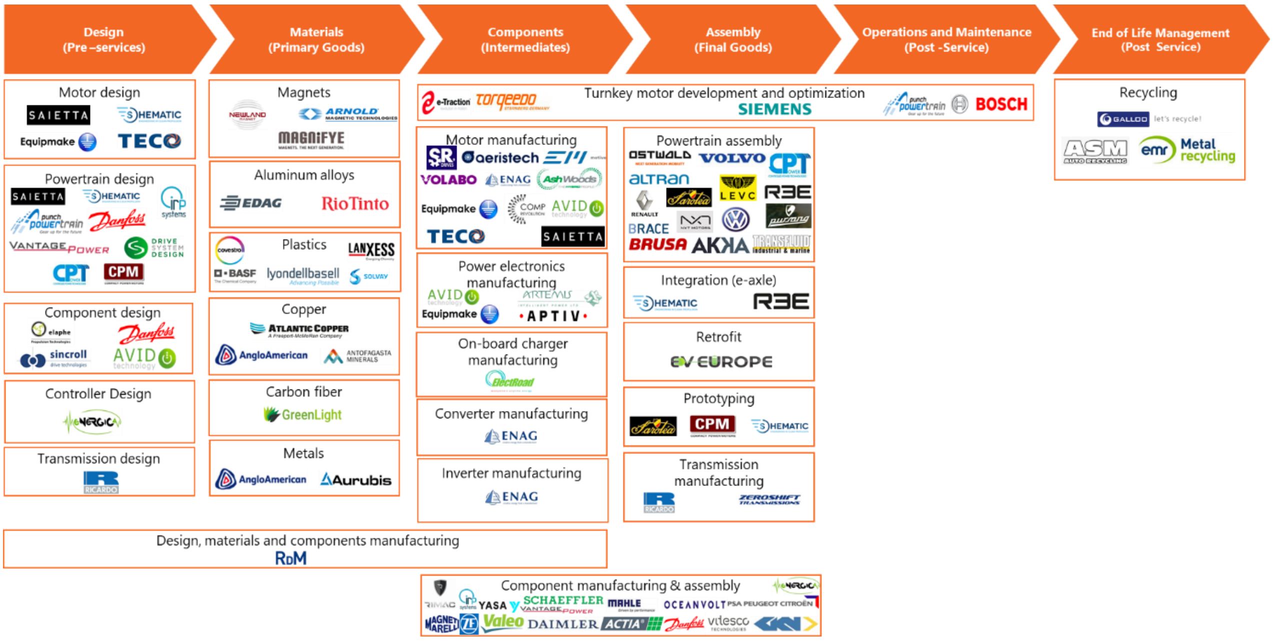
Source: ICF, 2020

When it comes to innovation, many components manufacturers are still largely or exclusively focused on ICE technologies. While OEMs are increasing their investments in EVs the range of available EV models is still limited compared to ICE vehicles.

The primary goals with powertrain innovation are to optimise size and weight, enable new vehicle concepts and improve overall efficiency and performance to make better use of the battery. Thus, key areas of innovation are e-axles (integration of motor and power electronics), innovative software controls, skateboard platforms, in-wheel motors and innovation in motor design and materials to improve power density and efficiency.

Incumbents such as Bosch, Continental, ZF and Schaeffler have strengthened their portfolios of powertrain products and are innovating in the areas of e-axles, on-board chargers and new form factors. Furthermore, in Figure 4.16 are exemplified some of the key European market players, divided by segment of the Electric Power Trains VC.

Figure 4.16 European Key Market Participants – Electric Power Trains



Source: Cleantech Group, 2020

[89] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

Early-stage European innovation funding (through Horizon 2020 and European Investment Bank instruments) has largely been focused on battery technologies. For instance, Shematic, a provider of innovative technologies for motor customisation, is a key innovator that has received funding in Europe in the past five years. In comparison to North America, funding for innovation in electric drivetrains has been limited in Europe.

When it comes to investments, more than €50 billion are invested in RD&D by European automakers. In addition, Continental has committed to invest an addition €300 million in powertrain electrification projects by 2021.[90] Thus, public RD&D funding from Horizon 2020 or Member State initiatives have not made - and are not expected to make - a substantial difference unless directed towards target areas and early stage technologies that have not yet received the required private investment.

Furthermore, Asian automakers are investing in overseas production to leverage lower production costs and compete with European and North American manufacturers. For instance, BYD has already built electric bus manufacturing facilities in Europe[91] and the US and Nidec plans to invest €1.5 billion in overseas EV production.[92]

4.3.5 Threats and challenges – Electric Power Trains

Investment related policy

There is currently a lack of broad, supply- and demand-side policies to drive automaker investment into EV manufacturing capacity in Europe

Cost

On average, an EV costs at least 40% more to the end customer than a comparable ICE vehicle and the wait times to get an EV are often long with limited configuration options, such as equipment, design and motor. Although there are positive trends towards cost-reduction and configuration improvements, currently, many potential buyers are strongly influenced by factors such as price and availability.

Lack of incentives

Currently, only 12 European countries offer bonus payments or premiums to buyers of EVs, although most offer some tax reduction or exemption for buyers and owners. This results in fragmentation inhibiting broad market uptake and consumer demand that widely varies across Europe.

Lack of vertical integration and dependence on raw materials

Although the automotive supply chain is well established in Europe, around 60% of the content of EVs originates from outside the traditional supply chain. Traditional suppliers may only capture a small share of the EV market, especially if they lack competence in battery production and electric motor manufacturing. In addition, for almost all parts European manufacturers are heavily relying on imported raw materials from third countries. This greatly impacts the future development of this VC, as well as overall European competitiveness and independence of this sector. China is the biggest supplier of CRMs

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[90] Continental, 2017, *Continental Ready for Next Growth Spurt with Innovative Powertrain Technologies*, Available at: https://www.continental.com/en/press/press-releases/powertrain-strategy-2020-30468, [Accessed on: 24/11/2020]

[91] BYD Europe, 2020, Available at: https://www.bydeurope.com/byd-europe, [Accessed on: 24/11/2020]

[92] Fukutomi, S., 2020, *Nidec aims to disrupt global EV supply chain with cheaper motors*, Available at: https://asia.nikkei.com/Business/Electronics/Nidec-aims-to-disrupt-global-EV-supply-chain-with-cheaper-motors, [Accessed on: 24/11/2020]

into Europe, with a share of ~40%, followed by South Africa, Russia, Democratic Republic of Congo (DRC) and Brazil.

Brexit

The UK is a large market and stands out in terms of private investments in early stage companies and investments in RD&D. More than 42% of the European companies in this VC are headquartered there. Similar to other VCs, the future of European cooperation in this sector remains to be clarified following Brexit and current trade and cooperation agreements.

Covid-19

The Covid-19 pandemic has stressed the automotive industry, with manufacturing activity halting for weeks to months due to the strict quarantine measures taken by the different Member States. However, existing EU policies around EVs are being maintained and countries like France and Germany have announced increased EV support measures for the remainder of 2020.

In comparison, as a response to the Covid-19 crisis, China has identified the auto market as a key target for economic stimulus, encouraging cities to temporarily relax car permit quotas while simultaneously strengthening targeted New Energy Vehicle measures and extending EV purchase subsidies.

4.3.6 Future EU potential – Electric Power Trains

Policy support

This VC has received a much-needed policy support in recent years. More specifically, the 2016 European strategy for low-emission mobility, and a number of files under the "Clean Energy for All Europeans" legislative package and the European Green Deal that are focused on decarbonising the transportation sector in the EU and introducing measures to boost the wider uptake of EVs across the EU. In addition, the EC indicated plans for CO_2 standards for cars and vans, as well as incentivising the adoption of low- and zero-emission vehicles across the EU.

ICE Bans

A number of Member States and cities have announced bans on ICE vehicles in the next 10-20 years. For instance, there are reports that Austria[93], Germany[94] and the Netherlands[95] plan banning the sale of new non-EVs from 2030, France[96] and Spain[97] from 2040,

[93] Republik Österreich, 2020, *Aus Verantwortung für Österreich - Regierungsprogramm 2020–2024*, Available at: https://www.dieneuevolkspartei.at/Download/Regierungsprogramm_2020.pdf, [Accessed on: 24/11/2020]

[94] Böll, S., 2016, *Bundesländer wollen Benzin- und Dieselautos verbieten*, Spiegel, Available at: https://www.spiegel.de/auto/aktuell/bundeslaender-wollen-benzin-und-dieselautos-ab-2030-verbieten-a-1115671.html, [Accessed on: 24/11/2020]

[95] NL Times, 2017, *New Dutch government's plans for the coming years*, Available at: https://nltimes.nl/2017/10/10/new-dutch-governments-plans-coming-years, [Accessed on: 24/11/2020]

[96] BBC News, 2017, *France set to ban sale of petrol and diesel vehicles by 2040*, Available at: https://www.bbc.com/news/world-europe-40518293, [Accessed on: 24/11/2020]

[97] Burch, I. and Gilchrist, J., 2020, *Survey of Global Activity to Phase Out Internal Combustion Engine Vehicles*, The Climate Center, Available at: https://theclimatecenter.org/wp-content/uploads/2020/03/Survey-on-Global-Activities-to-Phase-Out-ICE-Vehicles-update-3.18.20-1.pdf, [Accessed on: 24/11/2020]

Belgium[98] plans to ban corporate diesel and petrol cars, Sweden[99] and Denmark[100] will ban new diesel and petrol vehicle sales by 2030. These measures if implemented at large could help accelerate demand for EVs and in turn the strength of the VC.

Emissions standards

In December 2018, the EU reached an agreement to reduce CO_2 emissions from new cars by 37.5% by 2030 compared to 2021. This would require a wider uptake of EVs, which could strengthen the electric power trains VC. In addition, future fuel economy standards for cars and vans for 2021-30 and a CO_2 emissions standard for heavy-duty vehicles (2020-30) with specific requirements or bonuses for EVs could substantially strengthen this VC.

Growth potential

For the EU to meet its current targets for clean transport and mobility, there is a need for a much wider uptake of EVs and the potential for growth for the electric power trains VC are extensive.

4.3.7 SWOT – Electric Power Trains

Strengths *Internal attributes, characteristics and factors that give competitive advantage to the EU in the global VC.*	**Weaknesses** *Internal attributes, characteristics and factors that weaken the competitiveness of the EU in the global VC.*
• The automotive supply chain is well established in Europe, with the electric power trains VC relatively small with large potential. • The European electric power trains VC is characterised by a large number of innovators based in Europe. • European automakers and manufacturers are strong and are increasing their investments in this VC. • EU-28 public investment increased to €41 million in 2018, but stayed roughly stable during the 2011-2018 period. • For the studied period, the EU-28's trade balance has remained positive. • Between 2009 and 2018, EU-28 exports to the RoW increased, however, imports also increased. • For the same period, the production value of electric power trains in the EU-28 has more than doubled.	• Lack of broad, supply- and demand-side policies to drive automaker investment into EV manufacturing capacity. • Limited uptake of EVs due to higher costs, often long wait times for consumers and limited configuration options. • Fragmented and largely varied uptake of EVs across Europe and a lack of incentives in the majority of European countries. • Lack of vertical integration. • Very strong dependence on components and raw materials from third countries. • Compared to the RoW, Europe is lagging behind in both early and late stage private investments.

[98] D'Hoore, J. and Dujardin, D., 2020, *Vivaldi-ploeg wil vanaf 2026 enkel elektrische bedrijfswagens*, De Tijd, Available at: https://www.tijd.be/politiek-economie/belgie/federaal/vivaldi-ploeg-wil-vanaf-2026-enkel-elektrische-bedrijfswagens/10252108.html, [Accessed on: 24/11/2020]

[99] Kristensson, J., 2019, *Ny regering – nu väntar förbud mot bensinbilar*, NyTeknik, Available at: https://www.nyteknik.se/fordon/ny-regering-nu-vantar-forbud-mot-bensinbilar-6945094, [Accessed on: 24/11/2020]

[100] Morgan, S., 2018, *Denmark to ban petrol and diesel car sales by 2030*, Euractiv, Available at: https://www.euractiv.com/section/electric-cars/news/denmark-to-ban-petrol-and-diesel-car-sales-by-2030/, [Accessed on: 24/11/2020]

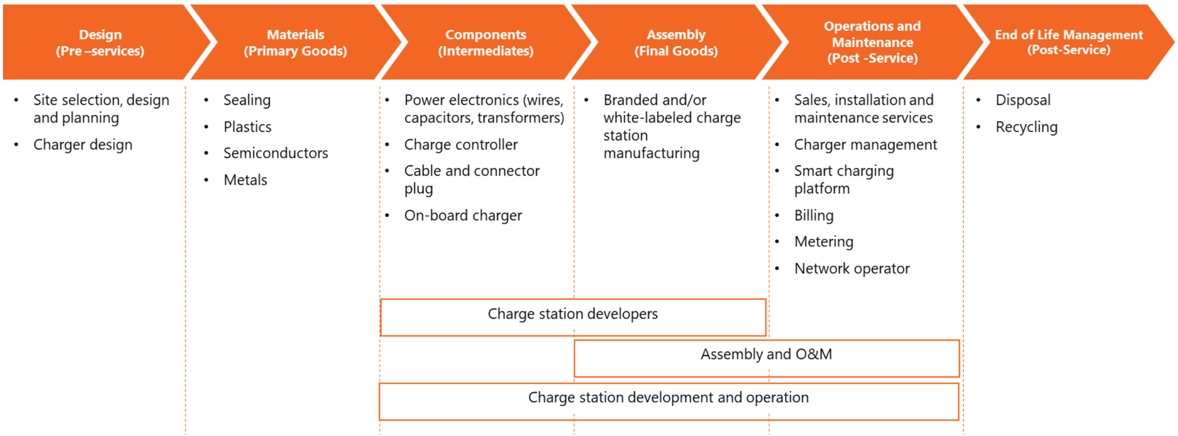
Opportunities *External situations and factors that can strengthen the competitive advantage of the EU or provide the EU with new sources of competitive advantage.*	**Threats** *External situations and factors that can create problems for the EU compromising its competitive advantage to a certain extent.*
• This VC can be supported through strengthened policy support both at EU and Member State level. • Member States announcing bans on ICE vehicles are expected to accelerate EV adoption and innovation. • Future fuel standards for cars and vans and a CO_2 emissions standard, as well as bonuses for EVs, are expected to strengthen their wider uptake in the EU.	• Very strong competition from third countries that are characterised by large internal markets and state support through policies and financing. • The UK is a large market and one of the largest RD&D investors in this VC, as well as home to a very large part of the European companies. The outcome of Brexit could have an impact weakening the VC. • The Covid-19 pandemic and resulting lockdowns in various EU countries had an impact on the production facilities of the VC. Stronger policy support would be beneficial to be able to strengthen the VC in the post-COVID recovery period.

4.4 Electric Vehicles Charging Infrastructure

4.4.1 Scope of the VC – EV Charging Infrastructure

The scope of the EV Charging Infrastructure VC covers equipment and services used to deliver power to EVs and the accompanying software, charging stations, chargers and charging equipment accessible to the general public or fleets for EV and PHEV; and associated software. However, this VC does not include construction materials for garages and station parking, private charging equipment and transmission and distribution infrastructure. Separating public from private charging infrastructure production is also challenging. The structure of the EV Charging Infrastructure VC split by segment of activity is elaborated in Figure 4.17.

Figure 4.17 EV Charging Infrastructure VC Structure



Source: Cleantech Group, 2020.

4.4.2 European market overview[101] – EV Charging Infrastructure

The European EV charging infrastructure market is relatively new but a promising and growing sector. It is represented amongst other organisations by the European Association for Electromobility (AVERE), Transport & Environment (T&E), and the European Automobile Manufacturers Association (ACEA).

In the last few years, there were several important policy developments at the European level that enhanced the growth of the VC. In January 2013, the adoption of the clean fuels strategy[102] established the intention of the EU[103] to reduce its dependence on foreign oil imports and to improve air quality, by supporting the market development of alternative fuels and investment in their infrastructure.

In 2014, the Alternative Fuels Infrastructure Directive recommended introducing a minimum level of EV charging infrastructure across the EU-28 (i.e. one public recharging point for every ten EVs, it also encouraged wireless charging and battery swapping solutions). The

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[101] Note: When this document refers to "Europe" it includes all countries that are part of the European single market – this covers the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. In some cases, the data is extracted at aggregated EU-28 or EU-27 level. Datasets, reports and information that was extracted for the period before 2018, refers to the EU-28 and includes the UK in the analysis.

[102] European Commission, 2013, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Clean Power for Transport: A European alternative fuels strategy*, 24 January 2013, COM/2013/017 final, Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013PC0017&from=EN

[103] Croatia joined the EU in 2013, so in this case the historical EU-27 data refers to the EU Member States including the UK and excluding Croatia.

Directive also required information about the location of charging points to be more accessible, helped standardise technical specifications, and recommended using smart charging/intelligent metering where possible.

In 2018, with the adoption of the “Clean Energy for All Europeans” legislative package, the EV charging VC was further strengthened - more specifically, as a result of Directive 2018/844 on the Energy Performance of Buildings (EPBD), which requires the installation of at least one electric recharging point into all new non-residential buildings; and at least one in five parking spaces in these buildings to be pre-equipped with conduits for electric cables to enable charging points.

In June 2018, the EC proposed to allocate 60% of the CEF €42.3 billion budget to projects that contribute to achieving climate objectives, including the development of charging infrastructure for EVs.

All of these developments in combination with various national initiatives and projects, for the promotion and integration of EVs, contribute to an upswing in infrastructure development, which can be traced in data presented by the European Alternative Fuels Observatory (EAFO). In 2011, the EU[104] “*had roughly 4,000 ‘normal’ charging points (<22kW), eight years later, this number had swelled by 4,150% to approximately 170,000. An additional 22,000 ‘fast’ chargers (>22kW) brought the total amount of charging points in the EU to over 190,000 in 2019*”[105].

Although the US is trailing Europe in charging points, it could catch-up later this decade: a result of the market shifting from a policy-driven to profitability-driven dynamic. Wood Mackenzie estimates that North American homeowners will install 2 million more charging points than China and 3 million more than Europe. The main reasoning behind this is that more Americans live in single-family homes, and it is easier to install charging points at single family homes than multi-family complexes. China will likely remain the leader through 2030, driven by the country’s recent announcement to invest nearly €1.3 billion to install 200,000 EV chargers by the end of 2020 as part of a COVID-19 recovery stimulus.

4.4.3 European industry size and VC – EV Charging Infrastructure

In 2020, 19,543 public fast charging (i.e. >22kW) and 175,318 normal charging (i.e. up to 22kW) points were deployed in the EU, up from 3,396 and 44,786, respectively, in 2015; fast public charging points per 100km highway have steadily increased over the past decade.

Similar to EVs, charging infrastructure deployment has been steadily increasing but this growth is fragmented across Member States and dependent on local and national support schemes. Estimates indicate that there is currently one public charging point for every five EVs, in addition to semi-public and private charging points.

When it comes to active companies and innovators in this VC, 30% of the companies in the Cleantech database are headquartered in Europe.[106] Charging infrastructure companies in Europe, are mainly concentrated in Germany (34%) and the UK (13%).

[104] Croatia joined the EU in 2013, so in this case the historical EU-27 data refers to the EU Member States including the UK and excluding Croatia.

[105] Autovista Group, 2020, *Boosting Europe’s EV charging infrastructure*, Available at: https://autovistagroup.com/news-and-insights/boosting-europes-ev-charging-infrastructure, [Accessed on: 24/11/2020]

[106] According to the analysed data from the Cleantech Group’s database (see section 3.2.2 for more details).

According to a recent report on the transition to zero-emission mobility by the European Automobile Manufacturers Association[107], just four countries, covering 27% of the total surface area of the EU-28, accounted for 76% of all charging points in the EU-28. The countries with the largest EV charging infrastructure were the Netherlands (37,037 charging points), Germany (27,459), France (24,850) and the United Kingdom (19,076), while, the four countries with the lowest number of charging points were Bulgaria (108), Malta (100), Greece (50) and Cyprus (36), collectively totalling just 294 charging points (although these countries also have considerably smaller populations). However, even when adjusted for chargers per capita, these countries do still need to accelerate their deployment of charging points. This could be due to the slower adoption of EVs across these countries, which in turn might be due to other factors such as economic activity, citizen purchasing power, or insufficient tax adjustments and stimuli for adoption of EVs.

According to EC estimates, "*at least 2.8 million electric charging points will be needed across the EU by 2030 [which] means a 20-fold increase is required by the beginning of the next decade*"[108].

In the rest of the world, as of October 2019, China was leading in terms of number of EV chargers installed, with over 466,000 public charging points. Availability of charging points has expanded rapidly in recent years to support the country's aggressive EV push. The US is lagging in EV charging infrastructure with just over 60,000 public charging points deployed as of October 2019. By 2017, only 25% of the workplace and public chargers needed by 2025 to support the transition to EVs were in place, similarly to the European situation, deployment has been uneven across the US and led by local governments and utilities.

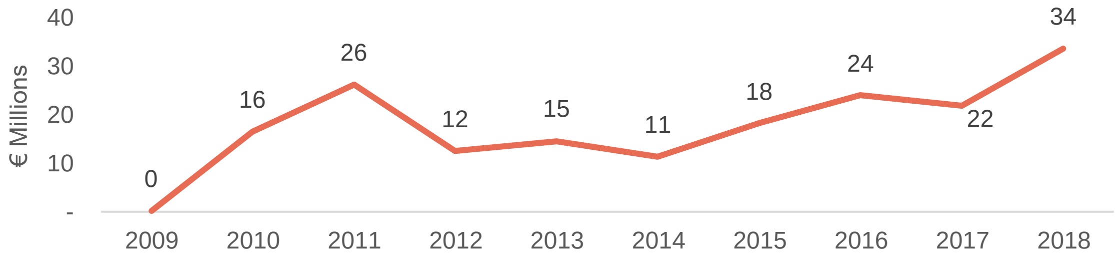
4.4.4 Innovation and investment in RD&D – EV Charging Infrastructure

The data on public investment in RD&D is available for a limited group of countries covered by the IEA. EU-28 public investments in this VC have increased over the last decade to reach €34 million in 2018. For the 2016-2018 period, out of the countries for which the IEA has data, France was the largest public investor with €24.6 million, followed by the UK with €23.1 million.

[107] European Automobile Manufacturers Association, 2019, *Making the Transition to Zero-Emission Mobility – 2019 Progress Report – Enabling Factors for Alternatively-Powered Cars in the EU*, Available at: https://www.acea.be/uploads/publications/ACEA_progress_report_2019.pdf (Note: latest data year was 2018, hence EU-28)

[108] Transport & Environment, 2020, *Recharge EU: how many charge points will Europe and its Member States need in the 2020s,* Available at: https://www.transportenvironment.org/sites/te/files/publications/01%202020%20Draft%20TE%20Infrastructure%20Report%20Final.pdf

Figure 4.18 EU-28 Public RD&D Investments in the EV Charging VC[109]



Source: ICF, 2020

Over the 2015-2019 period, 14% of the total value of global private venture capital investments in early stage companies active in the EV charging infrastructure VC was in European companies.[110] When assessing the number of investments, this percentage grows to 18%, suggesting that the average size of investments is higher outside Europe. The volume of early stage investments in European companies increased during that period to reach €15 million in 2019. Spain (€15 million) and the UK (€11 million) benefited from most of these investments during the period 2015-2019, but were still far behind China (€89 million), the US (€63 million) and, to a lesser extent, Australia (€19 million).

The situation is even worse in terms of late stage private investment, since European companies only benefited from 3% (€30 million) of the global value of investments during the 2015-2019 period.[111] The US captured the vast majority of these investments (close to €1 billion) followed by China (€112 million), both largely outperforming Europe in this sector.

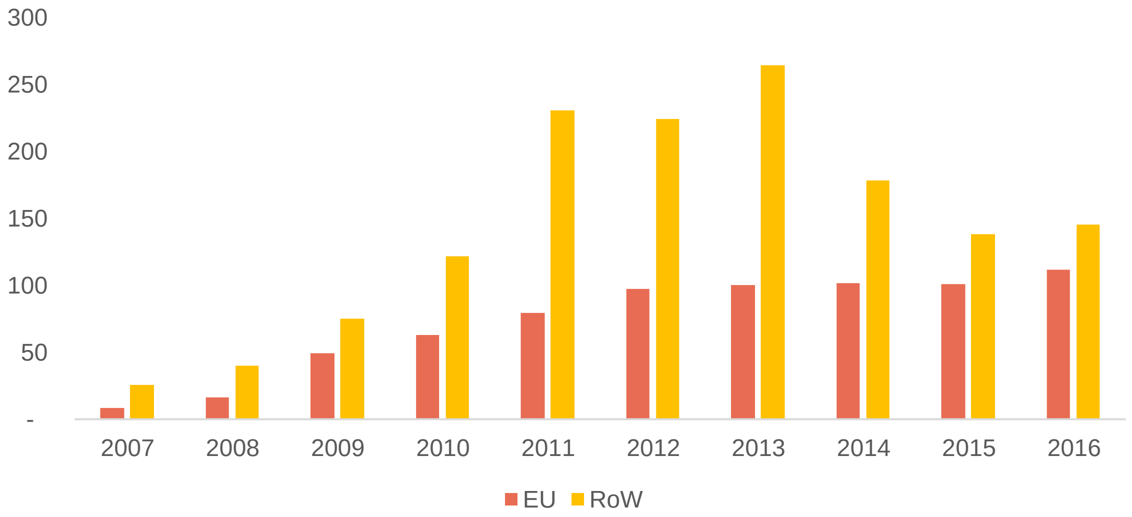
Unsurprisingly, given the above investment trends, over the decade 2007-2016, more patent applications linked to EV charging infrastructure were filed in the RoW than in the EU-28. However, over the studied period the number of patent applications in the EU-28 has been increasing, while patents in the RoW have been declining and thus the difference between EU-28 and RoW decreased over time, as illustrated in Figure 4.19 below. In addition, five out of the ten top countries filing these patents were in the EU-28. Specifically, Germany, France and Sweden stand out in terms of the number of high-value patent applications over the 2014-2016 period for which data is available.

[109] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

[110] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the USA and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

[111] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details).

Figure 4.19 Patent applications EU-28 vs rest of the world – EV Charging Infrastructure[112]



Source: ICF, 2020

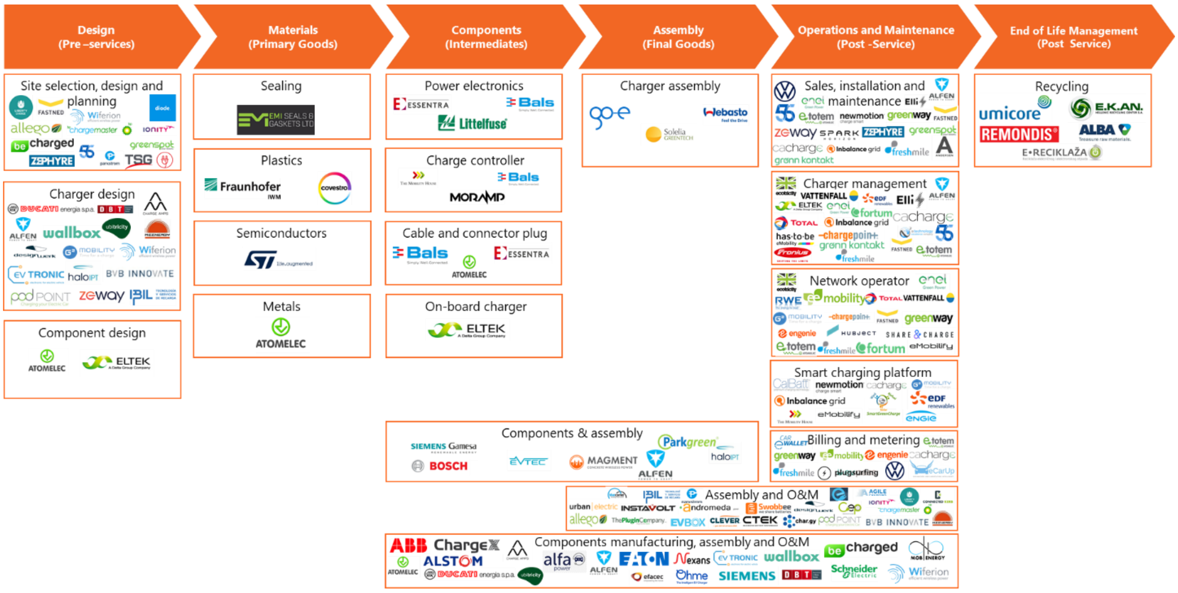
EV charger deployment has mostly been a land-grab, with activity centred around deploying as many charging stations as possible to capture market share – the next phase of the market is expected to focus more on reaching under-served segments (i.e. private charging stations) and value-add services (e.g. smart charging, innovative payment methods, etc.) to improve profitability.

Emerging technologies include predictive maintenance, smart charging, vehicle to grid solutions, peer-to-peer energy trading and autonomous payments using blockchain. For instance, innovative charging stations, such as robotic chargers (Mob-Energy), battery swapping stations (Zeway), wireless charging (Magment and Blue Inductive) have received investment in the past five years, as well as innovators developing solutions for specific use cases, such as Liberty Charge (on-street charging for residential areas), Inbalance Grid (end-to-end solutions for cities and commercial applications), Cacharge (solutions for parking garages) and ChargeX (commercial facilities and multi-family homes).

Figure 4.20 provides an overview of some of the key European market players, divided by segment of the EV Charging Infrastructure VC.

[112] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

Figure 4.20 European Key Market Participants – EV Charging Infrastructure



Source: Cleantech Group, 2020

4.4.5 Threats and challenges – EV Charging Infrastructure

Cost

The cost and financing required for the development of EV charging infrastructure is one of the main challenges for this VC. There is a need to strike the right balance between adequate charging infrastructure deployment and appropriate investment that encourages EV uptake, which at the same time will not lead to underutilised and obsolete assets. With evolving technologies and standards, there is also a risk for EV infrastructure to become rapidly outdated, creating further investor uncertainty.

Range anxiety and lack of information

This remains a major barrier to EV uptake, either due to actual lack of charging infrastructure or unawareness that it exists. Although charging infrastructure deployment has increased in line with EV uptake, there is a lack of centralised information around where charging points are located.

Varying national regulation

Local and legal requirements for charging points differ across Member States, creating legal and regulatory barriers when building out cross-state networks. This also creates uncertainties for the end-users.

Covid-19

At the time of writing this report, there were no known EV charging equipment producing facilities that were fully closed due to the Covid-19 pandemic, however, there might be delays and slowed production[113], especially in some of the countries that were particularly badly hit by the pandemic and were forced to implement full lockdowns. One of the main impacts of the ongoing pandemic for this VC is the impact on EV sales and generally car sales, with EU producers changing their forecasts and announcing a record 25% drop of sales[114].

4.4.6 Future EU potential – EV Charging Infrastructure

Policy support

The VC benefited from increasing political support over the last years and new support schemes are still being developed laying the ground for further growth. The 2016 European strategy for low-emission mobility indicated standardisation and interoperability as being crucial to minimise barriers to EV charging across the EU-28 and to the development of standards for induction charging, batteries and charging plugs for electric buses and motorbikes.

Some of the policy proposals under the European Green Deal are expected to accelerate the shift to sustainable and smart mobility, including a 90% reduction in transport emissions by 2050 and increasing the EU's climate ambitions for 2030 and 2050. The EC plans to support the deployment of public recharging and refuelling points where gaps exist.

In November 2019, German automakers pledged to roll out one million charging points for EVs across Germany by 2030.[115] Furthermore, European governments are setting out plans for expanding networks. For example, in February 2020, "*Romania gained approval from European competition regulators for a €53 million public support scheme for charging stations*".[116] In July 2020 the eCharge4Drivers[117] project was announced. It will conduct demonstrations across key cities in the EU to better understand consumers' perspectives on charging infrastructure, which is expected to help develop targeted policies to address key concerns and shortcomings.

Growth potential

The EC estimates that approximately 2 million public charging points will be needed by 2025 to ensure the EU remains on track to achieve its climate objectives. One of the estimates indicates that the EU needs a fifteen-fold increase in public charging points by 2030 to support the EU's goal of becoming climate neutral; and to this end, 3 million public charging points will need to be available by 2030.

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[113] MarketWatch, 2020, *Impact of COVID-19 on the Electric Vehicle Charging Stations Market*, Available at: https://www.marketwatch.com/press-release/impact-of-covid-19-on-the-electric-vehicle-charging-stations-market-2020-08-31?mod=mw_more_headlines&tesla=y, [Accessed on: 24/11/2020]

[114] European Automobile Manufacturers Association, 2020, *EU car sales forecast 2020: Record drop of 25% expected this year, says ACEA,* Available at: https://www.acea.be/press-releases/article/eu-car-sales-forecast-2020-record-drop-of-25-expected-this-year-says-acea, [Accessed on: 24/11/2020]

[115] Simon, F., 2019, *'No way around electrification,' BMW says,* Euractiv, Available at: https://www.euractiv.com/section/electric-cars/news/no-way-around-electrification-bmw-says/, [Accessed on: 24/11/2020]

[116] Autovista Group, 2020, *Boosting Europe's EV charging infrastructure*, Available at: https://autovistagroup.com/news-and-insights/boosting-europes-ev-charging-infrastructure, [Accessed on: 24/11/2020]

[117] eCharge4Drivers, 2020, Available at: https://echarge4drivers.eu/, [Accessed on: 24/11/2020]

According to the European Green Deal, the EC is looking to also support the use of alternative transport fuels and build out associated refuelling infrastructure, which would diversify the types of low- or no-emission charging/fuelling points needed (hydrogen, biofuels, etc.). In addition, private corporations announced expansion in their European production facilities – most notably, Tesla's announcement for opening their first European factory in Germany.

Mergers and acquisitions

In recent years, big energy firms started looking towards investing in the rising market demand for electric infrastructure: BP acquired the UK's largest EV charging company, Chargemaster, Shell acquired charging provider NewMotion, Total secured Europe's largest concession contract for EV charging in the Netherlands, EDF bought a majority stake in Pod Point.[118] Furthermore, Total invested in Chargetrip and acquired G2mobility to accelerate their EV charging business, including designing smart charging stations, optimizing energy use and selling integrated services; EDF invested in and created a joint venture with Nuvve (a US-based smart charging company), partnered with Ubitricity and partnered with Nissan to develop value-add smart charging services; Enel developed their own EV charging station for consumers, the JuiceBox, and have been active in projects to promote charging infrastructure and innovative technologies.

Additionally, some manufacturers devoted private funding to build out charging networks to drive adoption of EVs. The most prominent example of this is Ionity, a joint venture between BMW, Daimler, Ford and Volkswagen Group.

4.4.7 SWOT – EV Charging Infrastructure

Strengths *Internal attributes, characteristics and factors that give competitive advantage to the EU in the global VC.*	**Weaknesses** *Internal attributes, characteristics and factors that weaken the competitiveness of the EU in the global VC.*
• European EV charging infrastructure VC is relatively new, but it represents a promising and growing sector. • EU-28 public investment in this sector has increased tremendously over the past decade. • This VC is becoming more represented and supported through EU policies. Some policy proposals under the European Green Deal are expected to accelerate the shift to sustainable and smart mobility. • Several EU Member States are setting out plans for expanding EV charging networks and boosting investments in this VC.	• Cost-efficiency and financing for the development of this infrastructure is one of the challenges for this VC. • Lack of centralised information on the location of EV charging points across Europe. • Average size of investments in early and late stage companies is higher outside of Europe. • Share of investments in European companies remained small in recent years, in contrast to significant growth in the RoW. • While there are ambitions for an increase in EV ownership, there is still no specific EU Regulation which pushes the EV charging market and which aligns its ambition with the EU's climate neutral ambitions.
Opportunities *External situations and factors that can strengthen the competitive advantage of the EU or provide the EU with new sources of competitive advantage.*	**Threats** *External situations and factors that can create problems for the EU compromising its competitive advantage to a certain extent.*

[118] Autovista Group, 2020, *Boosting Europe's EV charging infrastructure*, Available at: https://autovistagroup.com/news-and-insights/boosting-europes-ev-charging-infrastructure, [Accessed on: 24/11/2020]

• Historically, the EU-28 has filed fewer patent applications than RoW, however, the trend shows a declining gap implying strong competitive positioning. • Europe is home to 30% of the active companies in the EV charging infrastructure sector, presenting opportunities for innovation and growth given the right framework conditions. • Increased competitiveness of electric mobility and various technological innovations in the VC. • Increased opportunities for mergers and acquisitions.	• Charging infrastructure across Europe is developing more in certain countries creating an uneven geographically distribution which could impact the pan-European market. • Manufacturers and project developers outside the EU are growing faster mainly due to higher needs in their respective internal markets. • Limited appropriate valuation for renewable electricity sourcing in transport. • Covid-19 pandemic has had a major impact on the car industry in Europe, which in turn reduces the strength of the EV charging VC.

4.5 Prefabricated buildings

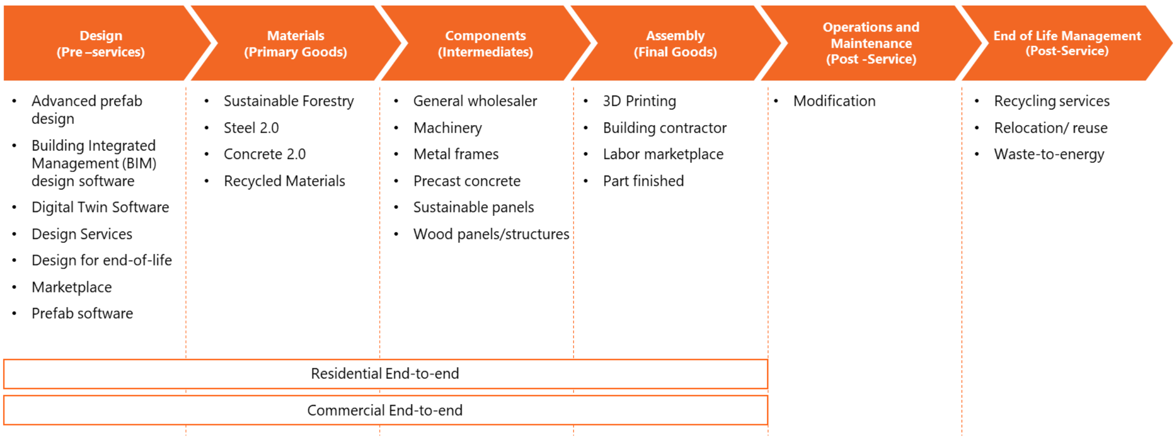
4.5.1 Scope of the VC – Prefabricated Buildings

The scope of the Prefabricated Buildings VC includes technologies enabling the offsite construction of residential, commercial and industrial buildings resulting in lower carbon footprint (e.g. efficiency gains), offsite material design and assembly as well as installation at construction site related to building envelop. This VC does not include the transportation of materials to the construction site, appliances and other non-construction assets, building plumbing and electrical system installation are also excluded similarly to activities linked to building retrofits.

It is important to recognise that this VC, is composed of a very large number of construction and architecture firms that are most of the time micro-enterprises or SMEs, making it more difficult to complete an exhaustive mapping of their activities. In addition, the assumption taken was that prefabricated buildings are a de facto a less carbon intensive than on-side construction and hence all prefabricated solutions are taken into account in the VC analysis. There is also a risk of double counting as for example the production code prefabricated structural components for building or civil engineering, of cement, concrete or artificial stone, is related to any kind of components used on a building or infrastructures (civil engineering). It can be a cement pipe for a massive wastewater system or a water tank or a veranda. If it is applied to a prefabricated building, it will count twice, one for the building and another for the component. In the scope of this study, it was not possible to do a more granular analysis of this VC. However, it is certainly a sector that would benefit from additional scrutiny in the future.

The structure of the Prefabricated Buildings VC split by segment of activity is elaborated in Figure 4.21.

Figure 4.21 Prefabricated Buildings VC Structure



Source: Cleantech Group, 2020.

4.5.2 European market overview[119] – Prefabricated Buildings

There is an increasing infrastructure demand due to increase in population and urbanisation, which opens markets for faster and more efficient construction. Some of the

[119] Note: When this document refers to "Europe" it includes all countries that are part of the European single market – this covers the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. In some cases, the data is extracted at aggregated EU-28 or EU-27 level. Datasets, reports and information that was extracted for the period before 2018, refers to the EU-28 and includes the UK in the analysis.

trends in the building industry include an aging and dwindling construction workforce, increasing cost of labour and skills shortages, which in turn are causing low productivity.

On the other hand, prefabrication is safer, often cheaper, more productive and attracts different skilled workers. In addition, prefabrication results in higher quality, since the construction is carried out in a controlled factory environment.

This VC is represented amongst others by the European Federation of Premanufactured Buildings (EFV) and the European PropTech Association – PropTech House. The latter organisation, founded in 2019, combined with their partners, aims to help start-ups and scale-ups to grow and succeed through promoting cross border collaboration and access to European funding. They are also aiming to advocate for an EU policy framework that fosters greater innovation and adapts to new technologies across the European real estate industry.

In 2016, across the EU-28, construction and demolition waste represented 35% of all waste generated[120]. In prefabricated constructions, most rework costs can be avoided, thus reducing on-site waste, while at the end-of-life phase, structures can be more demountable or have greater ability to be repurposed, recycled or reused.

In the EU, the operation of buildings is responsible for 40% of energy consumption and 36% of CO_2 emissions[121]. EU policies and targets, including the EU environmental obligations to reduce building GHG emissions by 80-95%, the level(s) framework for sustainability assessment[122], the Common European Sustainability Building Assessment (CESBA) initiative[123], the Roadmap to a Resource Efficient Europe[124] and the new Circular Economy Action Plan[125] all promote buildings sustainability, energy efficiency and aim to reduce waste, to which prefabricated buildings can contribute with efficiency gains.

From 2020 to 2025, the European prefabricated building market was projected (prior to the Covid-19 pandemic) to expand at a 5% compound annual growth rate (CAGR) as a result of the maturation of digital tools, changing consumer perception, increased design complexity, quality, and sustainability, and demand for small to midsize housing units. By 2022, it is estimated that over 70,000 prefabricated units will be sold and installed across Northern Europe, with Germany representing a sizable amount of this.[126] However, these numbers could be impacted with a short-term decline due to the crisis and the expected market contraction in the building sector. Sweden is the European market leader in this

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[120] Eurostat, 2020, *Waste statistics for 2016*, Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics#Total_waste_generation, [Accessed on: 24/11/2020]

[121] European Commission, 2020, *In focus: Energy efficiency in buildings*, Available at: https://ec.europa.eu/info/news/focus-energy-efficiency-buildings-2020-feb-17_en, [Accessed on: 24/11/2020]

[122] European Commission, 2020, *Level(s) - The European framework for sustainable buildings*, Available at: https://ec.europa.eu/environment/eussd/buildings.htm, [Accessed on: 24/11/2020]

[123] Common European Sustainable Built Environment Assessment, 2020, Available at: https://www.cesba.eu/, [Accessed on: 24/11/2020]

[124] European Commission, 2011, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Roadmap to a Resource Efficient Europe,* 20 September 2011, COM(2011) 571, Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0571&from=EN

[125] European Commission, 2020, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A new Circular Economy Action Plan For a cleaner and more competitive Europe*, 11 March 2020, COM(2020) 98, Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0017.02/DOC_1&format=PDF

[126] Mordor Intelligence, 2020, *European Prefabricated Buildings Market - Growth, Trends, And Forecasts (2020 - 2025),* Available at: https://www.mordorintelligence.com/industry-reports/european-prefabricated-buildings-industry-study, [Accessed on: 24/11/2020]

sector with 80% of the new build housing integrating prefabricated elements, 45% of new build single family houses and 35% of new build multi-family buildings using prefabricated modules. Other leading European countries include Austria, Switzerland, Denmark and Norway.

When compared to the rest of the world, the global modular construction market size is projected to grow from €85.4 billion in 2020 to €107.9 billion by 2025, at a CAGR of 5.7% from 2020 to 2025. Currently, the Asia-Pacific region is the fastest growing market in the prefabricated housing sector, which is likely due to a growing middle class and increasing urbanisation. North America is the second largest market, driven by factors such as consumer preference for green buildings and sustained investments in commercial real estate.

