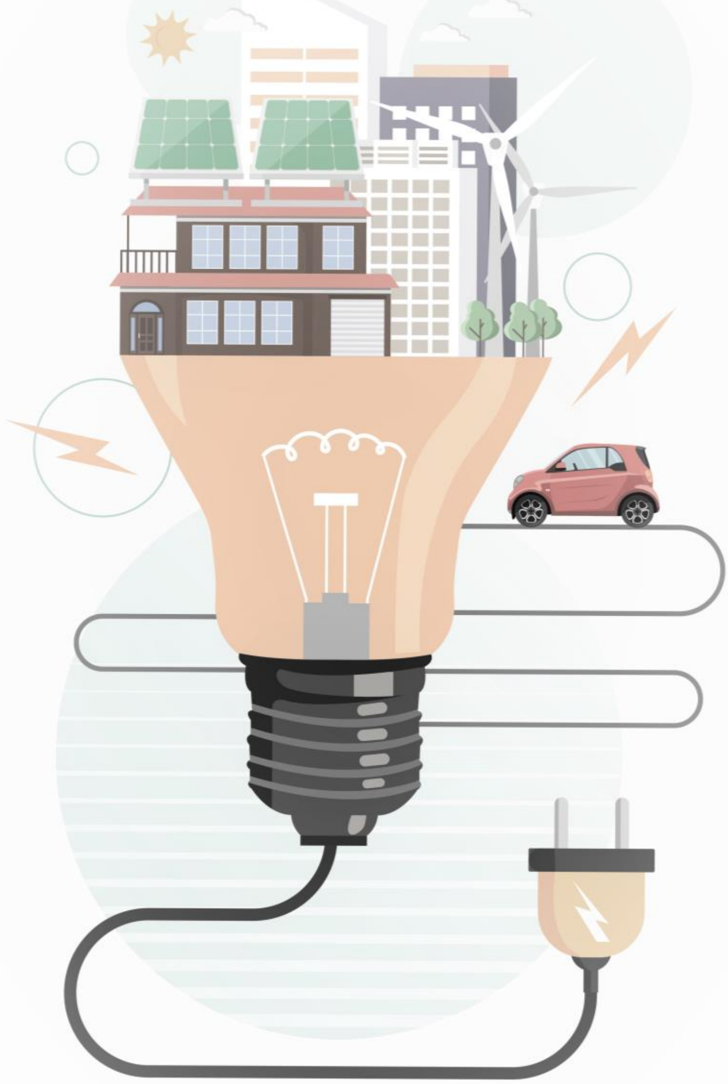
ASSET Study on

International Strategic Partnerships in Energy

A cross comparison of publications, patents, and projects



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About the ASSET project

The ASSET Project (Advanced System Studies for Energy Transition) aims at providing studies in support to EU policy making, research and innovation in the field of energy. Studies are in general focussed on the large-scale integration of renewable energy sources in the EU electricity system and consider, in particular, aspects related to consumer choices, demand-response, energy efficiency, smart meters and grids, storage, RES technologies, etc. Furthermore, connections between the electricity grid and other networks (gas, heating and cooling) as well as synergies between these networks are assessed.

The ASSET studies not only summarize the state-of-the-art in these domains, but also comprise detailed qualitative and quantitative analyses on the basis of recognized techniques in view of offering insights from a technology, policy (regulation, market design) and business point of view.

Authors

This study has been developed as part of the ASSET project by Guidehouse.

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EXECUTIVE SUMMARY

As part of the European Commission's strategic long-term vision, dubbed 'A Clean Planet for All' and the EU Green Deal outlining the path to a prosperous, modern, competitive and climate-neutral economy by 2050, mobilising industry and a strong emphasis is given on cooperation with international partners. In particular, international cooperation is relevant in the area of renewable energy sources (RES) technology for various reasons: Firstly, the EU's market share on the global market for renewable energy technologies is shrinking and technology offerings will, therefore, need to reflect diverse needs and developments outside of the EU. Secondly, to adapt to foreign markets and successfully deploy RES technology in other regions of the world, localised partnerships are needed.

Moreover, technological leadership based on world-class research and development (R&D) is key for commercial success on RES markets. Consequently, international cooperation is not only needed at the later stages of the RES value chain to penetrate foreign markets, but even more so at the first stage, technology development, to guarantee a strategic fit between product and market need.

Reflecting these global trends, the EU is putting a stronger emphasis on international R&I cooperation in the upcoming framework programme for research and innovation, Horizon Europe, compared to its predecessor Horizon 2020. To benefit from new global opportunities Horizon Europe aims at strategic partnerships with key partner countries, and stronger international cooperation. Consequently, with this study we substantiate the question which international partners the EU should focus on, to foster cooperation in the area of RES technology.

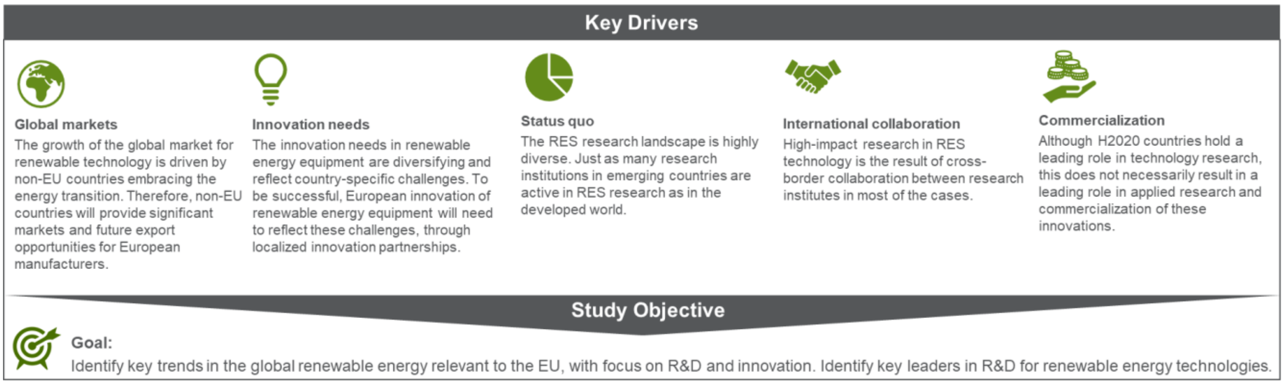

Figure 1: Key drivers and the objectives of the study

Approach

The focus of this study is on RES technology R&D and research cooperation as the foundation of the RES technology life cycle and future market success, as illustrated in the picture below.