Rapid industrialisation in developing nations, low productivity in North America and affordable housing for the growing middle class in the Asia-Pacific region are rapidly accelerating growth in this VC. Some of the countries around the world also implement policy measures to support this VC and to strengthen the active companies in this domain. For instance, China has a governmental target for 30% of new buildings to be prefabricated by 2026 and has implemented cash bonuses and tax exemptions for prefabricated buildings. The US International Code Council (ICC) building code was modernised to allow the increased height of mass timber building from 6 to 18 stories, enabling high-rise timber frame prefabricated buildings.

4.5.3 European industry size and VC – Prefabricated Buildings

Currently, Europe is home to 44% of the companies active in the prefabricated buildings industry and mapped by the Cleantech Group. In addition, seven out of the top ten countries where these companies are located are in Europe, with UK and France standing out in terms of number of headquarters. More specifically, the UK is home to 24%, France to 21% and Italy to 12% of the prefabricated buildings companies in Europe.[127]

Between 2009 and 2018, the production value of prefabricated buildings in the EU-28 has increased steadily by 40 % – from €31.85 billion (2009) to €44.38 billion (2018). France and Italy accounted for around one third of the EU-28 production value of prefabricated buildings.

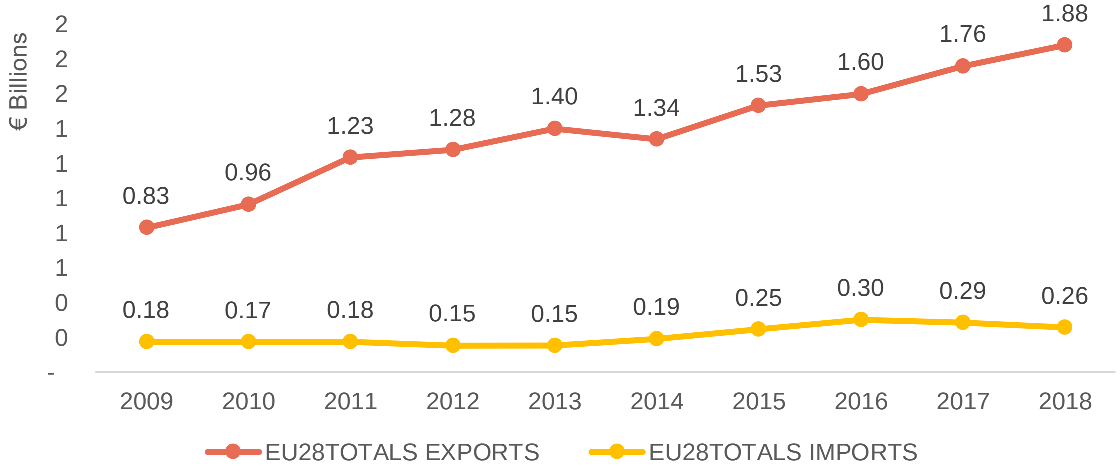
For the same period, EU-28 exports to the RoW have increased from €0.83 billion in 2009 to €1.88 billion in 2018, which is remarkable given the localised nature of this VC. On the other hand, imports have been relatively stable around €0.18 billion in 2009 to €0.26 billion in 2018, resulting in a positive trade balance with an increasing trend. The EU-28 share of global exports remained at 17.6% from 2016 to 2018, with the top EU-28 exporters being the Netherlands, Germany and the Czech Republic. The Czech Republic exported mostly to Germany amongst EU-28 countries and the UK has mainly imported from the Netherlands. It remains to be seen to what extent this trade will be influenced by post-Brexit trade negotiations.

Key competitors on the global scale in this VC include China, with a share of global export equivalent to the EU-28, together with the US, albeit representing a smaller share of global export. It is however important to stress that compared to other global VCs, the

[127] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the USA and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

prefabricated building VC is much more local due to obvious logistical and transport reasons.

Figure 4.22 Total EU-28 Imports & Exports – Prefabricated Buildings[128]

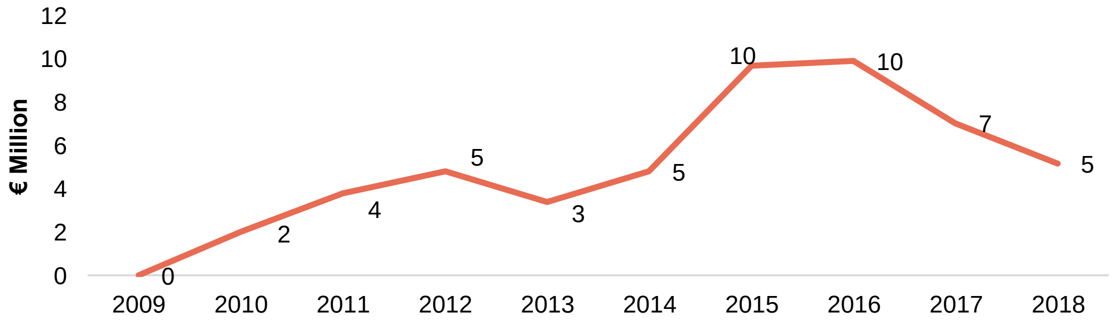


Source: ICF, 2020

4.5.4 Innovation and investment in RD&D – Prefabricated Buildings

The data on public investment in RD&D is available for a limited group of countries covered by the IEA. The IEA database does not contain any code dedicated to prefabricated buildings, the analysis therefore focused on investment related to the following codes: Building operation and efficient building equipment (122) and other building operations and efficient building equipment (1224). Based on these data, starting from 2009, EU-28 public investments have been minimal. However, they did increase to €5 million by 2012, peaking at €10 million in 2016 and 2017, before following a downward trend to €5 million in 2018. Out of the EU-28 countries for which the IEA has data, France was by far the largest public investor, followed by Denmark and Austria.

Figure 4.23 EU-28 Public RD&D Investments in the Prefabricated Buildings VC[129]



Source: ICF, 2020

Over the 2015-2019 period, 40% (€109 million) of the total value of global private investments in early stage companies active in the prefabricated building VC was in European companies. Overall, UK-based companies benefited from 90% (€100 million) of

[128] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

[129] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

these early stage investments.[130] Over the same period, American companies benefited from €157 million in early stage investments, indicating strong activity in this sector in the US. The data available on late stage investment confirm the strong position of American companies in this sector as they benefited from more than €1.5 billion of investment over the 2014-2019 period. The number of data entries available at this stage for the European market does not allow for a geographical comparison.

Some of the factors for growth in this sector included increasing acceptance and feasibility of alternative methods and materials for prefabricated constructions, as environmental, efficiency and cost gains became apparent. Across Europe, there are numerous RD&D sustainable building material projects and initiatives.[131] These have facilitated the production of sustainable building materials to be integrated into prefabricated buildings. There is also growth potential linked to the industrialisation of deep renovation. H2020 projects funded under the Energy-efficient Buildings Public-Private Partnership (EeB PPP) achieved very good results, demonstrating low intrusiveness, reduced building time by 30%, and a return on investment of 15%.[132]

Although still nascent, advanced assembly technologies like 3D printing have the potential to reduce labour cost and increase replicability (e.g. companies like Branch Technology have already been utilising these technologies[133]). 3D printing solutions also offer solutions for bespoke elements to be integrated in prefabricated buildings.

Innovation in component design is enabling faster and more efficient logistics and assembly. For instance, MADi, a company based in Italy, has developed foldable prefabricated homes for quick assembly and easy transportation[134]. Digital tools like BIM and Digital Twins demonstrate that designs can be refined, monitored and improved by integrating on-site feedback. In 2016, ARUP partnered with BAM Construction, Freiner & Reifer, and the Built Environment Trust to create a building design utilising exclusively reusable materials and prefabricated methodology in showcasing how the built environment can implement the integration of circular economic thinking.[135]

It is expected that property technology (PropTech) and construction technologies are the markets within which investors will view innovation in modular or prefabricated construction, however, the two are very similar and often overlap. By the end of 2018, global venture capital investment into construction technologies reached €5 billion, up from just €296 million in 2016. As already flagged above, this market is largely driven by North American

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[130] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the US and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

[131] EeB PPP, 2019, Energy efficient Buildings Project Review 2019, Available at: http://www.ectp.org/fileadmin/user_upload/documents/E2B/0_EeB_PPP_Project-Reviews_Roadmaps/EeB_PPP_Project_Review_2019.pdf, [Accessed on: 24/11/2020]

[132] European Commission, 2020, *Commission Staff Working Document Support from the EU budget to unlock investment into building renovation under the Renovation Wave*,14 October 2020, SWD(2020) 550 final, Available at: https://ec.europa.eu/energy/sites/ener/files/swd_-_a_renovation_wave_for_climate_neutrality_and_recovery.pdf

[133] Branch Technology, 2020, Available at: https://www.branch.technology/, [Accessed on: 24/11/2020]

[134] M.A.DI. Home, 2020, Available at: https://madihome.com/, [Accessed on: 24/11/2020]

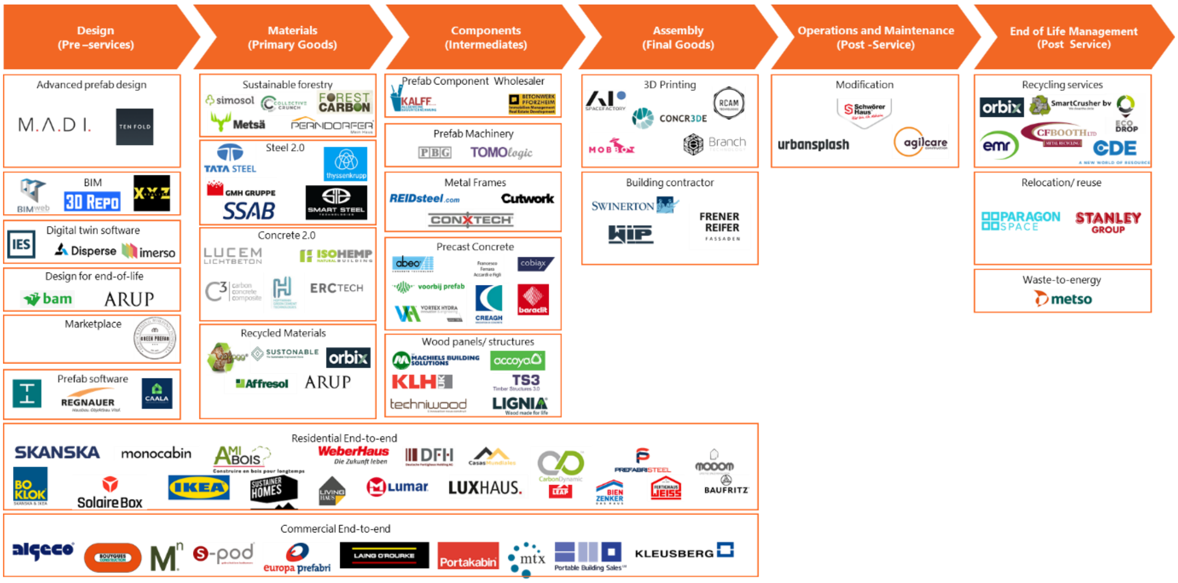
[135] ARUP, 2020, *The Ellen MacArthur Foundation: the transition to a circular economy*, Available at: https://www.arup.com/our-firm/arup-partnerships/ellen-macarthur, [Accessed on: 24/11/2020]

innovators, with important deals from modular construction innovators like Katerra and Veev (both US based).

The UK leads the European PropTech market with €692 million raised between 771 companies. The DACH region (Germany, Austria and Switzerland) follows in second place with 515 PropTech companies and €286 million raised to date. Among the top 15 most active venture capital investors, eight are based in Germany, with VitoOne (venture arm of Viessmann) being the most active investor in the region with 15 portfolio PropTech companies.[136]

Furthermore, Figure 4.24 provides an overview of some of the key European market players, divided by segment of the Prefabricated Buildings VC.

Figure 4.24 European Key Market Participants – Prefabricated Buildings



Source: Cleantech Group, 2020

4.5.5 Threats and challenges – Prefabricated Buildings

Access to finance

Due to the lack of data on performance and durability of buildings constructed via modern methods of construction and high market fragmentation, insurers and lenders may deem insolvency risk to be high and so can overprice or refuse support, slowing progress. Difficulties securing mortgages might also occur.

High fragmentation

Both the market and its supply chains are fragmented which might represent a difficulty for manufacturing capacity and scalability. For instance, in Germany in 2018, the top five prefabricated housing developers (WeberHaus, SchwörerHaus, Danwood, Equistone, DFH) represented approximately 30% of the market: beyond these top five developers, market shares are all below 3%.

High capital costs

[136] PropTech, 2020, European PropTech Trends 2020, Available at: https://proptech1.ventures/download-research, [Accessed on: 24/11/2020]

The data on the cost of construction using prefabricated elements is not robust yet and, as techniques evolve, upfront factory costs are high, requiring assemblers to benefit from economies of scale to ensure competitive costs.

Skill gap & digitalisation

New skills and expertise will need to be built up and invested in, particularly digital and design skills. As the industry is historically tech-averse this may be a concern. High levels of investment in training and education will be required, building on existing efforts such as the BUILD UP Skills initiative.[137] According to a survey by the Association of German Chambers of Commerce and Industry (DIHK), 93% of the construction companies believe that digitalisation will influence every one of their processes. Despite this high level of awareness, the sector remains largely un-digitalised, as the same survey revealed that only 6% of construction companies considered making full use of digital planning tools, while 100% of building materials firms believe they have not yet exhausted their digital potential.[138]

Industry knowledge

The lack of familiarity and certainty with the different materials and techniques, difficulties with the planning systems and complying with building regulations can lead to lower deployment.

Consumer perception

There are still some negative perceptions due to past failures rather than new technologies delivering quality and more cost-effective buildings from consumers, developers and wider industry. Difficulties related with durability, making adjustments and repairs to the properties also cause some apprehension from the consumers.

Brexit

In this VC, the UK is a large market and stands out in terms of private investments in late stage companies, as well as in terms of the number of European company headquarters. The UK is also the leader in the European PropTech market with the highest amount of funding raised. Similar to other VCs, the future of European cooperation in this sector remains to be clarified with the ongoing Brexit talks and the upcoming trade and cooperation agreements. Given the outcome of the negotiations, since the UK is a big importer from the rest of the EU (especially from the Netherlands) there might be certain trade disruptions.

Covid-19

The construction industry is closely linked to the fluctuations in the global economy. Following post-Covid-19 market shocks revenues in the European construction industry are predicted to decline 15 – 20% in 2020 but may rebound to pre-Covid-19 levels in 2022.[139] Pre-Covid-19, the European construction market, excluding infrastructure, was growing at

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[137] European Commission, 2020, *BUILD UP Skills*, Available at: https://ec.europa.eu/easme/en/section/horizon-2020-energy-efficiency/build-skills, [Accessed on: 24/11/2020]

[138] Roland Berger, 2016, *Digitization of the construction industry*, Available at: https://www.rolandberger.com/en/Publications/Digitization-of-the-construction-industry.html; and European Commission, 2020, *European Construction Sector Observatory - Analytical Report - Improving the human capital basis - March 2020*, Available at: https://ec.europa.eu/docsroom/documents/24261

[139] S&P Global, 2020, *Europe's Construction And Building Materials Sector Should Hold Up Better Than After The Last Crisis*, Available at: https://www.spglobal.com/ratings/en/research/articles/200616-europe-s-construction-and-building-materials-sector-should-hold-up-better-than-after-the-last-crisis-11527921, [Accessed on: 24/11/2020]

a CAGR of 4.4% to reach around €2,350 billion by 2023 driven by low interest rates and economic stability.[140]

4.5.6 Future EU potential – Prefabricated Buildings

EU funding and policy support

Europe aims to become the first climate-neutral continent by 2050 and in order to achieve this energy efficient, innovative building technologies and materials will be of crucial importance. Proposals as part of the European Green Deal are expected to further support this VC by emphasising the need for a big increase in energy efficiency for new buildings, which are contributing to the overall EU goal of climate neutrality. For the example, the EC is proposing a Renovation Wave initiative, which aims to invest in the large-scale renovation of the European building stock and create construction jobs, while doubling the annual rate of renovation. This initiative counts on prefabricated systems being part of the overall solution.

Risk assurance

At the European level, the De-risking Energy Efficiency Platform (DEEP)[141] is a pan-European open-source database containing detailed information and analysis of over 10,000 industrial and buildings-related energy efficiency projects. It builds performance track records and helps project developers, financiers, and investors better assess the risks and benefits of energy efficiency investments across Europe.

Increasing market consolidation

Mergers, acquisitions and corporate engagement with this market is expected to reduce fragmentation and improve efficiencies via economies of scale.

Improving digital tools

Building information modelling (BIM) and Digital Twin software are improving the replicability and learning capacity of prefabricated building design and assembly monitoring. The use of these are being encouraged via the EU BIM task group, whilst in Germany BIM will become mandatory for public infrastructure projects by 2021. By using these digital tools performance can be tracked throughout the entire lifecycle of the building in a continuous cycle that will provide info back to design.

4.5.7 SWOT – Prefabricated Buildings

Strengths *Internal attributes, characteristics and factors that give competitive advantage to the EU in the global VC.*	**Weaknesses** *Internal attributes, characteristics and factors that weaken the competitiveness of the EU in the global VC.*
• This VC is well supported through EU policies and has its representation at the European level. • The European VC is characterised by numerous active developers and world leading innovators.	• Access to finance remains a large issue for this VC, mainly due to insurers and lenders seeing insolvency risk to be high. • Logistics are restrictive – transport regulation can increase project costs, which creates a

[140] Research and Markets, 2019, *Europe Construction Industry Databook Series - Market Size & Forecast (2014 - 2023) by Value and Volume across 40+ Market Segments in Residential, Commercial, Industrial, Institutional and Infrastructure Construction*, Available at: https://www.researchandmarkets.com/reports/4747893/europe-construction-industry-databook-series, [Accessed on: 24/11/2020]

[141] De-risking Energy Efficiency Platform (DEEP), 2020, Available at: https://deep.eefig.eu/, [Accessed on: 24/11/2020]

- Prefabrication is considered to be safer, higher quality, often cheaper, more productive and attracting different skilled workers.
- Europe is home to 44% of the active companies in the prefabricated buildings industry.
- Between 2009 and 2018, the production value of prefabricated buildings in the EU-28 increased steadily by 40 percent.
- EU-28 exports to the RoW increased from €0.83 billion in 2009 to €1.88 billion in 2018, while imports largely remained stable at around €0.2.
- For the same period, the EU-28 trade balance has remained positive with an increasing trend.

trade-off between how much a structure is prefabricated and how easy it is to transport.

- Both the market and its supply chains are fragmented with many small players.
- High capital costs that require economies of scale which, in Europe, are still not being achieved to the required extent.
- The lack of familiarity and certainty with the different materials and techniques, difficulties with the planning systems and complying with building regulations can lead to very limited utilisation.
- There are still some negative perceptions of this VC due to past failures.
- New skills and expertise will need to be built up and invested in, particularly digital and design skills, which may be difficult to implement in practice.
- Late stage investments, both in Europe and in the rest of the world remain volatile.

Opportunities

External situations and factors that can strengthen the competitive advantage of the EU or provide the EU with new sources of competitive advantage.

- Moderate European growth in this VC compared to the RoW.
- This VC and the innovators in this market could largely benefit from upcoming legislative proposals as part of the European Green Deal, as well as through the foreseen EU funding part of the post-Covid-19 recovery package.
- As the market scales, insolvency risks are expected be alleviated.
- Improving market confidence and data aggregation could improve replicability and enable economies of scale.
- Various opportunities for mergers, acquisitions and corporate engagement with players and innovators in this VC could lead to a reduction in fragmentation and improved efficiencies.
- National targets and initiatives are considered very important in strengthening this VC.
- Improving digital tools are enhancing the replicability and learning capacity of prefabricated building design and assembly monitoring. This creates additional opportunities for deployment.

Threats

External situations and factors that can create problems for the EU compromising its competitive advantage to a certain extent.

- Since the UK is a big importer from the rest of the EU (especially from the Netherlands), a failure to reach a post-Brexit trade agreement could create certain trade disruptions.
- Following the Covid-19 market shocks, revenues in the European construction industry are predicted to decline by 15-20% in 2020, but may rebound to pre-Covid-19 levels in the next few years.

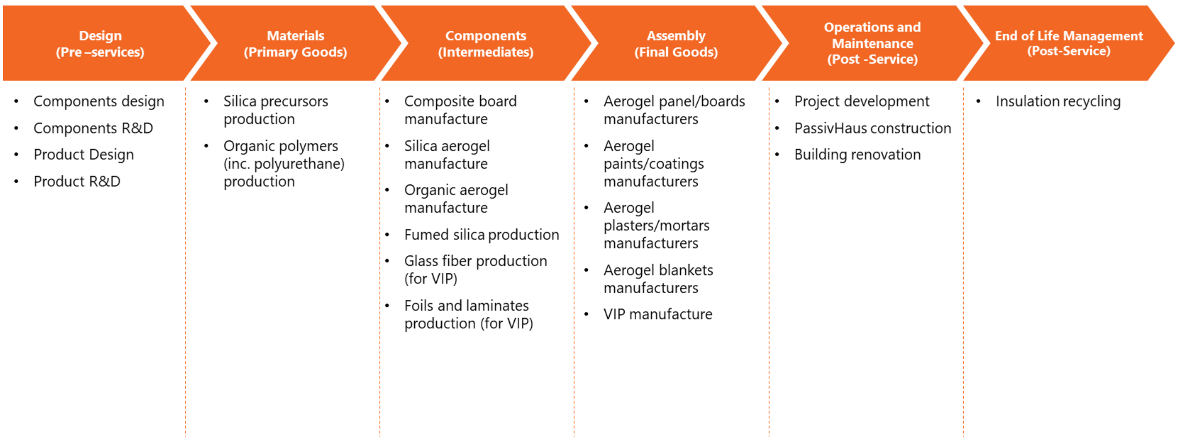
4.6 Superinsulation Materials

4.6.1 Scope of the VC – Superinsulation Materials

The scope of the Superinsulation Materials VC covers materials that can contribute to achieving ultra-low energy usage during building operations or achieving lower carbon footprints of buildings. It also covers innovation, design, production and installation of insulation materials that either improve existing materials or introduce new materials such as aerogels. However, it does not include production of other building fabric components (i.e. glazing, roofs, doors). It also includes application to other sectors (e.g. oil & gas).

The structure of the Superinsulation Materials VC split by segment of activity is elaborated in Figure 4.25.

Figure 4.25 Superinsulation Materials VC Structure



Source: Cleantech Group, 2020.

4.6.2 European market overview[142] – Superinsulation Materials

Key drivers for strengthening the superinsulation materials VC include the general demand for increased energy efficiency and cost savings on heating/cooling for space-limited applications, and the retrofit suitability of the materials.

Regional regulation such as the 2016 EU Strategy on Heating and Cooling[143] provided a framework for integrating efficient heating and cooling into EU energy policies advising on preventing energy leakage from buildings.

The EU Energy Performance of Buildings Directive (EPBD), revised in 2018 as part of the "Clean Energy for All Europeans" legislative package, requires Member States to set minimum standards on insulation in new buildings and major renovations. In addition, national legislative initiatives, such as Grenelle de l'Environnement in France, set additional standards and incentives for the renovation of buildings. Furthermore, the EU developed

[142] Note: When this document refers to "Europe" it includes all countries that are part of the European single market – this covers the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. In some cases, the data is extracted at aggregated EU-28 or EU-27 level. Datasets, reports and information that was extracted for the period before 2018, refers to the EU-28 and includes the UK in the analysis.

[143] European Commission, 2016, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – An EU Strategy on Heating and Cooling*, 16 February 2016, COM(2016) 51 final, Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016DC0051&from=EN

the Level(s) framework for assessing and reporting the broader environmental sustainability of buildings.

Additionally, market developments in this sector have been supported through the RD&D Framework Programmes, as well as national project funding.

Another driver for the development of this VC is the falling cost of production and increasing demand for retrofit of insulation in space-limited applications. The demand for non-flammable insulation is expected to support aerogel commercialisation, while legislation mandating minimum energy efficiency standards, as well as corporate commitments to net zero or reduced emissions, are expected to support greater application in commercial buildings.

Adopting ambitious EU energy efficiency and emissions targets, as well as mechanisms to achieve them, in addition to a timely transposition of the EPBD and related legislation by the Member States is largely expected to enhance this VC and to boost the adoption of energy efficient technologies. Furthermore, national initiatives such as the 'Insulation Challenge' in the Netherlands contribute by improving the market penetration of more innovative materials.

Finally, innovation hubs such as the European Construction Technology Platform (ECTP)[144] and BUILD UP[145] can foster innovation. Some industry groups target specific technologies or applications including the Vacuum Insulation Panel Association (VIPA) and various Passivhaus groups. Engagement of building designers could also support greater commercial deployment, e.g. via the Architects Council of Europe (ACE).

4.6.3 European industry size and VC – Superinsulation Materials

According to the analysed data from the Cleantech Group database, 31% of the currently active companies in the superinsulation material VC are headquartered in Europe. In addition, six out of the top ten countries where the most headquarters in this VC are located are within Europe, with UK, France and Spain leading the European share of headquarters.

Between 2009 and 2018, the annual production value of superinsulation materials in the EU-28 has steadily increased between €4.24 billion to €5.50 billion. Germany and the UK jointly accounted for around 34% of total EU-28 production in 2018.

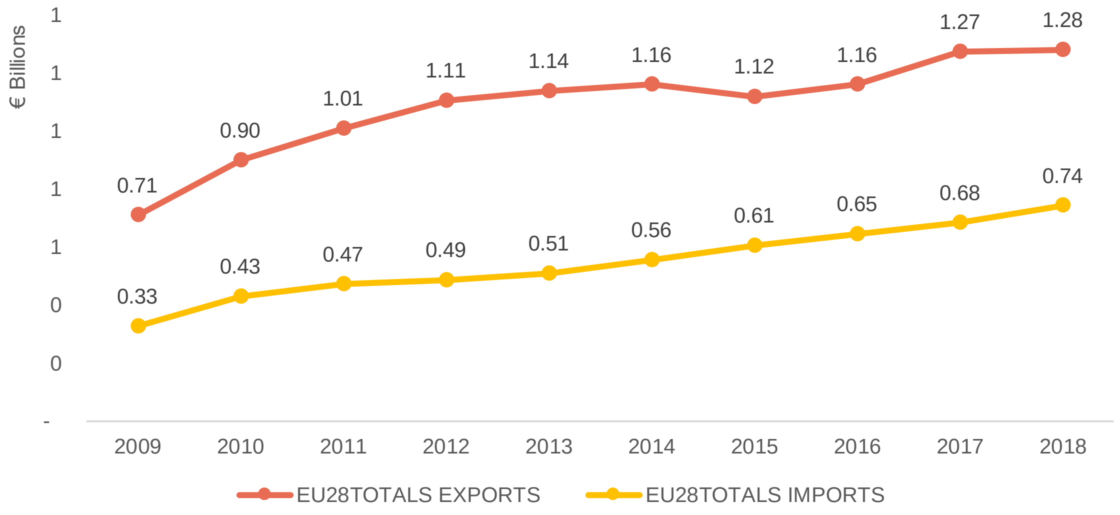
For the same period, EU-28 exports to the RoW increased by 80% from €0.71 billion in 2009 to around €1.28 billion in 2018. On the other hand, imports from the RoW have also increased from €0.33 billion in 2009 to €0.74 billion in 2018.

The EU-28 share of global exports has remained at 16% from 2016 to 2018. Top EU-28 exporters were Germany, Poland and the UK. Between 2016 and 2018, six out of the top ten global exporters were EU-28 Member States. Key competitors were US and China. In addition, for the same period, six out of the top ten global importers were also EU-28 Member States. Germany was the largest EU-28 importer followed by France.

[144] ECTP, 2020, *European Construction, built environment and energy efficient building Technology Platform (ECTP)*, Available at: http://www.ectp.org/, [Accessed on: 24/11/2020]

[145] Build Up, 2020, *European Portal for Energy Efficiency in Buildings*, Available at: https://www.buildup.eu/en, [Accessed on: 24/11/2020]

Figure 4.26 Total EU-28 Imports & Exports – Superinsulation Materials[146]



Source: ICF, 2020

Over the 2009-2013 period, the EU-28 trade balance increased from €0.38 billion to €0.63 billion, but then declined to €0.54 billion by 2018. Member States with the higher positive trends were Germany, the Netherlands and Poland, and those with the lowest negative trends were France, Italy and Romania. Member States with the largest improving trade balance were Poland and Germany.

France has imported mostly from within the EU-28, with 65% of the total imports from Germany and Belgium. Germany has exported mostly to EU Member States, with Poland being the largest importer followed by France.

Compared to the rest of the world, there is an initial market for production and installation of advanced insulation in the US, Japan and China. These markets are often supported by building regulations and standards (e.g. BREEAM, LEED), with the US offering tax rebates and credits. The US-based Aspen Aerogels is a market leader and benefited from sizeable venture investments after being founded in the 2000s. Development of aerogels was supported mainly by application of aerogels in the oil and gas industry. Over the past decade however Aspen Aerogels has lost around €250 million as the market diversified itself.[147]

Increased private investment in the RoW is expected to increase competition with Europe. Notably, there has been increased activity recently in this sector in Asia.

4.6.4 Innovation and investment in RD&D – Superinsulation Materials

The data on public investment in RD&D is available for a limited group of countries covered by the IEA. There is minimal EU-28 public investment in this area and it peaked in 2015 at €10 million, subsequently declining to €5 million in 2018. Out of the countries for which the IEA has data, France was by far the largest investor, followed by Canada and Denmark. Nine out of the top ten countries where these investments occurred were in the EU-28.

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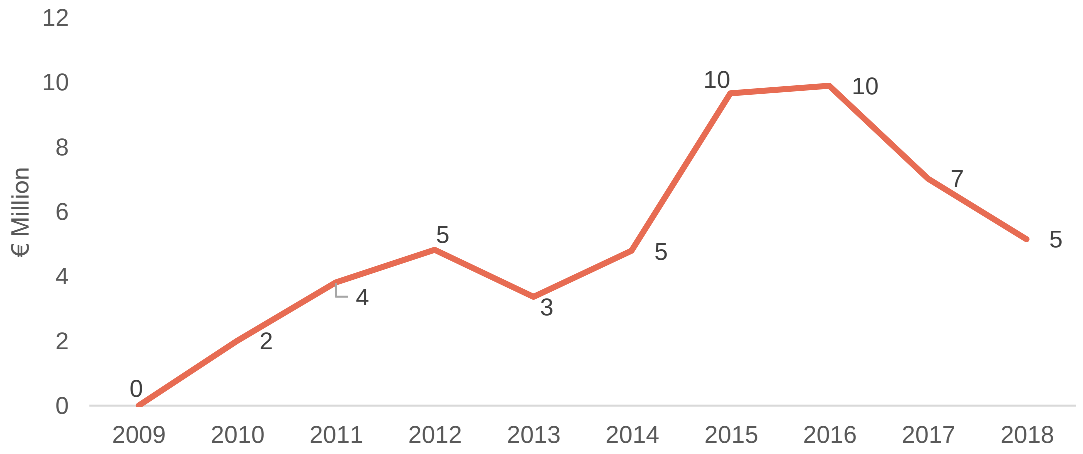
[146] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

[147] Collins, R., 2019. Aerogels 2019-2029: Technologies, Markets and Players. Available at: https://www.idtechex.com/en/research-report/aerogels-2019-2029-technologies-markets-and-players/644 [Accessed on 10/12/2020].

Figure 4.27 EU-28 Public RD&D Investments in the Superinsulation Materials VC[148]

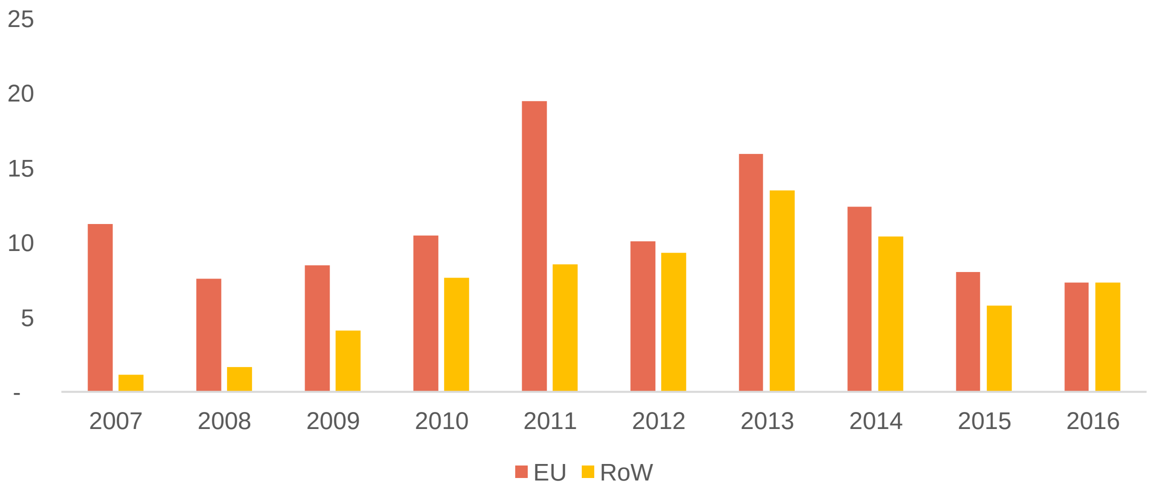


Source: ICF, 2020

The availability of data[149] for the share of private investments in early and late stage companies for this VC is very limited and thus conclusions on this matter cannot be made reliably.

Over the 2007-2016 period, more patent applications were filed in the EU-28 (62%) than in the RoW (38%). Especially, over the 2007-2011 period, the number of patent applications increased from 11 to 19 per year, yet over 2011–2016, the number of patent applications declined from 19 to seven per year. Six out of the top ten countries globally for patent applications are in the EU-28. Germany and France stand out in terms of the number of high-value patent applications over the 2014-2016 period.

Figure 4.28 Patent applications EU-28 vs rest of the world – Superinsulation Materials [150]



Source: ICF, 2020

Conventional insulation materials have remained the preferred option for most insulation applications. However, superinsulation has gained prominence for "*areas where it can offer*

[148] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

[149] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details).

[150] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

a cost advantage due to a space-saving effect, improved service-life (lower servicing/support cost) or advanced product properties (resistance against chemicals, high or low temperature, etc.)"[151]. There are two main recognised superinsulation technology groups: Vacuum Insulation Panels (VIPs) and Advanced Porous Materials (APMs), which are mostly aerogel materials.

VIPs offer lower thermal resistance per unit price than conventional materials and have been widely marketed and deployed for space-limited applications. Development has been supported by use in alternative applications, for instance in packaging and refrigeration.

The global market for aerogels remains small at around €170 million, with only a fraction of the market in building insulation. Applications have been limited, for example, to achieve requirements for low energy loss, reduced space, as well as around windows or doors. Much of the early stage research on aerogels has taken place at research institutes supported by European funding. Corporate innovation is well established with strong examples such as the German BASF group. Limited research and a focus on end-of-life treatment could be likely due to a small market and long product lifecycles.

There are continued efforts to reduce costs in the production of super-insulating aerogel materials. There are notable developments in Europe, for example, Keey Aerogel in France is developing novel production processes (e.g. Silicic acid hydrothermal synthesis and multi-solvent Low Temperature Super-Critical Drying). In Sweden, Svenska Aerogel's production of Quartzene® is performed under almost ambient conditions and is therefore considerably less expensive than traditional aerogels produced by supercritical drying or resin reinforcement. Application of aerogels for paints, plasters and mortar appears to be attractive.

Additionally, there have been recent innovations in non-silica organic aerogels. For instance, BASF in particular has commercialised polyurethane-based aerogel. There also appears to be some innovation in VIPs, i.e. incorporating aerogels. Silica appears to be more commonly used as the core, with glass fibre less commonly used.

Regarding future deployment, demand for superinsulation is considered to be a function of climate adaptation, cost of energy and cost of living area. If cost of living area is low, non-super insulation is expected to remain attractive. High growth in aerogels is expected but from a low base. Non-superinsulation is expected to be attractive from a cost perspective (e.g. mineral wools) and potentially from a lifecycle impact perspective (e.g. insulation from recycled materials or polyurethane foam produced from CO_2-based polyols, as supplied by Covestro, Aramco and Econic Technologies). Application of phase change materials in insulation panels and other technologies (e.g. non-superinsulation coatings) may compete with superinsulation for achieving low energy usage in commercial buildings.

Chemical corporates (e.g. BASF, Cabot) are engaging in internal innovation using their RD&D budgets. There has also been vertical integration of the supply chain for materials and components manufacture, such as BASF's investment in silica production and Evonik's acquisition of Silbond.

Furthermore, Figure 4.29 provides an overview of some of the key European market players, divided by segment of the Superinsulation Materials VC.

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[151] Koebel, M., Rigacci, A., and Achard. P., 2012, *Aerogel-based thermal superinsulation: an overview*, Journal of Sol-Gel Science and Technology, Springer Verlag, 2012, 63 (3), pp.315-339. Available at: https://www.dora.lib4ri.ch/empa/islandora/object/empa%3A5435/datastream/PDF/Koebel-2012-Aerogel-based_thermal_superinsulation-%28published_version%29.pdf

Figure 4.29 European Key Market Participants – Superinsulation Materials

Source: Cleantech Group, 2020

However, in recent years there have been low levels of early-stage investment and few examples of investment in early-stage companies. This is valid for both the European and North American markets.

There are notable large-scale VIP production facilities set up outside Europe. Non-European companies have also set up offices in Europe to facilitate the import of VIPs into Europe. For instance, Fujian Super Tech Advanced Material established an office in Ireland under the ‘Metra Group’ and Siltherm (also a Chinese manufacturer) set up Siltherm Europe.

4.6.5 Threats and challenges – Superinsulation Materials

Cost

Generally, superinsulation materials have higher upfront costs than traditional insulation materials. For housebuilders, beyond regulatory requirements, optimising capital cost remains a priority. Aerogel-based insulation products still have relatively high production costs and remain economically unattractive for most applications.

Although production costs are falling, VIPs are generally more difficult to install than non-superinsulation, increasing installation times and cost. Upfront and overall cost will remain a critical challenge for adoption of superinsulation aerogel materials.

Technical limits of VIPs

VIPs are more difficult to manufacture than polyurethane foams or mineral wools. For example, unlike conventional insulation, VIP products cannot be cut to fit which narrows their application.

Lack of private investment

There have been few examples of start-ups attracting private investment. Two such companies include Active Aerogels in Portugal and Green Earth Aerogel Technologies in Spain.

End-of-Life Management

Although most manufacturers claim their products are recyclable, there is sparse evidence of strategies for end of life strategy treatment or the recycling of superinsulation materials. This could present issues in the long term. However, the life-cycle impact of superinsulation innovations compared to alternative insulation materials remains unclear.

4.6.6 Future EU potential – Superinsulation Materials

Policy support

The "Clean Energy for All Europeans" legislative package - and more specifically the EPBD[152] and EED[153] - have emphasised the need for efficient and common standards in this VC. It is expected that this VC will be supported through the transposition by each Member State of these Directives, as well as the upcoming proposals under the European Green Deal. The EC has adopted the 2030 climate target plan in September 2020 increasing the GHG emissions reduction target to 55% by 2030 in comparison to 1990 levels.

Some continued support may be required to help maintain efforts by EU companies to lower costs, particularly around innovation support, and especially given the currently very low levels of public RD&D expenditure. Regulation should also be carefully considered. In order to maintain and even increase the competitiveness of the EU superinsulation materials VC, it is important for future policy proposals to be technologically unbiased so as not to exclude certain materials.

Growth potential

There is a considerable opportunity for growth in terms of innovation and market share, both in the EU and abroad. Given the very high number of buildings in the EU in need of renovation, and the suitability of some superinsulation materials, it is expected that there will be considerable opportunities for growth in this sector.

4.6.7 SWOT – Superinsulation Materials

Strengths *Internal attributes, characteristics and factors that give competitive advantage to the EU in the global VC.*	**Weaknesses** *Internal attributes, characteristics and factors that weaken the competitiveness of the EU in the global VC.*
• Strong EU policy support. • Well-established market players with effective capacity for innovation and production. • For the studied period, EU-28 companies filed more patents their RoW counterparts. • Between 2009 and 2018, the annual production value of super insulation material in the EU-28 has steadily increased. • For the same period, EU-28 exports to the RoW have increased by 80%.	• Not a very large VC. • Not enough private investment in start-ups. • Some start-ups have not grown in recent years and others are no longer active altogether. • Superinsulation materials have higher upfront costs. • More difficult to install than non-super insulation materials. • VIPs are harder to manufacture and have narrower applications than simpler materials.

[152] Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency (Text with EEA relevance), Official Journal L 156, 19.6.2018, p. 75–91. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.156.01.0075.01.ENG

[153] Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency (Text with EEA relevance), Official Journal L 328, 21.12.2018, p. 210–230. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.328.01.0210.01.ENG

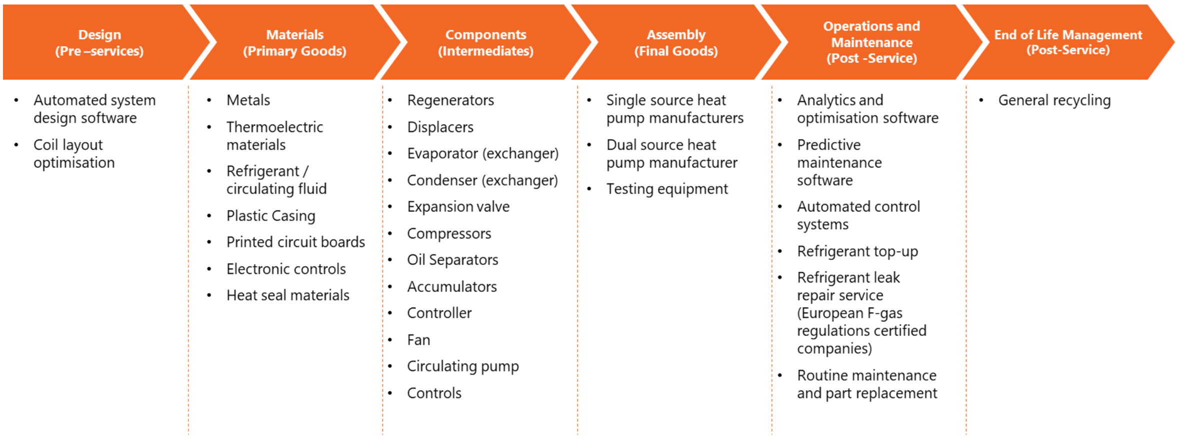
• The EU-28 share of global exports has remained at 16% from 2016 to 2018. For the same period, six out of the top ten global exporters are EU-28 countries.	
Opportunities *External situations and factors that can strengthen the competitive advantage of the EU or provide the EU with new sources of competitive advantage.*	**Threats** *External situations and factors that can create problems for the EU compromising its competitive advantage to a certain extent.*
• Considerable opportunities for growth in terms of market, deployment and innovation. • Additional opportunities for support and strengthening of this VC through policy and investment measures.	• Imports are on the rise into the EU-28: from €0.33 billion in 2009 to €0.74 billion in 2018. • External developers and innovators grow fast. • End-of-Life Management treatment or recycling of superinsulation materials is limited for the moment. • Non-EU players entering the EU market more aggressively.

4.7 Heat Pumps

4.7.1 Scope of the VC – Heat Pumps

The scope of the Heat Pumps VC covers air-, ground- and water- source heat pumps including piping, valves, heat exchanger, oil separator, compressors, evaporators, condensers, accumulators, electronic expansion valve, pumps, refrigerant, controllers and fan motors. However, this VC does not include thermostat/controls and heat emitters. The structure of the Heat Pumps VC split by segment of activity is elaborated in Figure 4.30.

Figure 4.30 Heat Pumps VC Structure



Source: Cleantech Group, 2020.

4.7.2 European market overview[154] – Heat Pumps

The European heating industry is a well-established economic sector and a world leader in highly efficient heating systems. The European heat pump sector counts a few mostly large corporations and numerous SMEs. The heat pump VC is well represented through several industry associations – most notably the European Heat Pump Association (EHPA).

In 2017, the sector employed more than 191,000 people directly or indirectly across Europe. However, employment in the sector declined by 20% between 2015 and 2017. Member States with the largest group of employees in the heat pump sector were Spain, Italy and France.