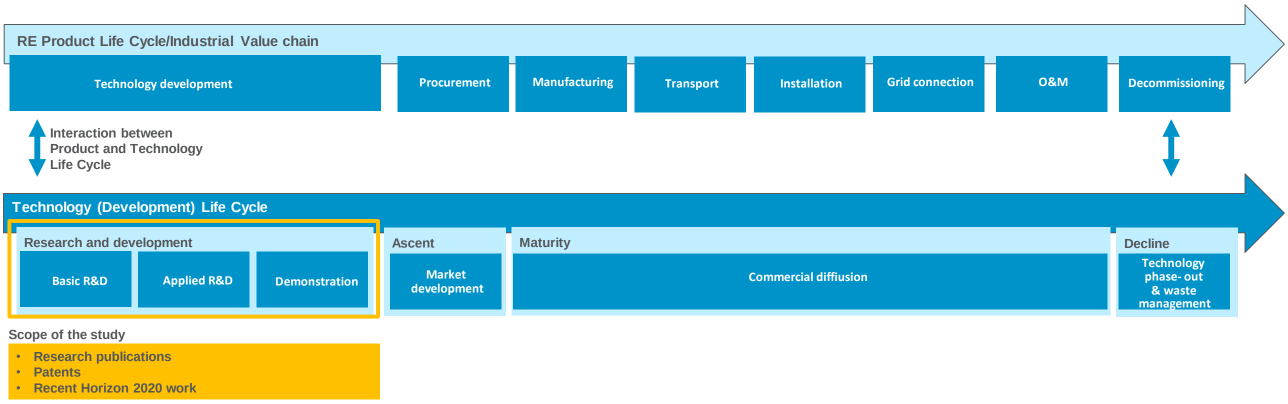

Figure 2: Scope of the study

In most cases, market success is the result of highly competitive products, which are in turn the result of world-class R&D. Since technology R&D thrives on international cooperation, we identified potential partners for an increased research cooperation on country- and institutional-level. To do so, we developed a data driven approach, based on three pillars,

- an analysis of scientific publications on RES technology,
- an analysis of patent filings on RES technology,
- as well as an analysis of RES research projects within the H2020-framework.

Thereby, we develop complementary insights on technology R&D – from basic, to applied R&D and demonstration – and on international collaboration in RES research on a country level, outlined in this executive summary. Furthermore, we provide detailed information about RES research on an institutional level in the main report and appendix, developed by means of the publication analysis, which can only be presented here in an aggregated manner.

Results of the analysis

Results of the analysis of scientific publications

Through the analysis of scientific publications,[1] we identified 1900 research institutions in about 100 countries worldwide; one third thereof located in Horizon 2020-member states, indicating the important role of the EU in RES research. The remaining two thirds are located in the rest of the world (ROW), where institutions from emerging countries have outnumbered institutions in the developed world, highlighting the growing importance of emerging economies in the RES research landscape. In addition to these high-level results, the analysis revealed insights on specific countries and technologies, out of which only a few are presented in the figure below.

[1] We considered the 500 most cited publications from various journals, published in 2014-2019, for each of the 11 analysed technology fields.

Non-H2020 countries – most active countries

China and USA are by far the most important players in RES research. Both countries prevail in almost all RES research fields.
- USA: 300 research institutions, thereof 20 top-ranked
- China: 200 research institutions, thereof 20 top-ranked

Other active countries include
- Developed countries: Canada, South Korea, Japan, Australia, Taiwan
- Emerging economies: India, Iran, Brazil, Malaysia, Pakistan, South Africa

Other **emerging economies show a diverse picture** – high visibility of south/southeast Asia, limited visibility for Africa and LAC

H2020 countries – most active countries

Europe has an **overall strong position** in RES R&D worldwide with more than 600 research institutions active in the RES field

British and German institutions lead the rankings

CEE countries have a limited visibility and should be stimulated to be more active

Leading countries maintain **strong collaboration with non-European countries**, with Great Britain and Nordics being most active

Non-H2020 countries – focused technologies

Developed economies (USA, Canada, Australia, Japan) specialized in **new technologies**, such as ocean energy, hydrogen and smart grids

Developing economies focus on **bioenergy**; cooperation in this field may be interesting for Taiwan, Iran, India, and Malaysia

Other interesting country/technology matches include:
- China is taking over leadership in global wind research, dominates PV and is very active in smart grids
- Malaysia for CSP
- Brazil and Egypt for hydropower
- Egypt and Canada – hydrogen, networks and ocean energy
- Indonesia and India for geothermal energy
- Saudi Arabia, Japan and Singapore for hydrogen
- Hong-Kong and Nigeria for heat pumps

H2020 countries – focused technologies

Particularly strong in PV, Wind, Ocean

Whilst top-ranked countries are active in all research fields, some have a particularly strong stand in one technology (Ocean – GBR, Hydro – SWE/NLD, Wind – DNK)

Figure 3: Key insights from publication analysis

Moreover, we identified three institutions each from developed non-H2020 countries, emerging non-H2020 countries as well as H2020 countries as key players in their respective R&D field. These institutions can be targeted for an increased research cooperation on institutional level between non-H2020 and H2020 countries. Results of the analysis for all 11 analysed technology fields are listed in the table below.

Table 1: Potential target institutions increased research cooperation

R&D field	Institution name and country: Non-H2020 – developed economies		Non-H2020 – emerging economies		H2020	
PV	National Institute for Materials Science	JPN	Shanghai Jiao Tong University	CHN	Ecole Polytechnique Federale De Lausanne	CHE
PV	University of Rochester	USA	King Abdullah University of Science and Technology	SAU	Polytechnic University of Milan	ITA
PV	Korea University	KOR	Central South University	CHN	Helmholtz Zentrum Berlin	DEU
CSP	University of Auckland	NZL	Universiti Teknologi Malaysia	MYS	University of Toulouse	FRA
CSP	Arizona State University	USA	Ferdowsi University of Mashhad	IRN	Polytechnic University of Turin	ITA
CSP	City University of Hong Kong	HKG	Tsinghua University	CHN	Centre National De La Recherche Scientifique	FRA
Wind	Deakin University	AUS	Chinese Academy of Sciences	CHN	Technical University of Denmark	DNK
Wind	Electric Power Research Institute	USA	Chongqing University	CHN	Aalborg University	DNK
Wind	National University of Singapore	SGP	Tsinghua University	CHN	Polytechnic University of Catalonia	ESP
Hydropower	Georgia Institute of Technology	USA	Dalian University of Technology	CHN	Wageningen University and Research Centre	NLD
Hydropower	University of Washington	USA	North China Electric Power University	CHN	University of Padua	ITA
Hydropower	National Tsing Hua University	TWN	Beijing Normal University	CHN	Spanish National Research Council	ESP
Ocean energy	University of British Columbia	CAN	University of Cape Town	ZAF	Plymouth University	GBR
Ocean energy	Woods Hole Oceanographic Institution	USA	Dalian University of Technology	CHN	University of Santiago De Compostela	ESP
Ocean energy	Oregon State University	USA	Peking University	CHN	Delft University of Technology	NLD
Geothermal energy	Kyushu University	JPN	King Saud University	SAU	Eth Zurich	CHE
Geothermal energy	United States Geological Survey	USA	Gadjah Mada University	IDN	University of Iceland	ISL
Geothermal energy	Commonwealth Scientific and Industrial Research Organization	AUS	Chinese Academy of Sciences	CHN	Rwth Aachen University	DEU
Bioenergy, Biofuels	University of Southern Queensland	AUS	National Cheng Kung University	TWN	Technical University of Denmark	DNK
Bioenergy, Biofuels	University of Illinois At Urbana Champaign	USA	Chinese Academy of Sciences	CHN	University of Bologna	ITA
Bioenergy, Biofuels	National Renewable Energy Laboratory	USA	University of Malaya	MYS	Ghent University	BEL
Smart Grids	Princeton University	USA	Singapore University of Technology and Design	SGP	Gazi University	TUR
Smart Grids	University of Waterloo	CAN	Peking University	CHN	Aarhus University	DNK
Smart Grids	University of Sydney	AUS	Nanyang Technological University	SGP	Ecole Normale Superieure	FRA
Hydrogen, Fuel Cells, Synfuels	University of Adelaide	AUS	King Abdulaziz University	SAU	Max Planck Society	DEU
Hydrogen, Fuel Cells, Synfuels	Tohoku University	JPN	Dalian Institute of Chemical Physics	CHN	Ecole Polytechnique Federale De Lausanne	CHE
Hydrogen, Fuel Cells, Synfuels	California Institute of Technology	USA	Nanyang Technological University	SGP	Centre National De La Recherche Scientifique	FRA
Storage	University of Washington	USA	Nanyang Technological University	SGP	Istituto Italiano Di Tecnologia	ITA
Storage	Griffith University	AUS	Chinese Academy of Sciences	CHN	Centre National De La Recherche Scientifique	FRA
Storage	Pacific Northwest National Laboratory	USA	Tsinghua University	CHN	Karlsruhe Institute of Technology	DEU
Heat pumps	University of Wollongong	AUS	Hong Kong Polytechnic University	HKG	Aalto University	FIN
Heat pumps	University of Tokyo	JPN	Guangdong University of Technology	CHN	University of Padua	ITA
Heat pumps	N/A		Xi An Jiaotong University	CHN	University of Naples Federico Ii	ITA

Results of the analysis of patent filings

In addition to research institutions, we analysed patent filings within various RES technology fields.[2] The number of patent filings per country reveals a similar picture as the number of institutions active in RES research. This leads to the conclusion that a strong position in the early phases of technology R&D, i.e. basic and applied R&D, usually results in a strong position in the later phases of technology R&D and ultimately commercialization of new technologies. Similar to the number of research institutions, USA and China by far outpace other countries in terms of patent filings. Japan is ranked third with some distance to the two front runners, taking a very strong role in late-phase R&D. Furthermore, the results show that most countries are active in all research fields.

Results of the analysis of H2020-3.3 projects

Last, we analysed research projects within the H2020-3.3 funding line where non-H2020 countries are involved. The programme H2020-3.3 "Secure, clean and efficient energy" is H2020's major funding line for RES and other energy-related research. The results of this analysis highlight that only very few of these RES research projects - 21 in total - involve non-H2020 countries. In consequence, the RES research projects with non-H2020 cooperation represent only 1% of the overall budget of the H2020-3.3 programme, indicating a strong mismatch between the importance of non-H2020 countries in the RES research landscape and their involvement in H2020-funded projects.