Although the demand for heating solutions is partly declining thanks to improvements in building insulation and increasing cooling requirements, demand for space and process heating is still responsible for 42% of the Europe's final energy demand, with higher shares observed in Northern Europe due to the colder climate. In this context, a key driver of the demand for heat pumps in Europe are the policies put in place to phase-out oil and natural gas usage as observed in Sweden, Denmark, Norway and the Netherlands for example. Other factors driving the demand for heat pumps include developments in building energy management systems which integrate heat pumps and drive optimal usage. Evidence of digitalisation have been observed mainly in grid integration of heat pump systems and for dynamic heat network mapping.

[154] Note: When this document refers to "Europe" it includes all countries that are part of the European single market – this covers the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. In some cases, the data is extracted at aggregated EU-28 or EU-27 level. Datasets, reports and information that was extracted for the period before 2018, refers to the EU-28 and includes the UK in the analysis.

The decarbonisation of the heating sector requires a much faster uptake of heat pumps in Europe, in order to contribute effectively to 2030 and 2050 European climate and energy goals. For instance, hybrid solutions combining heat pump technology with a peak demand source (usually gas) will allow integration into a larger share of buildings. Future technology improvements are expected to increase the number of buildings suitable for heat pump deployment. Thus, better building envelopes will result in less heating needed to maintain ambient temperature.

European climate and energy legislation is setting up the framework - and to an extent driving - the further development of new-generation refrigerants with lower environmental impacts. These include RD&D efforts by incumbents such as the French Arkema, Italian HiRef, and start-ups like the Belgian Cooltech, which is developing a magnetic cooling solution. In addition, smart grids create opportunities for heat pumps as a grid balancing mechanism (e.g. Danish project Ecogrid 2.0).

This VC is characterised by the presence of many SMEs and vertically integrated industrials (producers) with moderately innovative products. However, the analysis has not revealed any dedicated venture capital funds for heat-pumps. As the technology impacts several different sectors, investors tend to be focused on those (e.g. commercial buildings, residential buildings) and invest in technologies that align with their existing investment focus.

When compared to the rest of the world, the European market has lagged China, Japan and the US but is now growing rapidly. Due to low market penetration (France, Spain and Italy account for 50% of current installations) Europe has high growth potential compared to the RoW. Demand in the US is driven by installation incentives, while market developments in the Asia-Pacific region are driven by construction sector growth.

4.7.3 European industry size and VC – Heat Pumps

Europe is a recognised market leader in the heat pump sector, responsible for many early market innovations. Around 59% of active companies in the heat pumps VC globally are headquartered in Europe.[155] Indeed, eight out of the top ten countries where these companies are located are within Europe. Heat pumps companies in Europe, are mainly concentrated in Germany (20%), the UK (18%), France and the Netherlands (with 11% each).

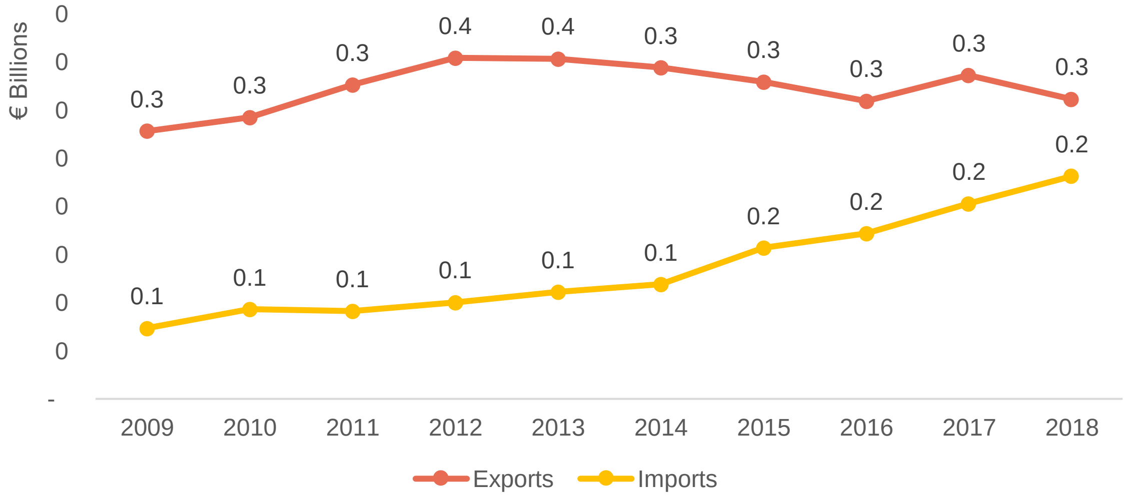
Between 2009 and 2018, the annual total production of heat pumps in the EU-28 has remained steady between €1.2 and €2 billion. Germany is the largest producer, followed by Sweden and France. These top producers account for more than half of the EU-28 production. In 2017, the turnover in the heat pumps sector added up to €22.7 billion in the EU-28. However, turnover in the sector has decreased by 23% between 2015 and 2017. The Member States that generated the large turnover were Italy, Spain and France.

As illustrated in Figure 4.31, between 2009 and 2018, EU-28 exports to the RoW were relatively stable at around €0.3 billion per year. This represented around 1% of global exports during the whole period. Top EU-28 Member States exporting outside the EU-28 during the 2016-2018 period were France, Germany and Italy. However, this VC is characterised by important volumes of intra-EU trade. When these intra-EU exports are considered, four out of the top ten global exporters during the 2016-2018 period are EU-28 countries (namely Italy, Germany, France and Poland). All of them are however far beyond

[155] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details).

China and to a lesser extent Mexico. As illustrated below, imports to the EU-28 increased over the 2009-2019 period, indicating an increased competitiveness of non-EU producers in the EU-28 market. Between 2009 and 2018, the EU-28 trade balance remained positive although declining due to the increased imports.

Figure 4.31 Total EU-28 Imports & Exports – Heat Pumps[156]

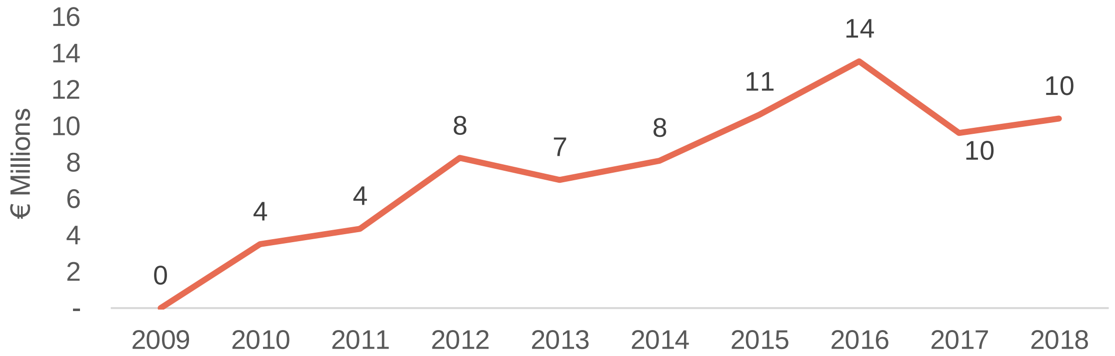


Source: ICF, 2020

4.7.4 Innovation and investment in RD&D – Heat Pumps

The data on public investment in RD&D is available for a limited group of countries covered by the IEA. Following a peak in investments in 2016 of €14 million, EU-28 public investments reached €10 million in 2018. Out of the countries for which the IEA has data, the largest public investors in Europe were Austria, followed by Switzerland and Denmark.

Figure 4.32 EU-28 Public RD&D Investments in the Heat Pumps VC[157]



Source: ICF, 2020

Over the 2014-2019 period, 28% of the total value of global private venture capital investments in early stage companies active in the heat pump VC was in European

[156] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

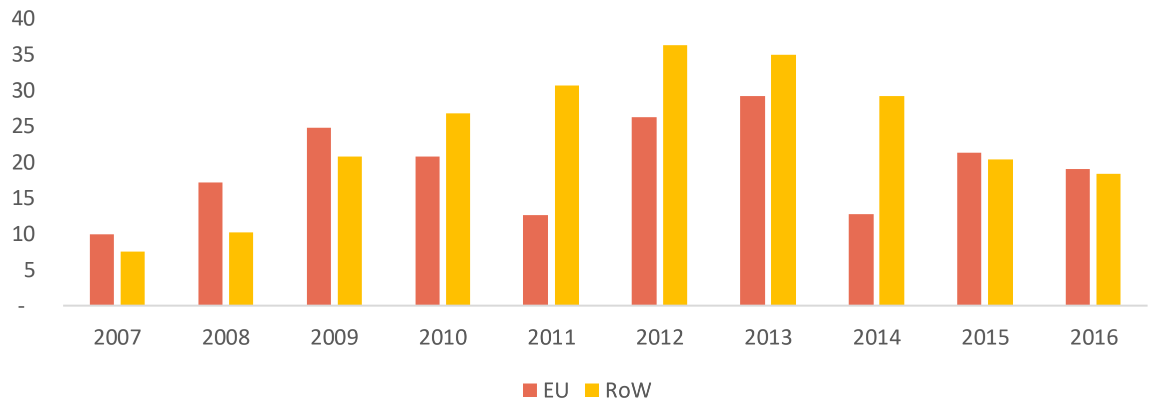
[157] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

companies.[158] This share is largely driven by two early stage investments operated in Norwegian companies in 2017, representing €26 million. North American companies attracted the vast majority of the early stage investment during the 2014-2019 period totalling €95 million and largely outperforming Europe. It is interesting to note that Israel also recorded a series of early stage investment totalling just under €8 million.

24% of the global late stage private investments in the heat pump VC go towards European companies. Although this is in the same range as the share of early stage investments discussed above, late stage investments show a more stable trend and represent €112 million distributed across 12 companies. The US also largely outperforms Europe in this market as investments in the US reached almost €300 million over the same period.

Over the periods 2007-2009 and 2015-2016, more patent applications linked to heat pump were filed in the EU-28 than in the rest of the world, demonstrating an innovative VC despite the lower level of private investments. However, from 2010 to 2014, more high value patent applications were filed in the RoW (55%) than in the EU-28 (45%). Germany and France stand out in terms of the number of high-value patent applications.

Figure 4.33 Patent applications EU-28 vs rest of the world – Heat Pumps[159]



Source: ICF, 2020

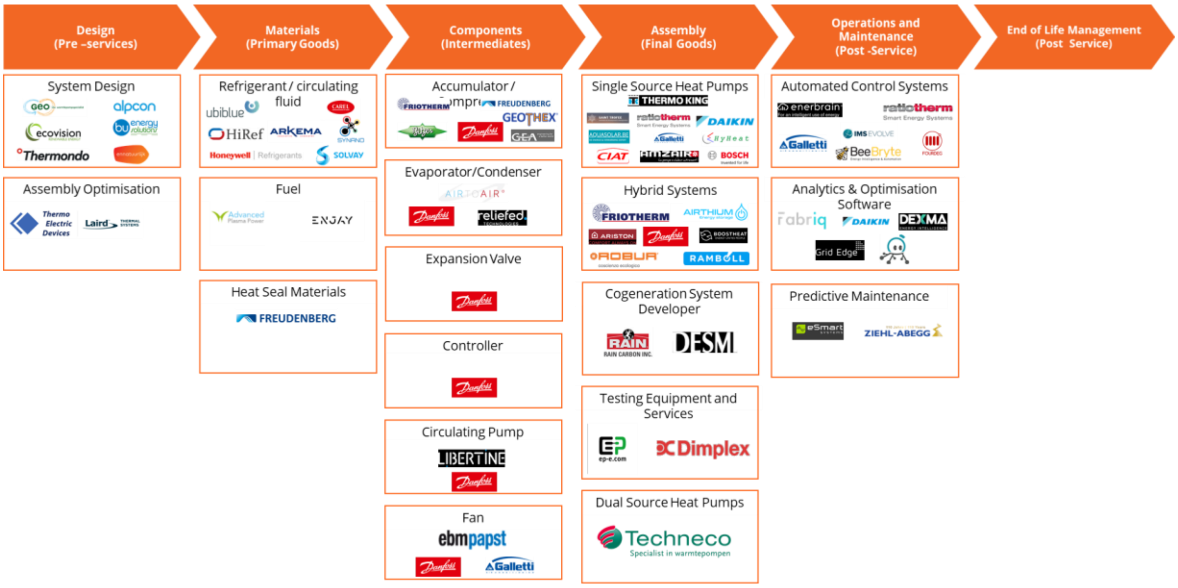
When it comes to innovations, SMEs and industrial groups exploring innovation through RD&D partnerships with universities (e.g. Galletti Group & University of Padova) are increasing and proving some of the potential for growth in this VC. Some of the areas of technical innovation include hybrid technology, refrigerant-free technology, electrochemical compressors, 3D extruded components, price/weather-based performance management software. While areas of business model innovation include 'plug and play' system solutions, heating/cooling as a service, flat rate heating charges. When compared to the rest of the world, the US has produced more innovators in Edge optimisation, predictive analytics compared to other regions while their European counterparts are still in their early stage in this domain. Large investments went into digital technologies (software, analytics) for optimising the running of heat pumps and into hardware solutions to improve on the efficiency of existing systems.

[158] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the USA and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

[159] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

In addition, European chemical companies with high RD&D capabilities are continuing to innovate in materials (and components). Furthermore, European start-ups are active in exploring IoT solutions for components as well as system performance (e.g. Ziehl-Abegg SE offers cloud-based fan monitoring and predictive maintenance). Figure 4.34 provides an overview of some of the key European market players, divided by segment of the heat pumps VC.

Figure 4.34 European Key Market Participants – Heat Pumps



Source: Cleantech Group, 2020

4.7.5 Threats and challenges – Heat Pumps

Skilled workers

Skills upgrades are needed to equip building experts with additional specialisations needed to provide integrated solutions. EU Member State policies in this domain, supported by the EU policy framework and funding for reskilling and job creation, might enhance the strength of this VC, building on existing support efforts such as the BUILD UP Skills initiative.[160]

Cost-efficiency

Heat-pump only systems are not yet sufficiently cost-effective. These systems are best utilised in situations with limited heating/cooling requirements or when combined with another energy source for peak demand. In addition, high cost of drilling and ground heat exchanger technologies are still limiting geothermal heat pump development.

Control system integration is required to achieve peak efficiency from geothermal systems. The high installation costs can potentially be offset by optimising performance and efficiency.

End-of-life

Refrigerant must be disposed of carefully to avoid toxicity/emissions. Heat pumps are subject to building and waste reduction regulations as well as the EU Fluorinated

[160] European Commission, 2020, *Build Up Skills*, Available at: https://ec.europa.eu/easme/en/section/horizon-2020-energy-efficiency/build-skills, [Accessed on: 24/11/2020]

Greenhouse Gas (F-Gas) Regulation which covers servicing and recovery of gases. In addition, further developments are needed for end-of-life solutions.

Covid-19

Employment in the sector has declined by 20% between 2015 and 2017. Member States that employ the most are Spain, Italy and France. As the Covid-19 pandemic is ongoing, it is too early to assess and quantify the exact impact on the heat pump VC. However, since the major employers in this sector are located in EU countries highly affected by the virus and who went through the strictest lockdown measures including closure of factories (i.e. Spain, Italy and France), it is expected to have some delays in production and project development.

4.7.6 Future EU potential – Heat Pumps

Policy support

The heat pump sector was strengthened by the adoption of legislation such as the revised Energy Performance of Buildings Directive, the Renewables Directive, the Energy Efficiency Directive, the F-Gas Regulation and the introduction of new Ecodesign rules for heating products. The Renovation Wave strategy adopted by the EC is moreover considering strengthening the renewable heating and cooling target and introducing a requirement for minimum proportions of renewable energy in buildings. It also aims at facilitating access of waste and renewable heat and cool into energy systems[161].

Growth potential

The European heat pump market has been growing steadily and shows potential for future growth of around 10% annually. In turn, installed stock is expected to double within the next 6-7 years. There is a big potential for growth in large markets (France, Italy, Germany), which are underdeveloped considering sales per thousand households. The analysis shows that there is an opportunity for some cogeneration providers to enter the heat pump manufacturing space. Schemes for building renovation, energy efficiency and tax reductions in Sweden, Germany and France successfully helped increase heat pump market penetration. Such support schemes of institutional or financial nature could accelerate the deployment of heat pump units and boost the heating and cooling market development.

In addition, some of the identified growth areas in this VC include domestic hot water and exhaust air heat pumps.

4.7.7 SWOT – Heat Pumps

Strengths *Internal attributes, characteristics and factors that give competitive advantage to the EU in the global VC.*	**Weaknesses** *Internal attributes, characteristics and factors that weaken the competitiveness of the EU in the global VC.*
• Europe is a recognised market leader with a well-established heat pump sector. • For the 2016-2017 period, annual total production of heat pumps in the EU-28 has	• Sector turnover decreased by 23% between 2015 and 2017. • For the studied period, share of investments in European companies has experienced a downturn.

[161] European Commission, 2020, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives*, 14 October 2020, COM(2020) 662 final, Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662

remained steady, although there is a slight decrease in 2018.

- Between 2009 and 2018, EU-28 exports to the RoW were relatively stable at around €0.3 billion, peaking in 2012/13 at around €0.4 billion.
- In each year from 2007 to 2016, more patent applications were filed in the EU-28 than in the RoW.
- Large private investment has gone into digital technologies (software, analytics) for optimising the running of heat pumps and into hardware solutions to improve on the efficiency of existing systems.
- Strengthened through recent energy & climate policies and expected to be further supported by the upcoming proposals under the European Green Deal.

- Lower average size of investments in Europe compared to the RoW for early and late stage private companies.
- Heat-pump only systems are not yet sufficiently cost-effective compared to other technologies.

Opportunities

External situations and factors that can strengthen the competitive advantage of the EU or provide the EU with new sources of competitive advantage.

- Current deployment is far below potential. Decarbonisation of the heating sector requires a much faster uptake of heat pumps in the EU, in order to contribute effectively to 2030 and 2050 European climate goals.
- The European heat pump market has been growing steadily and shows potential for future growth of around 10% annually.
- Smart grids create opportunities for heat pumps as a grid balancing mechanism.
- Developments in digitalisation and building management systems, which integrate heat pumps drive optimal usage.
- When compared to the RoW, the European market has lagged behind but is now growing rapidly.
- When it comes to innovations, consortia projects have proved the feasibility of key innovations, but commercial availability has not yet been realised.
- European chemical companies with high RD&D capabilities are continuing to innovate in materials (and components).
- European start-ups are active in exploring IoT solutions for components as well as system performance.

Threats

External situations and factors that can create problems for the EU compromising its competitive advantage to a certain extent.

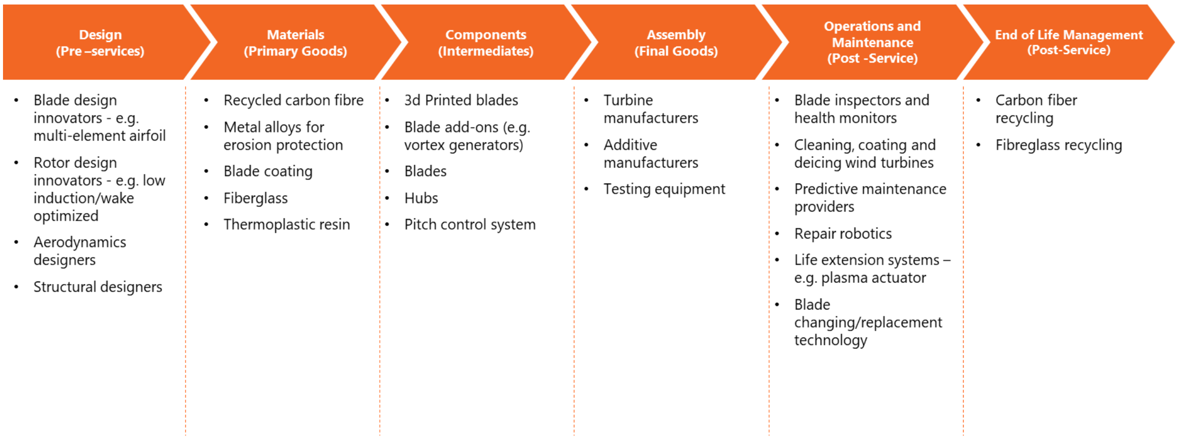
- Skills upgrades are required to equip building experts with additional specialisations needed to provide integrated solutions. Member State policy in this domain is supported by EU policy framework and funding for reskilling and job creation might enhance the strength of this VC.
- High cost of drilling and ground heat exchanger technologies limiting geothermal heat pump development.
- Further developments are needed for end-of-life solutions.
- EU-28 heat pump imports have been slowly increasing.

4.8 Wind Rotors

4.8.1 Scope of the VC – Wind Rotors

The scope of the wind rotors VC covers onshore and offshore blades and hubs – including all systems inside the hub (e.g. pitch control) and in the case of a direct drive turbine, it also includes the annular generator (rotor & stator). This VC does not include the elements within the nacelle (high/low speed shafts, gearbox, generator, controller, brake etc.), the yaw driver/ motor, or tower. The only operation and maintenance and end-of-life activities included in the VC are those linked to the blades and rotor. The structure of the Wind Rotors VC split by segment of activity is presented in Figure 4.35.

Figure 4.35 Wind Rotors VC Structure



Source: Cleantech Group, 2020.

4.8.2 European market overview[162] – Wind Rotors

In 2019, wind power accounted for more than 15% of the EU's electricity consumption[163]. The sector employs over 350,000 people, represents more than €25 billion of new investments and exports €8bn of goods and services every year[164]. According to the EC's climate neutrality strategy, published on 28 November 2018[165], the EU will need five times more wind energy capacity by 2050 to achieve climate neutrality. Additionally, the wind sector is also addressed in the new Industrial Strategy for Europe[166] in the context of

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[162] Note: When this document refers to "Europe" it includes all countries that are part of the European single market – this covers the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. In some cases, the data is extracted at aggregated EU-28 or EU-27 level. Datasets, reports and information that was extracted for the period before 2018, refers to the EU-28 and includes the UK in the analysis.

[163] Walsh, C. et al., 2020, *Wind energy in Europe in 2019 – Trends and statistics*, WindEurope, Available at: https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Statistics-2019.pdf, [Accessed on: 24/11/2020]. Note: At the time of data collection of the report the data for EU-28 refers to EU + UK.

[164] Reve, 2020, *Wind power is already 15% of Europe's electricity*, Available at: https://www.evwind.es/2020/03/03/wind-power-is-already-15-of-europes-electricity/73883, [Accessed on: 24/11/2020]

[165] European Commission, 2018, *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank – A Clean Planet for all – A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy*, 28 November 2018, COM(2018) 773 final, Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773

[166] European Commission, 2020, *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions – A New Industrial Strategy for Europe*, 10 March 2020, COM(2020) 102 final, Available at: https://ec.europa.eu/info/sites/info/files/communication-eu-industrial-strategy-march-2020_en.pdf

supporting industry towards climate neutrality and the Offshore Renewables Strategy[167]. The strategies are expected to be a driver for this VC.

The EU-28 wind energy market has been a growing market over the last years. According to the 2018 figures, the majority of the global capacity installed is located in China (36%) followed by the EU-28 (30%) and the US (16%). In 2019, with the addition of 15.4 GW of newly installed wind power, the EU-28 installed capacity surpassed 200 GW (183 GW onshore and 20 GW offshore). Installed capacity in Europe has been steadily growing and forecasts predict that it will continue to do so to meet the 2030 policy targets[168]. These forecasts are reinforced by the EC's proposal to raise the GHG emission abatement target to at least 55% by 2030 compared to 1990. Additionally, according to EC estimates, supported by the industry and the IEA[169], in order to keep temperature rises below 1.5°C there is a need for between 240 and 450 GW of offshore wind power by 2050 globally.[170]

Most European capacity has to date been deployed onshore. However, the high potential of offshore wind energy is driving European countries to increasingly generate wind power at sea. With 20 GW of installed offshore wind capacity, Europe is the world leader in this sector supplying 90% of the global capacity to date[171]. The largest offshore wind power potential in Europe is in the North Sea region. Initially, due to the geography and topography of this area projects were not considered economically viable compared to onshore wind. However, with developments in technology, streamlined VCs and potential for considerably larger-scale project development, investments were increased and prices went down significantly, helped with substantial public investment in RD&D and price support. In recent years, a number of projects (e.g. in the Netherlands, Germany etc.[172]), were developed without subsidy and with a highly competitive energy price. Other areas with potential for offshore wind include the Mediterranean, Baltic Sea and the Atlantic coast.

4.8.3 European industry size and VC – Wind Rotors

The European wind energy sector that produces, installs and operates wind turbines is well organised with a strong industry association (WindEurope) representing the industry's interest at European level. Europe is a recognised market leader in the wind energy and wind rotor sectors. According to the selected sample data by the Cleantech Group, 48% of active companies in the wind sector are headquartered in Europe compared to the RoW.[173] Specifically, for wind rotors the share of European companies is 58% with most being headquartered in Germany, Denmark, the UK and France. Between 2009 and 2018, the annual production value of wind rotors in the EU-28 has remained roughly steady between €6.3 billion (in 2010) and €10.3 billion (in 2016). However, the wind turbines industry in

[167] European Commission, 2020, EU strategy on offshore renewable energy. Available at: https://ec.europa.eu/energy/topics/renewable-energy/eu-strategy-offshore-renewable-energy_en#documents [Accessed on: 10/12/2020]

[168] Tardieu, P. et al., 2017, *Wind energy in Europe: Scenarios for 2030*, WindEurope, Available at: https://windeurope.org/about-wind/reports/wind-energy-in-europe-scenarios-for-2030/

[169] IEA, 2019, *Offshore Wind Outlook 2019*, Available at: https://www.iea.org/reports/offshore-wind-outlook-2019

[170] European Commission, 2020, *Onshore and offshore wind*, Available at: https://ec.europa.eu/energy/topics/renewable-energy/onshore-and-offshore-wind_en, [Accessed on: 24/11/2020]

[171] WindEurope, 2019, *Our energy, our future – How offshore wind will help Europe go carbon-neutral,* Available at: https://windeurope.org/about-wind/reports/our-energy-our-future/

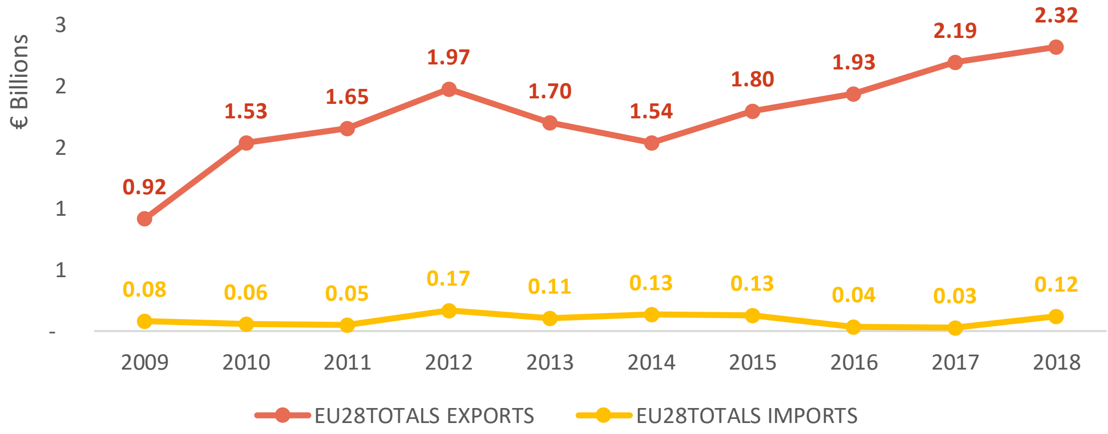
[172] In 2017, the first projects to be awarded a subsidy free contract were Ørsted's OWP West and Borkum Riffgrund West 2 (now merged as Borkum Riffgrund 3) in Germany. This was followed by other projects being awarded a no subsidy contract, namely Vattenfall's Hollandse Kust Zuid 1&2 and 3&4 offshore wind farms in the Netherlands.

[173] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details).

Europe is under increased pressure and the wind turbines supply chain is struggling, mainly due to competition from China, where economies of scale lead to reduced costs at a faster rate than in the Europe.

Between 2009 and 2018, EU-28 exports to RoW increased steadily, reaching €2.32 billion in 2018. Conversely, imports have remained constant between €0.03 billion and €0.17 billion. The EU-28 share of global exports increased from 28% in 2016 to 47% in 2018. During that period, leading EU-28 exporters were Denmark, Germany, and Spain while key RoW competitors in terms of export were China and India.

Figure 4.36 Total EU-28 Imports & Exports – Wind Rotors[174]



Source: ICF, 2020

Between 2009 and 2018, the EU-28 trade balance remained positive and with a rising trend. The countries with the higher positive trends were Denmark, Germany and Spain, and that with the lowest negative trend was the UK. Germany and Denmark's exports were mostly to other EU-28 countries and the UK has imported mostly from within the EU-28 as well. Portugal and the Netherlands had increasingly positive trends over the period, suggesting they have been strengthening their position as exporters of wind rotors.

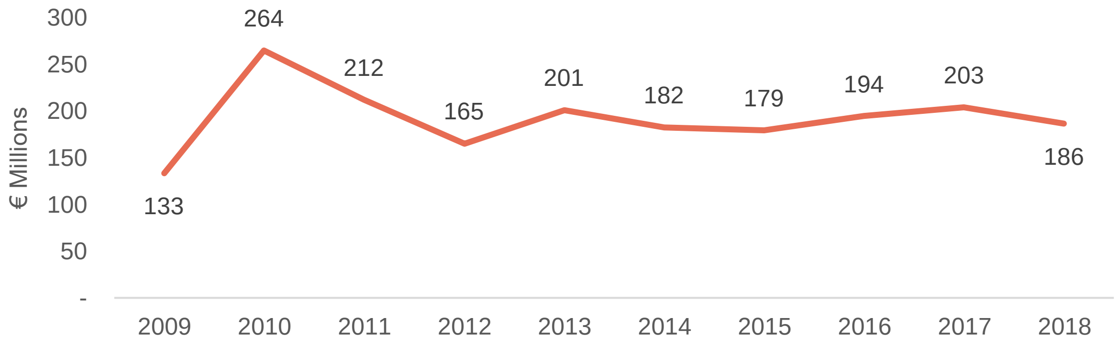
4.8.4 Innovation and investment in RD&D – Wind Rotors

Over the years the sector has demonstrated its ability to innovate. For example, Europe is leading in all parts of the VC of sensing and monitoring systems for offshore wind turbines, including in research and production. Historically, more patent applications in the wind energy sector have been filed in Europe than in the RoW and, in 2016, Europe was still leading in the field of patent applications. This is especially true for the EU-28 wind rotors sector, which saw 67% of the high value patent application between 2014 and 2016.

The wind energy sector has benefited from sustained levels of public RD&D funding from the EU-28 over the last decade. The sector can also count on strong internal resources given its important annual turnover. For the 2009-2018 period, EU-28 public investment has remained roughly constant at around €180-200 million per year. For the 2016-2018 period, out of the countries for which the IEA has data, Japan was by far the largest investor, followed by the US, Germany and the UK. Total EU-28 investment for this period was totalled €583 million, which is slightly more than Japan's figure.

[174] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

Figure 4.37 EU-28 Public RD&D Investments in the Wind Rotors VC[175]



Source: ICF, 2020

Furthermore, innovators in the wind rotors VC have managed to attract considerable levels of early stage and late stage investments compared to the RoW, strongly reinforcing their competitiveness. This trend is expected to continue and further strengthen with the support of the Industrial and Offshore Wind policy strategies.

Over the 2014-2019 period, 17% of the total value of global private venture capital investments in early stage wind sector companies was in European companies.[176] When assessing the number of investments, this percentage grows to 38%, suggesting that the average size of investments is higher outside of Europe. In addition, four out of the top ten countries where these investments happened were in Europe. France and Sweden stand out in terms of total size of investments in early stage companies over the studied period. Specifically, for wind rotors, 69% of the total amount of early stage private investments and 81% of the investments happened in Europe, with Latvia, Spain, France and Sweden standing out.

Over the 2014-2019 period, 7% of the total value of global private investments in late stage wind sector companies was in European companies.[177] When assessing the number of investments, this percentage grows to 22%, suggesting that the average size of investments is higher outside of Europe. The UK and France stand out in terms of total size of investments in late stage companies over the past six years. When it comes to private investments in late stage wind rotor companies, 63% of the total amount of investments and 67% of the investments happened in Europe – specifically in the Netherlands, Germany and France.

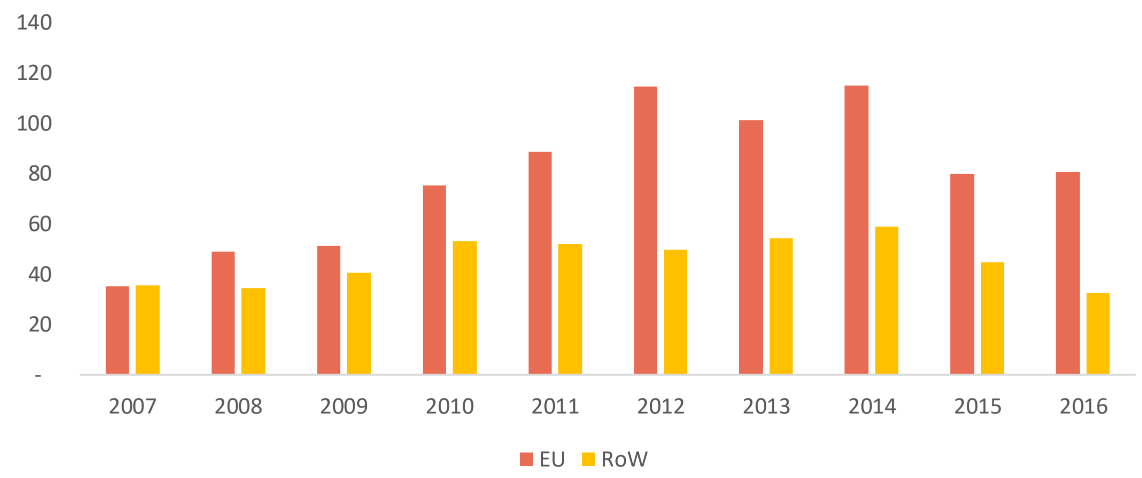
Historically, more patent applications in the wind rotor VC have been filed in the EU-28 than in the RoW, demonstrating the ability of European businesses to innovate and generate value added. Specifically, over the 2014-2016 period, 67% of high value patent applications in the wind rotors VC occurred in the EU-28, compared to 67% if one considers the full wind energy VC. Denmark and Germany stand out in terms of number of high-value patent applications over the studied period. Internationally, the US and Japan represents the biggest threats in terms of intellectual property and high-value patents as they ranked third and fourth in terms of number of high-value patents applications between 2014 and 2016.

[175] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

[176] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the USA and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

[177] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details).

Figure 4.38 Patent applications EU-28 vs rest of the world – Wind Rotors[178]

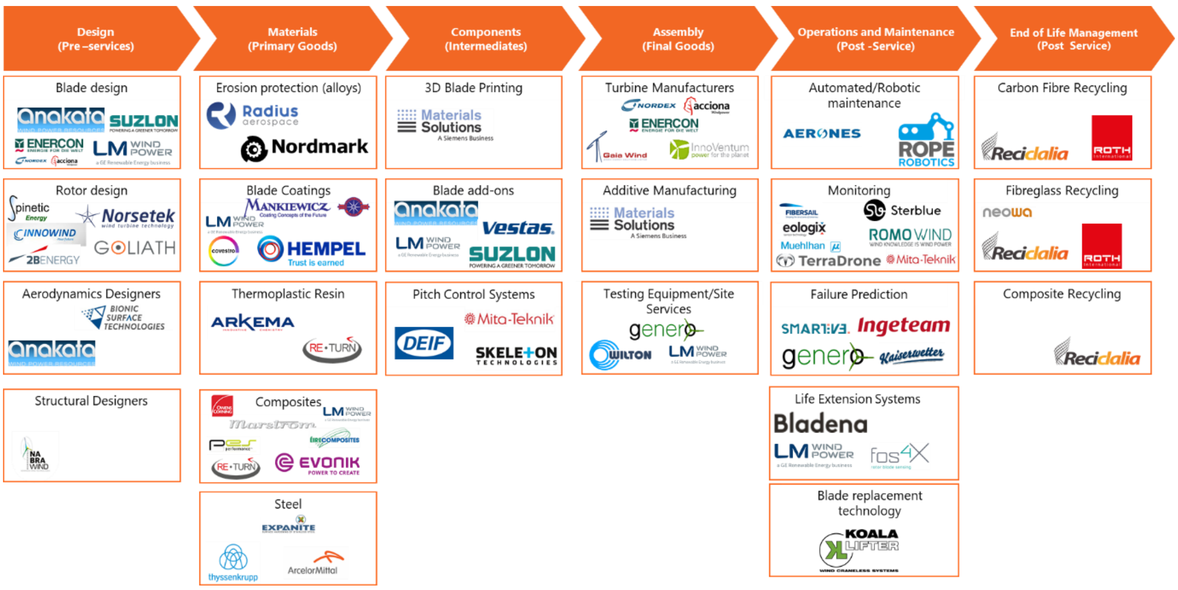


Source: ICF, 2020

Some of the key innovation trends in this VC include improvements in economics and generation efficiency as the market moves towards the use of longer blade and larger rotors increasing the size of the swept area and providing access to higher wind speed but also generating manufacturing economies of scale, and lower operations and maintenance (O&M) costs. In addition, digitalisation (in-blade sensors, transducers, dynamic modelling software, etc.) plays a key role in improving performance and output of rotors and blades and further digitalising of O&M technologies for predictive maintenance and downtime prevention is expected.

Figure 4.39 provides an overview of key European market players and innovators, divided by segment of the Wind Rotors VC.

Figure 4.39 European Key Market Participants – Wind Rotors



Source: Cleantech Group, 2020

[178] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

4.8.5 Threats and challenges – Wind Rotors

External dependencies

One of the major threats for the further development of the wind rotors VC and overall wind VC is its dependency on critical raw materials that are largely sourced outside Europe. A recent EC study concluded that for wind to play its role in the transition towards climate neutrality in Europe, the annual materials demand will increase from 2-fold up to 15-fold (i.e. for rare earths such as dysprosium, neodymium, praseodymium and terbium under the most severe scenario) between 2018 and 2050 depending on the material and the scenario considered[179]. The EC concluded in its 2020 report on CRM for Strategic Technologies and Sectors in the EU that: "*The supply risk of the rare earth materials in permanent magnets (PM) generators for wind turbines is one of the most concerning feature of wind industry related to raw materials*"[180]. There is an additional dependency of the EU for the sourcing of these materials given the near monopoly of China on the production of not only rare earth materials but also permanent magnet manufacturing.

One of the crucial recent measures in remedying these external dependencies on CRMs is the European Action Plan on Critical Raw Materials. As well as the launch of a European Raw Materials Alliance, which is largely expected to strengthen this VC.

Costs

Project development is capital intensive and costs increase for transportation of larger, heavier blades which require more planning at the design phase, and potentially difficult transportation logistics. Additionally, weight savings are possible through hybrid reinforcement (e-glass/carbon, e-glass/aramid) but can be more than one and a half times the initial cost.

Permitting

Difficulty in permitting of new project development due to minimum setback distances to housing, noise limits, high nature safeguarding distances, average tip height restrictions, among other factors.

Recycling

There are several challenges linked to the recycling of wind turbines. Planning for blade recycling relies heavily on visual inspection, which does not offer accurate assessment of the sub-surface materials. Additionally, much of the composite materials used in blades are made of a thermosetting matrix, which cannot be re-moulded for later use. In the EU it is strictly regulated what material can go into landfills and one of the main issues is with the end-of-life of wind turbine blades, which other than being stored, sometimes "*are burned in kilns that create cement or in power plants, but their energy content is weak and uneven and the burning fiberglass emits pollutants*"[181]. Currently, wind turbines have a recyclability

[179] Carrara, S., Alves Dias, P., Plazzotta, B. and Pavel, C., 2020, *Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system*, EUR 30095 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16225-4 (online), doi:10.2760/160859 (online), JRC119941, Available at: https://ec.europa.eu/jrc/en/publication/raw-materials-demand-wind-and-solar-pv-technologies-transition-towards-decarbonised-energy-system

[180] European Commission, 2020, *Critical Raw Materials for Strategic Technologies and Sectors in the EU – A Foresight Study*, Luxembourg: Publications Office of the European Union, ISBN 978-92-76-15336-8, Available at: https://ec.europa.eu/docsroom/documents/42881

[181] Martin, C., 2020, *The latest landfill problem comes from the renewable energy industry*, Bloomberg, Available at: https://fortune.com/2020/02/05/wind-turbine-fiberglass-landfill-disposal-renewable-energy/, [Accessed on: 24/11/2020]

rate of 85% to 90% and making them "*100% recyclable is an important task for the wind industry as the EU heads towards a circular economy*"[182].

The decommissioning of Europe's old wind capacity (e.g. 178 MW decommissioned in 2019) might also lead to new opportunities in this market by creating a new recycling market. The EC notes for example in its 2020 reports on CRM that recycling might to a large extent, secure the magnet-producing industries in the EU in the short term, whilst in the long-term primary mined sources could be developed. Research and innovation in this space might also reinforce the strengths of the EU wind rotor VCs in the long term.[183]

Foreign competition

With 210 GW of installed wind energy capacity (2019), China has overtaken Europe as the region with the largest installed wind energy capacity. Additionally, RD&D funding in wind energy has been growing considerably in Japan over the last decade (from €6 million in 2009 to €203 million in 2018) with strong governmental support to the Japanese floating wind energy industry. For the 2014-2019 period, the vast majority of early stage and late stage investments in the wind energy sector – and not in the wind rotors VC only – were made outside of Europe with the US and India benefiting from large investment volume.

Brexit

Since the UK is a global leader in wind energy, Brexit is likely to have an impact on the wind VC, particularly given the strong emphasis on local supply chain development and UK sourcing as a precondition for award of a Contract for Difference (CfD)in the UK market. In addition, some of the laws adopted as part of the "Clean Energy for All Europeans" legislative package, such as the Directive 2012/27/EU on energy efficiency and Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action had to be amended and the respective EU-wide targets recalculated[184] following Brexit. The Brexit process is creating uncertainty for the timely development of some wind (and interconnection) projects in the North Sea.

Covid-19

Finally, European wind energy and wind rotors companies rely on both European and global supply chains for raw materials and components. Consequently, the knock-on effect of the slowdown due to Covid-19 can already be observed. Since many components originate from China, European players experienced disruption in their supply in February and March 2020, although Chinese supply is quickly ramping back up. According to initial data from WindEurope, the overall effects on international supply chains for wind energy from Covid-19 is expected to be moderate.

Initially, due to Covid-19, a number of factories in Spain and Italy that manufacture various wind energy components were closed, but beyond that most of Europe's wind energy

[182] WindEurope, 2020, *Circular Economy: Blade recycling is a top priority for the wind industry,* Available at: https://windeurope.org/newsroom/news/blade-recycling-a-top-priority-for-the-wind-industry, [Accessed on: 24/11/2020]

[183] European Commission, 2020, *Critical Raw Materials for Strategic Technologies and Sectors in the EU – A Foresight Study*, Luxembourg: Publications Office of the European Union, ISBN 978-92-76-15336-8, Available at: https://ec.europa.eu/docsroom/documents/42881

[184] Decision (EU) 2019/504 of the European Parliament and of the Council of 19 March 2019 on amending Directive 2012/27/EU on energy efficiency and Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action, by reason of the withdrawal of the United Kingdom of Great Britain and Northern Ireland from the Union (Text with EEA relevance), Official Journal L 85I , 27.3.2019, p. 66–68, Available at: https://eur-lex.europa.eu/eli/dec/2019/504/oj

factories continued to operate during the Covid-19 country-wide lockdowns. The Netherlands, Lithuania and Greece have announced that they will deliver on their 2020 auction schedules, while some other European countries (Germany, France, Spain, Ireland, the UK) have extended their auction bidding procedures.[185] The reduced manufacturing output in important countries throughout the VC is expected to cause up to 30% reduced wind installations compared to previous years[186]. Due to the uncertainty of the evolution of the Covid-19 pandemic, it is too early to judge what would be the exact impact on production, revenues and the future timeline of project delivery for the sector. In the short-term, uncertainties from the global Covid-19 pandemic are likely to lead to reduced liquidity in debt markets as lenders focus on managing their liquidity and will be less keen to lend more capital to large wind projects.