Country classification

Based on the results of our analysis we classified countries according to their performance in early- and late-phase R&D as well as international research cooperation. The results are presented in the table below. Out of the non-H2020 countries, three are classified as front runners, the US, China and Japan. In addition, India, Canada and Australia are classified as top, due to their overall good performance in all three indicators. However, noting the differences in countries' political systems and the EU's international relations, efforts to increase research cooperation would need to take different approaches for different countries. On the one hand countries with strong political ties to the EU can be targeted for a research cooperation through top-down approaches, such as the alignment of research agendas and priorities on national level. On the other hand, for research cooperation with countries, however, where political relations are potentially strained, a bottom-up approach is more appropriate through research cooperation on institutional level. Also, IP ownership needs to be considered with some less developed countries.

[2] We analysed patent filings listed in the IRENA INSPIRE database, from the most recent three-year timespan, for most of the analysed technologies 2014-2016.

Country	Early-phase R&D				Late-phase R&D			Research Cooperation			Overall Rating
	Research Institutions	Top-ranked Institutions	Rating	Leading Technologies	Patents	Rating	Leading Technologies	Internat. Collaboration	Rating	H2020-3.3 Cooperation projects	
Non-H2020 countries											
United States	303	22	Front Runner	Grids, Ocean	21.806	Front Runner	PV, Enablers	74%	Top	-	Front Runner
China	218	23	Front Runner	Hydrogen, Storage	55.498	Front Runner	CSP, PV, Enablers	67%	Intermediate	4	Front Runner
India	126	0	Top	Bioenergy, Grids	1.117	Top	Wind, Enablers	47%	Intermediate	2	Top
Canada	58	5	Top	Hydropower, Grids, Ocean	2.219	Top	Enablers, Wind, Bio	61%	Intermediate	-	Top
South Korea	57	3	Top	PV, Storage		Missing Data		66%	Intermediate	2	Missing Data
Japan	54	3	Top	Hydrogen, Ocean	11.874	Front Runner	PV, Enablers	81%	Front Runner	1	Front Runner
Iran	46	6	Top	Wind, CSP		Missing Data		59%	Intermediate	-	Missing Data
Australia	37	4	Top	Ocean, Grids	1.913	Top	Bio, CSP, Enablers	78%	Top	2	Top
Brazil	32	2	Intermediate	Bio, Hydropower	313	Intermediate	Wind, Enablers, Bio	69%	Intermediate	-	Intermediate
Taiwan	30	1	Intermediate	Bioenergy, PV		Missing Data		71%	Top	-	Missing Data
Malaysia	24	4	Top	Bioenergy, CSP	40	Intermediate	Enablers, Hydro, Bio	65%	Intermediate	-	Intermediate
Pakistan	18	1	Intermediate	Wind, Grids		Missing Data		91%	Front Runner	-	Missing Data
South Africa	18	0	Intermediate	Hydrogen, CSP	808	Intermediate	Bio, Enablers, CSP	61%	Intermediate	2	Intermediate
H2020 countries											
United Kingdom	92	15	Front Runner	Ocean, Wind	961	Top	Enablers, Wind	73%	Top	5	Front Runner
Germany	87	10	Top	Hydropo., Geo., Hydrogen	2.823	Top	Enablers, Wind, CSP	72%	Top	10	Top
France	67	6	Top	Ocean, CSP	1.004	Top	Enablers, PV, CSP	72%	Top	6	Top
Turkey	58	10	Top	Geothermics, Heat pumps	47	Intermediate	Wind, CSP	70%	Top	1	Top
Italy	52	6	Top	Geothermics, Hydropower	117	Intermediate	Hydrop., Bio, Wind	64%	Intermediate	4	Intermediate
Spain	45	6	Top	Hydropower, Bio	591	Intermediate	CSP, Wind	74%	Top	4	Top
Sweden	22	4	Top	Hydrop., Geo., Heat pumps	244	Intermediate	CSP, Wind	76%	Top	1	Top
Portugal	19	0	Intermediate	Hydropower, Ocean	47	Intermediate	Wind, Hydropower	80%	Front Runner	-	Top
All H2020 MS	627	84	Front Runner	Hydrop., Ocean, Geo.	7.040	Top	Enablers, Wind, CSP	70%	Top	22	Front Runner

Front Runners | Top | Intermediate | Missing Data

Figure 4: Country classification according to publication, patent, and project analysis

Conclusions

The conducted analysis of recent scientific publications, patents and H2020 projects allows for insights into a diverse RES technology R&D landscape, reveals recent trends, important players and the status quo of research cooperation in this thematic area. International R&D collaboration has the potential to accelerate the energy transition by sharing knowledge and engaging various actors, from developed and emerging economies. With respect to the EU's strategic goal of maintaining its leading position in RES technology R&D, the following recommendations are developed in this study:

- The US and China by far outpace other countries in terms of numbers and ranking of research institutions. These two countries should be the focus for strategic partnerships in RES research, but very clear intellectual property rights should be established for this cooperation.
- It is necessary to distinguish between established European technologies, which, in cooperation with non-EU economies can further facilitate global update of RES technologies and technologies, where non-EU countries may have additional AV to the already existing EU technologies and concepts. For example
  - India, Malaysia and Brazil can be very good partners for bioenergy and Canada, US and Brazil for hydro energy – supporting the existing European IP and manufacturers to help other economies build their hydro resources in a more efficient manner
  - On the other hand, Europe is very strong in offshore wind, hydrogen production or ocean energy (in particular France, Germany, Spain and Sweden) and can help

other markets benefit from these advancements, by cooperation with. F.ex. Australia, Canada, Japan or South Africa).

- The EU – whilst being a front runner in basic and applied RES technology R&D – performs only average compared to other developed economies in bridging the gap between innovation and commercialization of new RES technologies. Therefore, funding schemes on EU level may put a higher emphasis on late-phase R&D and the collaboration between research institutions and industry, in particular. Thereby, public funding can not only cover gaps in the R&D landscape but even more so, steer private investments in R&D. Likewise, public research funding can be interlinked with other financing instruments, e.g. venture capital, needed at later stages in the technology life cycle.

- A higher emphasis on international collaboration beyond EU-borders in the H2020 successor enables the EU to better align the goals of the already existing research collaboration with non-H2020 countries with the EU's strategic goals set out in the SET Plan.

- In choosing partners for an increased R&D cooperation, e.g. through bilateral innovation alliances with H2020-countries, the benefit for the EU can be maximized by aiming at countries with a high number of top-ranked research institutions. For example:

    - Bioenergy – University of Malaya in Malesia could partner with the University of Ghent

    - Hydropower- Georgia Institute of Technology might be interested in partnering stronger with the Spanish National Research Council

    - Offshore wind- US EPRI might want to cooperate more with the Aalborg University in Denmark

    - Hydrogen- Max Plank Society might want to cooperate more that the University of Adelaide, Australia

    - Ocean energy- University of British Columbia may want to strengthen ties with the Delft University of Technology.

For more details, please, read Table 1 and Figure 4.

In addition, international R&D collaboration has the potential to enhance the EU's market positioning for growing international RES technology markets. To capitalise on these opportunities, the following recommendations are developed in this study:

- Research cooperation needs to put a stronger focus on emerging economies and their respective RES market needs to reflect the growing importance of emerging economies as markets for RES technologies as well as the high number of research institutions active in these countries.

- To develop stronger RES research capabilities in central and eastern European countries can be a useful step to strengthen RES value chains in emerging economies within H2020 and thereby drive inclusive growth on a European level.

- International research cooperation needs to be embedded in strong political frameworks guaranteeing access to RES markets, compliance with IPR regulation and knowledge transfer in both directions. Otherwise, knowledge drain from H2020 members in combination with third countries aggressive industrial strategies might pose a significant challenge to the EU’s positioning as a RES technology leader in the long-term.

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ABBREVIATIONS

ACER	Agency for the Cooperation of Energy Regulators
API	Application Programming Interface
BRP	Balance Responsible Party
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CBA	Cost Benefit Analysis
CCS	Carbon Capture and Storage
CEF	Connecting Europe Facility
CSP	Concentrated Solar Power
DOE	US Department of Energy
DSO	Distribution System Operator
EC	European Commission
EENS	Expected Energy Not Served
EERA	European Energy Research Alliance
ENTSO-E	European Network of Transmission System Operators for Electricity
EPRG	Energy Policy Research Group
EPRI	Electric Power Research Institute
ETS	Emission Trading Scheme
EU	European Union
FCR	Frequency Containment Reserve
GDP	Gross Domestic Product
H2020	Horizon 2020
IMF	International Monetary Fund
IPR	Intellectual Property Rights
JRC	Joint Research Centre
NPV	Net Present Value
OPEX	Operational Expenditure
P2X	Power-to-X
PH	Pumped Hydro
PHES	Pumped Hydro Energy Storage
PV	Photovoltaic
R&D	Research and Development
RD&D	Research, Development and Deployment
RE	Renewable Energy
RES	Renewable Energy Sources
RG	Regional Group
R&I	Research and Innovation
SCC	Societal Cost of Carbon
SET Plan	Strategic Energy Technology Plan
SEW	Socio-Economic Welfare
SJR	Scimago Journal Rank
SoS	Security of Supply
TEN-E	Trans-European Networks for Energy
THE	Times Higher Education
TRL	Technology Readiness Level
TSO	Transmission System Operator
vRES	variable Renewable Energy Sources

1 INTRODUCTION

In November 2018, the European Commission presented its strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050. In this Communication, entitled 'A Clean Planet for All', the Commission concludes that 'internationally, over the coming years the EU should expand its cooperation closely with its international partners'. This is particularly relevant in the area of international cooperation on energy technology innovation for two important reasons:

1. The European Union will only represent a small share of the global market for renewables in the next decades, which means that innovation will need to reflect many needs and developments outside of the EU; European manufacturers and European innovation of renewable energy equipment will need to take those into account to be successful, and for applications in Europe which might combine European and other continents' products, one needs to be aware of such potential differences.

2. The decentralised nature of most renewable energy technologies will require localised partnerships for successful deployment on other continents, to address specific localised innovation challenges within emerging countries.

The emergence of new renewable energy markets across the globe is widening the scope for international cooperation. At the same time, some international partners are now demonstrating increasing specialisation in certain energy technologies, facilitated through R&I (research and innovation) cooperation with other countries, as the global energy transition accelerates.

Reflecting these global trends, the EU is putting a stronger emphasis on international R&I cooperation in the upcoming framework programme for research and innovation, Horizon Europe, which is superseding the current programme Horizon 2020. In particular, a recent orientation paper, outlining a strategic plan for the implementation of Horizon Europe in years 2021-2024, states that 'the EU needs to […] benefit from new global opportunities, by pursuing strategic partnerships with key partner countries, and by promoting international cooperation.[3]

Consequently, with this study we want to substantiate the question which international partners the EU should focus on, to foster cooperation in the area of RES technology. Therefore, we discuss key trends in the global renewable energy markets with a focus on research and development (R&D) and identify key R&D leaders for various renewable energy technologies, considering basic and applied R&D as well as technology demonstration.