4.8.6 Future EU potential – Wind Rotors

Policy support

The European wind energy sector benefits from continuous policy support at EU and national levels, with increasingly high capacity targets being set-up contributing to driving the market (e.g. Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources[187], National Energy and Climate Plans, etc.). In November 2020, the EC launched the *EU Strategy to harness the potential of offshore renewable energy for a climate neutral future*[188], which aims to strengthen, among other technologies, the EU Offshore Wind sector and the respective VCs that support it, including the one for wind rotors. Finally, the effectiveness of national and EU recovery plans will be crucial for the future development of the wind VC and recovering from the impact of the Covid-19 pandemic.

Growth potential

While part of the European market is maturing there are still important development opportunities across Europe, notably in South and Eastern Europe. The global wind rotor market is expected to grow at a CAGR of 7% through 2023. Worldwide, the largest market growth is expected in Asia Pacific since the electricity demand in emerging economies, led by India and China, is expected to increase substantially. This creates both a threat and a major opportunity for Europe to expand its expertise and to increase its volume of rotors delivered into Asian markets.

The trend toward unsubsidised offshore wind farm deployment in the EU (e.g. Vattenfall's Hollandse Kust (zuid) 1 and 2, and the Hollandse Kust (zuid) 3 and 4 projects in the Netherlands) is accelerating competition and driving further innovation, efficiency and price reductions. However, according to the project team's analysis, for offshore wind, technical limitations related to maximum operable length of turbine blades may stall efficiency gains.

[185] WindEurope, 2020, *COVID-19 Wind Information Hub – Impact on Wind Supply Chain*, Available at: https://windeurope.org/newsroom/covid19/, [Accessed on: 24/11/2020]

[186] WindEurope, 2020, *COVID-19 Wind Information Hub – Impact on Wind Supply Chain*, Available at: https://windeurope.org/newsroom/covid19/, [Accessed on: 24/11/2020]

[187] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (Text with EEA relevance), Official Journal L 328, 21.12.2018, p. 82–209, Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L2001

[188] European Commission, 2020, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future*, 19 November 2020, COM(2020) 741 final, Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A741%3AFIN&qid=1605792629666

Additionally, regarding future onshore wind developments, there are difficulties in permitting of new project sites due to minimum setback distances to housing, noise limits, high nature safeguarding distances, average tip height restrictions, among other factors, which creates limitations to the projects' size, capacity, and sometimes leads to delays related to permitting. Europe's ageing wind fleet may lead to repowering of old sites if new regulations enable financially feasible development.

Mergers and acquisitions

In the last few years, a number of important mergers contributed to Europe's leading position in this segment. Mergers and acquisitions are usually driven by companies that want "*to consolidate their position in the market by increasing their market share and economies of scale, creating synergies, and lowering risk (for example aligning RD&D resources), compared to individually developing new technologies and products*"[189].

The strategic partnership of Vestas and Mitsubishi into the Mitsubishi Vestas Offshore Wind (MVOW) joint venture in 2013, in order to create the scale required to successfully develop the offshore wind market, created an important signalling effect in the market. It has proved successful in enabling Europe to showcase innovative, large-scale turbines which can be exported further afield (for example, MVOW turbines are now being planned for deployment on the East Coast of the UA).

In April 2016, Nordex and Acciona WindPower merged to become Nordex Acciona, while in April 2017, Siemens Wind Power and Gamesa merged to become Siemens Gamesa Renewable Energy[190]. This created two of the largest global technology leaders in the development and manufacturing of wind turbines.

When it comes to future developments, the consolidation of the market is expected to continue, which would allow leading European companies to strengthen their position and increase their market share in growing markets, such as North America. It is also expected to have further mergers, especially in production areas where there are synergies, which would cut down production and project costs for the new merged entities. Additionally, through acquisitions certain European players could expand their portfolio and be able to increase their levels of innovation and competitiveness.[191]

Finally, large wind energy is becoming more popular with a broader set of energy and "non-energy" investors such as pension funds and infrastructure investors (e.g. a number of projects in Denmark and the Netherlands that now consider large wind projects as a viable long-term investments).[192]

[189] Telsnig, T., Vazquez Hernandez, C., 2019, *Wind Energy Technology Market Report*, EUR 29922 EN, European Commission, Luxemburg, 2019, ISBN 978-92-76-12569-3, doi:10.2760/223306, JRC118314. Available at: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC118314/jrc118314_1.pdf

[190] Telsnig, T., Vazquez Hernandez, C., 2019, *Wind Energy Technology Market Report*, EUR 29922 EN, European Commission, Luxemburg, 2019, ISBN 978-92-76-12569-3, doi:10.2760/223306, JRC118314. Available at: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC118314/jrc118314_1.pdf

[191] Lacal-Arántegui, R., 2019, *Globalization in the wind energy industry: contribution and economic impact of European companies*, Renewable Energy, Volume 134, April 2019, Pages 612-628, Available at: https://www.sciencedirect.com/science/article/pii/S0960148118312904?via%3Dihub

[192] Deign, J., 2019, *Institutional Investors Fuel M&A Frenzy in Europe's Wind Market,* Greentech Media, Available at: https://www.greentechmedia.com/articles/read/institutional-investors-fuel-ma-frenzy-in-europes-wind-market, [Accessed on: 24/11/2020]

4.8.7 SWOT – Wind Rotors

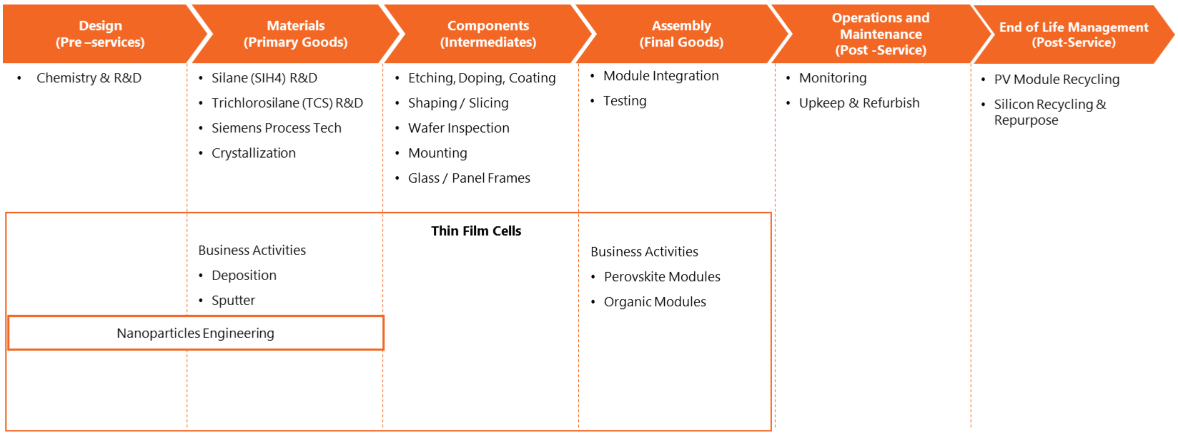
Strengths *Internal attributes, characteristics and factors that give competitive advantage to the EU in the global VC.*	**Weaknesses** *Internal attributes, characteristics and factors that weaken the competitiveness of the EU in the global VC.*
• European wind energy sector is a well-organised and well-established economic sector. • Europe is a recognised market leader with very well established wind market players. • EU-28 exports of manufactured goods for the wind industry have increased steadily, especially for wind rotors. • Between 2009 and 2018, EU-28 trade balance remained positive, with a rising trend. • Europe's wind players are characterised by their ability to innovate. • There are sustained levels of public RD&D funding in the studied period.	• While Europe is strong in innovating in the wind rotor VC, foreign competitors tend to be stronger in large volume technological developments and production capacity, due to large home markets and extensive state support. • The main challenge facing onshore and offshore wind project development remains permitting (lack of public acceptance or competition with other economic activities (fishermen, tourism) and timely execution, which translates into higher costs for end-users. • The wind rotor VC is highly dependent on China for the sourcing of rare earth materials and this dependency will increase in the future.
Opportunities *External situations and factors that can strengthen the competitive advantage of the EU or provide the EU with new sources of competitive advantage.*	**Threats** *External situations and factors that can create problems for the EU compromising its competitive advantage to a certain extent.*
• The EU wind industry receives strong policy support at EC level. This is expected to further strengthen the wind rotor VC. • Significant market development opportunities exist, notably in South and Eastern Europe. • The maturity of the wind sector provides further opportunities for highly competitive wind projects and greater numbers of unsubsidised offshore wind farms. • There are opportunities for repowering of existing wind power sites. • Creation of multi-functional offshore wind farm projects (combining multiple revenue-generating activities) is a big opportunity to increase both the cost-efficiency and technological advantages of the projects. • Decommissioning of the aging European wind fleet is expected to become a growing business sector.	• China is leader by installed wind capacity. This trend is growing mainly pushed by local needs and state supported industry and manufacturers. • Japan is growing its RD&D funding. With large industrial capacity and a number of acquisitions in EU companies this trend is considered a threat to EU manufacturers. • US and India are leaders in early stage and late stage investments. • Brexit has impact on cross-border infrastructure and offshore wind projects. This could impact the wind rotor VC since the UK is a major consumer, producer and RD&D investor, as well as overall EU targets for wind energy, which are recalculated between the EU. • Covid-19 has impacted some European factories within the wind rotor VC. While stagnation caused by the Covid-19 lockdown is not expected to have long lasting harmful impacts on the VC, some project delivery delays have been observed.

4.9 Photovoltaic Solar Panels

4.9.1 Scope of the VC – Photovoltaic Solar Panels

The scope of the Photovoltaic Solar Panels (hereafter referred to as Solar PV) VC covers photovoltaic panels for converting solar energy into direct current electricity, poly-silicon production and precursors, thin film production, silicon repurposing and recycling. However, this VC does not include balance of system, solar farm development, concentrated solar power or cable boxes. The structure of the Solar PV VC split by segment of activity is elaborated in Figure 4.40.

Figure 4.40 PV Solar Panels VC Structure



Source: Cleantech Group, 2020.

4.9.2 European market overview[193] – Photovoltaic Solar Panels

All energy scenarios, proposed by the EC, for future development and achieving the 2050 climate goals foresee a key role for solar PV power[194].

There is potential in the European solar PV industry, its VC and future solar market expansion. Currently, solar PV covers around 3% of the EU electricity demand, with some estimates predicting it could reach 15% by 2030.[195] Additionally, European research centres are supported and aimed at developing cutting-edge industrial solutions along the whole VC. The annual turnover of the European PV industry is estimated at around €5 billion, with additional potential that remains untapped especially when it comes to economic growth and job creation.[196]

[193] Note: When this document refers to "Europe" it includes all countries that are part of the European single market – this covers the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. In some cases, the data is extracted at aggregated EU-28 or EU-27 level. Datasets, reports and information that was extracted for the period before 2018, refers to the EU-28 and includes the UK in the analysis.

[194] European Commission, 2018, *In-Depth Analysis in Support of the Commission Communication COM(2018) 773 A Clean Planet for all A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy*, 28 November 2018, Available at: https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

[195] L'Institut Photovoltaïque d'Île-de-France, 2020, *Press Release – The European solar value chain raises concerns over lack of positive signals for the industry in the Green Deal*, Available at: https://ipvf.fr/press-release-the-european-solar-value-chain-raises-concerns-over-lack-of-positive-signals-for-the-industry-in-the-green-deal/, [Accessed on: 24/11/2020]

[196] L'Institut Photovoltaïque d'Île-de-France, 2020, *Press Release – The European solar value chain raises concerns over lack of positive signals for the industry in the Green Deal*, Available at: https://ipvf.fr/press-release-the-european-solar-value-chain-raises-concerns-over-lack-of-positive-signals-for-the-industry-in-the-green-deal/, [Accessed on: 24/11/2020]

When it comes to European legislation, the main driver was EU Directive 2009/28/EC, which formalised obligatory renewable energy targets for EU Member States by 2020 (e.g. 18% in Germany). It was then amended by the “Clean Energy for All Europeans” legislative package and more specifically by Directive 2019/944 on common rules for the internal market for electricity and Directive 2018/2001 on the promotion of the use of energy from renewable sources, which stipulated into the legal framework the new 2030 targets for renewables.

Additionally, over the last years there were a number of important national initiatives that boosted the European solar PV VC.[197] Key examples include:

- A central driver for Spain’s 2019 increase in solar was a series of auctions in 2017 that awarded contracts for 4 GW by a 2019 deadline.
- Germany’s continued PV demand increases are largely driven by self-consumption / feed-in premiums for commercial PV systems of 40 kW to 750 kW. Germany installed 4 GW of solar PV in 2019, 2.9 GW in 2018, and 1.7 GW in 2017.
- In Poland, small systems (<50 kW) do not need permits for grid-connection, as a result, most of the growth has happened in self-consumption systems (550 MW out of 784 MW installed in 2019 were self-consumption).
- In Italy, the rooftop segment has been the primary driver of the solar PV market in recent years. The government has provided financial incentives for rooftop facilities and a net metering program for systems lower than 200 kW in power.
- The Netherlands brought over 20 MW of PV solar online since 2011 through the SDE+ subsidy program, which was renewed for 2020.

4.9.3 European industry size and VC – Photovoltaic Solar Panels

In 2018, there were 118,000 people employed directly or indirectly in the Solar PV sector in the EU-28. According to the analysed EurObserver database, employment in the sector has increased by 30% between 2017 and 2018. The Member States that employed the most workers in this sector were Germany, France and the Netherlands. Combined they accounted for 60% of the total in 2018.

According to the selected sample data by the Cleantech Group, 32% of active companies in the Solar PV VC are headquartered in Europe compared to the RoW, showing a strong concentration of leading companies in Europe.[198] European solar PV companies, are mainly concentrated in Germany (35% of the total), France (12%) and Italy (8%).

Between 2009 and 2018, the annual production value of Solar PV in the EU-28 experienced a sharp reduction from €7.5 billion in 2009 to €2 billion in 2018. This period was marked by the end of the first solar power boom in Europe. Germany and Italy accounted for more than half of the EU production of Solar PV during that period.

In 2010, the EU-28 Solar PV market grew by 104%, and did not see growth at the same level until 2019, when it again grew by 104%, adding 16.7 GW of capacity to the market

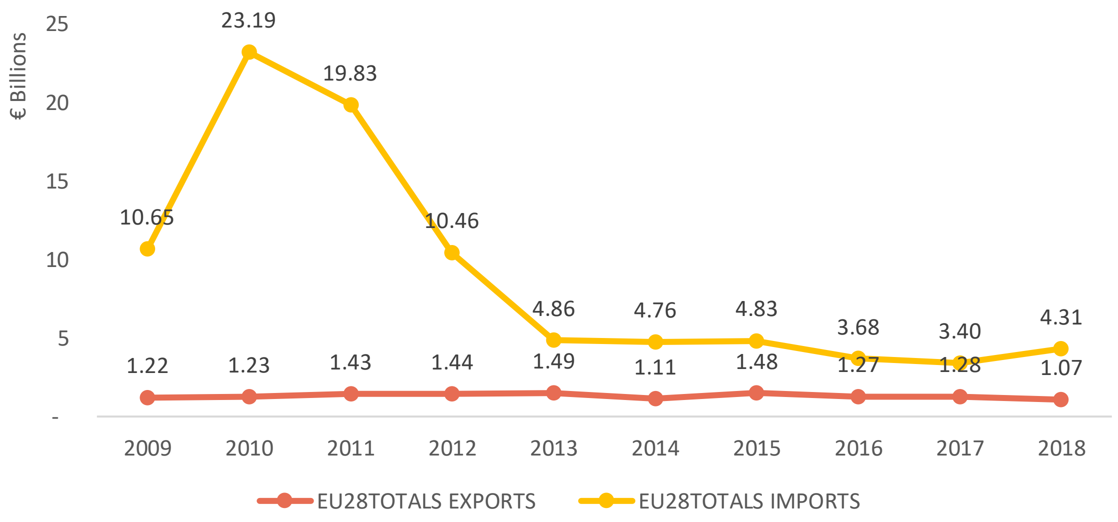
[197] SolarPower Europe, 2020, *EU Market Outlook for Solar Power (2019-2023)*, Available at: https://www.solarpowereurope.org/wp-content/uploads/2019/12/SolarPower-Europe_EU-Market-Outlook-for-Solar-Power-2019-2023_.pdf?cf_id=15434

[198] According to the analysed data from the Cleantech Group’s database (see section 3.2.2 for more details).

compared to 8.2 GW in 2018 and marking a second European solar boom.[199] For the studied period, the EU-28's top five solar markets were Spain, Germany, the Netherlands, France and Poland. In 2019, they accounted for 75% of the total solar installations in the EU-28. Between 2019 and 2023, the EU-28 is expected to add 105.7 GW of solar energy, led by Germany (+26.7 GW), Spain (+19.6 GW), Netherlands (+15.7 GW), France (+13.1 GW), and Italy (+9.5 GW).

In 2018, turnover in the EU-28 Solar PV sector was €14 billion. Between 2017 and 2018, turnover in the sector increased by 29%, marking the recovery of the sector. In 2018, Germany, France and the Netherlands together accounted for 65% of this turnover. EU-28 imports have strongly decreased over the years from €23 billion in 2010 to €4.3 billion in 2018. On the other hand, EU-28 exports, albeit smaller, have remained stable over the last decade in the range of €1.1-1.4 billion.

Figure 4.41 Total EU-28 Imports & Exports – Photovoltaic Solar Panels[200]



Source: ICF, 2020

Between 2016 and 2018, the EU-28 share of global exports remained around 2-3%, emphasising the lack of competitiveness of EU-28 Solar PV companies on global markets. In this context the top EU-28 exporters were Germany, Italy, and France. For the same period, only one out of the top ten global exporters was an EU-28 country, namely Germany which ranked 6th with an export value of €7 billion. Germany was however largely outperformed by China (€44 billion), South Korea (€11 billion), Malaysia (€11 billion) and Japan (€10 billion). Between 2016 and 2018, two out of the top ten global importers were EU-28 countries. China was the largest importer, followed by the US and Japan.

Between 2009 and 2018, the EU-28 trade balance remained negative albeit with an improving trend from €-21.95 billion in 2010 to €-3.24 billion in 2018. The countries with a positive trade balance were Croatia, the Czech Republic, Luxembourg and Slovenia, while those with the lowest negative trend were the Netherlands and UK. Czech Republic exports were mainly within the EU-28, while the UK imported from both within and outside the EU-28.

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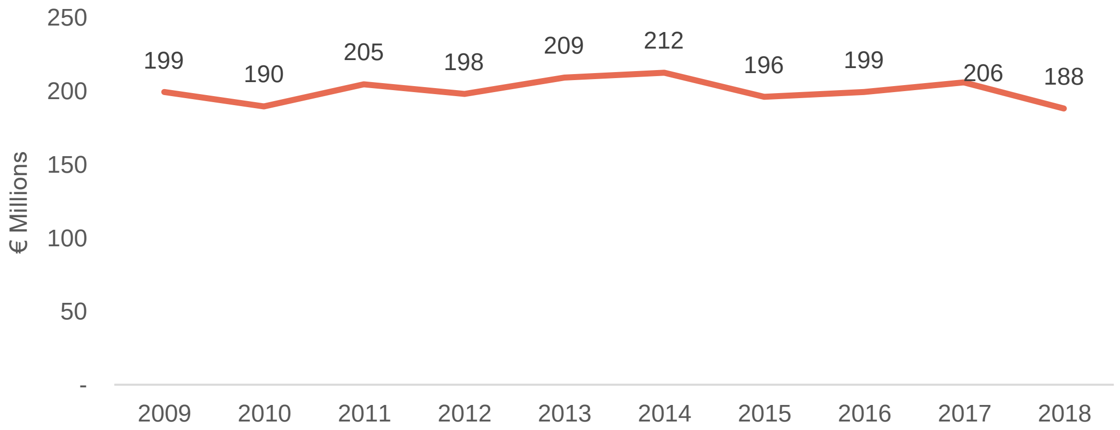
199 SolarPower Europe, 2020, *EU Market Outlook for Solar Power (2019-2023)*, Available at: https://www.solarpowereurope.org/wp-content/uploads/2019/12/SolarPower-Europe_EU-Market-Outlook-for-Solar-Power-2019-2023_.pdf?cf_id=15434

200 Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

4.9.4 Innovation and investment in RD&D – Photovoltaic Solar Panels

The data on public investment in RD&D is available for a limited group of countries covered by the IEA. Between 2009-2018, EU-28 public investment remained constant in the range of €190 million to €210 million annually. Out of the countries for which the IEA has data, Germany was by far the largest investor, followed by Japan, France and Switzerland.

Figure 4.42 EU-28 Public RD&D Investments in the PV Solar Panels VC[201]



Source: ICF, 2020

Over the 2015-2019 period, 17% of the total value of global private investments in early stage companies active in the Solar PV VC was in European companies.[202] When assessing the number of investments, this percentage increases to 29%, suggesting that the average size of investments was larger outside of Europe. The volume of early stage investments varied considerably from one year to the other during that period and showed an overall decline.

Over the same period, 44% of the total value of global private investments in late stage companies was in European companies.[203] Over the 2015-2019 period, the European late stage investments have increased from €29 million to €150 million, whereas in contrast, the investments in the rest of the world have decreased from €205 million to €64 million, indicating a strong confidence from private investors in the innovations being developed by European Solar PV companies. The UK, Sweden and Germany stand out in terms of total size of investments in late stage companies over the studied period, but still remain behind the US that benefited from most of the tracked investments.

In 2019 and 2020, the majority of solar PV investments in Europe were made to mature companies at the growth and project financing stages, with a focus on solutions for reduction in project deployment soft costs (e.g. Lightsource BP, Solarcentury). In 2019 and 2020, thin film technologies (e.g. Saule, Oxford PV, Solaxess) and solar glass technologies (e.g. Grenzebach, Polysolar) were the primary recipients of seed level funding.

Over the last decade, more patent applications have been filed in the RoW than in the EU-28 which accounted for 29% of the overall high-value patent applications. In Europe, France

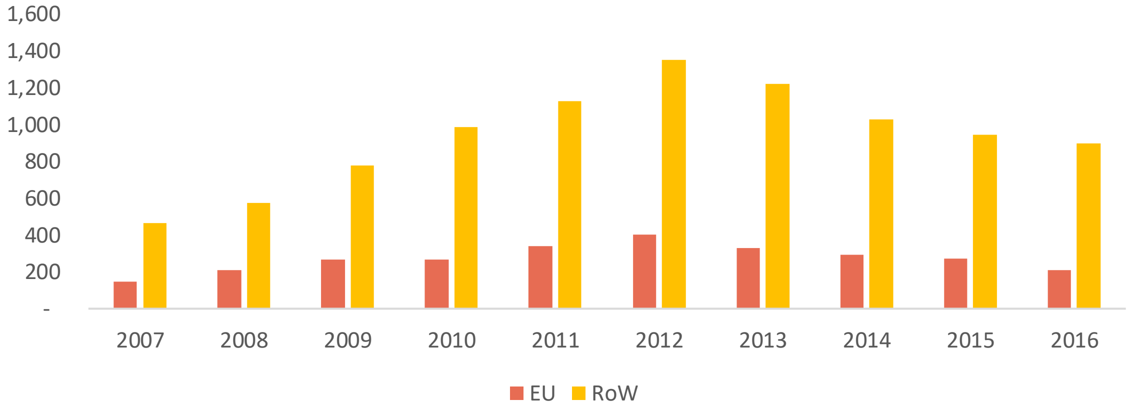
[201] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

[202] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the USA and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

[203] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details).

and Germany stand out in terms of number of high-value patent applications over the 2014-2016 period.

Figure 4.43 Patent applications EU-28 vs rest of the world – Photovoltaic Solar Panels[204]



Source: ICF, 2020

In terms of recent innovations, some of the most notable developments include Oxford PV's silicon-perovskite innovations that have surpassed the silicon solar cell efficiency limit, promising to make thin films more efficient and cost effective. It is also preparing to launch production of a 100 MW silicon heterojunction solar cell line with Meyer Burger in Germany in Q4 2020.

Thin film PV module production methods are streamlining manufacturing processes for better cost efficiencies and improved speed-to-market, e.g. Heliatek's vacuum roll-to-roll production and Saule's inkjet perovskite printing process. Flexible thin films are allowing deployment of solar assets to less traditional spaces, such as the sides of buildings, top of carports, top of boats, and even blinds in a building.

In addition, developments in agrivoltaics, building-integrated photovoltaics (BIPV) and floating solar have enabled the use of cost-efficient solar power for a wide variety of locations. PV module recycling technology is accelerating, now with more means for recycling and repurposing thin film cells as well. LuxChemtech (Germany) has patented new chemically treat solar cells for efficient extraction of semiconductors and metals.

Figure 4.44 provides an overview of some of the key European market players, divided by segment of the Solar PV Panels VC.

[204] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

Figure 4.44 European Key Market Participants – Photovoltaic Solar Panels

Source: Cleantech Group, 2020

In 2018, European funding contributed €5.4 million to the "ESPResSo" (Efficient Structures and Processes for Reliable Perovskite Solar Modules) project for research into novel emerging hybrid organic-inorganic perovskite-based solar cell technology. The European Investment Bank (EIB) has financed breakthrough thin film solar PV innovation with investment in Oxford PV (€15 million, 2017)[205] and loans to Heliatek (€80 million, 2016)[206].

In 2019, the EU pledged a €1 trillion set of investments in clean energy innovation, energy efficiency and renewable energy to reach 2030 energy and climate goals, while also pledging to discontinue fossil fuel investments after 2021.[207]

4.9.5 Threats and challenges – Photovoltaic Solar Panels

Foreign competition

China emerged as a leader in PV module production after a heavy wave of outsourcing from Germany, Spain, and Italy in the late 1990's, following government incentives that created an outsized demand. Policies in China included generous tax incentives for producers, and feed-in tariffs for project developers. German-made PV modules are now 80% cheaper than they were in 2010, but still three times more expensive than Chinese-made.[208] The period of China's acceleration also included heavy M&A activity, with many IP-holding early-stage start-ups being acquired by Chinese PV companies. Breakthrough materials innovation promises one of the best paths to competitiveness for producers

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[205] European Investment Bank, 2017, *Germany: EU bank grants EUR 15m to Oxford Photovoltaics Germany*, Available at: https://www.eib.org/en/press/all/2017-397-eu-bank-grants-eur-15m-to-oxford-photovoltaics-germany, [Accessed on: 24/11/2020]

[206] European Investment Bank, 2016, *Germany: Heliatek raises EUR 80 million to finance large manufacturing expansion and support worldwide market development*, Available at: https://www.eib.org/en/press/all/2016-213-heliatek-raises-eur80-million-to-finance-large-manufacturing-expansion-and-support-worldwide-market-development, [Accessed on: 24/11/2020]

[207] European Commission, 2020, *The European Green Deal Investment Plan and Just Transition Mechanism explained,* Available at: https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_24, [Accessed on: 24/11/2020]

[208] Fialka, J., 2016, *Why China Is Dominating the Solar Industry*, Scientific American, Available at: https://www.scientificamerican.com/article/why-china-is-dominating-the-solar-industry/, [Accessed on: 24/11/2020]

hoping to gain global market share. China's reduction of subsidies has contributed to a shrinking rate of increase in installations (45.1 GW in 2018, 30.1 GW in 2019).

Project planners in the US have accelerated planning and deployment of projects in the past two years to still qualify for the investment tax credit, including a 546 MW Orsted project in Permian, Texas, and a €263 million 234 MW Cove Mountain complex in Utah. The US is expected to continue with PV installations despite the 30% phase-out of the Investment Tax Credit (ITC) scheme in January 2020; solar developers have stockpiled panels ahead of the 30% ITC, utility-scale projects are already in the pipeline, and oversupply of PV modules will drive prices down enough to offset loss of ITC.

Raw materials dependence

Similar to renewable energy VCs, the raw materials needed for the development of solar PV modules (e.g. germanium, cadmium, tellurium, silicon, selenium, gallium, indium and silver etc.)[209] are largely imported from outside of Europe. This creates strong European dependence on third countries, especially considering the expected role of solar PV in reaching the 2050 climate neutrality target. The 2020 Foresight Study of the EC on Critical Raw Materials for Strategic Technologies and Sectors in the EU concluded that: "*A medium supply risk is associated with raw materials used in PV technologies. Since crystalline silicon technologies dominate the global production of solar panels, special attention should be payed to silicon*"[210]. The study also identified the manufacturing of solar cells as the weakest link of the Solar PV VC in the EU due to the strong competition from China. Crucial measures such as the recently announced European Raw Materials Alliance[211], similar to the successful European Battery Alliance[212], are expected to substantially enhance the strength of VCs such as the solar one by aiming at reduction of these external dependencies.

Brexit

The UK is a large market for Solar PV and stands out in terms of private investments in early and late stage companies. Post Brexit, the future of European cooperation in this sector remains to be clarified. Since the UK is a big importer from the EU, without certainty on trade there may be disruptions.

4.9.6 Future EU potential – Photovoltaic Solar Panels

Policy support

Solar represents 5% of the energy mix currently, but could account for as much as 36% by 2050. The European Green Deal and the European Climate Law foresee the establishment of different instruments to accelerate the transition towards decarbonised electricity in Europe (e.g. InvestEU, Horizon Europe, etc.)..

Growth potential

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[209] European Commission, 2020, *Raw material demand for wind and solar energy*, JRC120228, Available at: https://ec.europa.eu/jrc/sites/jrcsh/files/jrc120228_-_raw_material_demand_two-pager_pubsy_final.pdf

[210] European Commission, 2020, *Critical Raw Materials for Strategic Technologies and Sectors in the EU – A Foresight Study*, Luxembourg: Publications Office of the European Union, ISBN 978-92-76-15336-8, Available at: https://ec.europa.eu/docsroom/documents/42881

[211] European Raw Materials Alliance, 2020, Available at: https://erma.eu/

[212] European Battery Alliance, 2020, Available at: https://www.eba250.com/

In addition to the support being provided at EU level, different Member States are supporting the deployment of Solar PV installations in their territories, including for example:

- France's PV project auctions have built a pipeline for projects to start construction in 2020 and beyond.
- Poland is expected to exceed 1 GW of PV (from 813 MW in 2019) in the coming years as a result of pipelines built during government auctions, a 2019 VAT reduction (23% to 8%), and a new rooftop rebate scheme (Moj Prad) for 2 kW-10 kW projects.
- Spain has a target of 37 GW solar PV installed capacity by 2030 (currently 8.7 GW), there are no tendered projects scheduled for 2020, it is expected that without a new auction, private PPAs will need to make up the bulk of the gap to the capacity goal.
- The Netherlands has an 8 GW pipeline of projects from state auctions waiting to come online, 1 GW transmission upgrade to come.
- Hungary established a 10-year €130 million feed-in tariff initiative in 2017 and an auction system that added 348.5 MW of PV in 2019 and is expected to add 1 GW in 2020.

Mergers and acquisitions

Recent M&A activities have shown corporates taking a vested interest in the European solar project development market, e.g. Shell's acquisition of Sonnen and BP's acquisition of Lightsource, both in 2019.

4.9.7 SWOT – Photovoltaic Solar Panels

Strengths *Internal attributes, characteristics and factors that give competitive advantage to the EU in the global VC.*	**Weaknesses** *Internal attributes, characteristics and factors that weaken the competitiveness of the EU in the global VC.*
• Strong and established VC that is well represented at European and national level. • Strong policy support at both European and national level. • Europe has a unique RD&D ecosystem with a large number of innovators and developers. • Strong market and a growing need for PV installations in order to meet the ambitious climate and energy targets of the EU.	• Insufficient European and national financial instruments for a wider support. • Slow uptake of solar rooftop installations despite its huge potential in Europe. • Outdated PPA structures – limited issuance of corporate PPAs and legal barriers to cross-border PPAs. • Insufficient development of solar self-consumption schemes in Europe and regulatory uncertainties. • Lack of incentives to develop smart and flexible solar installations in competitive public tenders. • Over the last decade, more patent applications filed in RoW than in the EU-28.
Opportunities *External situations and factors that can strengthen the competitive advantage of the EU or provide the EU with new sources of competitive advantage.*	**Threats** *External situations and factors that can create problems for the EU compromising its competitive advantage to a certain extent.*
• The timely and adequate transposition of the "Clean Energy for All Europeans" legislative package and some of the upcoming legislative	• External low-cost production, especially from China and threat of dumping.

acts under the European Green Deal could boost to a great extent the VC.

- Big market opportunities for solar expansion in Europe, which could be a chance for existing and new European PV manufacturers to grow.
- Opportunity to establish European solar innovation expertise as a global leader.
- Opportunities for job creation by addressing re-skilling and upskilling of existing workers.
- Opportunity to create a European PV recycling industry.
- Opportunities for mergers and acquisitions and strengthening of European players.
- Digitalisation extends solar's lifetime, capabilities, energy flexibility and consumer involvement.

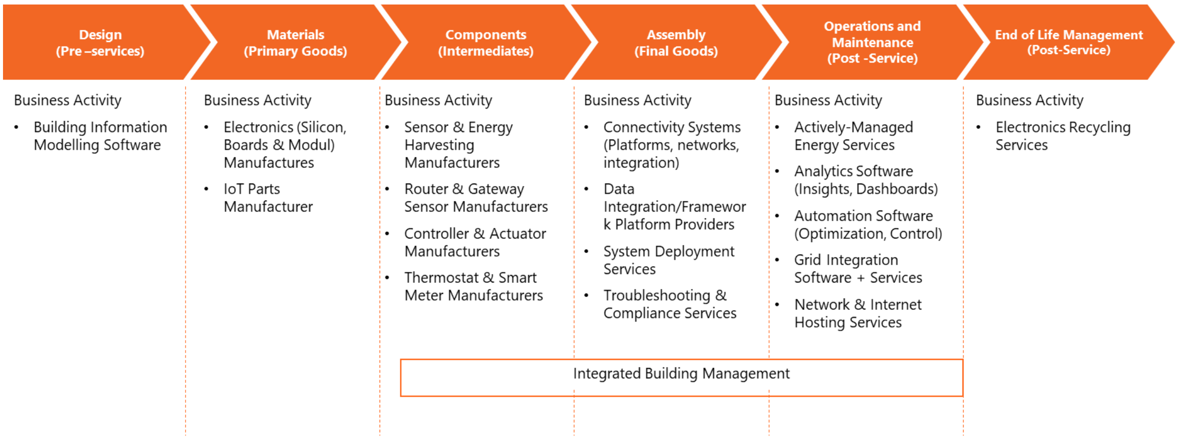
- Slower EU production progress than external competitors.
- Outcome-focused approach to policy and investment, focusing funds on deployment of end-projects and not adequately focusing on development of the EU industrial and research base to innovate in solar and own more elements of the supply chain.
- Incentives focused on reduction of capital expenditures at the grid level and not on developing technology that maximises flexibility and speed, such as digitalisation infrastructure and soft cost reduction services.
- Policy makers need to keep up with advances on digitalisation, innovation and changes in consumer preferences.
- Similar to other VCs, the raw materials needed for the development of solar PV modules are largely imported from outside of Europe, however, the recently announced Critical Raw Materials Alliance is a strong development towards remedying this dependence.

4.10 Building Energy Management Systems

4.10.1 Scope of the VC – BEMS

The scope of the Building Energy Management Systems (BEMS) VC covers digital integrated systems (including hardware and software) built to manage energy in public, commercial and residential buildings. It also covers systems designed to manage the interaction between these buildings and the grid. This implies elements including: smart meters, building automation and control technologies, HVAC management systems, hardware and software designed to enable buildings' participation in market services, energy resource management systems and microgrids. This VC does not include grid management technologies and, hardware and software designed to facilitate energy management outside the building system. These technologies are covered in the Grid Energy Management Systems VC. The structure of the BEMS VC split by segment of activity is presented in Figure 4.45.

Figure 4.45 BEMS VC Structure



Source: Cleantech Group, 2020.

4.10.2 European market overview[213] – BEMS

Energy efficiency is a key part of Europe's climate and energy policies. This was reflected in past legislation (e.g. Energy Efficiency Directive 2012, Action Plan for Energy Efficiency 2007) and is fully integrated in 2030 new target plan (i.e. 2030 framework for climate & energy policies and the "Clean Energy for all Europeans" legislative package) and the 2050 ambition (i.e. 2050 roadmap, which established energy efficiency as central to European energy policies).

In addition, the Energy Performance of Buildings Directive (EPBD) requires Member States to set minimum energy performance standards and contains provisions relating to building energy automation and control systems. Stringent building codes and Energy Performance Certificates have also helped the EU-28 to establish pathway for BEMS' adoption as an integral part of meeting energy and climate requirements. Furthermore, European buildings are additionally subject to national emissions reductions targets stipulated under the EU Effort Sharing rules, and subject to national energy taxation, regulations, incentives, which drives the adoption of BEMS across different Member States. Support schemes and national fiscal stimulus for private and public building owners are creating a market for higher-efficiency products and services (specific incentives for the use of energy management systems were for example put in place in Belgium, Czech Republic, Greece and the UK)[214].

Over the last 15 years, Europe's adoption of BEMS had steady growth, particularly in Western Europe and in the commercial building sector. However, BEMS still remains a less attractive market for small and medium-sized building owners where energy cost savings represent a smaller portion of the potential buildings' operation cost savings.

The rate of BEMS uptake has slowed over last two years and currently it is not on track to meet the 2020 targets in line with broader energy efficiency targets. Additionally, the Covid-19 pandemic will have a short-term impact on the 2020 trends overall. The EU is expected to meet its 2020 energy efficiency target of 10% reduction compared to 2005 levels. However, currently it is not on track for a 30% reduction by 2030.

Currently, European businesses have reduced investments in the short-term due to the Covid-19 pandemic. However, in the long-term stakeholder pressure to address climate change are expected to drive the growth of the European BEMS market. Additionally, technologies including BEMS, which fall into the energy efficiency category, are being promoted by the EC as key measures for meeting EU targets.

In buildings, the successful use of BEMS' information and integration with other digital services allow for the provision of non-energy benefits (e.g., use of space, air quality, comfort, worker productivity, health, reduction in operations and maintenance costs, and enhanced corporate public relations and brand), reinforcing the business case for BEMS and making a direct link with space utilisation. This is becoming a differential metric particularly in the commercial building market and driving innovation in data-driven solutions

[213] Note: When this document refers to "Europe" it includes all countries that are part of the European single market – this covers the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. In some cases, the data is extracted at aggregated EU-28 or EU-27 level. Datasets, reports and information that was extracted for the period before 2018, refers to the EU-28 and includes the UK in the analysis.

[214] Economidou, M., Todeschi, V., Bertoldi, P., 2019, *Accelerating energy renovation investments in buildings – Financial & fiscal instruments across the EU*, EUR 29890 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-12195-4, doi:10.2760/086805, JRC117816, Available at: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC117816/accelerating_energy_renovation_investments_in_buildings.pdf

which can optimise underutilised space.[215] In addition, pilot projects enabling building owners to gain revenues from participating in grid services, especially when combined with integrated renewables and energy storage (i.e. through prosumers and/or aggregator companies) are creating additional incentives for the development of the BEMS market and VC.

Some of the associations and bodies representing the BEMS VC at the European level include the European Building Automation and Controls Association (EUBAC), the Europe Regional Network of the World Green Building Council and Build Europe, amongst others.

4.10.3 European industry size and VC – BEMS

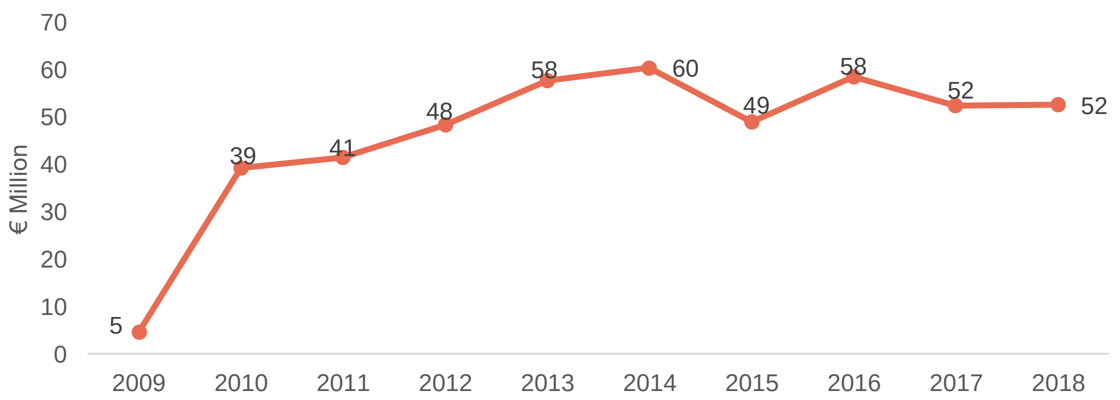
Based on the analysis of the sample of companies tracked by the Cleantech Group, 36% of active companies in the BEMS sector are headquartered in Europe with a strong concentration in the UK (38%) and in France (20%).[216]

Globally, the BEMS VC is largely fragmented with numerous actors. Hardware manufactures and the supply market is dominated by Asian players, mainly due to competitiveness and low costs. Whereas designers and system integrators are more active in Europe on a national basis, largely developing business models based on regulatory allowances and revenue opportunities. While market dynamics are driven by the local contexts, some transnational trends include North American and European buildings owners prioritising energy savings while Asian building owners prioritise worker productivity as the main drivers for adopting new technology in their respective commercial building markets.

4.10.4 Innovation and investment in RD&D – BEMS

The data on public investment in RD&D is available for a limited group of countries covered by the IEA. EU-28 public investments have grown tremendously over the 2009-2018 period with a tenfold increase from €5 million in 2009 to €52 million in 2018. Of the countries for which the IEA has data, Canada was by far the largest investor and France was the second largest public investor in this VC for the studied period.

Figure 4.46 EU-28 Public RD&D Investments in the BEMS VC[217]



[215] Northeast Energy Efficiency Partnerships, 2020, Available at: http://www.wdw.neep.org/sites/default/files/resources/FinalCommercialSectorBusinessModels.pdf

[216] Missing

[217] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

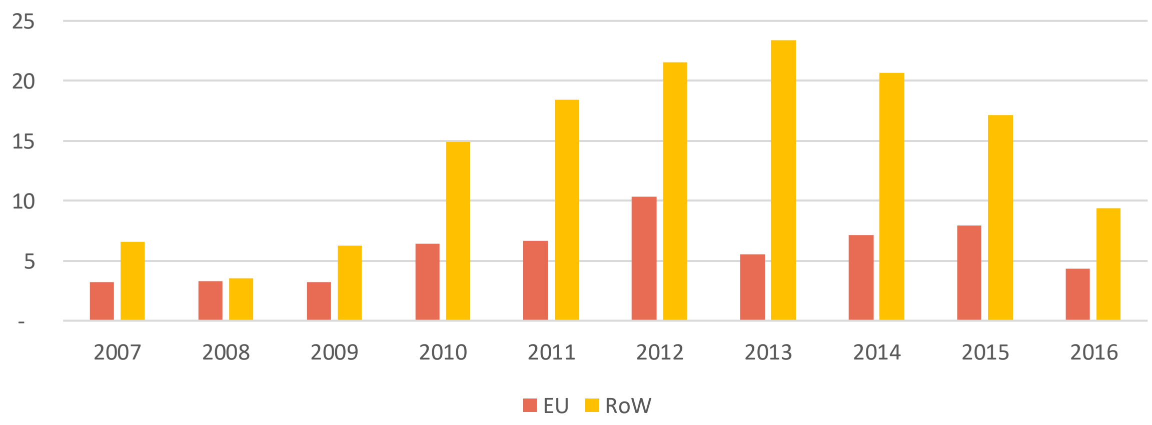
Source: ICF, 2020

Over the 2015-2019 period, 23% of the total value of global private investments in early stage companies active in the BEMS VC was in European companies.[218] When assessing the number of investments, this percentage grows to 32%, suggesting that the average size of investments is higher outside of Europe. The volume of early stage investments in European companies has grown significantly in recent years to reach €67 million in 2019. In Europe France (€43 million), Germany (€28 million) and the UK (€26 million) benefited from most of the investments during the 2015-2019 period, but they were outperformed by the US (€277 million) and China (€109 million) that both benefited from substantial early stage investments. With €31 million of early stage investment during the same period, Australia also performed strongly in the BEMS VC.

Over the same period, only 8% of the total value of global private venture capital investments in late stage companies was in European companies.[219] The European share of late stage private investments has declined from 36% in 2015 to just 2% in 2019 compared to total global investment. This is due to the extensive boost in late stage private investments outside Europe (from €80 million in 2015 to €758 million in 2019) rather than decreased numbers inside Europe. The US (€1 billion), China (€814 million) and to a lesser extent Canada (€135 million) hosted the vast majority of companies benefiting from these late stage investments, illustrating their strong innovation potential and attractiveness to private investors.

Over the 2007-2012 period, the number of patent applications in the EU-28 and RoW was on the rise. However, for the 2013-2016 period patents filed in the EU-28 and RoW both experienced a downward trend. Overall, more patent applications have been filed in the RoW than in the EU-28. For the studied period, the EU-28 accounted for 29% of the overall high value patent applications. In addition, five out of the top ten countries where these patents were filed were in Europe. More specifically, Germany, France and the UK stand out in terms of number of high-value patent applications over the 2014-2016 period.

Figure 4.47 Patent applications EU-28 vs rest of the world – BEMS[220]



Source: ICF, 2020

[218] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the USA and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

[219] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details).

[220] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

Overall, there is a healthy venture market globally for both early and late-stage innovation companies, although European innovation remains largely focused on commercial buildings, where energy savings and business models are easier to scale compared to residential.

There is a large focus on advanced building automation, analytics and integrated building management (both hardware and software). In Europe, some of the emerging themes concerning innovation include Artificial Intelligence-heat management, energy-efficiency-as-a-service, and grid integration services.

Algorithms and optimisation analytics are expected to be deployed to support European companies in adapting to abrupt and significant changes in energy consumption due to the Covid-19 pandemic, adjusting for consumption anomalies, and accurately managing energy supply without interruption.

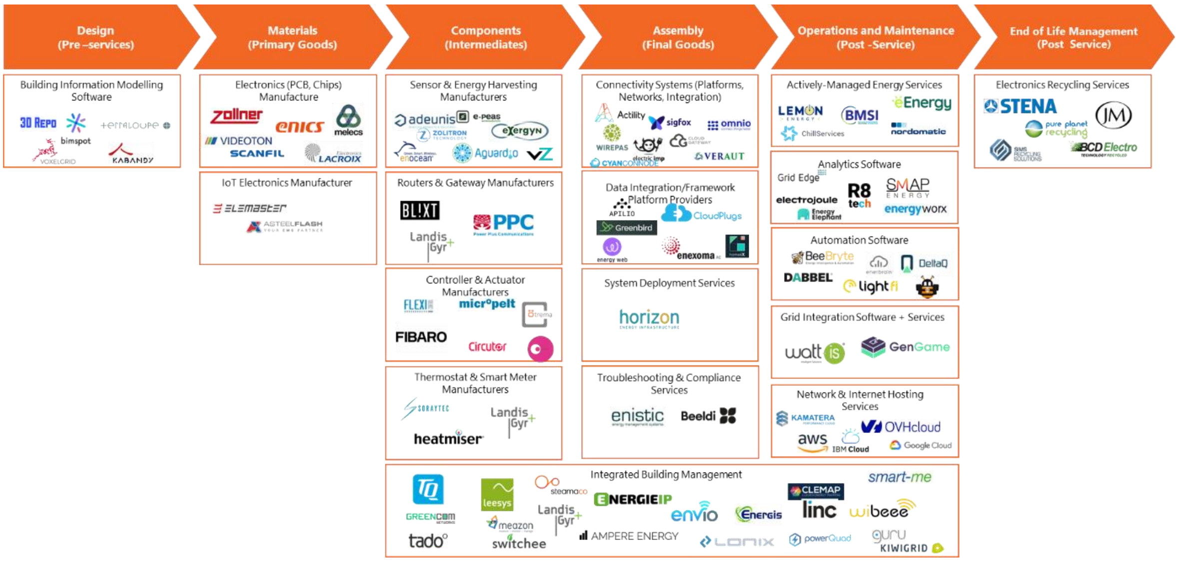
When it comes to investments, major European energy players are deploying more diversified, downstream, vertically integrated offerings, and are consequently using BEMS to strategically move into new markets. Thus, they focus on the end customer, acquisitions of smaller players, as well as general increase in investment activity.

Most of the building energy management incumbents are partnering, investing or acquiring start-ups with IP differential based on core domain expertise on advanced technology. The larger players integrate their respective technologies into broader Internet-of-Things (IoT) Platforms, where the corporates position themselves as value-adding partners and act as a market catalyst and help European innovators to accelerate global market strategy.

During the studied period, the European investment scene has transitioned from a largely venture capital led market, to a market led by corporate venture capital with corporates who are making strategic investments to optimise their own emissions. European investments are largely focused on solutions for commercial and industrial innovation.

Figure 4.48 provides an overview of some of the key European market participants across each segment of the BEMS VC.

Figure 4.48 European Key Market Participants – BEMS



Source: Cleantech Group, 2020

4.10.5 Threats and challenges – BEMS

Lack of timely transposition of EU-28 rules

EU-28 countries failed to accelerate efforts to achieve national 2020 energy efficiency targets, as some EU legislation was not fully implemented across the different Member States (as evident from the 2014 EC infringement procedures[221]) partly due to the 2008 economic crisis. This lack of timely transposition of the rules has resulted, amongst other things, in an unsatisfactory uptake of BEMS market adoption throughout Member States, as well as an overall shortfall in reaching the 2020 targets.

Financing challenges

There is currently a limited return on investment as the use of BEMS leads to marginal benefit gains, resulting in an untapped potential and lack of investments across Member States. Finding a way to incentivise investments without negatively impacting market competitiveness has been a core challenge for the BEMS market in Europe.

Supplier fragmentation

The presence of different market actors with conflicting interests, has led to widespread use of less-efficient technologies which in turn has slowed efforts to incorporate more advanced BEMS solutions in buildings across Europe. In addition, many of the sub-component manufacturers are non-European companies, on which certain European manufacturers rely heavily.

Interoperability

Fragmented, duplicative and overlapping connectivity solutions (e.g. Bluetooth, Lora, Sigfox) create problems between new and existing systems, especially for the ones manufactured outside of Europe using various technological standards.

Brexit

The UK market is one of the largest for BEMS in Europe and it is also home to the largest number of European companies in this sector. Thus, Brexit is expected to have an impact on the VC and also to reduce EU competitiveness in the BEMS VC over the short to medium turn, depending on the outcome of trade negotiations.

4.10.6 Future EU potential – BEMS

Policy support

The "Clean Energy for All Europeans" legislative package and more specifically the EPBD[222] and the EED[223] have emphasised on the need for efficient and common standards in this VC. It is expected that this VC will be supported through the transposition by each Member States of these Directives as well as the upcoming proposals under the European Green Deal.

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[221] European Commission, 2015, *Report on 2014 infringements: Commission enforces correct implementation of EU law,* Available at: https://ec.europa.eu/commission/presscorner/detail/en/IP_15_5326, [Accessed on: 24/11/2020]

[222] Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency (Text with EEA relevance), Official Journal L 156, 19.6.2018, p. 75–91. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.156.01.0075.01.ENG

[223] Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency (Text with EEA relevance), Official Journal L 328, 21.12.2018, p. 210–230. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.328.01.0210.01.ENG

The proposed European Climate Law, which would codify the EU's goal to become climate neutral by 2050 in accordance with the European Green Deal, would help to ensure buildings are more energy efficient and provides a strong opportunity for BEMS uptake. Additionally, all new buildings planned for construction after December 2020 are to be nearly zero-energy, driving need to conserve energy and utilise BEMS in a large proportion of future builds.

4.10.7 SWOT – BEMS

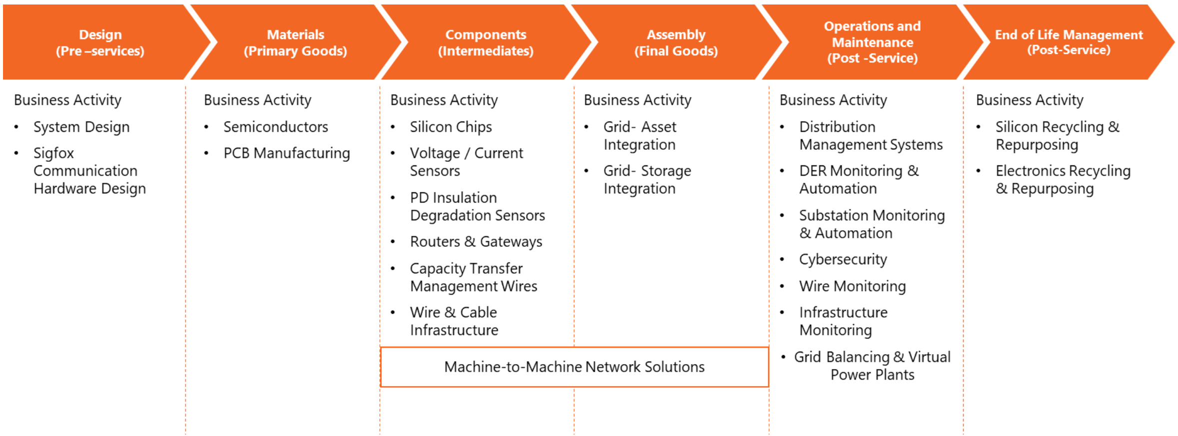
Strengths *Internal attributes, characteristics and factors that give competitive advantage to the EU in the global VC.*	**Weaknesses** *Internal attributes, characteristics and factors that weaken the competitiveness of the EU in the global VC.*
• Energy efficiency measures and policies are strongly supported by EU policy-makers and currently are one of the pillars for the upcoming proposals under the European Green Deal. • Strong national energy taxation, regulations, incentives, which drive the adoption of BEMS across a number of EU Member States. • Over the last 15 years, Europe's adoption of BEMS has a steady growth, particularly in Western Europe and in the commercial building sector. • EU-28 public investments have grown tremendously over the 2009-2018 period with a tenfold increase. • Share of investments in European companies has grown significantly in recent years.	• Not a very large VC. • Presence of different market actors with conflicting interests led to widespread use of less-efficient technologies. • Reliance by some EU companies on non-EU sub-component manufacturers. • Limited return on investment leading to untapped potential and insufficient investment opportunities in EU Member States. • Lack of timely transposition of EU rules that leads to inability to meet the set energy efficiency targets and hampers the potential opportunity for growth in this VC. • Average size of private investments in both early and late stage companies is higher outside Europe. • For the studied period more patent applications filed in the RoW than EU-28.
Opportunities *External situations and factors that can strengthen the competitive advantage of the EU or provide the EU with new sources of competitive advantage.*	**Threats** *External situations and factors that can create problems for the EU compromising its competitive advantage to a certain extent.*
• Considerable opportunities for growth in terms of market, deployment and innovation. • EU level policy (i.e. the European Green Deal) and the proposed Climate Law have positioned the EU for an increased BEMS focus over North America and Asia. This could result in a major boost to the competitiveness of this VC. • Major EU energy players are utilising BEMS to strategically move into new markets. • Most BEMS incumbent suppliers are partnering, investing or acquiring innovative start-ups in this VC. • Algorithms and optimisation analytics are expected to be deployed to support EU companies in adapting to abrupt and significant changes in energy consumption due to the Covid-19 pandemic.	• Fragmented, duplicative and overlapping connectivity solutions with insufficient common standards hamper the wider uptake of BEMS solutions. • The UK market is one of the largest in Europe and as many of the European companies are headquartered there, the outcome of post-Brexit trade negotiations could impact this VC and EU competitiveness in this sector.

4.11 Grid Energy Management Systems

4.11.1 Scope of the VC – Grid EMS

The scope of the Grid EMS VC covers digital integrated systems to manage, coordinate, monitor and control utility-connected grids for the efficient transmission and distribution of electricity. The analysis includes hardware and software operating on transmission and distribution networks, communication hardware, distributed energy resource management devices as well as power and Volt/VAR control systems. However, this VC does not include smart meters, inverters, other on-building energy systems (e.g. plug loads), demand response or grid edge technologies (many of these are already included in the BEMS VC). The structure of the Grid EMS VC split by segment of activity is presented in Figure 4.49.

Figure 4.49 Grid EMS VC Structure



Source: Cleantech Group, 2020.

4.11.2 European market overview[224] – Grid EMS

In Europe, better incorporation of variable renewable energy sources in the electricity mix and increased electrification have driven consistent investments in the grid, totalling nearly €43 billion in 2019[225], with rising expenditures allocated to upgrading and refurbishing the existing grid. It is estimated that annual investments of €95 to €145 billion would be needed in the power sector in 2021-2050 period to enable a transition to a low carbon energy supply by 2050[226]. This includes both investments in electricity generation (€54 to €80 billion per year), electricity transmission and distribution grids (€40 to €62 billion per year), and additional investments in storage and demand response[227].

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[224] Note: When this document refers to "Europe" it includes all countries that are part of the European single market – this covers the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. In some cases, the data is extracted at aggregated EU-28 or EU-27 level. Datasets, reports and information that was extracted for the period before 2018, refers to the EU-28 and includes the UK in the analysis.

[225] IEA, 2020, *Smart Grids*, IEA Paris, Available at: https://www.iea.org/reports/smart-grids

[226] Van Nuffel, L., Rademaekers, K., Yearwood, J., and Graichen, V., 2017, *European Energy Industry Investments*, prepared for the European Parliament's Committee on Industry, Research and Energy (ITRE) by Trinomics, IP/A/ITRE/2013-046, PE 595.356, Available at: http://trinomics.eu/wp-content/uploads/2018/05/European-energy-industry-investments.pdf

[227] Van Nuffel, L., Rademaekers, K., Yearwood, J., and Graichen, V., 2017, *European Energy Industry Investments*, prepared for the European Parliament's Committee on Industry, Research and Energy (ITRE) by Trinomics, IP/A/ITRE/2013-046, PE 595.356, Available at: http://trinomics.eu/wp-content/uploads/2018/05/European-energy-industry-investments.pdf

Some of the important and largest European associations that represent this VC include amongst others smartEn[228] dealing with smart grids, E.DSO[229] representing a large number of European distribution operators, ENTSO-E[230] representing the transmission system operators, and Eurelectric[231] representing the power industry. The European Technology & Innovation Platform Smart Networks for Energy Transition (ETIP SNET) also plays an important role in guiding RD&D to support Europe's energy transition.

In addition, BRIDGE, an EC initiative which is funded under Horizon 2020, was established in November 2015 as a cooperation group for all low carbon energy (LCE) Smart-Grid and Storage projects funded under Horizon 2020.[232] Its associated projects have seen €237 million of European investment since the group was established.

Innovation in smart and connected grid technologies has historically prioritised system efficiency developments or improvements to meet renewable energy standards. However, the prevalence of connected grid technologies has given more choice to customers, and the market began to shift towards technologies to bring in more customer participation in recent years. Reliability through interoperability have become a primary value proposition.

New technologies in the smart grid space created a learning curve amongst both project installers and end users of distributed energy resources (DERs). For instance, in Denmark, SEAS-NVE[233] resolved this issue in the previous decade by training installers on how to handle customer complaints, remote monitoring and automation of Distributed Energy Resource (DER) assets are now reducing the gaps between utilities and customers.

In addition, it is expected that cyber and grid security will see a more central role in European energy grid planning and upgrades in coming years. In early 2019, the EC issued a recommendation[234] that energy network operators should work to increase the cybersecurity of the grid by using the latest technology when building new infrastructure and try to upgrade older systems with new security technologies, operators were required to submit their implementation plans within 12 months.

Western European nations are expected to invest €112 billion in smart grid infrastructure by 2027 through investments in battery storage, and distribution automation.

When compared to the rest of the world, new grid projects and grid upgrades have been slowing down in China, dropping 11% in 2019, largely as a result of grid reform to encourage private investment in distribution networks which continues, albeit at a slower pace. Reforms began in 2015 and 400 pilot projects were initially approved, but only 100 are currently in development.

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[228] Smart Energy Europe (SmartEn), 2020, Available at: https://smarten.eu/

[229] European Distribution System Operator (E.DSO), 2020, Available at: https://www.edsoforsmartgrids.eu/

[230] European Network of Transmission System Operators for Electricity (ENTSO-E), Available at: https://www.entsoe.eu/

[231] Eurelectric, 2020, Available at: https://www.eurelectric.org/

[232] BRIDGE is a European Commission initiative which unites Horizon 2020 Smart Grid, Energy Storage, Islands, and Digitalisation Projects to create a structured view of cross-cutting issues which are encountered in the demonstration projects and may constitute an obstacle to innovation. Source: https://www.h2020-bridge.eu/

[233] SEAS-NVE, 2020, Available at: https://www.seas-nve.dk/eng

[234] European Commission, 2019, Commission Recommendation of 3.4.2019 on cybersecurity in the energy sector, C(2019) 2400 final, Available at: https://ec.europa.eu/energy/sites/ener/files/commission_recommendation_on_cybersecurity_in_the_energy_sector_c2019_2400_final.pdf

The US overtook China in 2019 to lead grid investment (12% increase) for the first time in ten years. However, the US is unlikely to see major government support for smart grids in the coming years, as President Donald Trump dissolved the National Institute of Standards and Technology (NIST) Smart Grid advisory committee in 2019 as a part of federal budget cuts. The appointment of President-elect Joe Biden in November 2020 might however change this situation.

According to the latest report by the IEA, globally spending on digital grids now makes up nearly a fifth of networks investment, this upward trend can be observed for the 2014-2019 period[235]. As grids are becoming more digital, decentralised and smart, investment depends less on traditional equipment and more on new drivers such as smart meters, secure telecommunication infrastructure with higher bandwidth to facilitate network automation and control, and EV charging infrastructure.

Due to the Covid-19 pandemic, globally energy investment is set to fall by one-fifth in 2020 or almost €338 billion – in capital spending compared with 2019[236]. This is mainly due to reduced economic activity that in turn resulted in reduced fuel supply, rather than a reduction in investments in the power sector (generation and grid). Europe's estimated decline in investments is around 17%, with investments in electricity grids, wind and efficiency holding up better than distributed solar PV and oil and gas, which see steep falls.[237]

4.11.3 European industry size and VC – Grid EMS

Based on the analysis of the sample of companies tracked by the Cleantech Group, 30% of the active companies in the Grid Energy Management Systems VC are headquartered in Europe with a strong concentration in the UK (27% of all companies in Europe) and Germany (12%).[238]

Over the 2009-2018 period, the production value of the Grid Energy Management Systems VC across the EU-28 increased by 42% to reach €12.06 billion in 2018. For this period, Germany and the UK jointly accounted for more than half of the EU-28 production. For the same period, EU-28 exports to the RoW have increased significantly from €3.76 billion to €8.68 billion, illustrating the strong position of EU-28 companies in this VC. On the other hand, imports also increased but at a slower rate from €1.07 billion in 2009 to €3.55 billion in 2018. From 2016 to 2018, the EU-28 share of global exports remained at around 15%. Germany (€32 billion) was the leading global exporter during that period in front of key competitors such as China (€21 billion), the US (€15 billion), Mexico (€10 billion) and Japan (€8 billion). Additionally, three out of the top five global importers were EU countries. The US was the largest importer followed by Germany, China and Mexico.

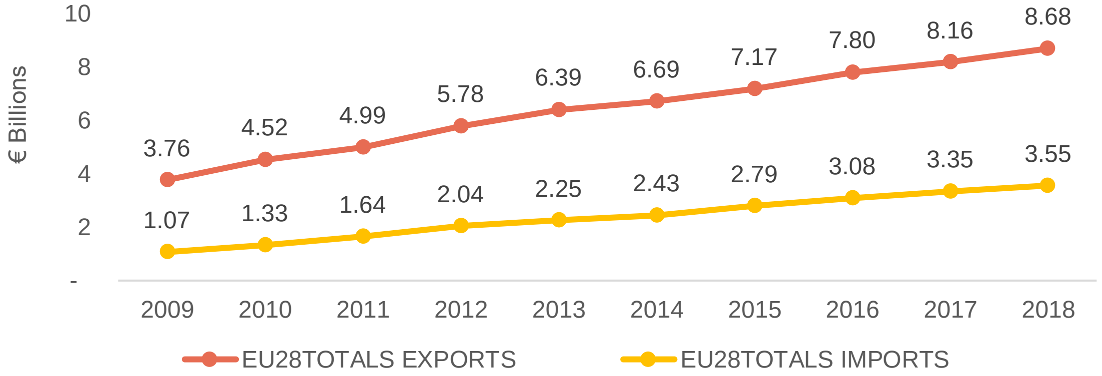
[235] IEA, 2020, *World Energy Investment 2020*, IEA Paris, Available at: https://www.iea.org/reports/world-energy-investment-2020

[236] IEA, 2020, *World Energy Investment 2020*, IEA Paris, Available at: https://www.iea.org/reports/world-energy-investment-2020

[237] IEA, 2020, *World Energy Investment 2020*, IEA Paris, Available at: https://www.iea.org/reports/world-energy-investment-2020

[238] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the US and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

Figure 4.50 Total EU-28 Imports & Exports – Grid EMS[239]



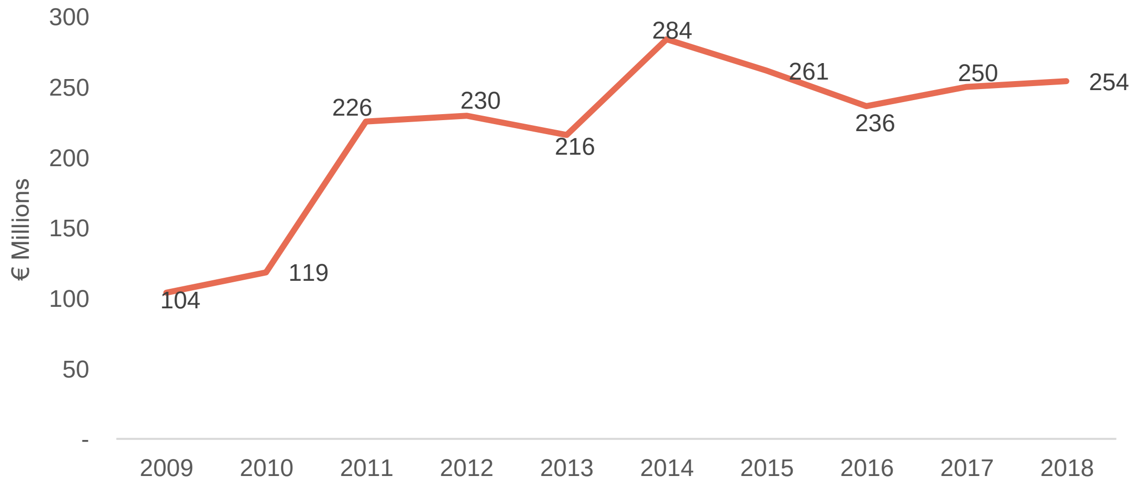
Source: ICF, 2020

Between 2009 and 2018, the EU-28 trade balance remained positive with an increasing trend. Member States with the higher positive trends included Germany, Romania and Hungary; those with the lower negative trends were the UK, Spain and Finland. Both Hungary and Poland had an improving trade balance. Germany and the UK exported to both EU-28 Member States and non-EU-28 countries.

4.11.4 Innovation and investment in RD&D – Grid EMS

The data on public investment in RD&D is available for a limited group of countries covered by the IEA. EU-28 public investment increased from €104 million in 2014 to €254 million in 2018. Of the countries for which the IEA has data, Germany was by far the largest investor, followed by Canada and the US.

Figure 4.51 EU-28 Public RD&D Investments in the Grid EMS VC[240]



Source: ICF, 2020

Over the 2015-2019 period, 27% of the total value of global private venture capital investments in early stage companies active in the Grid Energy Management Systems VC

[239] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

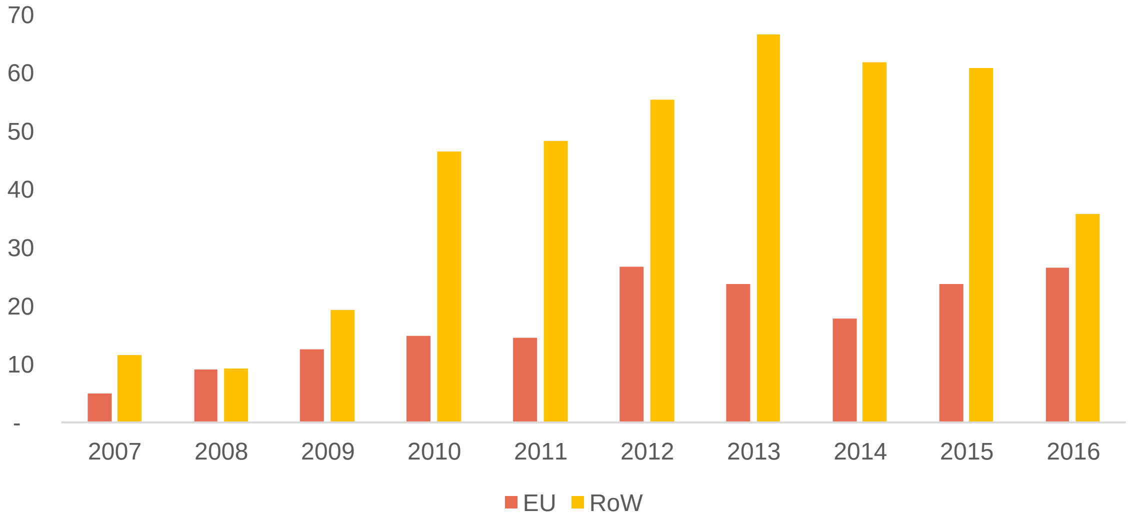
[240] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

was in European companies.[241] When assessing the number of investments, this percentage grows to 43%, suggesting that the average size of investments was higher outside of Europe. The VC saw over 150 investments during that period for a total of €477 million, showing a very active market in terms of innovation and appetite from venture capitalist investors. In Europe, the UK (€74 million) and Germany (€19 million) stand out in terms of total size of investments in early stage companies over the studied period but both remain behind the US that benefited from close to 50% of these early stage investments (i.e. €235 million during 2015-2019). China and Israel also performed very well in terms of early stage investments attracting respectively €66 million and €27 million.

In terms of late stage investments in innovative companies, Europe attracted 23% of the total value of global late stage investment tracked by the Cleantech Group.[242] The volume (€3.5 billion) and number (167) of late stage investments confirm the dynamism of this VC at a global level. At the European level, France (€368 million), Germany (€218 million) and the UK (€208 million) were the leaders, but were largely outperformed by the US (€2 billion) and to a lesser extent China (€398 million). Additionally, Israel attracted €233 million in terms of late stage investments.

For the 2007-2016 period, more patent applications were filed in the RoW than in the EU-28. During that period, 29% of the high-value patents applications were submitted in the EU-28. While six out of the top ten countries where these patent applications were filed are in the EU-28, Japan and the US lead this ranking.

Figure 4.52 Patent applications EU-28 vs rest of the world – Grid EMS[243]



Source: ICF, 2020

When it comes to European funded research for RD&D, one of the most important contributions comes from the Horizon 2020 and the Horizon Europe Framework Programme. Under Horizon 2020, nearly €6 billion has been allocated to research and innovation in the area of energy, with approximately €700 million allocated to projects in the

[241] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the USA and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

[242] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details).

[243] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

field of Smart grids, Storage and Energy systems during the period 2014-2020 (WP2014-2015: €239 million, WP2016-2017: €166 million, WP2018-2019: €174 million).

Some of the recent developments in this VC include new opportunities emerging around grid-integrated storage, as Europe moves to create a more resilient and responsive grid that is able to cope with the intermittent renewable generation and changing demand. Projects in Germany and France are actively evaluating how storage can be an asset for electricity grids.

Substation automation software is becoming a primary tool for utilities to close efficiency gaps, especially in grids that increasingly incorporate variable generation from renewables. Digital twin technologies are providing new means of substation monitoring, diagnostics and prognostics to optimise asset performance and prevent downtime.

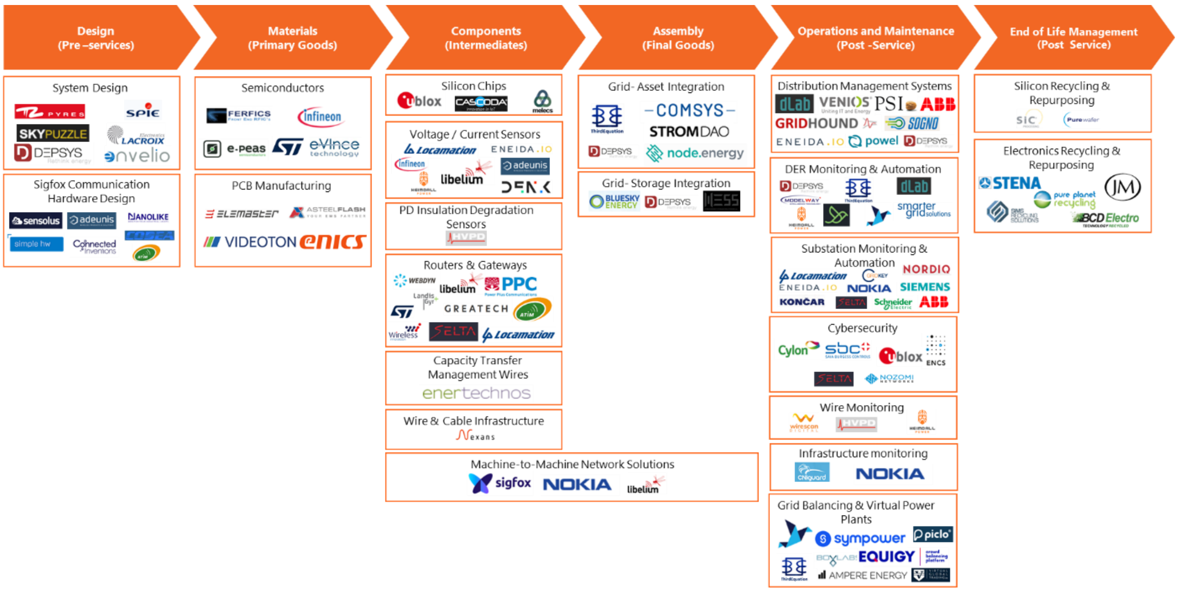
Buyers of DERs in the previous decade had fears of “lock-in” when procuring systems, concerned that they would not be able to switch utility service providers. New European policies coupled with innovations in grid balancing services and virtual power plants, not only offer new markets to grids, but enable customers to become prosumers and actively participate in the market.

High Voltage Direct Current (HVDC) projects are being planned in Germany, linking offshore wind reserves in the North Sea to high population zones in the South. Also, work has already begun on the France-Italy link which cuts beneath the Alps. All of these projects are designated as European Projects of Common Interest (PCIs) and are eligible for European funding through mechanisms such as the Connecting Europe Facility (CEF).

Corporates with significant and sustained investment in grid connectivity and digitalisation are beginning to see tangible results. In just ten years, Enel reduced the System Average Interruption Duration Index (SAIDI, an indicator of grid quality) by 65%, and it is currently spending nearly one-third of its investment budget on digital technology.

Figure 4.53 provides an overview of some of the key European market players, divided by segment of the Grid Energy Management Systems VC.

Figure 4.53 European Key Market Participants – Grid EMS



Source: Cleantech Group, 2020

Utilities around the world have indicated they are increasingly adopting sophisticated software tools. Utilities and grid companies in Europe (Iberdrola, Enel, RTE and E.ON) and in the US (Exelon, Duke and Edison International) reported record spending on software in 2019. Additionally, utilities are investing in telecommunication technology, viewing the digitalised grid as an end-to-end interaction system with customers. –The German regional utility RWE is for example currently working with Deutsche Telekom to link a million households in the north of the country to fast broadband connections by 2026.

4.11.5 Threats and challenges – Grid EMS

Congestion management costs

Costs for congestion management have increased in recent years. According to some European TSOs initiatives to provide flexibility at a time when solar and wind are decreasing in price have led to decreased revenue, making it challenging to keep reinvesting in upgrades and innovations. For instance, Germany spent €1.4 billion in 2017 to curtail 10,200 GWh of wind and match with storage.[244]

Changing business models

Grid charges, slow permitting for larger grid projects, and dated business models have a large impact on the abilities of grid companies to invest and innovate. The traditional business model of grid companies is, by and large, dominated by the assets employed and the revenue streams secured under antiquated rate-of-return regulation.[245] However, the increasing penetration of renewables, new digital focused players, aggregators, decentralised digital platforms, new algorithms, artificial intelligence and the IoT are unleashing new sources of value and disrupting the traditional asset based grid business models.[246] This represents both a threat and an opportunity for actors in this VC.

Cyber Security

Increased digitalisation of assets and expanded touchpoints with customers have made the grid more vulnerable to cyber-attacks, leaving some end users sceptical of the long-term benefits of usage. The proliferation of the smart grid and Internet of Things (IoT) has "*led to the deployment of billions of networked sensing devices, increasingly further out to the grid edge. This paradigm shift has led to unprecedented data collection, network visibility, and situational awareness, it has also drastically increased vulnerability*"[247]. While some estimates state that global smart grid cybersecurity spending will reach €2.7 billion by

[244] Simon, F., 2019, *As wind and solar power rise, EU seeks more grid 'flexibility'*, Euractiv, Available at: https://www.euractiv.com/section/energy/news/as-wind-and-solar-power-rise-eu-seeks-more-grid-flexibility/, [Accessed on: 24/11/2020]

[245] Glachant, J., 2019, *New business models in the electricity sector*, EUI RSCAS, 2019/44, Florence School of Regulation, Energy, Electricity, European University Institute Research Repository, Available at: http://hdl.handle.net/1814/63445;

Sioshansi, F., 2019, *New Electricity Business Models*, Energy Central, Available at: https://energycentral.com/c/gr/new-electricity-business-models-heavy-light-and-ghost

[246] Rosetto, N., Dos Reis, P., Glachant, J., 2019, *New business models in electricity: the heavy, the light, and the ghost*, Policy Briefs, 2019/08, Florence School of Regulation, Energy, Electricity, European University Institute Research Repository, Available at: http://hdl.handle.net/1814/63464

[247] Nhede, N., 2017, *Grid automation drives increase in utility cybersecurity investments – report*, Smart Energy International, Available at: https://www.smart-energy.com/industry-sectors/smart-grid/cybersecurity-technologies-navigant-research/, [Accessed on: 24/11/2020]

2026[248] this spending might be inadequate to curb the risks of the biggest threat to modern grids[249].

Data ownership

Adaptation to changes in data ownership regulations may not have yet caught up. In the EU, the customer owns their data, and recent energy regulations give them more control over that data, some data will be critical to utilities' prediction of demand and flexibility.

Regulation

Currently, policies do not fully support utility-side innovation. Many regulatory regimes reward cost savings, whereas smartening the grid often produces other qualitative or softer benefits (e.g. enabling other technology or business models; reducing emissions; creating jobs) that cannot be easily rate-based. In the UK for example, the regulatory framework (RIIO) rewards companies that innovate by offering incentives to encourage the growth of smart grids.[250]

International regulation

A new US Presidential executive order banning many foreign-supplied transmission grid devices could harm European company's export markets.[251]

Brexit

The UK market is one of the largest in the Europe and it is also home to a large amount of innovators and developers in this sector. Depending on the outcome of the negotiations Brexit could reduce the competitiveness of the EU in the Grid Energy Management Systems VC for the short to medium term,.

However, Brexit is not expected to slow down interconnectivity. In 2019, the share of electricity transmission Projects of Common Interest (PCIs) between the EU and the UK that were either on schedule or ahead of schedule increased for the second year in a row despite the uncertainty around the future arrangement of the internal electricity market following Brexit. Future European potential

4.11.6 Future EU potential – Grid EMS

Policy support

The implementation of the "Clean Energy for All Europeans" legislative package is expected to have an impact on the energy market and the Grid Energy Management Systems VC by

[248] Nhede, N., 2017, *Grid automation drives increase in utility cybersecurity investments – report*, Smart Energy International, Available at: https://www.smart-energy.com/industry-sectors/smart-grid/cybersecurity-technologies-navigant-research/, [Accessed on: 24/11/2020]

[249] Unwin, J., 2019, *Energy companies need to do more on cybersecurity: Report*, Power Technology, Available at: https://www.power-technology.com/news/inmarsat-research-programme-cybersecurity-report/, [Accessed on: 24/11/2020];

Butler, N., 2018, *Why cyber attack is the biggest risk for energy companies*, Financial Times, Available at: https://www.ft.com/content/109350ea-c6f2-11e8-ba8f-ee390057b8c9, [Accessed on: 24/11/2020]

[250] Ofgem, 2010, *RIIO - a new way to regulate energy networks*, Available at: https://www.ofgem.gov.uk/ofgem-publications/64031/re-wiringbritainfspdf#:~:text=RIIO%20stands%20for%20Revenue%3DIncentives,fail%20to%20deliver%20for%20consumers, [Accessed on: 24/11/2020]

[251] The White House, 2020, *President Donald J. Trump Executive Order on Securing the United States Bulk-Power System*, Available at: https://www.whitehouse.gov/presidential-actions/executive-order-securing-united-states-bulk-power-system/, [Accessed on: 24/11/2020]

emphasising the importance of digitalisation in the next generation of grid systems. It is expected that this VC will be well supported in the future given the upcoming legislative proposals needed to deliver the climate neutrality objective.

The EU has implemented 10% of interconnection of grid infrastructure (all EU Member States must have transmission systems in place capable of carrying electricity across borders to neighbouring countries, and vice versa) capacity by 2020, which will rise to 15% by 2030. HVDC projects are underway to meet this need and will require an increase in remote management and automation technologies to manage the new interconnections between variable sources of power.

Funding support

Reliable flexibility trading is a priority to ensure citizen participation in new energy markets, which is one of the main focuses of the energy market policies of the “Clean Energy for All Europeans” legislative package. To this end, the EC would support projects setting up markets and platforms to procure energy services through a combination of local markets (congestion management) and wholesale & balancing markets. This is largely expected to have a positive impact on this VC.

4.11.7 SWOT – Grid EMS

Strengths *Internal attributes, characteristics and factors that give competitive advantage to the EU in the global VC.*	**Weaknesses** *Internal attributes, characteristics and factors that weaken the competitiveness of the EU in the global VC.*
• Well represented VC with strong developers, innovators, utilities, grid companies and their respective European associations. • Key VC for the energy transition and incorporation of larger amounts of renewables in the European grid. • Expected growth in this market both in terms of production value and grid investments. • Over the 2009-2018 period, production value of EU-28 countries increased by 42%. • For the same period, EU-28 trade balance remained positive with an increasing trend. • EU-28 exports to RoW have increased significantly while imports have but at a slower rate. • From 2014 to 2018 EU-28 public investment has more than doubled.	• Current policies do not fully support utility-side innovation and instead reward cost savings, while smartening the grid is often overlooked • Costs of deploying modern digital solutions for grid management have been on the rise and correct estimations have been difficult for governments. • Due to the energy transition, costs for congestion management have increased in recent years. • Increasing grid charges, slow permitting for larger grid projects, and dated business models have a large impact on the abilities of grid companies to invest and innovate. • In the 2007-2016 period, more patent applications were filed in RoW than EU-28.
Opportunities *External situations and factors that can strengthen the competitive advantage of the EU or provide the EU with new sources of competitive advantage.*	**Threats** *External situations and factors that can create problems for the EU compromising its competitive advantage to a certain extent.*
• Strong EU policy that is expected to continue with future proposals of the European Green Deal. • European and national funding support is expected to continue with future RD&D opportunities.	• Smart grids, digitalisation and IoT systems also being increased cybersecurity risks. • New US legislation banning foreign-supplied grid devices could have a negative impact on EU exports to this market. • UK market is one of the largest in Europe and it is also home to many innovators and

• Horizon 2020 provides strong RD&D support and future Horizon Europe expected to continue this trend. • European corporates with significant and sustained investment in grid connectivity and digitalisation beginning to see tangible results. • Opportunities in cross technology cooperation with non-energy players (e.g. telecom technologies), synergies and M&As.	developers in this sector. Post Brexit, this is likely to impact the VC. However, this issue is not expected to slow down interconnectivity.

4.12 Hydrogen Production

4.12.1 Scope of the VC – Hydrogen Production

The scope of the Hydrogen Production VC aims to cover sustainable production hydrogen, including hardware and processes for non-carbon-based production. This includes hardware, systems, components and processes for production including mature electrolysis (EL) technologies (Alkaline (AE), Proton Exchange Membrane (PEM), Anion Exchange Membrane (AEM), Solid-Oxide (SO)), as well as emerging novel solutions (Photo Electrochemical, Biogas/Biomass (microbial, bio gasification), Plasmalysis, Plasmolysis, Non-membrane EL, and Pressurized EL). The basis for this definition relates to the future opportunity for clean hydrogen production as a key element for the EU to achieve climate neutrality.

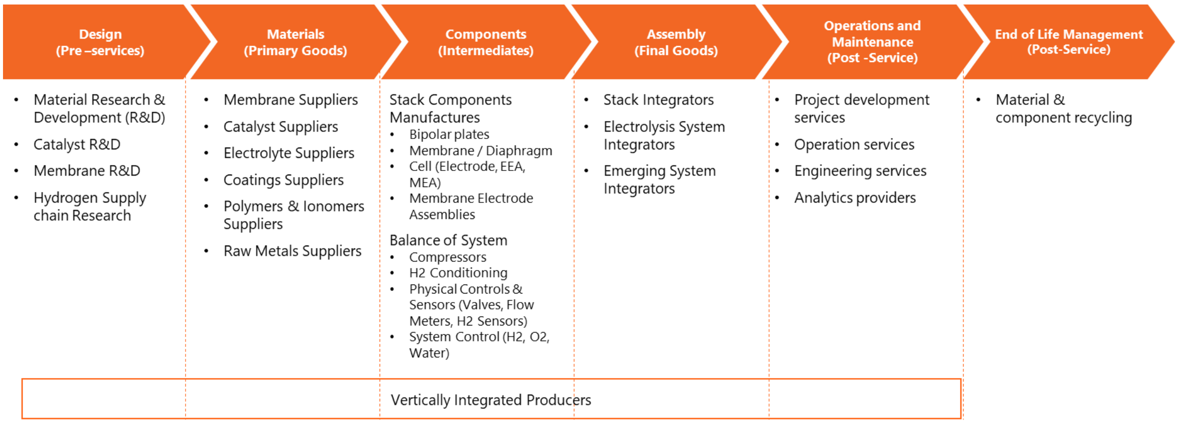
Consequently, this VC does not cover power supply and power electronics, thermal management components, plant operators, coal gasification and gas reformer developers / integrators.

While the scope of the VC allows for an analysis of a number of specific clean hydrogen aspects, such as patents, private investment, etc., there are major difficulties in drawing strong conclusions around production and trade because the market has been historically dominated to date by 'grey' (i.e. fossil-fuel derived) hydrogen, mainly produced using Steam Methane Reformation (SMR).

One of the other limitations for this VC is the overlap with parts of other VCs (integrated processing, compression, deployment), because some players are cross-cutting (e.g. some hydrogen production system integrators also work in integration fuel cells, hydrogen storage etc).

The structure of the Hydrogen Production VC split by segment of activity is elaborated in Figure 4.54.

Figure 4.54 Hydrogen Production VC Structure



Source: Cleantech Group, 2020.

4.12.2 European market overview[252] – Hydrogen Production

In Europe, the historical importance for the development of this VC has been the deployment of alkaline electrolysers, due to market demand for hydrogen for fertiliser manufacturing. Europe has several strong electrolyser manufacturers, across different countries, and now has a diverse, large player base. Around 50% of electrolyser manufacturers globally are in Europe. The hydrogen production VC is well represented in Europe with a strong and active association – Hydrogen Europe.

Since 2008, the European Fuel Cells and Hydrogen Joint Undertaking (FCH1JU and FCH2JU) public-private partnerships, under the Horizon 2020 framework, have proven efficient in developing hydrogen production technologies, however technologies did to reach high technology readiness level (TRL) for large-scale deployment yet.

When it comes to policy-making, the tightening of emission regulations and other European policies (e.g. the overhauled Renewable Energy Directive (REDII), CERTIFHY etc.) have driven initial development for green hydrogen production as an energy vector for decarbonising energy use across different industries.

Globally, low carbon and renewable hydrogen is not yet available cheaply and at the required scale. This can be directly linked to the cost of renewable energy, electrolysers and other low carbon production technologies. The capital expenditure for EU electrolysers, for example, sits at 45% of the total cost per kilogram of hydrogen. Opportunities remain for further innovations and large-scale project deployments to help bring down the overall levelised costs of clean hydrogen production. The Innovation Fund (EU ETS financing mechanism) offers a significant potential boost to help prospective industrial consortia to make key investments linked to renewable power production.