[3] (European Comission 2019)

2 CURRENT DEVELOPMENTS IN RES R&D

In the following section, we set the stage for our analysis, by reflecting on current developments in the RES landscape, with focus on R&D. Initially, we explore the status quo of RES R&D and manufacturing in Europe, as well as the role of R&D in the industrial value chain. Then, keeping in mind recent trends in R&D, we draw conclusions on the relevance and types of cooperation in RES R&D in the remainder of the chapter.

2.1 Positioning of the EU in the Global RES Sector

Historically, the EU has been a motor for the uptake of RE markets through early technology development, further supported by RE support schemes, feed-in tariffs in particular. Today, RE is a global market and with RE auctions in place, RES are becoming increasingly cost competitive, resulting in higher deployment rates worldwide. Europe's early mover advantage as well as an ambitious policy framework is reflected in its share in renewable energy investment of 22%, out of a total of 288 bn. USD worldwide (2018), according to IRENA. Thereby, Europe is one of the major markets for RE investments. Nevertheless, its share has been shrinking since an all-time high in 2011 with about 45% of global RE investments. Since then Asia and Oceania, in particular China, have increased their investment share substantially.[4]

Moreover, Europe takes a strong role in RES manufacturing. In fact, RES technology and low-carbon technologies in general are a major trade commodity for the EU, resulting in a substantial trade surplus. According to EurObserv'ER, the EU has a share of 29% in global RES technology exports (2017), resulting in net exports of about 1.3 bn. EUR.[5] Thereby, the EU is leading global RES technology export, closely followed by China with 25% (2016). The US and Japan follow with 13% and 10% respectively (2017). Taking a closer look at exports of specific RES technologies, we find a diverse picture. Whereas the EU dominates global exports in wind energy with a share of 91% (2017), its share in solar PV export is comparably low with 16%. These figures reflect reversed roles for the EU in these two sectors. Whilst the EU is a net importer of PV equipment, with China being the largest exporter in this sector, the EU has a strong surplus in exports of wind technology, serving markets worldwide. For biofuels and hydropower, the EU takes a strong role as well with a share of 31% and 50% in global exports, respectively.

The EU's positioning as a regional and global RES manufacturing hub results in significant job creation in this sector. Out of 11 mill people employed in the global RE sector, 11% are based in the EU (2018), according to IRENA.[6] Global RE employment is concentrated in a few countries, with the EU ranking second after China which represents 37% of all RE jobs, and before Brazil (10%), the US (8%) and India (7%).

These figures on investment, exports and employment reflect the growing importance of Asian countries within the global RE sector. This is particularly true for China, which 'rapidly transformed itself into a leading global centre for clean tech manufacturing through an ambitious – sometimes aggressive – government-supported industrial strategy' (European Commission 2018). As a means to sustain the EU's competitive level in the field of the energy transition, the EU adopted the Strategic Energy Technology (SET) Plan. The plan includes a strong research and innovation (R&I) programme on R&I agenda alignment and joint research activities between

[4] (IRENA 2020)
[5] (EURObservER 2018) Figures include intra-EU trade.
[6] (IRENA 2019) Direct and indirect employment.

countries.[7] Specifically, RES and the energy transition in general take a prominent role in Horizon 2020, the EU's current framework programme to fund research, technological development and innovation. Within the programme, a dedicated funding line, H2020-3.3, supports research on "secure, clean and efficient energy" and allocates a share of 7.7% of H2020's overall budget of 77 bn. EUR to this research field.[8]

2.2 Role of R&D in the Industrial Value Chain

Technology R&D is the foundation of market success in the technology-driven RES sector. As presented above, Europe has been the leader in renewable energy technologies by investing in R&D and early demonstration of technologies ahead of most other countries in the world.

Therefore, in this section we will further explore the role of R&D in the technology life cycle and the RES sector's value chain.

An industrial value chain comprises all critical factors that are required for the development and delivery of a certain product and can synonymously be described through the product life cycle. The value chain or product life cycle includes, among many others, all aspects of industry activity from technology development, to manufacturing, to installation and decommissioning.[9] An example of this value chain for RES is shown in Figure 5. The concept illustrates the necessity to go through all stages of the chain to develop and sustain commercial activity in a certain industry sector.

Similar to the product life cycle, the technology life cycle describes the different stages a technology passes through in its lifetime, from R&D to its ascent in the market, maturity and lastly decline, illustrated in Figure 5. In contrast to the product life cycle, however, the technology life cycle does not consider one individual product but rather the underlying technology that is the foundation of a certain product. Both concepts, the product and technology life cycle are interlinked. In particular, the technology development stage in the product life cycle is closely related to the R&D stage in the technology life cycle. Furthermore, a technology's decline, when it is outdated and surpassed by other, higher-performing technologies, may lead to the replacement of respective products based on this technology. In the RES sector, for example, outdated wind assets are repowered with new technology, even before the assets' technical lifetime is reached.

In this study we focus on the R&D stage in the technology life cycle, which can be further broken down into three phases, basic R&D, applied R&D, and demonstration of a technology.[10] Through this focus, we do not only explore the foundations of the RES technology life cycle but also the foundation of the RES industry's value chain.[11]

The results of the R&D stage in the technology life cycle are commonly documented through research publications and patents. Whilst research publications usually cover the earlier phases

[7] (European Commission 2017)
[8] (European Commission 2013)
[9] (U.S. Department of Energy 2014)
[10] (IRENA 2013),
[11] Please note that nomenclature for the product life cycle/technology life cycle/technology development cycle in literature is not entirely consistent and the wording used here might be different from other publications.

of the technology life cycle, basic R&D and applied R&D, patents usually play a prominent role in the later phases of technology R&D. In particular, patenting is used in the applied R&D and demonstration phase to secure intellectual property rights for the achieved knowledge gains. Consequently, by analysing research publications in this report we are able to derive insights on the early phase of technology R&D. The subsequent analysis of patent filings on the contrary concentrates on late-phase R&D, bridging the gap from technology R&D to commercialization. In the remainder of the report, we use this wording – early- and late-phase R&D – keeping in mind that there is a fluent transition between these two, and a one-on-one mapping from publication or patent to R&D phase may not be possible in each individual case.