Europe had a hydrogen production investment spike around 2012-14, but interest stalled due to the high cost of renewables technology. Although Europe has historical competency across the hydrogen supply chain, from fundamental RD&D to systems design and applied engineering, "clean" hydrogen remains limited in the European energy mix (since it is predominantly demonstration scale projects), and hydrogen production currently is still largely produced from fossil fuels (i.e. as "grey" hydrogen).

When it comes to the rest of the world, Japan, the US, Canada and the South Korea have strong market competence, driven by early movements in the hydrogen fuel cell market. This happened through policies such as the Clean Energy Manufacturing Initiative in the US, the New and Renewable Energy Portfolio Standard in South Korea and the Ene-Farm programme in Japan. In addition, China is making rapid scaling manufacturing and has strong fundamental science, but more applied research lags the regions mentioned above.

4.12.3 European industry size and VC – Hydrogen Production

When it comes to manufacturing power, 37% of active companies in the hydrogen sector are headquartered in Europe.[253] In addition, seven out of the top ten countries where these

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[252] Note: When this document refers to "Europe" it includes all countries that are part of the European single market – this covers the 27 Member States of the European Union, Iceland, Norway, Lichtenstein, the UK and Switzerland – whenever data is available for them. In some cases, the data is extracted at aggregated EU-28 or EU-27 level. Datasets, reports and information that was extracted for the period before 2018, refers to the EU-28 and includes the UK in the analysis.

[253] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the USA and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

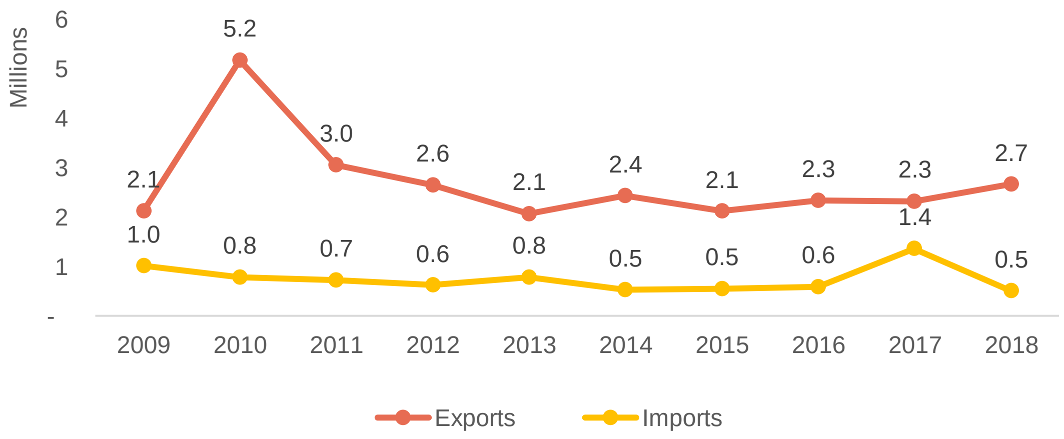
companies are located are European. More specifically, the share of companies in Europe, are mainly centred in the UK (20%) and France (28%).

Between 2009 and 2018, the annual production value of (mainly grey) hydrogen in the EU-28 has remained steady around €1.2 billion with a peak in 2011/2012 at €1.6 billion. Germany and the Netherlands jointly account for around half of the EU-28 production in 2018. Current production codes prevent a split of hydrogen production into 'grey' and 'clean' rendering it difficult to ascertain how significant the different aspects of this market are.

Indeed, this complexity of the hydrogen production market also means that any analysis of imports and exports suffers from the same lack of granularity and definition. That being said, the overall significance of this market is minimal, since it focuses solely on trade in hydrogen gas and not the production technology itself. Therefore, for the 2009 to 2018 period, EU-28 exports to the RoW have increased from only around €2.1 million in 2009 to €2.7 million in 2018, with a peak in 2010 of around €5.2 million. Imports have slowly decreased by 50% from €1 million in 2009 to €0.5 million in 2018. The EU-28 share of global exports has remained at 2% from 2016 to 2018, with top EU-28 exporters being the Netherlands, Belgium and Germany.

Between 2016 and 2018, six out of the top ten global exporters were European countries. Key competitors are Canada and the US. For the same period eight out of the top ten global importers were European. US is the largest importer, followed by Belgium, France and Netherlands.

Figure 4.55 Total EU-28 Imports & Exports – Hydrogen Production[254]



Source: ICF, 2020

Between 2009 and 2018, the EU-28 trade balance has remained positive with a peak in 2010 around €4.38 million and after that it has a declining trend. The countries with the higher positive trends were the Netherlands, Slovakia, and Hungary, while the ones with the lower negative trends were France and Belgium. The Netherlands exported mostly to other EU-28 countries while Belgium, the largest EU-28 importer, has imported mostly from within the EU-28.

[254] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

Currently, hydrogen costs are at €5-8/kg for water electrolysis and need to reach €1.5-3/kg to be competitive with conventional fuels for transport, amongst other applications, once a 2030 carbon price is considered.

Hydrogen Valleys, which seek to deploy, in a coordinated manner, entire systems across the VC, will impact future EU competitiveness by proving the technical and economic readiness of a hydrogen ecosystem, including production, distribution and storage, and final use.

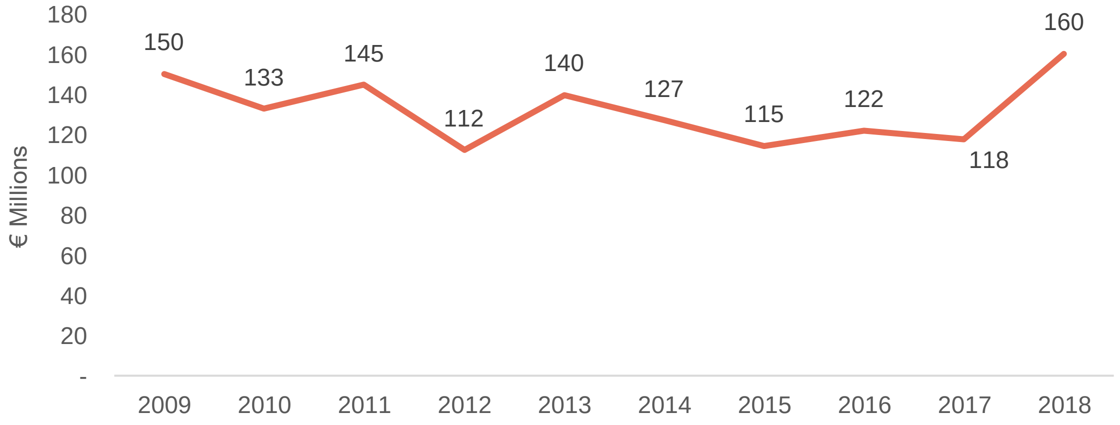
Existing funding mechanisms, including CEF Transport and Energy will support the VC with €8.7 billion investment into the EU hydrogen sector and will be required to scale hydrogen production market. Under specific conditions, project beneficiaries from the Innovation Fund could combine their award with that of CEF in order to achieve more ambitious deployment objectives.

The pace at which China's export market grows may largely impact effectiveness of the future European market. Long-term success of the European hydrogen supply chain is expected to be largely based on progress of non-European states growing their domestic demand.

4.12.4 Innovation and investment in RD&D[255] – Hydrogen Production

The data on public investment in RD&D is available for a limited group of countries covered by the IEA. Over the 2009-2018 period, EU-28 public investment has remained relatively stable with an increase in 2018 compared to the years before. Out of the countries for which the IEA has data, Japan is by far the largest investor, followed by France and Switzerland. In addition, six out of the top ten countries where these investments happened are in Europe.

Figure 4.56 EU-28 Public RD&D Investments in the Hydrogen Production VC



Source: ICF, 2020

Over the 2014-2019 period, 14% of the total value of global private venture capital investments in early stage companies was in European companies.[256] When assessing the

[255] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

[256] According to the analysed data from the Cleantech Group's database (see section 3.2.2 for more details). The Cleantech Group investment database is global. However, while there is confidence regarding the coverage of VC investments in the USA and the EU, data from emerging markets (notably China) can be underestimated due to this information not being made public.

number of investments, this percentage decreases to 13%, suggesting that the average size of investments was slightly higher in Europe.

The share of investments in European companies has increased significantly in recent years. Especially after 2015 when investment value grew from €2 million to €20 million in 2019, similarly the RoW also had a tenfold increase in investments from €11 million (2015) to €112 million (2019). Furthermore, three out of the top eight countries where these investments happened are in Europe. Specifically, Germany stands out in terms of total size of investments in early stage companies over the studied period.

Over the 2015-2019 period, 9% of the total value of global private investments in late stage companies was in European companies.[257] When assessing the number of investments, this percentage increases to 20%, suggesting that the average size of investments was higher in the RoW. The data for share of investments in European companies is not available for some of the years. However, the investment value in 2019 was €52 million, whereas the investment in the RoW has increased tenfold between from €27 million in 2016 to €288 million in 2019. Three out of the top five countries where these investments happened are in Europe. More specifically, Germany (number) and France (number) stand out in terms of total size of investments in late stage companies for the 2015-2019 period.

Globally, after a post-2014 drop off, investment into hydrogen start-ups accelerated. The record was in 2019 with €430 million invested over 42 deals. Despite the presence of venture capital investors in the space, there is an increasing roster of global and European corporates (e.g. oil and gas majors, steel manufactures, industrial asset owners) strategically investing, who see hydrogen as a key part of their long-term decarbonisation strategy.

European equity investment into hydrogen production start-ups amounts to €108 million, which accounts for 33% of global investments in the segment.

European equity investment into hydrogen storage start-ups is around €181 million, accounting for 70% of global investment into the segment. The German-based Hydrogenious LOHC Technologies is the major successful innovator in Europe, raising €103 million equity funding over the space of seven years.

European equity investment into hydrogen processing start-ups is at €4.2 million, with most investment coming out of North American innovators, totalling €53 million in equity funding.

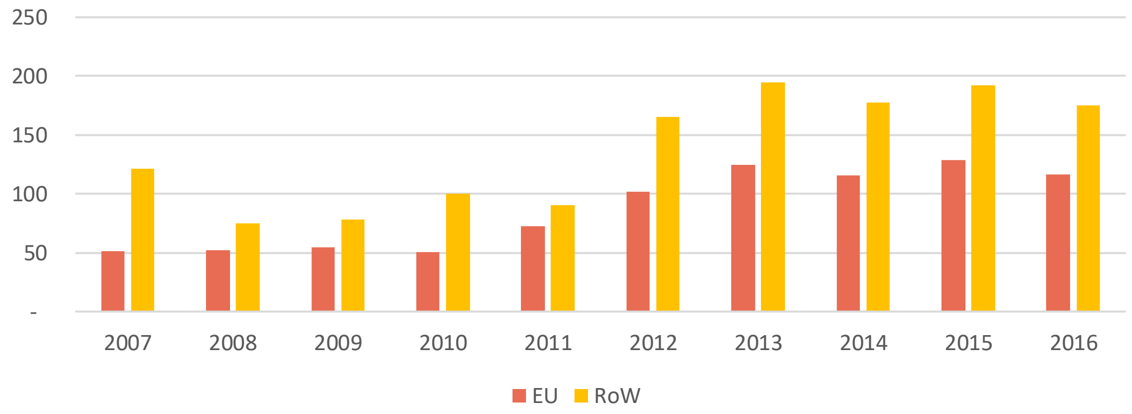
European equity investment into hydrogen infrastructure start-ups amounts to €32 million, accounting for 5% of the total segment funding. Investments into US-based Nikola Motor, have driven recent investments in the segment, with plans to deploy 700 hydrogen fuelling stations across Europe and the US.

European equity investment into hydrogen utilisation start-ups has reached €109 million, which can be largely attributed to the high volume of venture investment into European fuel cells innovators back in 2012-2014.

Over the 2007 – 2016 period, the number of patent applications has increased in both the EU-28 and RoW. Over this period, the EU-28 accounted for about 40% and RoW for 60% of the patent applications. Furthermore, four out of the top ten countries where these patent applications happened are in Europe, where France (number) and Germany (number) stand out in terms of number of high-value patent applications over the 2014-2016 period.

[257] According to the analysed data from the Cleantech Group’s database (see section 3.2.2 for more details).

Figure 4.57 Patent applications of Hydrogen Production VC EU-28 vs rest of the world[258]



Source: ICF, 2020

In addition to electrolysis, there is a range of emerging European hydrogen production options. Emerging technologies include producing hydrogen from biomass, waste, sunlight using thermochemical, photochemical, photoelectrochemical or biological methods. Although these options remain largely at seed / series A round of funding, they may provide breakthroughs in terms of cost and environmental impacts.

In July 2020, the EC published the EU Hydrogen Strategy[259], which has pledged to support emerging technologies for hydrogen production including "from marine algae, from direct solar water splitting, or from pyrolysis processes with solid carbon as side product, while paying due attention to sustainability requirements"[260].

Combining well established technologies such as Steam Methane Reforming (SMR) and coal gasification with carbon capture plays a role under different EU Member State roadmaps and programmes, additional funding of carbon capture and storage infrastructure is expected to fall under other EU support programmes.

Europe's hydrogen innovation has a core industrial focus, with players seeing the potential for using hydrogen for energy sector integration. Mobility and power applications are also being explored and piloted.

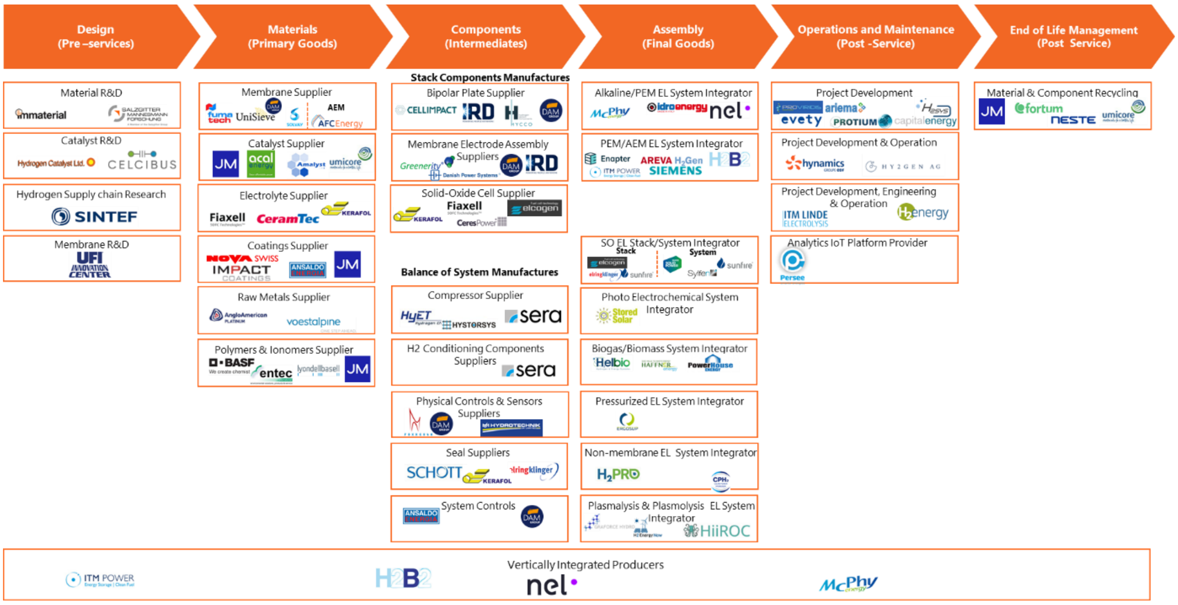
Furthermore, in Figure 4.58 are exemplified some of the key European market players, divided by segment of the Hydrogen Production VC.

[258] Note: at the point in time the data was gathered the UK was still part of the EU, hence EU-28.

[259] European Commission, 2020, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A hydrogen strategy for a climate-neutral Europe, 08 July 2020, COM(2020) 301 final, Available at: https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

[260] European Commission, 2020, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A hydrogen strategy for a climate-neutral Europe, 08 July 2020, COM(2020) 301 final (see p.17), Available at: https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

Figure 4.58 European Key Market Participants – Hydrogen Production



Source: Cleantech Group, 2020

In comparison to the rest of the world, North America has emerged as a hub for innovative hydrogen technologies development. The US Department of Energy is funding early stage players, with strong innovation hubs centred in California and Canada.

4.12.5 Threats and challenges – Hydrogen Production

External dependencies

Hydrogen storage technologies and fuel cells requires around 30 raw materials, of which 13 materials, according to a recent EC study[261], are regarded as critical for the European economy, with Platinum Group Metals (PGM), being the most important. The EC concluded in its 2020 report on CRM for Strategic Technologies and Sectors in Europe that while active dematerialisation effort has enabled PGM intensities in PEM fuel cells to be reduced by 80% since 2005. However, despite a fairly diversified supply base for many raw materials, there is European dependency on the import of CRMs including PGMs. The largest suppliers of PGMs include China, South Africa, Russia and Zimbabwe which over time could impact European production of key hydrogen production and storage technologies.

Technology readiness and cost

For technologies ready for deployment, solutions have been more expensive due to the absence of volume, and for emerging technologies, further European RD&D is still required to progress to a higher TRL.

Policy & Regulation

Technologies have lacked consistent policies to support their introduction into the market and generate the needed cost-efficient volumes. In addition, for some EU Member States the slow implementation and limited awareness of existing legal framework, administrative

[261] Carrara, S., Alves Dias, P., Plazzotta, B. and Pavel, C., 2020, *Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system*, EUR 30095 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16225-4 (online), doi:10.2760/160859 (online), JRC119941, Available at: https://ec.europa.eu/jrc/en/publication/raw-materials-demand-wind-and-solar-pv-technologies-transition-towards-decarbonised-energy-system

processes and legislation applicable to technologies have caused delays, additional costs, and have deterred investments across Europe.

Hydrogen infrastructure scaling

Despite large RD&D funding commitments, there has been a lack of infrastructure funding from public and private sources to enable a decline of hydrogen production costs, which in turn has failed to stimulate wider demand across Europe.

Fragmented market

Europe has independent stack suppliers across the supply chain, with little supply chain optimisation, compared to other leading countries with more vertically integrated players.

Policy dependencies

The EU Hydrogen strategy expects certain policy changes to allow electrolysis plants to access cheap electricity, as well as expecting that the transposition of the 2018 REDII[262] will allow for the procurement of green electricity to count towards CO_2 and renewable fuel standards. However, both of these assumptions are not a certainty and it remains to be seen to what extent and when they would be implemented.

Dependency on public / private sector collaboration

The European hydrogen production VC is dependent equally on private funding and European grants and loans for its success.

Grey Hydrogen

In the coming decade, grey hydrogen combined with carbon capture (to produce low carbon fossil based hydrogen) is expected to be attractive from a cost perspective[263]. In the short and medium term low carbon fossil based hydrogen has the potential to play a role to rapidly reduce emissions from existing hydrogen production and support the parallel and future uptake of renewable hydrogen.

Upstream bottlenecks

Development for materials, manufacturing processes and design concepts remain key bottlenecks in the existing European hydrogen production supply chain.

Covid-19

Although, some hydrogen project developers do not see large implications from the Covid-19 pandemic for the hydrogen production VC and long-term projects, there is a general threat that the ongoing situation might delay green ambitions and investments in sustainable transition technologies. Hydrogen Europe recognises three major risks for the "green

[262] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (Text with EEA relevance), Official Journal L 328, 21.12.2018, p. 82–209, Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L2001

[263] Note: "Estimated costs today for fossil-based hydrogen are around 1.5 €/kg for the EU, highly dependent on natural gas prices, and disregarding the cost of CO_2. Estimated costs today for fossil-based hydrogen with carbon capture and storage are around 2 €/kg, and renewable hydrogen 2.5-5.5 €/kgfossil-based hydrogen with CCS has an estimated cost of around 2.5 Euro/kg, while renewable hydrogen is 2.5-5 Euro/kg versus 1.5 -1.7 Euro/Kg for fossil based hydrogen." Source: European Commission, 2020, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A hydrogen strategy for a climate-neutral Europe, 08 July 2020, COM(2020) 301 final (see p.4), Available at: https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

hydrogen" sector.[264] In the short term, small "*companies which form the backbone of the technology providers are likely to suffer a major shortage of liquidity due to a steep drop in revenues which will result in staff cuts or even bankruptcy*"[265]. For the mid to long term consequences, the association points out that if climate and environmental policy commitments take a backseat in economic recovery plans in Europe and elsewhere large companies which were planning major investments in clean technology could abandon or scale-down these plans. Finally, the crisis situation and the way it is tackled may make investors "*less inclined to finance the planned growth of the [hydrogen] sector*".[266]

4.12.6 Future EU potential – Hydrogen Production

Policy support and corporate initiatives

Rapid decline in the cost of renewable energy, technological developments and the urgency to drastically reduce greenhouse emissions, are accelerating funding and strategic commitments from EU Member States.

The EU Hydrogen Strategy provides a concrete policy pathway for European hydrogen technologies (both mature and developing) to reach scale and has rapidly decreased the timeframe for the market to be globally competitive. Some of the VC-specific proposed plans include an increase of production capacity six-fold by 2024 and installing 40 gigawatts of electrolysers by 2030, up from 250 megawatt of global capacity today.

Following the widespread Covid-19 pandemic the EC has proposed a stimulus package to support EU companies, industries and the green transition, which would also include green hydrogen production among other technologies.[267]

Finally, industrial hydrogen consortia, organisations (e.g. Hydrogen Europe and Hydrogen Europe Research) and targeted initiatives such as the European Clean Hydrogen Alliance are expected to continue to drive down costs in the European hydrogen production supply chain and to be major contributors to the growth and expansion of this VC.

Growth potential

The hydrogen production VC is one of the sectors with the highest potential for growth, driven by ambitious energy transition plans, EU energy and climate goals, and oil and gas companies looking to diminish the impact of their stranded assets. This would require scaling up of the EU hydrogen industry as this technology is foreseen to be a major factor in the EU's energy transition in the coming decades. One mechanism for supporting this objective is to reinforce existing and planned hydrogen industrial clusters to further boost the competitiveness of EU businesses. For example, large hydrogen and power-to-x infrastructure projects are not currently specifically included as a cluster in TEN-E, thereby

[264] Hydrogen Europe, 2020, Post COVID-19 and the Hydrogen Sector - A Hydrogen Europe Analysis, Available at: https://hydrogeneurope.eu/sites/default/files/Hydrogen%20Europe%20Analysis_Post%20COVID-19%20and%20the%20Hydrogen%20Sector_final.pdf, [Accessed on: 24/11/2020]

[265] Hydrogen Europe, 2020, Post COVID-19 and the Hydrogen Sector - A Hydrogen Europe Analysis, Available at: https://hydrogeneurope.eu/sites/default/files/Hydrogen%20Europe%20Analysis_Post%20COVID-19%20and%20the%20Hydrogen%20Sector_final.pdf, [Accessed on: 24/11/2020]

[266] Hydrogen Europe, 2020, Post COVID-19 and the Hydrogen Sector - A Hydrogen Europe Analysis, Available at: https://hydrogeneurope.eu/sites/default/files/Hydrogen%20Europe%20Analysis_Post%20COVID-19%20and%20the%20Hydrogen%20Sector_final.pdf, [Accessed on: 24/11/2020]

[267] European Commission, 2020, *NextGenerationEU: Commission presents next steps for €672.5 billion Recovery and Resilience Facility in 2021 Annual Sustainable Growth Strategy*, Available at: https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1658, [Accessed on: 24/11/2020]

recognising them as Projects of Common Interest[268] (although this is expected in the forthcoming TEN-E revision which would allow them to apply for CEF funding).

4.12.7 SWOT – Hydrogen Production

Strengths *Internal attributes, characteristics and factors that give competitive advantage to the EU in the global VC.*	**Weaknesses** *Internal attributes, characteristics and factors that weaken the competitiveness of the EU in the global VC.*
• Historical importance of this VC and strong European competency across the supply chain. • Strong EU-28 and national policy support in recent years. • Establishment of the European Clean Hydrogen Alliance and recognising the VC as crucial for Europe. • 37% of active companies in the clean hydrogen sector are headquartered in Europe. • Between 2009 and 2018, the annual production value of (mainly grey) hydrogen in the EU-28 remained steady at around €1.2 billion, illustrating existing capabilities on which clean hydrogen production can build. • Average size of private investments in early and late stage companies is higher in Europe than in the RoW.	• Technologies have lacked consistent policies to support their introduction into the market and generate the needed cost-efficient volumes. • Despite large RD&D funding commitments, there has been a lack of cost reduction infrastructure funding from public and private sources. • Europe has independent stack suppliers across the supply chain, with little supply chain optimisation, compared to other leading countries. • Development for materials, manufacturing processes and design concepts remain key bottlenecks in the existing European hydrogen production supply chain.
Opportunities *External situations and factors that can strengthen the competitive advantage of the EU or provide the EU with new sources of competitive advantage.*	**Threats** *External situations and factors that can create problems for the EU compromising its competitive advantage to a certain extent.*
• Wide variety of consortiums, organisations and industrial groups forming and/or growing are expected to continue to drive down costs in the European hydrogen production supply chain and to be major contributors to the growth and expansion of this VC. • Range of emerging European hydrogen production options, in addition to electrolysis. • Further European RD&D is still required to progress to a higher TRL. • The hydrogen production VC is one of the sectors with the highest potential for growth driven by ambitious energy transition plans, EU energy and climate goals, and oil and gas companies looking to diminish the impact of their stranded assets.	• Main competitors include Japan, the US, Canada and South Korea. China is making rapid scaling manufacturing and has strong fundamental science in this VC. • Long-term success of the EU hydrogen supply chain is expected to be largely based on progress of non-EU states growing their domestic demand. • Dependency of Europe on import of critical raw materials, particularly Platinum Group Metals from inter alia China, South Africa, Russia and Zimbabwe.

[268] Mete, G. and Reins, L., 2020, *Europe's new Hydrogen Strategy: the questions that still need answering*, Energy Post, Available at: https://energypost.eu/europes-new-hydrogen-strategy-the-questions-that-still-need-answering/, [Accessed on: 24/11/2020]

5 Conclusions and recommendations

This section covers the key conclusions drawn from designing the CAF and applying it to the 12 value chains. It includes:

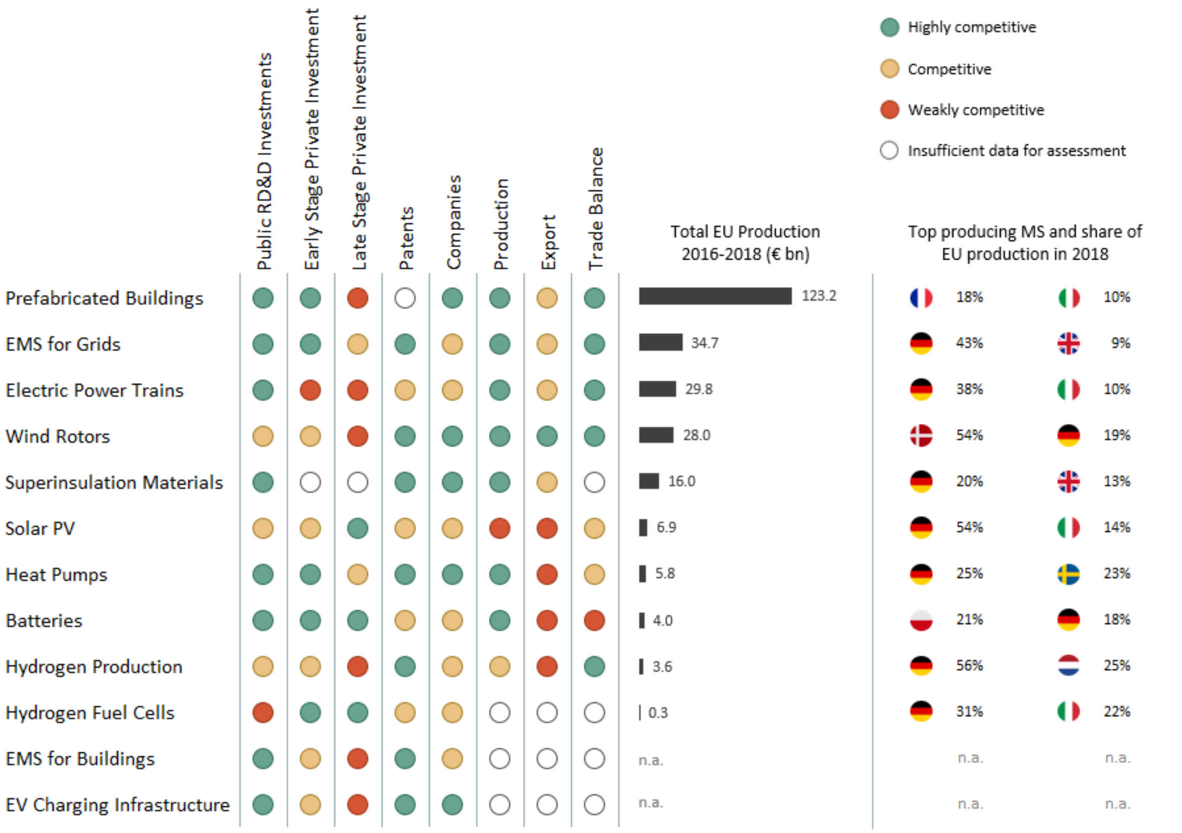
- A cross value chain assessment of the results of the 12 strategic outlooks from both a quantitative (e.g. comparison of share of exports, production) and a qualitative (e.g. market trends) perspective.
- Identification of the key transversal challenges for climate neutral value chains in Europe.
- Methodological conclusions from designing, refining and rolling out the CAF, including key opportunities for further developing the framework identified during the study, notably through discussion with the SC.
- Policy recommendations developed to address the transversal challenges.

5.1 Key conclusions from cross value chain analysis

This section summarises the key conclusions drawn from applying the CAF to the 12 climate neutral VCs and comparing results across them. This has enabled the main drivers, dynamics and trends regarding European competitiveness to be identified.

Figure 5.1 is based on the results of the data collection undertaken within Part 2 of the CAF. It illustrates: (i) how competitive a VC is based on each of the indicators; (ii) the size of EU-28 production; and, (iii) the top producing Member States and their share of total EU production in 2018.

Figure 5.1 Summary findings across the 12 assessed VCs for selected indicators



Source: ICF, 2020

The summary does not include a cross-VC assessment of employment and turnover, since the data on these indicators was only available for four out of the 12 VCs. For those indicators included, the judgement criteria for assessing competitiveness is based either on thresholds for the EU share of global totals or else on how the data has changed over the past years.

This section continues with a summary of each key indicator. Having reviewed all datasets and the relative positioning of the EU against non-EU competitors, the competitiveness of a VC is generally classified as high if the European share over global competition (if available) is larger than 25%, medium if it is between 10% and 25%, or low if it is below 10%. The exception to this rule is for company data where, due to the predominance of innovative EU and North American companies captured in the Cleantech Group database, competitiveness of a VC is classified as high if the European over global share is larger than 45%, medium if it is between 25% and 45%, or low if it is below 25%.

Production

EU-28 production between 2016 and 2018 was aggregated to compare the order of magnitude across VCs. Although the Prefabricated Buildings VC presents the highest production level, the data codes used in the analysis are not specific to low-carbon solutions, meaning that this total also includes traditional building products. This methodological issue also relates to Hydrogen Production, where the data codes do not differentiate between different forms of hydrogen production and therefore fail to illustrate that current clean hydrogen production in the EU-28 remains a minor part of total production. The largest EU-28 climate neutral VCs of the 12 analysed are Grid EMS, Electric Power Trains and Wind Rotors.

Competitiveness in production is based on the 10-year trend between 2009 and 2018. For three VCs, this full trend data was not available. The competitiveness of a VC is classified as high, medium or low when there is a growing, stable or decreasing trend, respectively. The production of Solar PV has decreased in the EU-28 and Hydrogen Production has remained mostly stable. Production in all other VCs for which data was available has grown over the period.

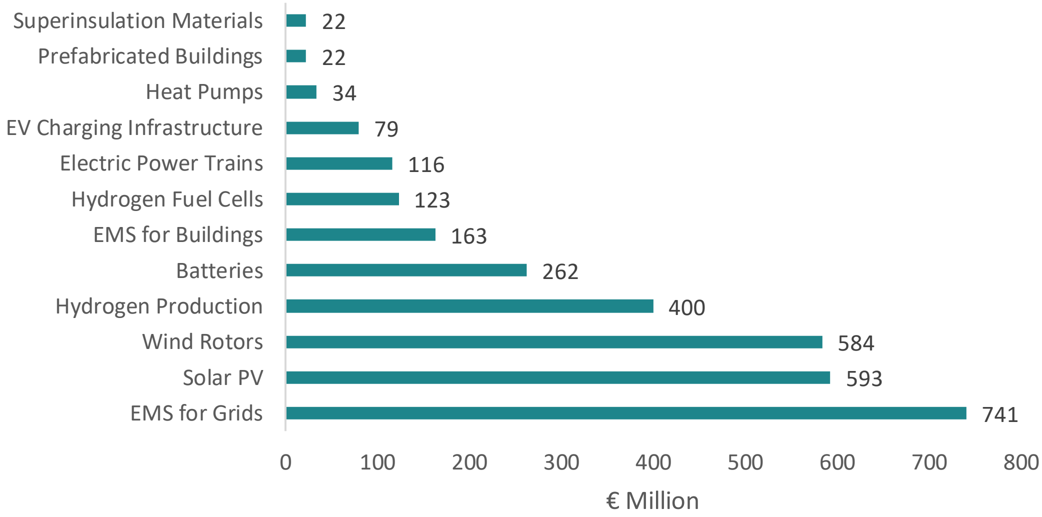
For those ten VCs for which data was available for 2018, the top two producing Member States have accounted for between 23% and 81% of total production within a given VC. Germany was the top producing country in seven out of the 10 VCs in 2018.

Public RD&D Investments

The gauge for public RD&D investments is also based on the 10-year trend between 2009 and 2018. The competitiveness of a VC is classified as high, medium or low if there is a growing, stable or decreasing trend respectively.

Investments have increased in the period across most of the 12 VCs. The exceptions are Wind Rotors, Solar PV and Hydrogen Production – for which investments remained mostly stable – and Hydrogen Fuel Cells – for which investments have decreased. This may be due to the fact that these VCs are more established and public RD&D investments in them have already been at high levels.

Figure 5.2 Total Public RD&D Investments in Europe between 2016 and 2018



Source: ICF, 2020

Private Investment (Venture Capital)

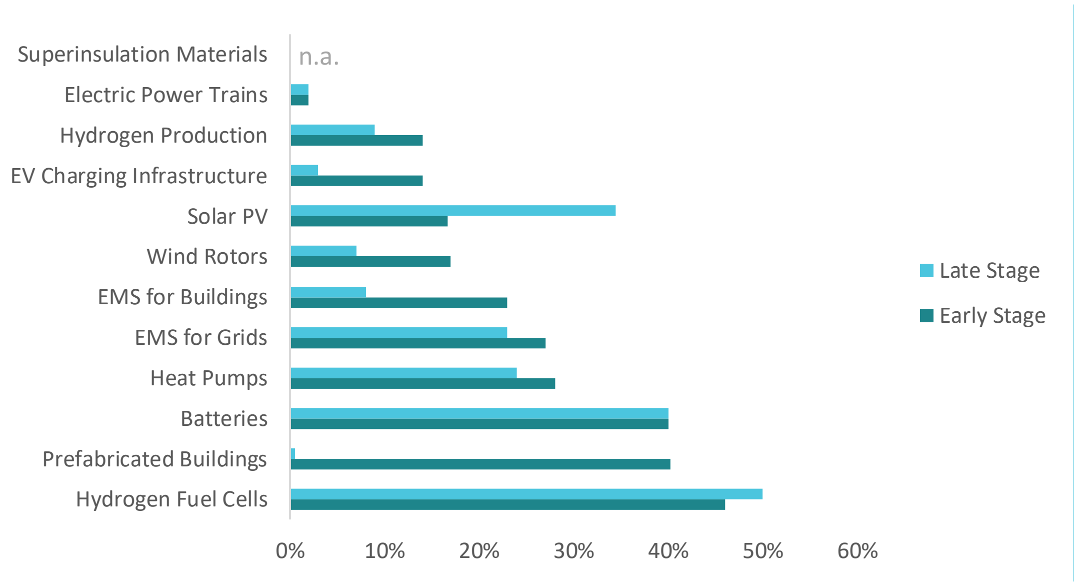
Competitiveness in private venture capital investment is based on the share of European over global venture capital investments between 2014 and 2019. This is based on data from the Cleantech Group database which covers mostly North America and Europe, since this is where there have traditionally been the largest venture capital flows. The competitiveness of a VC is classified as high if the European share is larger than 25%, medium if it is between 10% and 25% or low if it is below 10%.

Across most VCs, the share of European investments is higher for early stage than for late stage (with Solar PV and Hydrogen Fuel Cells being the exceptions). This suggests that Series B+ (late stage) investments in companies focused on low carbon technologies can potentially be expanded to strengthen EU competitiveness. While the Batteries VC is highly competitive in early and late stage investments, the Electric Power Trains VCs performed poorly in both.

To put these trends in a wider perspective, European investments in seed, series A, series B, and growth equity rounds of energy & power companies grew at a rate of nearly 19% from 2015 to 2020, and totalled EUR 1.8 billion in 2019, comprising 44% of global investments into the sector, versus an average of 20% in the previous four years. Likewise, investments at the seed through growth equity stages in transportation and mobility in Europe grew in the same period at a rate of 28% to total nearly EUR 2.8 billion in 2019, 10% of global investments in the sector (and 11% through Q3 2020).[269]

[269] Cleantech Group, 2020. i3 database. Conversion from USD to EUR based on https://xe.com.

Figure 5.3 European share of global private venture capital investments between 2014 and 2019



Source: ICF and Cleantech Group, 2020

Figure 5.4 European private venture capital investments between 2014 and 2019 at early and late stage[270]

	Total 2014-2019 (EUR millions)	
	Early	Late
Superinsulation Materials	-	-
Electric Power Trains	260	73
EV Charging Infrastructure	31	28
Hydrogen Production	68	28
Solar PV	348	13
Wind Rotors	227	57
EMS for Buildings	189	152
EMS for Grids	829	131
Heat Pumps	112	43
Batteries	1,430	130
Prefabricated Buildings	8	109
Hydrogen Fuel Cells	42	14

Source: ICF and Cleantech Group, 2020.

Patents

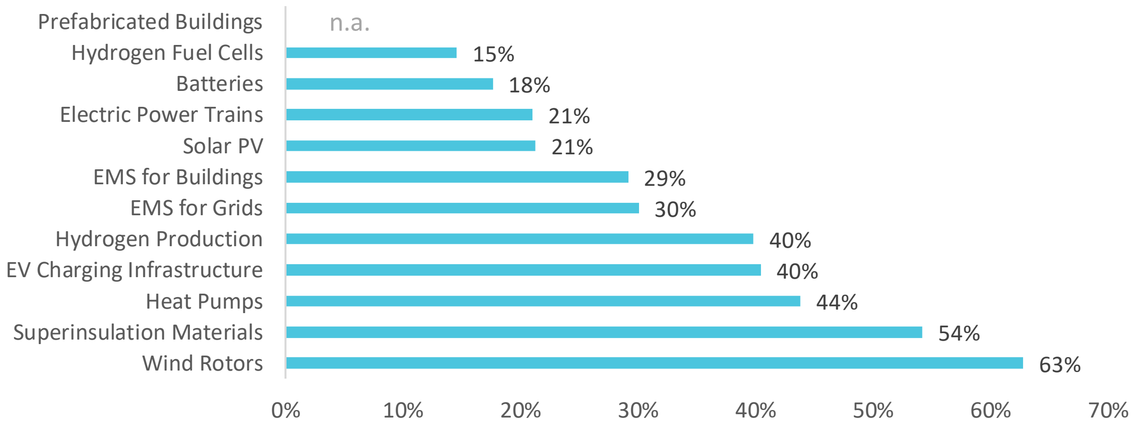
With regards to patents, the competitiveness judgement is based on the share of European over global high-value patent applications[271] between 2014 and 2016. The competitiveness of a VC is classified as high if the European share is larger than 25%, medium if it is between 10% and 25% or low if it is below 10%.

[270] As specified in the CAF, Early stage private investment is defined as seed or Series A investments. Late stage private investment is defined as Series B and beyond.

[271] As specified in the Part 2 of the CAF, high-value patent applications are patent families for which an application has been filed in more than one country. This is deemed to be an indicator of "high value" because applying for multiple patent protections implies the value the patent has for export.

The results indicate that Europe is highly competitive in more than half of the VCs analysed and weakly competitive in none, suggesting that Europe is a leading region for patent applications around climate neutral solutions globally. The European share of global high-value patent applications between 2014 and 2016 ranged between 15% for Hydrogen Fuel Cells and 63% for Wind Rotors.

Figure 5.5 European share of global high-value patent applications between 2014 and 2016



Source: ICF, 2020

Figure 5.6 Number of high-value patent applications between 2014 and 2016 in Europe per VC

	High Value Patent Applications (Total 2014-2016)
Prefabricated Buildings	-
Hydrogen Fuel Cells	101
Batteries	572
Electric Power Trains	286
Solar PV	776
EMS for Buildings	19
EMS for Grids	68
Hydrogen Production	361
EV Charging Infrastructure	314
Heat Pumps	53
Superinsulation Materials	28
Wind Rotors	1,059

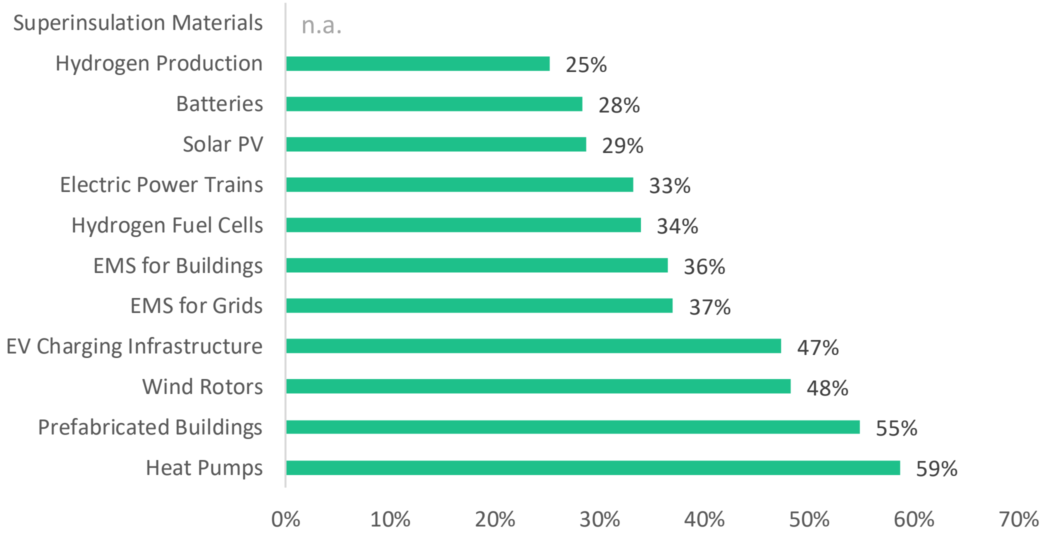
Source: ICF, 2020

Companies

Competitiveness in companies is based on the share of European companies included in the Cleantech Group database, which covers mostly innovative companies, but also to a certain extent more established market players. The competitiveness of a VC is classified as high if the European share is larger than 45%, medium if it is between 25% and 45% or low if it is below 25%.

The results indicate that European competitiveness is average in more than half of the VCs and weakly competitive in none. The European share of companies ranges between 25% for Hydrogen Production and 59% for Heat Pumps.

Figure 5.7 European share of global companies



Source: ICF and Cleantech Group, 2020

Figure 5.8 Indicative number of innovative European companies per VC as identified in the CAF

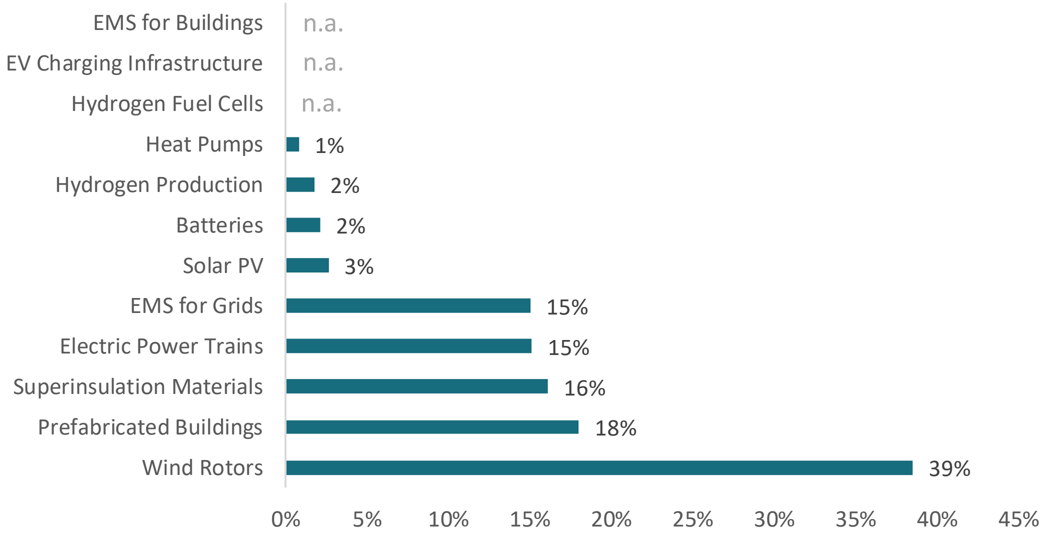
	Companies
Superinsulation Materials	-
Hydrogen Production	91
Batteries	125
Solar PV	189
Electric Power Trains	74
Hydrogen Fuel Cells	78
EMS for Buildings	289
EMS for Grids	194
EV Charging Infrastructure	107
Wind Rotors	622
Prefabricated Buildings	51
Heat Pumps	71

Source: ICF and Cleantech Group, 2020

Exports

Competitiveness in exports is based on the share of EU-28 over total global exports between 2016 and 2018. The competitiveness of a VC is classified as high if the EU-28 share is larger than 25%, medium if it is between 10% and 25% or low if it is below 10%. The EU-28 is strongly competitive only in the Wind Rotors VC where it dominates the global market with 39% of exports.

Figure 5.9 EU-28 share of global exports between 2016 and 2018



Source: ICF, 2020

Figure 5.10 EU-28 exports between 2016 and 2018

	Total 2016-2018 Exports (EUR million)
EMS for Buildings	-
EV Charging Infrastructure	-
Hydrogen Fuel Cells	-
Heat Pumps	957
Hydrogen Production	7
Batteries	2,716
Solar PV	3,628
EMS for Grids	24,630
Electric Power Trains	14,393
Superinsulation Materials	3,715
Prefabricated Buildings	5,239
Wind Rotors	6,441

Source: ICF, 2020

Trade Balance

VCs have been classified as highly competitive where the EU-28 has a positive trade balance that has been improving between 2009 and 2018. Conversely, a VC is deemed to be weakly competitive where the EU-28 has a negative trade balance that has been deteriorating between 2009 and 2018. The competitiveness of the Solar PV VC is gauged as medium because it is negative, but has shown some improvement in the period. The competitiveness of Heat Pumps is also gauged as medium because it is positive, however it has been deteriorating over time.

Market, Investment and Innovation Trends

Table 5.1, Table 5.2 and Table 5.3 summarise the key findings from the qualitative assessment across the four thematic areas, as undertaken within Part 1 of the CAF.

Table 5.1 Summary of Historic Market Trends across the Thematic Areas

Historic Market Trends			
Thematic Area	Drivers	Dynamics	Global Competitiveness
Mobility	• Increasing demand and regulation for low carbon transportation and alternative fuels have been driving market expansion.	• Technology adoption highly fragmented across Member States, being led largely by EV and infrastructure adoption in the western Member States. • Original Equipment Manufacturers (OEMs) increasing production of low emission vehicles, but sales mainly from Internal Combustion Engine vehicles (ICE). • OEMs locked into long-term trade agreements with Chinese manufacturers for batteries as EU lacked local capacity.	• Chinese industrial policy and investment has driven more aggressive growth in manufacturing capacity, outpacing EU and rest of the world.
Buildings	• EU targets to reduce 40% of energy consumption and 36% CO_2 emissions in buildings have contributed towards the promotion of building sustainability, energy efficiency, waste reduction and use of lower emission fuels for heating and cooling.	• Super insulating materials have experienced low demand in the EU resulting in relatively smaller market sizes. • APAC currently has the largest share in the prefabricated building market accounting for over 30% in 2018, due to growing middle class and increasing urbanization.	• US and APAC have more developed markets for buildings VCs, but EU market for heat pumps is emerging.
Clean Power	• EU Renewables Directive created obligatory renewable energy targets for EU members which set the pace for national government adoption of clean power technologies	• PV solar market demand concentrated heavily (75%) in 5 countries (Spain, Germany, Netherlands, France, and Poland). • Wind market seeing an active M&A environment led by large corporations.	• Chinese PV subsidy reduction led to reduction in local installations in 2018 and 2019, while the impending end of a tax credit in US led to increased planning and deployment of projects to qualify for subsidy in 2018 and 2019. • Innovation in the wind VC has been driven by global companies with EU-based production (e.g. PPG, Suzlon).
Integrators	• EU energy, sustainable buildings policy and regional funding programmes (e.g. Horizon 2020) greatly supported technology development of integrators and affiliated industry groups. Renewable electrification and grid integration has also been a major driver of investments.	• Trends across VCs are significantly different. • Adoption of buildings EMS has steadily increased over the last 15 years. • Green hydrogen production is still several years from mass market commercialisation. • Connectivity of assets has been improving in grids infrastructure.	• Hardware manufacturers and supply markets are dominated by Asia in EMS for buildings and hydrogen (Japan, and South Korea leading hydrogen markets, accompanied by US and Canada).

Table 5.2 Summary of Future Market Trends across the Thematic Areas

Future Market Trends			
Thematic Area	**Drivers**	**Dynamics**	**Global Competitiveness**
Mobility	• EU policy for low-emission vehicles, ICE bans, emissions standards, green deal, and planned investment in manufacturing capacity and new technology development should drive the EU market to meet increased local and international demand with EU supply.	• Low emission mobility and supporting technologies expected to increase rapidly across the EU, with Germany's existing manufacturing base (for EV's and batteries) lead.	• China likely to maintain manufacturing dominance based on policy, subsidies and planned investment in low emission mobility.
Buildings	• Challenging emissions targets and government legislation can encourage builders to adopt energy efficient technologies as demand for space cooling, sustainable building systems and building materials increase.	• Demand expected to increase for all three VCs due to more ambitious decarbonisation targets and the development of comprehensive building energy efficiency policy packages as part of the Green Recovery initiatives.	• EU market penetration low with moderate growth rates expected relative to rest of the world for prefabricated buildings and superinsulation materials. • China emerging as a key competitor based on coordinated government targets, incentives and investment.
Clean Power	• Europe's aims to become the first carbon-neutral continent and the EU green deal will continue to drive growth of PV and Wind markets.	• Unsubsidised levelized cost of energy for PV and Wind expected to be competitive with conventional generation. For PV Germany, Spain, Netherlands, France, and Italy are expected to lead capacity installation in the near future.	• China and US are reducing subsidies for Solar PV to encourage unsubsidised cost parity. • Wind demand expected to increase in APAC with rising electricity demand.
Integrators	• EU-level strategy, targets, policy and funding will continue to drive growth of the VCs. • Hydrogen production to be supported by public-private consortia to reduce costs.	• Buildings technology supported by EU energy efficiency first principle • Grids market set to expand due to planned investment in battery and other energy storage applications, and distribution automation. • Green hydrogen cost reduction requirement to compete with conventional fuels keeps it from being commercially viable in the short term.	• North America and China lead grid investment but Green Deal positions EU well to compete in EMS for Buildings. • In hydrogen, the main competition is likely to come from the Chinese market.

Table 5.3 Summary of Innovation and Investment Trends across the Thematic Areas

Innovation and Investment Trends		
Thematic Area	Innovation	Investments
Mobility	• Vibrant community of innovators across the VC except for end of life which is not well catered to. This is to be expected for an area of high growth.	• For climate neutral mobility, investment is driven by Original Equipment Manufacturers (OEMs), large energy corporations (e.g. Total, Shell) and venture capitalists actively supporting the development of new technology and infrastructure across the EU.
Buildings	• With regards to buildings, innovation is more evenly spread across the lifecycle of products as there is a focus on design technology for prefabricated buildings, on operations and maintenance for heat pumps and on the raw materials for superinsulation.	• Investment has mostly gone into digital technologies (software, analytics) for optimising the running of heat pumps. • Little early stage investment for superinsulation materials and prefabricated building technology in the EU. Large chemical corporates (e.g. BASF) investing in innovation via RD&D budgets.
Clean Power	• Innovation in solar PV is centred on higher efficiency cell materials and expanding use cases for PV modules. • In the wind rotors VC it is focused on blade design and materials, asset monitoring, and predictive maintenance. • End of life markets developing in both chains due to the fleet potential.	• Both PV and wind markets experiencing investment typical of more mature VCs where most of the funding focused on larger growth stage developers, project finance and M&A. • PV thin film and solar glass technologies were the focus of early stage investment. • Wind rotor investment is generally low and focused on O&M innovation.
Integrators	• Innovation in grids and buildings EMS focuses mainly in improving operation and management. • Innovation in the hydrogen VC is focused on exploring various feedstocks and pathways to produce hydrogen.	• EU commercial and industrial corporation are investing and partnering with technology providers in grids, buildings, and hydrogen to increase efficiency, reduce emissions and enable a pathway to decarbonisation.

5.1.1 Transversal challenges

The identification of the challenges was based on a review of the strategic outlooks and SWOT analysis developed for each VC. This review focused on the key factors hampering the competitiveness of European businesses across the 12 VCs (see Table 2.3). This resulted in the identification of 13 high-level challenges applying to either all VCs or a large proportion of them. These challenges can be divided into three broad groups:

- Challenges linked to mega-trends and contextual uncertainties – Challenges 1 to 3;
- Challenges impacting the supply of climate neutral solutions – Challenges 4 to 9; and
- Challenges impacting the demand for climate neutral solution and their deployment – Challenges 10 to 13.

Each challenge is briefly presented in Table 5.4, while the numbering of each VC is according to Table 2.3.

Table 5.4 The transversal challenges impact most VCs

	Challenges	Highly impacted VCs[272]
C1	**Digitalisation:** VCs need to better understand the implications of the increased digitalisation of our society, notably in terms of changing consumer behaviour, cybersecurity risks and data management.	All
C2	**Uncertainty:** Disruptive factors linked to Covid-19 and Brexit add a layer of uncertainty for existing VCs and potentially hamper the EU's ability to generate and sustain key climate neutral VCs.	All
C3	**End-of-life:** Limited end-of-life and recycling opportunities for some climate neutral solutions.	1,3,5,6,7,8,9
C4	**Data:** Insufficient market data on the latest innovation trends prevents the development of tailored public and private support mechanisms, thereby limiting access within VCs to private finance.	All
C5	**Cooperation:** Lack of European wide RD&D cooperative frameworks for some climate neutral VCs limits their development.	3,4,5,6,7,9,10,11
C6	**Finance:** Limited opportunities for climate neutral innovators to access private (e.g. venture capital and private equity) and public finance to achieve commercialisation.	2,5,6,7,9,10,11,12
C7	**Critical Raw Materials (CRMs**): Manufacturing of climate neutral solutions requires resilience and independence from CRM sought from abroad.	1,3,8,9
C8	**Fragmentation:** Market fragmentation and limited number of strong European players across some climate neutral VCs acts as a brake on stronger competitive positioning within global VCs.	1,2,4,5,6,7,10
C9	**Competition:** High levels of external competition, with increased growth of climate neutral players outside the EU benefiting from increased political support and leading to growing EU imports.	1,2,3,5,6,7,8,9,12
C10	**Incentives:** Insufficient incentives to support the deployment of innovative technologies.	All

[272] Note that this classification is based on the SWOTs and the highest impact. A VC not listed does not mean that there is no impact at all.

C11	**Transposition:** Lack of timely transposition of EU energy and climate rules hampering the growth of VCs.	All
C12	**Acceptance:** Public resistance to new technologies continues to inhibit their deployment.	5,8,9,11,12
C13	**Barriers:** Regulatory and permitting barriers slowing down the deployment of existing climate neutral solutions.	1,2,8,9,11

5.2 Methodological conclusions

This Section summarises the key conclusions drafted from refining the methodology and applying the CAF to 12 value chains. It also captures the key opportunities for further developing the framework identified during the study, notably through discussion with the SC.

5.2.1 Indicator selection

As detailed in section 2.2, desk research on secondary data and guidance of the study SC was sought for to develop a set of indicators that could be used to assess EU competitiveness of within climate neutral VCs. Although the set presented in Table 2.2 is not extensive, it covers multiple aspects of competitiveness and allows for a robust assessment.

No single indicator on its own can provide a robust enough assessment of EU competitiveness. However, a consolidated analysis of the indicators included in the CAF provides a robust and meaningful overview of European companies' competitive position within a specific climate neutral VC compared to other countries and regions. As explained in section 2.2.1, the CAF is built around two building blocks:

- The first block relates current competitiveness & market trends. This is assessed by looking at indicators linked to imports, exports, production, turnover and employment. These data provide a picture of the key players in Europe and globally, and allow to build a good understanding of how recent trends are shaping the market.
- The second block relates to innovation & future market trends. This is assessed by evaluating private venture capital investments in innovative companies, public investments in RD&D, the volume of patent applications and the number of innovative companies present in different part of the word with the objective to identify innovation trends and how they can shape and influence the market into the coming years.

5.2.2 Technological Coverage

The technological coverage is not aligned across the different indicators within a given VC. Each source (e.g. PRODCOM, COMTRADE, PATSTAT, IEA, EurObserv'ER) has a specific technological coverage and product definitions which do not necessarily match across the different sources. Annex 2 presents the data codes used to extract data from the sources and summarises the technological coverage of the 12 pilot VCs assessed in this study.

While it is not possible to obtain complete technological alignment between the indicators' coverage, this does not compromise the overview provided by the datasets nor the competitiveness assessment. However, it is essential to give sufficient consideration to the technological coverage and to adequately disclose these limitations when applying the framework to a given VC.

Box 5.1 Mismatch between the data codes in the different data sources

The results of the data collection need to be used within the context of the technological coverage of the different indicators to inform the strategic outlook. The Figure below shows an example for the Wind Rotors VC.

#	Quantititative Indicator	Data Source	Technological Coverage
1	Level of public investment in RD&D	IEA	Wind energy
2	Early stage private investment	CTG	Wind energy and wind rotors specifically
3	Late stage private investment	CTG	Wind energy and wind rotors specifically
4	Patent applications	PATSTAT	Wind energy and wind rotors specifically
5	Companies	CTG	Wind energy and wind rotors specifically
6	Employment	EurObserver	Wind energy
7	Production	PRODCOM	Wind powered electricity generating sets
8	Turnover	EurObserver	Wind energy
9	Imports & Exports	PRODCOM & UN COMTRADE	Wind powered electricity generating sets
10	Trade balance	PRODCOM & COMEXT	Wind powered electricity generating sets

5.2.3 Geographic Coverage

The geographic coverage is not aligned across the different indicators within a given VC. Each source (e.g. PRODCOM, COMTRADE, PATSTAT, IEA, EurObserv'ER) has a specific geographic coverage which does not necessarily match the coverage of the other sources.

In some cases, the data is available for all countries (i.e. Europe and RoW) and in others for only a selection of countries (e.g. EU-28 Member States, IEA members). Furthermore, some countries keep their data confidential in some of the databases (e.g. PRODCOM) for one or multiple years. Due to these limitations, for a few indicators, such as production, employment and turnover, it is not possible to compare EU-28 countries with RoW countries.

Again, this does not compromise the overview provided by the dataset nor the competitiveness assessment. However, it is essential to consider the geographic coverage and to adequately disclose any limitations associates with it when applying the framework to a given VC.

Box 5.2 Mismatch between the geographic coverage in the different data sources

The results of the data collection need to be used within the context of the geographic coverage of the different indicators to inform the strategic outlook. The Figure below shows an example for the Wind Rotors VC.

#	Quantititative Indicator	Data Source	Geographic Coverage
1	Level of public investment in RD&D	IEA	IEA member countries
2	Early stage private investment	CTG	Europe & RoW
3	Late stage private investment	CTG	Europe & RoW
4	Patent applications	PATSTAT	Europe & RoW, sourced from JRC
5	Companies	CTG	Europe & RoW
6	Employment	EurObserver	EU + UK
7	Production	PRODCOM	EU + UK
8	Turnover	EurObserver	EU + UK
9	Imports & Exports	PRODCOM & UN COMTRADE	EU from PRODCOM + RoW countries from UN COMTRADE
10	Trade balance	PRODCOM & COMEXT	EU from PRODCOM + RoW countries from COMEXT

5.2.4 Data gaps

Given the objective to make the CAF easily replicable across climate neutral VCs, the study team has sought to base it on data sources with a good coverage of climate neutral solutions and that could be easily accessed.[273] As presented in Table 5.5, some technologies are however not covered by some of the databases used in this study. There is for example very limited data coverage of employment and turnover in climate neutral VCs, as discussed in more details below.

Where data was not available for specific indicators, additional literature review and in-house expert judgment of the study team were used to complete the SWOT analyses and to inform the strategic outlooks. These have been properly referenced in the analyses.

[273] With the exception of the Cleantech Group database, which is not open source.

Table 5.5 Data Coverage for the 12 VCs

Indicator	Batteries	Hydrogen Fuel Cells	Electric Power Trains	Electric Vehicles Charging Infrastructure	Prefabricated Buildings	Superinsulation Materials	Heat Pumps	Wind Rotors	Photovoltaic Solar Panels	Building Energy Management Systems	Grid Energy Management Systems	Hydrogen Production
Level of public investment in RD&D	Y	Y	Y	Y	Y*	Y*	Y	Y	Y	Y	Y	Y
Early stage private investment	Y	Y	Y	Y	Y	Y*	Y	Y	Y	Y	Y	Y
Late stage private investment	Y	Y	Y	Y	Y	Y*	Y	Y	Y	Y	Y	Y
Patent applications	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Companies	Y	Y	Y	Y	Y	Y*	Y	Y	Y	Y	Y	Y
Employment	N	N	N	N	N	N	Y	Y	Y	N	N	N
Production	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y
Turnover	N	N	N	N	N	N	Y	Y	Y	N	N	N
Imports & Exports	Y	N	Y	N	Y	Y	Y	Y	Y	N	Y	Y
Trade balance	Y	N	Y	N	Y	Y	Y	Y	Y	N	Y	Y

* limited or imprecise coverage

Source: ICF, 2020.

5.2.5 Recommendations for filling data gaps and overcoming challenges associated with the CAF

Build the analysis on existing research and publications

The CAF combines qualitative and quantitative information to build a robust competitiveness assessment. When the quantitative data coverage is insufficient, more emphasis is given to the qualitative information publicly available or to alternative quantitative information. The scope of this additional information can of course vary greatly, depending on the resources allocated to these additional research aspects and their end goals.

Key sources consulted to cover the quantitative data gaps during this study include:

- EU policies and regulations;
- EU policy evaluation and assessment reports;
- Industry Interest Groups and association publications ; and,
- Recent articles and reports from the academic and grey literature.

To add a layer of confidence to the assessment based on the CAF, a good solution is to present the findings at external expert level and/or to a sample of stakeholders in order to challenge and validate them.

Improve monitoring of EU employment and turnover data in climate neutral solutions

The key source for employment and turnover data used was the EurObserv'ER database, which is limited to renewable energy technologies. In 2015, DG ENER published a report (*Assessing the Employment and Social Impact of Energy Efficiency*[274]) which discussed the lack of indicators of employment in this sector and proposed methods to estimate employment in energy efficiency VCs based on existing statistical data. The result of the study shows that more efforts are still required in this field, especially if there is desire by policy makers to assess more innovative climate neutral VCs outside renewable energy technologies. The scope of this study was not to build or create indicators, but rather to design a replicable CAF that allows for an assessment of European company competitiveness based on the quantitative and qualitative data available.

Box 5.3 Expanding EurObserv'ER

The key source for employment and turnover data used was the EurObserv'ER database, which provided valuable information to inform the competitiveness assessment. However, the database is limited to renewable energy technologies. Expanding the EurObserv'ER database to ensure it covers other relevant climate neutral solutions would certainly contribute to generating relevant insights into EU competitiveness.

The OECD Employment database[275] provides up-to-date statistics on employment per activity per country. However, the activity categories available in the database are broad (e.g. agriculture, construction, public administration) and not specific to particular VCs or strategic components.

The Eurostat Structural Business Statistics[276] provides data on indicators such as number of enterprises, turnover and value added grouped at NACE activity level. Even though the NACE activity classification is more specific than the OECD employment categories, it is still too broad and does not cover the VCs in this study. This could however represent a good source of information for the analysis of other VCs in the future.

Improve data codes coverage and alignment

Because many climate neutral solutions are innovative, they are not sufficiently covered within the traditional production and trade data codes. In addition, there is often a mismatch between the codes used in different databases as they might be too broad or too specific for the different indicators. This restricts the competitiveness assessment and ultimately limits policy initiatives targeted at driving competitiveness in those VCs. From a policy-making perspective, it would be interesting to address this by designing databases, defining data categories and codes, and collecting data as granular as possible, focusing in particular on harmonisation across the different indicators or databases.

[274] Cambridge Econometrics, 2015, *Assessing the Employment and Social Impact of Energy Efficiency*, prepared in cooperation with E3M Lab, Warwick Institute for Employment Research and ICF International, Available at: https://ec.europa.eu/energy/sites/ener/files/documents/CE_EE_Jobs_main%2018Nov2015.pdf, [Accessed on: 24/11/2020]

[275] OECD, 2020, *Employment database*, Available at:

http://www.oecd.org/employment/emp/onlineoecdemploymentdatabase.htm, [Accessed on: 24/11/2020]

[276] Eurostat, 2020, *Structural Business Statistics — Overview*, Available at: https://ec.europa.eu/eurostat/web/structural-business-statistics/overview, [Accessed on: 24/11/2020]

5.2.6 Further developments of the framework

The framework was designed according to the scope and objectives of this study and its application to the 12 VCs has created insightful results to inform EU competitiveness. Nevertheless, there is great potential to further develop the framework and to add more complexity to the analyses produced. This section explores some of these possibilities.

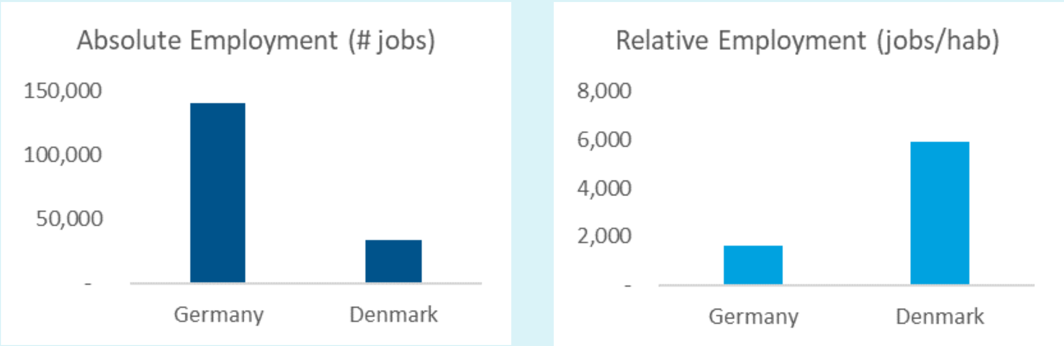
5.2.6.1 Data normalisation

The framework looks at the absolute indicators without normalising them or looking at the figures relative to a country's population or GDP. For example, Germany's GDP and population is much larger than Denmark's, which means that employment in a particular VC is likely to be intrinsically larger in Germany. By looking at the normalised indicator, instead of comparing the absolute number of people employed in each country (e.g. thousand employees), one would instead compare the fraction of the population that is employed in a particular VC (e.g. employees per thousand habitants). Similarly, this rationale can be applied for all the indicators and analysed from multiple perspectives (e.g. population, GDP).

When analysing absolute figures, the population and the size of an economy will often bias the results to some extent. Assessing the key indicators from a normalised perspective will potentially bring additional insights that can further inform on the competitiveness of the EU or its Member States in climate neutral VCs. It requires however having access to comparable data across geographies.

Box 5.4 Data normalisation can provide further insights and complexity to the analysis

The Figures below illustrate how normalising the data can alter the results. This example shows employment in the Wind Rotors VC in 2018. While Germany has more people employed in the wind VC than Denmark in absolute terms (number of jobs), a larger fraction of Denmark's population is employed in the wind sector (jobs per habitant).



5.2.6.2 Granularity of data analysis

The level of data analysed proposed in the CAF is aligned with the scope and objectives of this study. There are, however, always possibilities to go into more details and add further complexity to the assessment. Some examples discussed during this study include:

- The patent data extracted from PATSTAT provides information on which institutions submitted patent applications. Analysing the patent data jointly with the company data could provide interesting results and further inform the assessment of RD&D and innovative activities across the different stages of a VC. The patent codes are also more detailed than the trade and production codes which also allow for better understanding innovation trends within a VC.

- The trade data extracted from PRODCOM, COMTRADE and COMEXT can provide further insights into the key trading partners and for assessing re-import or re-export flows across EU Member States.

5.2.6.3 Raw materials

The framework does not include an in-depth analysis of the availability of raw materials that are relevant for each VC. This aspect has however been covered through additional literature research in the strategic outlooks, where relevant.

The raw materials can be looked at in detail through applying the analytical framework and undertaking the analysis proposed in Section 3 for a VC focused specifically on the raw material as the strategic component of interest.

5.2.6.4 Digitalisation

The framework does not include an in-depth analysis into how digitalisation impacts European company competitiveness in each VC. This aspect has been covered in the qualitative analysis and through additional literature research in the strategic outlooks when relevant.

5.3 Policy recommendations stemming from the VC analyses

Nine recommendations were identified to address the transversal challenges identified above and therefore contribute to enhance the competitiveness position of European businesses along the 12 analysed VCs. When considering these recommendations, it is important to bear the following points in mind:

- The overall evidence and research from this study indicates that robust policies have already been developed to support the competitiveness of some of the analysed VCs including, for example, wind rotors, solar PV and, more recently, hydrogen. This means that several recommendations will be more relevant to some VCs than others.

- The recommendations build on the existing body of support measures already in place, which is extensive in some areas, such as research and innovation. During the latter stages of the study, a flurry of new initiatives linked to the European Green Deal have been published and therefore some developments might need more in depth analysis to understand implication and impact to the strategic value chains analysed.

- When reviewing the positions of the various industry organisations for each VC, it is evident that the stakeholders appreciate the actions already taken at European level and are supportive of the ambition set out in the European Green Deal. Industry associations have also identified areas for further improvement and these have been considered in the drafting of these recommendations.

- The recommendations are formulated at a cross-VC level, with initial indications of how they could be implemented. However, more work would be required to define specifically how each recommendation can be applied in practice.

The recommendations are divided into two groups:

- Recommendations one to six (R1-R6) deal mainly with the supply side; and,
- Recommendations seven to nine (R7-R10) focus on demand issues.

R1. Use competitiveness assessments for enhanced dedicated funding

Proposal

Use competitiveness assessments to identify VC segments of strategic importance for the EU economy and the transition to climate neutrality, to inform the design of strategic plans and calls for proposals; and, where necessary, create or enhance dedicated funding 'windows' within investment programmes and mechanisms to ensure sufficient support across the innovation cycle.

This recommendation is based on and directly correlates to the following challenges – C2: Uncertainty, C4: Data, C6: Finance, and C10: Incentives, which cover all three of the main themes. In addition, since it has a cross-sectoral approach it addresses directly or indirectly all the studied VCs.

Rationale

The CAF developed in this study can be applied at different levels within a VC, shedding light on the competitiveness of EU businesses at each of these levels and within specific segments of the VCs (depending on data availability). It also sheds light on the positioning of EU businesses compared to different indicators, such as patenting activities, exports, imports, etc., providing an indication of which aspects of each VC need to be reinforced to strengthen EU competitiveness.

The CAF could therefore be used by the EC and other stakeholders to identify the VCs and segments within them requiring support – for example, overall support to the solar PV VC and design of financial instruments to leverage early and late stage private financing into the electric power train VC. It could also serve as a basis to identify the types of support required by each VC – for example, tools to support internationalisation of EU businesses active in the heat pump VC in order to enhance the EU export capabilities in this area. The result of the CAF analysis could be used to design specific support programmes, calls for proposals linked to existing programmes, or other support tools. This would complement the existing comprehensive competitiveness assessment developed by the EC to report on progress of clean energy sector competitiveness.[277]

Over time, building on the work done in this study, the completion of multiple competitiveness assessments based on the same framework would enable the identification of common challenges across VCs and help to determine which measures might best address these common challenges. This would allow technological silos to be broken down and further support those strategic sectors that can best enable the EU to reach its 2050 climate neutrality goal.

Operationalisation

The first step is to strengthen and harmonise the approaches adopted to complete competitiveness assessments across the different EC services and to ensure that there

[277] European Commission, 2020, *Commission Staff Working Document Clean Energy Transition – Technologies and Innovations Accompanying the document Report from the Commission to the European Parliament and the Council on progress of clean energy competitiveness*, 14 October 2020, SWD(2020) 953 final, Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020SC0953

is cross-sectoral oversight and that increased cross-EC services cooperation is leveraged. Prior to any assessments being conducted, a clear sectoral decarbonisation roadmap should be developed together with the industrial players to ensure the sector is actually contributing to decarbonisation. The competitiveness assessment will then help identify those segments in the VC requiring most support. It will also serve as a strong basis to design a clear intervention logic for new policy interventions and what their expected added value is. This would also help define the specific contribution of the respective EC services and (where needed) other stakeholders.

This assessment could then be used to inform the design of strategic plans and calls for proposals for existing instruments such as Horizon Europe, InvestEU, etc. Member States could also be encouraged to adopt similar approaches in the formulation of their Partnership Agreements, which will then be implemented through their Operational Programmes supported by European structural funds, as well as how they choose to allocate their share of the Just Transition Fund. It could also inform Member States' Recovery and Resilience Plans. The assessment could also assist in informing technology-specific facilities like the Connecting Europe Facility and the Trans-European Networks in Energy and Transport (TEN-E and TEN-T).

Finally, in order to ensure that the required funding for the strategic VCs is adequately allocated, it is recommended to create and/or to enhance the processes for establishing dedicated funding lots within the different programmes and mechanisms. This is especially important for certain parts of the VC cycle like innovation, market deployment and end-of-life, which are specific for each sector.

Efficient tailoring of existing centrally managed financing mechanisms will help accelerate investments into much-needed infrastructure for the transition towards decarbonisation – for example, through faster deployment of Grid EMS, hydrogen infrastructure, and EU-wide EV charging infrastructure capacities.

R2. European Clustering Strategy

Proposal

Review the current European Strategic Cluster Partnerships, and overarching EU clustering strategy, to determine whether it remains fit-for-purpose and able to support VCs of key importance to achieve climate neutrality by 2050.

This recommendation is based on and directly correlates to the following challenges – C1: Digitalisation, C2: Uncertainty, C4: Data, C5: Cooperation, C8: Fragmentation, C9: Competition, and C10: Incentives. It addresses directly or indirectly all the studied VCs.

Rationale

The new Industrial Strategy for Europe "*recognises clusters as a powerful economic development tool to support industrial innovation on the ground*"[278]. The Industrial Strategy calls for enhancing opportunities for clean industrial leadership, expanding the strategic autonomy of the European industrial ecosystems and accelerating the speed for

[278] European Commission, 2020, *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions – A New Industrial Strategy For Europe*, 10 March 2020, COM(2020) 102 final, Available at: https://ec.europa.eu/info/sites/info/files/communication-eu-industrial-strategy-march-2020_en.pdf, [Accessed on: 24/11/2020]

adopting climate neutral solutions by utilising the full potential of the largest common market in the world.

The study confirmed the importance of industrial clusters for the competitiveness of EU businesses across the studied VCs. For example, an industrial cluster exists for hydrogen in the Port of Rotterdam, which will support positioning the Netherlands around future hydrogen production. The study also identified the need to recognise and reinforce these clusters to further boost the competitiveness of EU businesses, e.g. currently large hydrogen and power-to-x infrastructure projects are not specifically included as a cluster in TEN-E, recognising them as Projects of Common Interest[279] (although this is expected in the forthcoming TEN-E revision which would allow them to apply for CEF funding). Given the European Strategic Cluster Partnerships were launched before the European Green Deal and the EC's objective to reach climate neutrality by 2050, it would be beneficial to review their structure and ensure they are still fit for purpose to help fulfil these new objectives.

Operationalisation

Many strategic VCs are characterised by insufficient market data on the latest innovation trends, which prevents the development of tailored public and private support mechanisms. To assess whether the current instruments like the European Strategic Cluster Partnerships are fit-for-purpose, there is a need for additional data collection and market insights to identify what should be the focus of new clusters, where should they be located given the structure of the European industrial landscape, how can existing instruments (e.g. Climate-KIC or KIC InnoEnergy) be used as a basis for the development of these clusters, etc. This should be the starting point of any future development in this regard. In addition, it should be ensured that the clusters do not become new silos, but rather are aimed at stimulating cross-sectoral cooperation. This includes having the ability for regulatory "sandboxing" for testing new technologies (i.e. by granting temporary dispensations from regulations for the duration of testing) and bringing them to a higher technology readiness level.

R3. Reinforce public financial instruments

Proposal

Maximise the opportunities offered by public financial instruments deployed in recent years (e.g. EIF equity investments, InnovFin Energy Demo Projects facility, etc.) to increase the flow of private finance towards climate neutral solutions, at the scale-up and commercialisation stage (i.e. venture capital and private equity) as well as around main market deployment.

This recommendation is based on and directly correlates to the following challenges – C2: Uncertainty, C6: Finance, C8: Fragmentation, C9: Competition, and C10: Incentives. In addition, it addresses directly or indirectly all the studied VCs.

Rationale

[279] Mete, G. and Reins, L., 2020, *Europe's new Hydrogen Strategy: the questions that still need answering*, Energy Post, Available at: https://energypost.eu/europes-new-hydrogen-strategy-the-questions-that-still-need-answering/, [Accessed on: 24/11/2020]

The analysis of the private investments made at early (i.e. seed, series A) and late stage (i.e. series B+) in companies active in the 12 climate neutral VCs analysed by the study, showed that while EU businesses are relatively successful at attracting early stage investments (the only VC benefiting from less than 10% of the early stage investments tracked by Cleantech Group covers electric power trains), they struggle to attract late stage investors (six VCs benefit from less than 10% of the late stage investments tracked by Cleantech Group and only three benefit from more than 25% of these investments).

This demonstrates the need to make the best use of existing grant programmes, financial instruments and advisory services to sustain the flow of private funds towards early stage investments and facilitate the access of growing EU businesses to late stage venture investments. As a necessary step towards increasing the flow of private finance towards climate neutral solutions, especially at scale-up, commercialisation and market deployment stages, it is considered that all public investment tools at the EC's disposal should be mobilised towards achieving the climate neutrality goal and efficiently delivering the green and digital transition in a post-Covid-19 economic recovery.

Operationalisation

The EC should continue its ongoing efforts to mobilise private innovation finance using public support schemes. Considering the launch of the Sustainable Europe Investment Plan in January 2020 and the agreement reached by EU leaders on the next Multiannual Financial Framework (MFF) and Next Generation EU in July 2020, the recommendation is not to create new mechanisms, but rather ensure that all tools at the EC's disposal with the potential to leverage private finance are oriented towards achieving climate neutrality goals.

This requires addressing three main types of intervention:

The provision of grant support to help innovators at key bottlenecks during their technological development (i.e. at proof-of-concept or commercialisation stage). Grant programmes should be designed in such a way as to leverage the optimal level of private investments (e.g. a good example is the Innovation Fund, which supports up to 60% of the 'relevant costs' of the project and has attracted 311 applications for large-scale project funding totalling over €21.7 billion in its first call);

The deployment of financial instruments (i.e. public loan, equity or guarantee schemes) specifically designed to support the deployment of low carbon solutions and trigger private investment by mitigating their risks exposure (e.g. InnovFin Energy Demo Projects facility which is covered by a first-loss guarantee by the EC); and,

The provision of advisory services to project developers to improve the bankability of their projects which will help leverage both public and private investment (e.g. as is proposed under the Project Development Assistance part of the Innovation Fund).

By mobilising these tools towards the climate goals and the energy transition, it is expected that they would support not only innovators and start-ups in each VC, but also market ready technologies by boosting public private partnerships, joint undertakings, Industrial Alliances (similar to the successful examples to date) and well as scaling-up start-ups These initiatives are expected to increase the strength of each VC. This would also build on Recommendation 1 to use the CAF to design specific calls for proposals or support activities using competitiveness assessments to ensure they focus on the VC segments requiring the most support.

R4. Reduce the dependency of CRMs

Proposal

Reduce the dependency of critical raw materials for innovative climate neutral solutions through increased focus on exploiting the EU own resources, developing the recycling sector and circular economy in line with the Action Plan on Critical Raw Materials.

This recommendation is based on and directly correlates to the following challenges – C2: Uncertainty, C3: End-of-life, C4: Data, C7: CRMs, C9: Competition, and C13: Barriers. It addresses directly or indirectly all the studied VCs.

Rationale

While this study does not include an in-depth analysis of the availability of raw materials of relevance for each VC, this element was analysed in the strategic outlooks. Those revealed that several analysed VCs are strongly dependent on imported raw materials: in particular, batteries, electric power trains, wind rotors and PV panels. During the ongoing Covid-19 pandemic, which initially strongly impacted international trade, the EU's dependence on third countries came to the fore. This situation exacerbates a number of risks for these VCs, including low substitution, low recycling rates for many materials, over-reliance on a limited number of exporters, which creates the risk of dumping, and the threat of new tariffs being imposed by third countries. All of these threaten, to varying degrees, the capabilities of the EU to reach its 2050 climate neutrality objective.

The strategic outlooks recognise the recent initiatives of the EC in tackling these challenges, especially with the recently adopted EU Action Plan on Critical Raw Materials Resilience and the support for and launch of the Critical Raw Materials Alliance (CRM Alliance). These developments are crucial for ensuring the twin issues of sustainability and security of supply are effectively tackled. Despite these positive developments, there remains an urgent need to define when and how efficient domestic mining and recycling abilities can be achieved.

Operationalisation

The first crucial challenge that needs to be tackled in this area regards insufficient data. To tackle this there is a need to thoroughly audit the crucial CRMs required to ensure the EU can reach its climate neutrality objective by 2050. Building on the recent EC study on the raw materials demand for wind and solar PV technologies[280], that aimed to estimate the future demand for raw materials in wind turbines and solar PV following several decarbonisation scenarios, the EC could complete the same analysis for all technologies deemed crucial to helping the EU to reach its climate neutrality goal. This would then feed into a concise assessment of the dependence of each material and its potential internal sourcing and/or replacement.

It would be beneficial for the EU to channel its recognised strengths in R&I for exploiting and processing raw material resources, particularly as increasing resource costs make hitherto uneconomic resources viable to exploit (e.g. as is the case with Finnish mine research and development mentioned in the Batteries strategic outlook). In addition,

[280] Carrara, S., Alves Dias, P., Plazzotta, B. and Pavel, C., 2020, *Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system*, EUR 30095 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16225-4 (online), doi:10.2760/160859 (online), JRC119941, Available at: https://ec.europa.eu/jrc/en/publication/raw-materials-demand-wind-and-solar-pv-technologies-transition-towards-decarbonised-energy-system

further investments into researching substitutes for some CRMs is also regarded as beneficial and feeds into tackling the challenge of economic uncertainty through strengthened science and innovation sector.

Furthermore, as indicated in the recent EU Circular Economy Action Plan, it is crucial for the EU to rapidly develop an efficient recycling sector and aim to close the production circle of the clean technology VCs. This represents an important growth opportunity for the EU and should be prioritised. Building on Recommendation 1, the CAF could be used to inform which activities should be supported.

R5. Coordinated sectoral strategies at EU level

Proposal

Build on the experience gained through establishment of the European Battery Alliance and the European Clean Hydrogen Alliance to adopt a more formal process to set-up coordinated sectoral strategies at EU level aimed at reinforcing the competitiveness of the EU in different industrial ecosystems. Adopting a stronger sectoral focus will require more intensive inter-service collaboration across the EC and the involvement of key stakeholders.

This recommendation is based on and directly correlates to the following challenges – C1: Digitalisation, C2: Uncertainty, C5: Cooperation, C8: Fragmentation, C9: Competition, and C10: Incentives. In addition, it addresses directly or indirectly all of the studied VCs.

Rationale

The study demonstrated the benefits of European sectoral alliances to reinforce the strengths and competitiveness of crucial climate neutral VCs. The study also recognised the considerable efforts of the EC in this regard, especially with the support and establishment of the European Battery Alliance, the European Clean Hydrogen Alliance and the European Raw Materials Alliance. The Industrial Strategy for Europe represents a very strong step towards ensuring support for the strategically important VCs for achieving the EU's climate neutrality goal.

However, more efforts are needed to develop new sectoral alliances and ensure that the sectoral strategies and EU alliances are well coordinated and aimed at reinforcing the competitiveness of the EU in different climate neutral sectors. This in turn will require a more intensive inter-service collaboration across the EC and the involvement of key stakeholders.

Operationalisation

Building on the recommendation already set out in the Industrial Strategy for Europe, the EC should build on the success of existing industrial alliances to identify VCs and industrial ecosystems either requiring similar types of support or a tailor-made approach. The detailed screening required to inform these decisions could be informed by the results of this study or use of the CAF to assess the competitiveness of other climate neutral VCs.

As demonstrated by the achievements of the European Battery Alliance, these alliances have the potential to not only increase the confidence and support of private investors in the VCs, but to also reinforce their overall industrial ecosystems by, for example, supporting standardisation efforts and supporting the development of a skilled workforce. This in turn is expected to reinforce the competitiveness of the EU in these crucial sectors.

R6. EU export strategies

Proposal

Develop EU export strategies for key climate neutral solutions, building on existing initiatives and networks, such as the Enterprise Europe Network.

This recommendation is based on and directly correlates to the following challenges – C2: Uncertainty, C4: Data, C5: Cooperation, C8: Fragmentation, C9: Competition, and C10: Incentives, which cover all three of the main themes. In addition, it addresses directly or indirectly all the studied VCs.

Rationale

Currently, the EU lacks a coherent export strategy for both climate neutral expertise and technologies. Actions taken towards enhancing the export of climate neutral products and services will strengthen VCs by helping to improve profitability and reinvestment levels amongst firms, as well as enhancing skills and competence levels amongst employees. In addition, this strategy should be closely linked to the EU climate diplomacy framework.

Operationalisation

To enhance the strength of strategic VCs, the EU's competitiveness vis-à-vis third countries needs to be either assessed further and/or reassessed, in cases where the levels of ambition, market opportunities and/or needs are greater than the current situation in a given sector. The focus of the assessment exercises should be on key components and VCs that are considered the most exposed to external competitions.

To help this effort, the datasets (i.e. those identified and used for this study) need to be more comprehensive and detailed for a more precise assessment. Filling the gaps of the available data and strengthening the most vulnerable VCs will bring the EU closer towards achieving strategic autonomy in sectors crucial for the energy transition in the COVID recovery period.[281]

A coherent export strategy for expertise, technologies, and final production is an instance where enhanced cooperation is expected to strengthen the vulnerable VCs and further enhance the EU's influence through maintaining strong exports for its already competitive VCs.

In addition, the establishment of an enabling platform could be considered for different Member States not located in the proximity (i.e. on the territory of another Member State) of the low-carbon infrastructure project to participate in its financing and development so as to be able to benefit later on from the energy as well as to count this towards the national and EU targets. This could be foreseen as part of the forthcoming update of the EU Projects of Common Interest (PCI) framework. This could be particularly beneficial in

[281] Anghel, S., Immenkamp, B., Lazarou, E., Leon Saulnier, J. and Wilson, A., 2020, *On the path to 'strategic autonomy' – The EU in an evolving geopolitical environment*, European Parliamentary Research Service, PE 652.096, Available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2020/652096/EPRS_STU(2020)652096_EN.pdf, [Accessed on: 24/11/2020]

VCs such as wind, solar and hydrogen, where large infrastructure and shared networks would be required to meet the set targets, as well as to achieve the cheapest price.