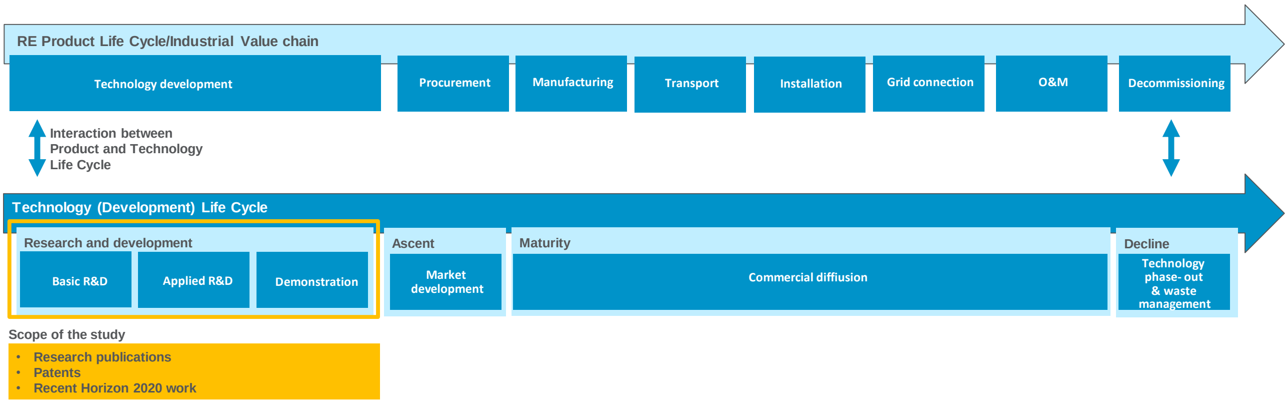


Figure 5: Relationship between product life cycle/industrial value chain and technology life cycle.

Taking a closer look at the relationship between patents and commercial activities, we do find a strong correlation between patent filings and the deployment of new technologies, illustrated by the example of wind energy in Figure 6. The rise in patent filings between 1999 and 2004 within the wind energy technology field is a precursor of an uptake in additional wind energy capacities. Increased research activities led to a more mature technology, resulting in the protection of IPR and a subsequent market development for wind energy. Therefore, we can conclude that R&D activities are not only a trailblazer for the development of new RES technology markets but are also a warranty to secure stakes in these markets.[12]

[12] (IRENA 2013), (IRENA n.d.)

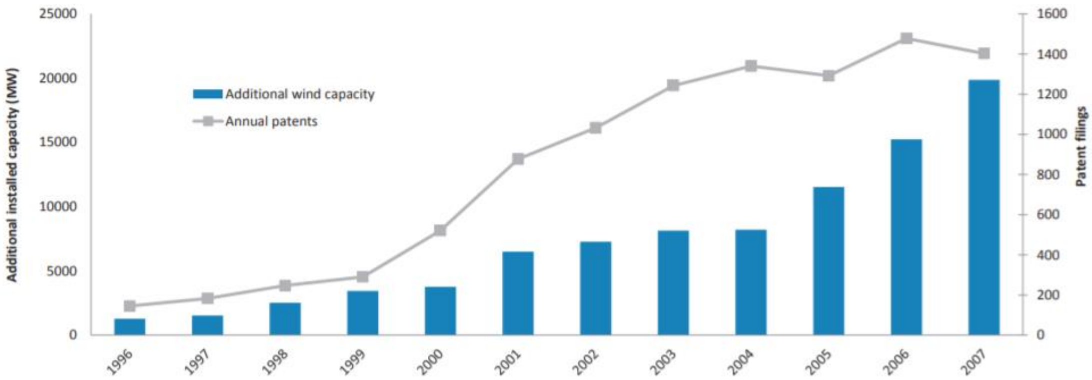


Figure 6: Patent filings and deployment of wind energy technology (IRENA 2013).

2.3 Trends in R&D

Keeping in mind the important role of R&D within an industrial value chain, in the following we want to explore trends within the global landscape of R&D with a focus on RES technology. Several major trends are noticeable in the field of R&D:

- First, the financial volumes globally spent on R&D of RES technologies are significantly increasing. According to REN21, the annual new investments in RES technology research more than doubled from 6.1 bn. USD in 2008 to a new all-time high of 13 bn. USD in 2018. This increase was driven by both an increase of government R&D spending, but also an increase in corporate R&D spending with a CAGR of 7% and 8.6%, respectively. These numbers reflect that the growth in corporate R&D spending outpaced the growth of government spending throughout the last few years since 2016, resulting in a split of 5.5 to 7.5 bn. USD in 2018, thus a surplus of 2 bn. USD for corporate R&D. Taking a look at the EU, we find that private investment in RES research takes on an even more prominent role with about three quarters of the total investment in 2015 according to the EC.[13] Nevertheless, public funding strategies – on national and EU-level – play a crucial role in leading the corporate R&D investments.[14]

- Second, Europe has led the global R&D spending with a share of 27% in 2017, closely followed by the Asia-Pacific region (excl. India, China) with a share of 25%. China represented 20% of global spending.[15] But internationalization of R&D on RES technologies is taking place and new players are on the rise. According to REN21, the largest growth in R&D spending in 2018 took place in China and the Asia-Pacific region (excl. India, China). According to BNEF, however, Europe led the global R&D spending with a share of 27% in 2017, closely followed by the Asia-Pacific region (excl. India, China) with a share of 25%. China represented 20% of global spending. The ranking changes, if we consider R&D investments as a share of GDP. Then, the EU ranks last among major economies, according to the EC, behind the US, Japan, Korea and Japan.[16] Consequently, there have been calls in the RES research landscape for stronger