R7. Support standardisation

Proposal

Support standardisation of climate neutral solutions in the EU and beyond to ensure interoperability, facilitate the deployment of new technologies across the EU and simplify market adoption of leading innovations in the internal single market and across global markets.

This recommendation is based on and directly correlates to the following challenges – C1: Digitalisation, C5: Cooperation, C8: Fragmentation, C9: Competition, and C13: Barriers, which cover all three of the main themes. In addition, it addresses directly or indirectly all the studied VCs.

Rationale

When it comes to deployment and market readiness, there are certain technologies and VCs that are more readily deployable than others. This recommendation is more relevant for those VCs with a higher impact of further digitalisation and cyber technologies, as well as those characterised by strong international competition.

There are already initiatives started at different levels by the EC's services such as the ICT Standardisation for the Digital Single Market[282]. However, it is beneficial if efforts are further strengthened and coordinated towards meeting the new climate neutrality goal of the EU.

Operationalisation

The EU's internal single market is the largest in the world and is one of the greatest levers through which the EU can enhance its competitiveness by utilising climate neutral solutions on a large pan-EU scale.

It is considered beneficial if the EC further supports standardisation of climate neutral solutions in the EU and beyond. This is expected to ensure interoperability and to facilitate the deployment of new technologies across the EU. These developments are crucial when it comes to cybersecurity, grid developments, wind rotors, solar panels, hydrogen production and transportation, as well as EV charging infrastructure.

Additionally, standardisation is expected to simplify market adoption of leading innovations in the internal single market, which would in turn strengthen production capacities for standard-compliant climate neutral solutions. Furthermore, it will reduce technological overlaps of infrastructure, such as incompatible EV charging systems across the union, and cybersecurity risks, such as for IoT devices connected to the grid.

Finally, standard-setting in Europe is considered to be a step towards industrial global leadership and digital innovation in climate neutral solutions. Here, the EU can spearhead innovations in the global market given its experience of successfully applied technology deployment, VC strengths and potential for growth.

[282] European Commission, 2020, *Shaping Europe's digital future – Standards*, Available at: https://ec.europa.eu/digital-single-market/en/standards, [Accessed on: 24/11/2020]

R8. Use the NECP progress reports, EU Semester process and other Member State planning tools to reinforce EU strategies

Proposal

Exploit further the NECP progress reports, EU Semester process and Member State Recovery and Resilience Plans to coordinate: (1) public investments towards climate neutral solutions across Europe; (2) the development of appropriate infrastructure to support the transition towards climate neutrality; (3) the contribution of national innovation/industrial ecosystems to the building of European strategic and climate neutral VCs; and (4) the contribution of Member State policies to both the European RD&D and EU competitiveness objectives, while achieving the EU climate ambition.

This recommendation is based on and directly correlates to the following challenges – C1: Digitalisation, C2: Uncertainty, C4: Data, C5: Cooperation, C6: Finance, C8: Fragmentation, C9: Competition, C10: Incentives, and C11: Transposition. In addition, it addresses directly or indirectly all the studied VCs.

Rationale

Although the objective of the study was to assess the competitiveness of EU businesses against other trading blocks, the analysis of the 12 climate neutral VCs showed that the shape of the VCs varies considerably from one Member State to the other depending on the strengths and weaknesses of each Member State and their policy priorities. Given the objective to reach climate neutrality by 2050 is an overarching European one and each Member State will play a key role in this journey (both in terms of developing their own policies and measures and fully transposing the European ones), the EC should use existing reporting processes to collect more robust and consistent information about the status of climate neutral VCs across Europe, identify supporting policies and measures to reinforce synergies and identify gaps in the landscape of support measures.

Operationalisation

Rather than creating new reporting processes, the EC should use existing channels to achieve the above objectives. These include among others:

- **EU semester process:** Member States' competitiveness is already one of the main focal points of the EU semester process, with each country report containing a large chapter on the "Competitiveness, reforms and investment". "Environmental sustainability" is another core focus of the EU semester reports, but there are currently no strong linkages between these two chapters of the country reports. It would therefore be beneficial to investigate how to use this process to identify national policies and measures supporting the competitiveness of climate neutral VCs.

- **NECP reporting process:** The Regulation on the governance of the energy union and climate action (EU/2018/1999) requires all Member States to submit progress reports on their NECP every two years. These reports will be used by the EC to monitor the progress of the EU as a whole towards achieving the climate and energy targets. Building on the recently published assessment of the 27

NECPs[283], the EC should continue to use the NECP reporting process to monitor the competitiveness of EU Member States in low carbon sectors and climate neutral VCs. As noted in the review of the NECPs: "*The approach to competitiveness varies between NECPs. Some followed a narrow definition looking at patents and researchers, or even just at power prices. Other plans cover technology deployment aspects and thus take a broader competitiveness approach to national suppliers of clean technologies, including the VCs to develop such solutions. However, most plans lack quantitative indicators and are therefore not measurable.*"[284] Based on this conclusion the EC could provide more guidance to Member States in this area to build a more robust picture of the competitiveness of climate neutral VCs across Europe. This process should also be used to reinforce synergies across support measures. Possible avenues include for example further strengthening and coordinating public investments towards climate neutral solutions across Europe. This is expected to enhance EU competitiveness by supporting the most vulnerable VCs, as well increasing investor confidence in VCs deemed crucial for the digital and energy transition in Europe.

- **Member States Recovery and Resilience Plans:** As part of the Recovery plan for Europe, Member States must draft Recovery and Resilience Plans setting out reforms and investments coherently and adequately addressing the challenges in the individual Member State. The guidance provided by the EC for the developments of these plans requires Member States to consider how the plan will support them to come out stronger from the COVID pandemic, be better prepared to address future challenges and reinforce the long-term competitiveness of the EU economy. Although no references are made to the competitiveness of specific VCs, the EC could use these plans to streamline recovery plans towards VCs of strategic interest for the EU economy.

R9. Reinforce the EU energy market

Proposal

Reinforce the EU low-carbon energy market by: (1) further strengthening the transposition mechanisms at hand and ensuring that adopted EU energy and climate legislation is correctly introduced on time into national laws; (2) coordinating large low-carbon infrastructure auctons (including RES) between Member States to enable a timely and scheduled connection of large projects and the respective enabling infrastructure to the grid; (3) increase interconnection between countries to at least 15% and ensure that barrier-free and easier trade of RES across the EU is possible and stimulated.

This recommendation is based on and directly correlates to the following challenges – C2: Uncertainty, C5: Cooperation, C8: Fragmentation, C11: Transposition, and C13:

[283] European Commission, 2020, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – An EU-wide assessment of National Energy and Climate Plans Driving forward the green transition and promoting economic recovery through integrated energy and climate planning*, 17 September 2020, COM(2020) 564 final, Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0564&from=EN

[284] European Commission, 2020, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – An EU-wide assessment of National Energy and Climate Plans Driving forward the green transition and promoting economic recovery through integrated energy and climate planning*, 17 September 2020, COM(2020) 564 final, Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0564&from=EN

Barriers, which cover all three of the main themes. In addition, it addresses directly or indirectly all the studied VCs.

Rationale

A number of challenges could be addressed by strengthening the EU energy market. Currently, the adoption speed of some crucial EU energy and climate laws is not transposed fast enough into national legislation. It is recognised that the EC puts strong efforts to facilitate timely and correct transposition by preparing implementation plans, guidance documents and expert group meetings.

However, there are still a number of active infringement proceedings of incorrect or late transposition cases for various legislative files[285] including, importantly, for the latest files of the "Clean Energy for All Europeans" legislative package (i.e. the Energy Performance of Buildings Directive, the Energy Efficiency Directive, and the Directive on the Internal Market for Electricity), as well as laws on Environmental protection and Climate mitigation. As recognised in the latest annual report on monitoring the application of EU law[286], fully implemented and enforced legislation is essential to reach current targets and to build a solid basis for raising the level of ambition to at least 55% reduction of GHG emissions by 2030.

There are opportunities for cross-border coordination of infrastructure development which are either not at all utilised or else are underutilised. Increasing the cooperation of Member States in coordinating the deployment of large-scale infrastructure projects and sharing best practices will ensure the stability of the grid and the achievement of the new ambitious targets. Finally, achieving the set electricity interconnection target of at least 15% is believed to be largely positive in strengthening the internal market for electricity by allowing larger capacities of RES to be transferred across the Union. These two measures are expected to aid the reduction of trade barriers through increased transposition and cooperation between Member States.

Operationalisation

As a first and necessary step it is considered that the transposition enforcement and follow-up mechanisms at the EC's disposal are strengthened in light of achieving the higher climate and energy targets. Even closer cooperation with the Agency for Cooperation of Energy Regulators (ACER), as well as with Member State national authorities is essential.

In addition, well-structured implementation plans with clear targets, information campaigns, guidance documents, and strong stakeholder engagement are some of the steps that could be taken towards reducing transposition and implementation issues. This is especially important when it comes to digitalisation, new technologies at grid level, and new entities like energy communities. These steps are in line with the framework set forth by the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action and should be aligned with Member State reporting.

Another important step is better coordination of large low-carbon infrastructure auctions between Member States. Further, cross-border auctions between involving several

[285] European Commission, 2020, *Annual reports on monitoring the application of EU law,* Available at: https://ec.europa.eu/info/publications/annual-reports-monitoring-application-eu-law_en, [Accessed on: 24/11/2020]

[286] European Commission, 2019, *Monitoring the Application of European Union Law 2019 Annual Report,* Available at: https://ec.europa.eu/info/sites/info/files/file_import/report-2019-annual-report-monitoring-application-eu-law_en.pdf, [Accessed on: 24/11/2020]

Member States could provide significant benefits. In addition, to exchanging best practices on structuring and carrying out the auctions, this stronger cooperation is expected to enable a scheduled connection of large infrastructure to the grid.

Close cooperation on a larger scale is deemed important not only for electricity and corresponding infrastructure, but also for enabling the future EU hydrogen market. This will need higher support and cross-country cooperation in order to reach the required levels of infrastructure availability (e.g. green/orange hydrogen production facilities, transporting and storage infrastructure).

Connection of a large volume of RES to the European grid without overburdening it is essential. Therefore, the increased interconnection capacity between countries is considered a highly beneficial measure to increase trade and reduce barriers. These steps could be done through the Regulation (EU) 2019/943 on the internal market for electricity, Regional Coordination Centres (Regional Transmission System Operator (TSO) level) and through common regional development plans.

R10. Develop strong demand-side policies to drive market developments in the EU and benefit from the first-mover advantage in climate neutral VCs.

Proposal

Develop strong demand-side policies to drive market developments in the EU and benefit from the first-mover advantage in climate neutral VCs. Demand-side policies must complement the set of existing policies and measures in place to support the competitiveness of EU businesses developing climate neutral solutions. Creating demand and markets for clean, climate-neutral, energy-efficient and circular products is critical to ensure the EU can achieve its climate neutrality objectives.

This recommendation is based on and directly correlates to the following challenges C9 Competition; 10 Incentives; C11 Acceptance and C13 Barriers. It addresses directly or indirectly all the studied VCs.

Rationale

The analysis of the VCs showed that in some of the most established climate neutral VCs (e.g. Wind Rotors), countries that were first to develop strong demand-side policies are still home to some of the world's leading companies in this field (e.g. Denmark, Spain and Germany). These three Member States remain leading global exporters, demonstrating their ability to capitalise on their first-mover advantage and making the case for the development of strong demand-side policies to achieve competitiveness. Analysis of the Solar PV VC tells another story however since despite the strong initial growth of the VC in Europe, which was largely driven by demand-side policies, European businesses now face fierce competition from other trading bocks and China in particular. This highlights the fact that the first-mover advantage should not be taken for granted and a continuous process of reflection and adapting industrial policies is required to address new challenges, promote technological improvements, and support competitiveness. This is especially true for products and commodities that can easily be traded across the globe.

Operationalisation

A first step to operationalise this recommendation would be to review the suite of demand-side policies already in place to support climate neutral VCs in Europe and beyond, to better understand their effectiveness and interactions with other policy interventions.

Indeed, recent academic reports have stressed the lack of attention given to demand-side policies and measures in the race to limit global warming to 1.5 °C above preindustrial levels, despite their crucial role in this context. One review concluded that: "*demand-side policy portfolios are required to drive the pace and direction of deep decarbonization pathways and keep the 1.5 °C target within reach […] Moreover, demand-side portfolios have potentially wider benefits and encompass fewer risks than supply-side options: they are closely associated with synergistic co-benefits for health, pollution, security, equity, living standards, and system costs*".

Demand-side policies and measures can take various shapes depending on their objectives. Some examples of demand-side policies and measures that could be used to support EU competitiveness in climate neutral VCs include:

Setting sectoral targets and emission limits at both EU and national level, as is currently being done across a range of VCs (see for example the decarbonisation pathways to 2030 issued by the European association representing the paper industry (Cepi) or a roadmap to decarbonising European cars by 2050 issued by Transport & Environment.

Setting minimum energy, environmental and/or circular economy and resource efficiency performance standards to drive the market towards more sustainable products, as is already largely done for energy-using products and other end-use products directly through Energy Labelling and Ecodesign Directives and indirectly through EPBD and EED.

Ban certain polluting products on the market as is already being done by the Directive on hazardous substances in electrical and electronic equipment or as is currently being programmed for fossil fuel vehicles across different European countries to support the EV market and other low-carbon vehicles (Norway was the first country to propose a ban on the sale of all petrol and diesel vehicles by 2025 in 2016. Other countries followed such as France that proposed to ban all petrol and diesel cars by 2040 in 2017).

Developing behavioural policies to drive consumer choices towards climate neutral solutions. This can take a variety of forms, from awareness raising campaigns, the development of endorsement labels like the EU Ecolabel or financial incentives.

Use of Green Public Procurement (GPP) to drive the demand for climate neutral solutions, linking GPP to top performing products such as those linked to an endorsement scheme such as the EU Ecolabel. This would stimulate technology innovation by giving the manufacturers a market.

The second step would be to design coherent policy packages targeting key climate neutral VCs, recognising that these are likely to be strongly sector-specific.

Finally, while not at the centre of this recommendation, it will be important to complement these demand-side policies with measures to create a level playing field for all businesses distributing their products and services on the EU market. Two ongoing policy initiatives at EU level are worth mentioning in this context: (1) the Carbon border adjustment mechanism, that aims to ensure that the competitiveness of EU industry is not jeopardised by carbon leakage; and (2) the green claims initiative, that aims to make environmental claims reliable, comparable and verifiable across the EU to reduce 'greenwashing' and help investor and consumer decision.

Annex 1. Datasets

As a result of applying the analytical framework to the 12 selected VCs, an Excel file has been prepared with the processed data collected for each VC. The workbook has an 'About' sheet with details on data coverage and sources, and ten sheets with the data and key results for each indicator listed in Table 2.2 including an inventory of innovative companies.

These documents are available at: https://ec.europa.eu/docsroom/documents/44064.

VC	Dataset
Batteries	*Dataset - Batteries.xlsx*
Hydrogen Fuel Cells	*Dataset - Hydrogen Fuel Cells.xlsx*
Electric Power Trains	*Dataset - Electric Power Trains.xlsx*
Electric Vehicles Charging Infrastructure	*Dataset - EV Charging Infrastructure.xlsx*
Prefabricated Buildings	*Dataset - Prefabricated Buildings.xlsx*
Superinsulation Materials	*Dataset - Superinsulation Materials.xlsx*
Heat Pumps	*Dataset - Heat Pumps.xlsx*
Wind Rotors	*Dataset - Wind Rotors.xlsx*
Photovoltaic Solar Panels	*Dataset - PV Solar Panels.xlsx*
Building Energy Management Systems	*Dataset – Building EMS.xlsx*
Grid Energy Management Systems	*Dataset – Grid EMS.xlsx*
Hydrogen Production	*Dataset - Batteries.xlsx*

Annex 2. Data Codes

The table below presents the codes that were used for collecting data in the competitiveness assessment undertaken for the 12 strategic components presented in Table 2.3. The information presented for the private investment, companies, employment, and turnover indicators is not extracted through code selection. Thus, these indicators are not cover in the table below. Section 3.2 provides detailed information about the process for collecting data from the 10 indicators listed in Table 2.2.

Value Chain	PRODCOM	COMEXT	COMTRADE	IEA RD&D	PATSTAT
Batteries	**27202300** Nickel-cadmium, nickel metal hydride, lithium-ion, lithium polymer, nickel-iron and other electric accumulators	**8507** Electric accumulators, incl. separators therefore, whether or not square or rectangular; parts thereof (excl. spent and those of unhardened rubber or textiles) **8507 60 00** Lithium-ion accumulators (excl. spent)	**8507** Electric accumulators, incl. separators therefor, whether or not square or rectangular; parts thereof (excl. spent and those of unhardened rubber or textiles) **8507 60 00** Lithium-ion accumulators (excl. spent)	**1311** Vehicle batteries/storage technologies **6311** Batteries and other electrochemical storage (excluding vehicles and general public portable devices)	**Y02E 70/40** Energy efficient batteries, ultracapacitors, supercapacitors or double-layer capacitors charging or discharging systems or methods **Y04S 10/14** Energy storage units supporting electrical power generation, transmission or distribution **Y02P 70/54** manufacturing of lithium-ion, lead-acid or alkaline secondary batteries. **Y02P 90/50** Energy storage in industry with an added climate change mitigation effect **Y02E 60/12** battery technology **Y02E 60/122** lithium-ion batteries **Y02E 60/124** alkaline secondary batteries, e.g. NiCd or NiMH **Y02E 60/126** Lead-acid batteries **Y02E 60/128** hybrid cells composed of a half-cell of a fuel-cell type and a half-cell of the secondary-cell type **Y02E 60/528** regenerative or indirect fuel cell, e.g. redox flow type batteries **Y02T 10/7005** batteries for electromobility **Y02T 10/7011** lithium ion battery for electromobility **Y02T 10/7016** lead acid battery for electromobility **Y02T 10/7038** Energy storage management for electromobility

Value Chain	PRODCOM	COMEXT	COMTRADE	IEA RD&D	PATSTAT
					Y02T 10/7044 Controlling the battery or capacitor state of charge for electromobility applications
Hydrogen Fuel Cells	**27904200** Fuel cells	*NO CODE*	*NO CODE*	**52** Fuel cells	**Y02P 70/56** Manufacturing of fuel cells **Y02P 90/40** Fuel cell technologies Manufacturing of fuel cells in production processes **Y02B 90/10** Applications of fuel cells in buildings **Y02B 90/12** Cogeneration of electricity with other electric generators **Y02B 90/14** Emergency, uninterruptible or back-up power supplies integrating fuel cells **Y02B 90/16** Cogeneration or combined heat and power generation **Y02E 60/50** Fuel cells **Y02E 60/52** fuel cells characterised by type or design **Y02E 60/521** Proton Exchange Membrane fuel cell (PEMFC) **Y02E 60/525** Solid Oxide fuel cell **Y02E 60/526** molten carbonate fuel cells **Y02W 30/86** Recycling of fuel cells
Electric Power Trains	**27111050** DC motors and DC generators of an output > 750 W but ≤ 75 kW (excluding starter motors for internal combustion engines) **27111070** DC motors and generators of an output > 75 kW but ≤ 375 kW (excluding starter motors for internal combustion engines) **27111090** DC motors and generators of an output > 375 kW (excluding starter motors for internal combustion engines)	**8501 32 00** DC motors and DC generators of an output > 750 W but <= 75 kW **8501 33 00** DC motors and DC generators of an output > 75 kW but <= 375 kW **8501 34 00** DC motors and DC generators of an output > 375 kW **8501 40 80** AC motors, single phase, of an output of > 750 W **8501 52 20** AC motors, multi-phase, of an output > 750 W but <= 7,5 kW	**850132** Electric motors and generators; DC, of an output exceeding 750W but not exceeding 75kW; **850133** Electric motors and generators; DC, of an output exceeding 75kW but not exceeding 375kW; **850134** Electric motors and generators; DC, of an output exceeding 375kW; **850140** Electric motors; AC motors, single-phase; **850152** Electric motors; AC motors, multi-phase, of an	**1312** Advanced power electronics, motors, EV/HEV/FCV systems	**Y02T 10/72** Electric energy management in electromobility **Y02T 10/7208** Electric power conversion within the vehicle **Y02T 10/7216** DC to DC power conversion **Y02T 10/7225** Using step - up or boost converters **Y02T 10/7233** Using step - down or buck converters **Y02T 10/7241** DC to AC or AC to DC power conversion **Y02T 10/725** AC to AC power conversion **Y02T 10/7258** Optimisation of vehicle performance **Y02T 10/7275** Desired performance achievement

Value Chain	PRODCOM	COMEXT	COMTRADE	IEA RD&D	PATSTAT
	27112250 Single-phase AC motors of an output > 750 W **27112403** Multi-phase AC motors of an output > 0,75 kW but ≤ 7,5 kW **27112405** Multi-phase AC motors of an output > 7,5 kW but ≤ 37 kW **27112407** Multi-phase AC motors of an output > 37 kW but ≤ 75 kW **27112530** Multi-phase AC traction motors of an output > 75 kW **27112540** Multi-phase AC motors of an output > 75 kW but ≤ 375 kW (excluding traction motors) **27112560** Multi-phase AC motors of an output > 375 kW but ≤ 750 kW (excluding traction motors) **279900Z1** Parts suitable for use solely or principally with electric motors and generators, electric generating sets and rotary converters, n.e.c.	**8501 52 30** AC motors, multi-phase, of an output > 7,5 kW but <= 37 kW **8501 52 90** AC motors, multi-phase, of an output > 37 kW but <= 75 kW **8501 53 50** AC traction motors, multi-phase, of an output > 75 kW **8501 53 81** AC motors, multi-phase, of an output of > 75 kW but <= 375 kW (excl. traction motors) **8501 53 94** AC motors, multi-phase, of an output of > 375 kW but <= 750 kW (excl. traction motors) **8503 00** Parts suitable for use solely or principally with electric motors and generators, electric generating sets and rotary converters, n.e.s.	output exceeding 750W but not exceeding 75kW; **850153** Electric motors; AC motors, multi-phase, of an output exceeding 75kW; **850300** Electric motors and generators; parts suitable for use solely or principally with the machines of heading no. 8501 or 8502;		**Y02T 10/7283** Optimisation of energy management **Y02T 10/7291** by route optimisation processing **Y02T 10/64** Electric machine technologies for applications in electromobility **Y02T 10/641** characterised by aspects of the electric machine **Y02T 10/642** Control strategies of electric machines for automotive applications **Y02T 10/643** Vector control **Y02T 10/644** Control strategies for ac machines other than vector control **Y02T 10/645** Control strategies for dc machines
Electric Vehicles Charging Infrastructure	*NO CODE*	*NO CODE*	*NO CODE*	**1314** Electric vehicle infrastructure (including smart chargers and grid communications)	**Y02T 90/10** Technologies related to electric vehicle charging **Y02T 90/12** Electric charging stations **Y02T 90/121** by conductive energy transmission **Y02T 90/122** by inductive energy transmission **Y02T 90/124** by exchange of energy storage elements **Y02T 90/125** Alignment between the vehicle and the charging station

Value Chain	PRODCOM	COMEXT	COMTRADE	IEA RD&D	PATSTAT
					Y02T 90/127 Converters or inverters for charging **Y02T 90/128** Energy exchange control or determination **Y02T 90/14** Plug-in electric vehicles **Y02T 90/163** Information or communication technologies related to charging of electric vehicle **Y02T 90/167** Systems integrating technologies related to power network operation and communication or information technologies for supporting the interoperability of electric or hybrid vehicles **Y02T 90/168** Remote or cooperative charging operation **Y02T 90/169** Aspects supporting the interoperability of electric or hybrid vehicles, e.g. recognition, authentication, identification or billing; **Y02T 10/91** Energy efficient charging or discharging systems for batteries, ultracapacitors, supercapacitors or double-layer capacitors specially adapted for vehicles **Y04S 30/11** Remote or cooperative charging
Prefabricated Buildings	**16232000** Prefabricated buildings of wood **25111030** Prefabricated buildings, of iron or steel **23612000** Prefabricated buildings of concrete **25111050** Prefabricated buildings, of aluminium **22232000** Prefabricated buildings, of plastics **23611200** Prefabricated structural components for building or civil engineering,	**9406 00 10** Prefabricated buildings made entirely or mainly from wood whether of not complete or already assembled **9406 00 20** Prefabricated buildings made entirely or mainly from wood whether of not complete or already assembled (excl. mobile homes) **9406 00 30** Prefabricated buildings made entirely or mainly from iron or steel	**940600** Buildings; prefabricated **940610** Buildings; prefabricated, of wood **940690** Buildings; prefabricated, not of wood **681091** Cement, concrete or artificial stone; prefabricated structural components for building or civil engineering, whether or not reinforced	**122** Building operation and efficient building equipment **1224** Other building operations and efficient building equipment	*NO CODE*

Value Chain	PRODCOM	COMEXT	COMTRADE	IEA RD&D	PATSTAT
	of cement, concrete or artificial stone	whether of not complete or already assembled **9406 00 80** Prefabricated buildings whether or not complete or already assembled (excl. mobile homes or those made entirely or mainly from wood, iron or steel) **9406 00 90** Prefabricated buildings whether or not complete or already assembled (excl. those made entirely or mainly from wood, iron or steel) **9406 10 00** Prefabricated buildings of wood, whether or not complete or already assembled; **9406 90** Prefabricated buildings, whether or not complete or already assembled (excl. of wood); **9406 90 38** Buildings, prefabricated, whether or not complete or already assembled, made entirely or mainly of iron or steel (excl. mobile homes and greenhouses); **9406 90 90** Prefabricated buildings, whether or not complete or already assembled (excl. mobile homes and those made entirely or mainly of wood, iron or steel);			

Value Chain	PRODCOM	COMEXT	COMTRADE	IEA RD&D	PATSTAT
		6810 91 00 Prefabricated structural components for building or civil engineering of cement, concrete or artificial stone, whether or not reinforced			
Superinsulation Materials	**23911230** Natural or artificial abrasive powder or grain, on a base of woven textile fabric only **23911250** Natural or artificial abrasive powder or grain, on a base of paper or paperboard only **23911290** Natural or artificial abrasive powder or grain on a base (excluding on a base of woven textile only, on a base of paper or paperboard only) **23991910** Slag wool, rock wool and similar mineral wools and mixtures thereof, in bulk, sheets or rolls **23991920** Exfoliated vermiculite, expanded clays, foamed slag and similar expanded mineral materials and mixtures thereof **23991930** Mixtures and articles of heat/sound-insulating materials n.e.c.	**6805 10 00** Natural or artificial abrasive powder or grain, on a base of woven textile fabric only, whether or not cut to shape, sewn or otherwise made up; **6805 20 00** Natural or artificial abrasive powder or grain, on a base of paper or paperboard only, whether or not cut to shape, sewn or otherwise made up; **6805 30 00** Natural or artificial abrasive powder or grain, on a base of materials other than woven textile fabric only or paper or paperboard only, whether or not cut to shape, sewn or otherwise made up; **6806 10 00** Slag-wool, rock-wool and similar mineral wools, incl. intermixtures thereof, in bulk, sheets or rolls; **6806 20** Exfoliated vermiculite, expanded clays, foamed slag and similar expanded mineral materials, incl. intermixtures thereof;	**680510** Abrasive powder or grain; natural or artificial, on a base of woven textile fabric only, whether or not cut to shape or sewn or otherwise made up **680520** Abrasive powder or grain; natural or artificial, on a base of paper or paperboard only, whether or not cut to shape or sewn or otherwise made up **680530** Abrasive powder or grain; natural or artificial, on a base of materials n.e.s. in heading no. 6805, whether or not cut to shape or sewn or otherwise made up **680610** Slag wool, rock wool and similar mineral wools (including intermixtures thereof), in bulk, sheets or rolls **680620** Exfoliated vermiculite, expanded clays, foamed slag and similar expanded mineral materials (including intermixtures thereof) **680690** Minerals; mixtures and articles of heat-insulating, sound-insulating or sound-absorbing mineral materials,	**122** Building operation and efficient building equipment **1224** Other building operations and efficient building equipment	**Y02A 30/24** Structural elements or technologies for improving thermal insulation; **Y02A 30/241** Thermal insulation technologies with adaptation potential; **Y02A 30/242** Slab shaped vacuum insulation; **Y02A 30/243** Slab shaped aerogel insulation; **Y02A 30/244** characterized by the use of locally available building materials **Y02A 30/245** of vegetal origin, e.g. thatching or straw **Y02A 30/246** of animal origin, e.g. wool or feathers **Y02A 30/247** using indigenous Earth materials, e.g. clay or stone **Y02A 30/248** Recycled materials, e.g. made of used tires, bumpers or newspapers **Y02A 30/256** Floors specially adapted for storing heat or cold **Y02A 30/257** Light dependent control systems for sun shading **Y02B 80/10** Insulation **Y02B 80/12** Slab shaped vacuum insulation **Y02B 80/14** Slab shaped aerogel insulation **Y02B 80/40** Floors specially adapted for storing heat or cold **Y02B 80/50** Light dependent control systems for sun shading

Value Chain	PRODCOM	COMEXT	COMTRADE	IEA RD&D	PATSTAT
		6806 90 00 Mixtures and articles of heat-insulating, sound-insulating or sound absorbing mineral materials (excl. slag-wool, rock-wool and similar mineral wools, exfoliated vermiculite, expanded clays, foamed slag and similar expanded mineral materials, articles of light concrete, asbestos-cement, cellulose fibre-cement or the like, mixtures and other articles of or based on asbestos, and ceramic products)	other than those of heading no. 6811 or 6812 or of chapter 69		
Heat Pumps	**28251380** Heat pumps other than air conditioning machines	**841861** Heat pumps (excl. air conditioning machines of heading 8415)	**8418** Refrigerators. Freezers and other refrigerating or freezing equipment, electric or other; heat pumps other than air conditioning machines of heading no. 8415	**144** Heat pumps and chillers	**Y02B 30/12** hot water central heating systems using heat pumps **Y02B 30/125** hot water central heating using heat pumps, combined with the use of heat accumulated in storage masses **Y02B 30/13** Hot air central heating systems using heat pumps **Y02B 30/52** Heat recovery pumps, i.e. heat pump based systems improving the overall efficiency **Y02B 10/40** Geothermal heat-pumps
Wind Generating Sets	**28112400** Generating sets, wind-powered	**8502 31 00** Generating sets, wind-powered	**850231** Electric generating sets; wind-powered, (excluding those with spark-ignition or compression-ignition internal combustion piston engines)	**32** Wind energy	**Y02E 10/70** Wind Energy **Y02E 10/72** Wind turbines with rotation axis in wind direction **Y02E 10/721** Blades or rotors **Y02E 10/722** Components or gearbox **Y02E 10/723** Control of turbines **Y02E 10/725** Generator or configuration **Y02E 10/726** Nacelles **Y02E 10/727** Offshore towers

Value Chain	PRODCOM	COMEXT	COMTRADE	IEA RD&D	PATSTAT
					Y02E 10/728 Onshore towers **Y02E 10/74** Wind turbines with rotation axis perpendicular to the wind direction
Photovoltaic Solar Panels	**26114070** Parts of diodes, transistors and similar semiconductor devices, photosensitive semiconductor devices and photovoltaic cells, light-emitting diodes and mounted piezo-electric crystals **26112240** Photosensitive semiconductor devices; solar cells, photo-diodes, photo-transistors, etc.	**8541 40** Photosensitive semiconductor devices, incl. photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes (excl. photovoltaic generators); **8541 40 90** Photosensitive semiconductor devices, incl. photovoltaic cells	**854140** Electrical apparatus; photosensitive, including photovoltaic cells, whether or not assembled in modules or made up into panels, light-emitting diodes (LED);	**312** Photovoltaics	**Y02B 10/10** Photovoltaic [PV] **Y02B 10/12** Roof systems for PV cells; **Y02B 10/14** PV hubs; **Y02E 10/50** Photovoltaic [PV] energy **Y02E 10/52** PV systems with concentrators **Y02E 10/54** Material technologies **Y02E 10/541** CuInSe2 material PV cells **Y02E 10/542** Dye sensitized solar cells **Y02E 10/543** Solar cells from Group II-VI materials **Y02E 10/544** Solar cells from Group III-V materials **Y02E 10/545** Microcrystalline silicon PV cells **Y02E 10/546** Polycrystalline silicon PV cells **Y02E 10/547** Monocrystalline silicon PV cells **Y02E 10/548** Amorphous silicon PV cells **Y02E 10/549** organic PV cells
Building Energy Management Systems	*NO CODE*	*NO CODE*	*NO CODE*	**122** Building operation and efficient building equipment **1221** Building management systems (including smart meters) and efficient internet and communication technologies **1222** Lighting technologies and control systems;	**Y02B 90/20** Systems integrating technologies related to power network operation and communication or information technologies mediating in the improvement of the carbon footprint of the management of residential or tertiary loads, i.e. smart grids as enabling technology in buildings sector (smart grids supporting the management or operation of end-user stationary applications in general, or like technologies with no associated climate change mitigation effect Y04S 20/00) **Y02B 90/22** Systems characterised by the monitored, controlled or operated end-user elements or equipments; **Y02B 70/32** End-user application control systems

Value Chain	PRODCOM	COMEXT	COMTRADE	IEA RD&D	PATSTAT
				1223 Heating, cooling and ventilation technologies; **1224** Unallocated building operations and equipment **1229** Other building operations and efficient building equipment;	**Y02B 70/325** involving home automation communication networks **Y02B 70/3208** characterised by the aim of the control **Y02B 70/3216** General power management systems **Y02B 70/3233** The system entering an energy saving mode, i.e. sleep, low-power or standby modes **Y02B 70/3241** Domotics or building automation systems **Y02B 70/3258** characterised by the end-user application **Y02B 70/3266** The end-user application being or involving home appliances **Y02B 70/3275** The home appliances being or involving heating ventilating or air conditioning [HVAC] units **Y02B 70/3283** The system involving the remote operation of lamps or lighting equipment **Y02B 70/3291** The end-user application involving uninterruptible power supply [UPS] systems or standby or emergency generators (for uninterruptible power supply systems or standby or emergency generators in the last power distribution stages Y04S 20/12) **Y02B 70/34** Smart metering supporting the carbon neutral operation of end-user applications in buildings **Y02B 70/343** Systems which determine the environmental impact of user behaviour **Y02B 70/346** Systems which monitor the performance of renewable electricity generating systems, e.g. of solar panels;
Grid Energy Management Systems	**27123170** Other bases for electric control, distribution	**853710** Boards, cabinets and similar combinations of apparatus for electric control	**853710** Boards, panels, consoles, desks and other bases; for electric control or	**612** Power generation	**Y02B 90/228** the element or elements being a direct current power network, grid or distribution line;

Value Chain	PRODCOM	COMEXT	COMTRADE	IEA RD&D	PATSTAT
	of electricity, voltage <= 1 000 V **27123203** Boards, cabinets and similar combinations of apparatus for electric control or the distribution of electricity, for a voltage > 1.000 V but <= 72,5 kV **27123205** Boards, cabinets and similar combinations of apparatus for electric control or the distribution of electricity, for a voltage > 72,5 kV	or the distribution of electricity, for a voltage <= 1.000 v **853720** Boards, cabinets and similar combinations of apparatus for electric control or the distribution of electricity, for a voltage > 1.000 v	the distribution of electricity, (other than switching apparatus of heading no. 8517), for a voltage not exceeding 1000 volts; **853720** Boards, panels, consoles, desks and other bases; for electric control or the distribution of electricity, (other than switching apparatus of heading no. 8517), for a voltage exceeding 1000 volts;	supporting technologies **62** Electricity transmission and distribution **6211** Cables and conductors (superconducting, conventional, composite core) **6213** Other transmission and distribution techs **6219** Unallocated transmission and distribution **621** Transmission and distribution technologies **6221** Load management (including renewable integration); **6222** Control systems and monitoring; **6223** Standards, interoperability and grid cyber security; **6229** Unallocated grid communication, control systems and integration	**Y02B 70/30** Systems integrating technologies related to power network operation and communication or information technologies for improving the carbon footprint of the management of residential or tertiary loads, i.e. smart grids as climate change mitigation technology in the buildings sector, including also the last stages of power distribution and the control, monitoring or operating management systems at local level (smart grids supporting the management or operation of end-user stationary applications in general, e.g. with no associated climate change mitigation effect Y04S 20/00); **Y02B 90/222** the elements or equipments being or involving energy storage units, uninterruptible power supply [UPS] systems or standby or emergency generators involved in the last power distribution stages (energy storage units involved in power generation, transmission or distribution Y04S 10/14 ; uninterruptible power supply systems or standby or emergency generators as end-user application Y04S 20/248); **Y02A 30/10** Adapting or protecting infrastructure or their operation in energy generation or distribution; **Y02E 60/70** Systems integrating technologies related to power network operation and communication or information technologies mediating in the improvement of the carbon footprint of electrical power generation, transmission or distribution, i.e. smart grids as enabling technology in the energy generation sector (smart grids relating to the energy generation sector in general, e.g. with no associated climate change mitigation effect Y04S 10/00);

Value Chain	PRODCOM	COMEXT	COMTRADE	IEA RD&D	PATSTAT
				622 Grid communication, control systems and integration; **629** Unallocated electricity transmission and distribution	**Y02E 40/70** Systems integrating technologies related to power network operation and communication or information technologies for improving the carbon footprint of electrical power generation, transmission or distribution, i.e. smart grids as climate change mitigation technology in the energy generation sector (smart grids relating to the energy generation sector in general, e.g. with no associated climate change mitigation effect Y04S 10/00); **Y04S 20/18** The element or elements being a direct current power network, grid or distribution line; **Y02B 70/3225** Demand response systems, e.g. load shedding, peak shaving **Y02E 60/723** the elements or equipments being or involving electric power substations **Y02E 60/724** the elements or equipments being or involving switches, relays or circuit breakers, e.g. intelligent electronic devices [IED] **Y02E 60/725** the elements or equipments being or involving protection elements, arrangements or systems **Y02E 60/726** the elements or equipments being or involving voltage regulating units **Y02E 60/727** the elements or equipments being or involving measuring units **Y02E 60/728** the measuring units being or involving phasor measuring units [PMU] **Y04S 10/545** Computing methods or systems for efficient or low carbon management or operation of electric power systems **Y04S 20/222** Demand response systems, e.g. load shedding, peak shaving **Y04S 20/224** Curtailment; Interruptions; Retail price responsive demand **Y04S 20/30** Smart metering

Value Chain	PRODCOM	COMEXT	COMTRADE	IEA RD&D	PATSTAT
					Y04S 20/52 Systems oriented to metering of generated energy or power
Hydrogen Production	**20111150** Hydrogen	**2804** Hydrogen, rare gases and other non-metals **280410** Hydrogen **28041000** Hydrogen	**2804** Hydrogen, rare gases and other non-metals **280410** Hydrogen	**51** Hydrogen **511** Hydrogen production **512** Hydrogen storage **513** Hydrogen transport and distribution **514** Other infrastructure and systems **515** Hydrogen end-uses (includes combustion, excludes fuel cells and vehicles) **519** Unallocated hydrogen	**Y02P 90/45** Hydrogen technologies in production processes **Y02T 90/40** Application of hydrogen technology to transportation" **Y02T 90/42** Hydrogen as fuel for road transportation **Y02T 90/44** Hydrogen as fuel in aeronautics **Y02T 90/46** Hydrogen as fuel in waterborne transportation **Y02E 60/30** Hydrogen Technology **Y02E 60/32** Hydrogen Storage **Y02E 60/321** storage of liquefied, solidified, or compressed hydrogen in containers **Y02E 60/322** storage of hydrogen in caverns **Y02E 60/324** reversible uptake of hydrogen by an appropriate medium **Y02E 60/325** uptake of hydrogen in carbon **Y02E 60/327** uptake of hydrogen in metal or rare earth metal, intermetallic compounds or metal alloy **Y02E 60/328** uptake of hydrogen in an organic compound or solution **Y02E 60/34** Hydrogen distribution **Y02E 60/36** Hydrogen production from non-carbon containing sources **Y02E 60/362** Hydrogen production from chemical reaction with metal hydrides **Y02E 60/364** Hydrogen production from decomposition of inorganic compounds **Y02E 60/366** Hydrogen production by water electrolysis **Y02E 60/368** Hydrogen production by photo-electrolysis

Value Chain	PRODCOM	COMEXT	COMTRADE	IEA RD&D	PATSTAT
					Y02E 70/10 Hydrogen from electrolysis with energy of non-fossil origin

Annex 3. Key indicators and questions underpinning the SWOT analysis

SWOT categories	Areas	Questions that need answers to ensure a complete SWOT	Source of information	Indicator and elements to consider at to inform the response
Strengths & Weaknesses (Internal)	**Innovation potential**	Is the value chain (or key components within it) benefiting from sustained and/or growing levels of R&D investment from the public sector?	T2 Level of public investment T2 turnover	- Volume of public investment EU vs RoW - Volume of public investment compared to turnover of the sector
		Does the EU value chain have access to internal financing?	T2 Turnover + literature review	- Turnover of the sector within the EU compared to global turnover
		Does the market recognise the potential for this value chain (component) to invest in innovation and generate financial returns?	T2 Early stage private investment	- Volume of investment EU vs RoW - Number of investment EU vs RoW
			T2 Late stage private investment	- Volume of investment EU vs RoW - Number of investment EU vs RoW
			Literature review	- Presence of specialised VC funds or business angels specifically targeting the value chain
		Is the value chain effectively translating investment into tangible Intellectual Property?	T2 Patent applications	- Number of patents application EU vs RoW
		Has the value chain already been recognised by the public / private sector through specific clustering initiatives?	T1 + Literature review review	Presence of climate neutral technology cluster programs & initiatives
		Do EU value chains comprise of leading innovative firms in the global value chain?	T2 Companies	Number of active companies in the VC EU vs RoW
	Key characteristics of the value chain	Does the value chain have an established and skilled labour market on which it can build or is it still emerging?	T2 Total sectoral employment	Established labour market vs emerging / constrained
		Is there core production competence and capability in the value chain within the EU?	T2 Production T1 result Literature review	- Production across the EU and within leading MS (value) compared to global production volume - Production capability within key parts of the value chain
		Are actors in the value chain well organised and able to advocate for their interests?	Literatrure review	- Presence of strong industry group able to advocate for the value chain's interests - Presence of long term strategy for the value chain
Opportunities & Threats (External)	**Policy environment**	Is the policy environment favourable for the development of the value chain in the EU?	Literature & policy review	- Presence of a EU strategies dedicated to the value chain - Presence of supporting policies in leading MS in the value chain
	Econmic environment	Is the economic environment favourable for the development of the value chain in the EU?	T1 result Literature review	- Ease og doing business index
		Is the EU perecived as a leading actor in the value chain and able to export to other non-EU countries?	T2 Imports and exports	- Import and export trends EU vs RoW

SWOT categories	Areas	Questions that need answers to ensure a complete SWOT	Source of information	Indicator and elements to consider at to inform the response
		Is the EU able to sustain a strong and positive trade balance?	T2 Trade balance	- Positive / growing trade balance for EU suppliers vs non-EU countries
	Social environment	Is the value chain operating in a favourable social environment?	Literature review	- Levels of climate neutral entrepreneurship
	Market condition*	Level of competition?*	T1 Number of economic actors active in the sector	Few actors vs many
		Risk of entry by non-EU competitors?*	T1 + expert judgement based on literature review	High barriers of entry into EU climate neutral markets / value chains
		Level of technology lock-in to existing value chains?*	T1 + expert judgement of switching costs of buyers	Low technology lock in value chain (or new market area) vs high lock in level
		Level of threat of vertical integration by buyers or suppliers?*	T1 + expert judgement based on literature review	Limited threat to EU suppliers from non-EU suppliers
		Level of substitutability of an industries value propositions?*	T1 + expert judgement based on literature review	Limited substitutability (protecting existing incumbents / business models)
	Other considerations: Covid-19	How strongly are the EU and global value chains expected to be disrupted by the Covid-19 crisis? Does this create new threats or opportunities for the EU actors?	Literature review	- Impact of Covid-19 on the policy environment - Disruption of the value chain in regions strongly affected by Covid-19

** Based on Porter's Five Forces competitiveness model*

Annex 4. References

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