[13] (European Commission 2017)
[14] (REN21 2019), (European Commission 2018), (European Commission 2018)
[15] (BNEF 2018)
[16] (European Commission 2018)

collaborations between institutions on national but also international level. For example, the EU's SET Plan opts for stronger collaborations and intensified cooperation between the European universities; calling for a cooperative culture of European universities to enable the development of solutions for the global energy challenge.[17]

- Third, the internationalization is accompanied by a greater diversification of the research fields. On one hand new research fields prepare the emergence of new technologies, such as storage, synthetic fuels, or ocean energy, besides the "traditional" RES wind, bio energy, solar. On the other hand, research fields diversify due to the manifold requirements of internationalized and diversified markets for RES technology. Consequently, interdisciplinary research gains more attention and the EU aims at moving from multidisciplinary study areas throughout the region towards a fully interdisciplinary education system.[18]

As a consequence of these trends, formerly pioneering countries in the field of RES, and the EU in particular, are at risk of losing their early-mover competitive advantage. For example, in 2018 Chinese solar PV manufacturers are dominating the global ranking of solar cell manufacturers with 7 out of 10 companies having Chinese origin and not a single one from the EU. Thus, within 14 years the situation reversed. Back in 2004, no Chinese company had been listed amongst the top 10 PV manufacturers, but 5 European ones.[19]

2.4 Relevance of Cooperation in RES R&D

Considering current trends shaping the R&D landscape, research cooperation is an important means to adapt to internationalization and diversification. First of all, international collaboration facilitates knowledge transfer between countries and hence, better access to information for all involved sides.

For example, China has significantly benefited from international R&D cooperation in the RE sector; not only through access to finance and relevant technologies, but also through the development of human resources.[20] From the EU's point of view, knowledge transfer enables an acceleration of the energy transition in the partnering country and thereby a market uptake for various RES technologies. Moreover, through knowledge transfer European partners are able to understand the country-specific deployment challenges, and gain market access through the development of customized solutions. In consequence, RES and other low-carbon technologies are emerging as a major trade commodity, with the EU benefiting from significant positive trade balances.

Finally, combining national activities in R&D can lead to the acceleration of climate action by combining strengths and sharing investment costs. To realise a fast energy transition, development and implementation of sustainable energy technologies need to be spread out globally within a short time frame. Although substantial international R&D collaborations already exist, there is plenty of room for improvement both in capacity and extent.[21]

[17] (European University Association 2017)
[18] (European University Association 2017)
[19] (European Commission 2018)
[20] (Z.Y. Zhao 2011)
[21] (TEC 2017)

2.5 Research Cooperation Types and Levels

In the previous chapter, we outlined the importance of research cooperation, not only to foster innovation itself, but also to ensure access to this knowledge. However, research cooperation can be designed and promoted on different levels, starting at the national level of research programme design, down to research cooperation at the level of individual projects. The different types of research cooperation and their benefits are described in Table 2.

Table 2: Research cooperation types

LEVEL OF RESEARCH COOPERATION	DESCRIPTION
(SUPRA-) NATIONAL LEVEL	Cooperation on national level is established through the alignment of national, or supra-national research roadmaps, innovation alliances and bilateral agreements between countries. E.g.: R&I cooperation between the African Union and the European Union
PROGRAM LEVEL	Cooperation through bilateral agreements between research organizations representing several research institutions, or dedicated programs to increase research cooperation. E.g. Cooperation between the Helmholtz Association of German Research Centers and the University of Alberta, Canada; Marie-Skłodowska-Curie Actions
INSTITUTIONAL LEVEL	Cooperation between individual research institutions through e.g. cooperation agreements, the co-financing of research institutes
PROJECT LEVEL	Cooperation between individuals and project teams, often fostered through personal relationships

Research cooperation on a macro level, such as innovation alliances, is suitable to align strategic goals between partnering countries, to develop suitable policy frameworks and thereby enable the systemic change that is required for the energy transition. Research cooperation on institutional and project level, however, is better suited to tackle specific innovation challenges, as set out in the EU's SET implementation plans for the 14 low-carbon energy sectors[22]. Cooperation on institutional and project level is fastest to implement and thereby able to deliver results within shorter time frames. In addition, the different cooperation types outlined here are suitable for different grades of international relations between the EU and third countries. The highest requirements are set by top-down approaches for an increased research cooperation on national level, building on strong bilateral relations. On the other hand, bottom-up approaches, focusing on increased research cooperation on institutional level are based on scientific exchange without the need for political cohesion. Also, IP ownership needs to be considered with some less developed countries.

This study focuses on institutional level cooperation, by providing insights on the research focus and impact of research institutions worldwide. In addition, we also provide information on a more aggregated, country level aiming at research cooperation on a national and program level.

[22] (European Commission 2017)

3 STUDY OBJECTIVES AND APPROACH

Against this background of key trends in global RES R&D and RES technology markets, the goal of this study is twofold:

- Identify leading institutions in R&D for various innovative energy technologies and, thereby, identify potential partner institutions for R&D cooperation.
- Identify leading countries in RES R&D and provide further insights into the research landscape of these countries, such as focus areas of selected key countries and existing cooperation projects between Horizon2020 members and third countries.

To meet this goal, we developed a data-driven approach, illustrated in Figure 7. The approach is based on three pillars,

- an analysis of scientific publications on RES technology,
- an analysis of patent filings on RES technology,
- as well as an analysis of RES research projects within the H2020-framework.

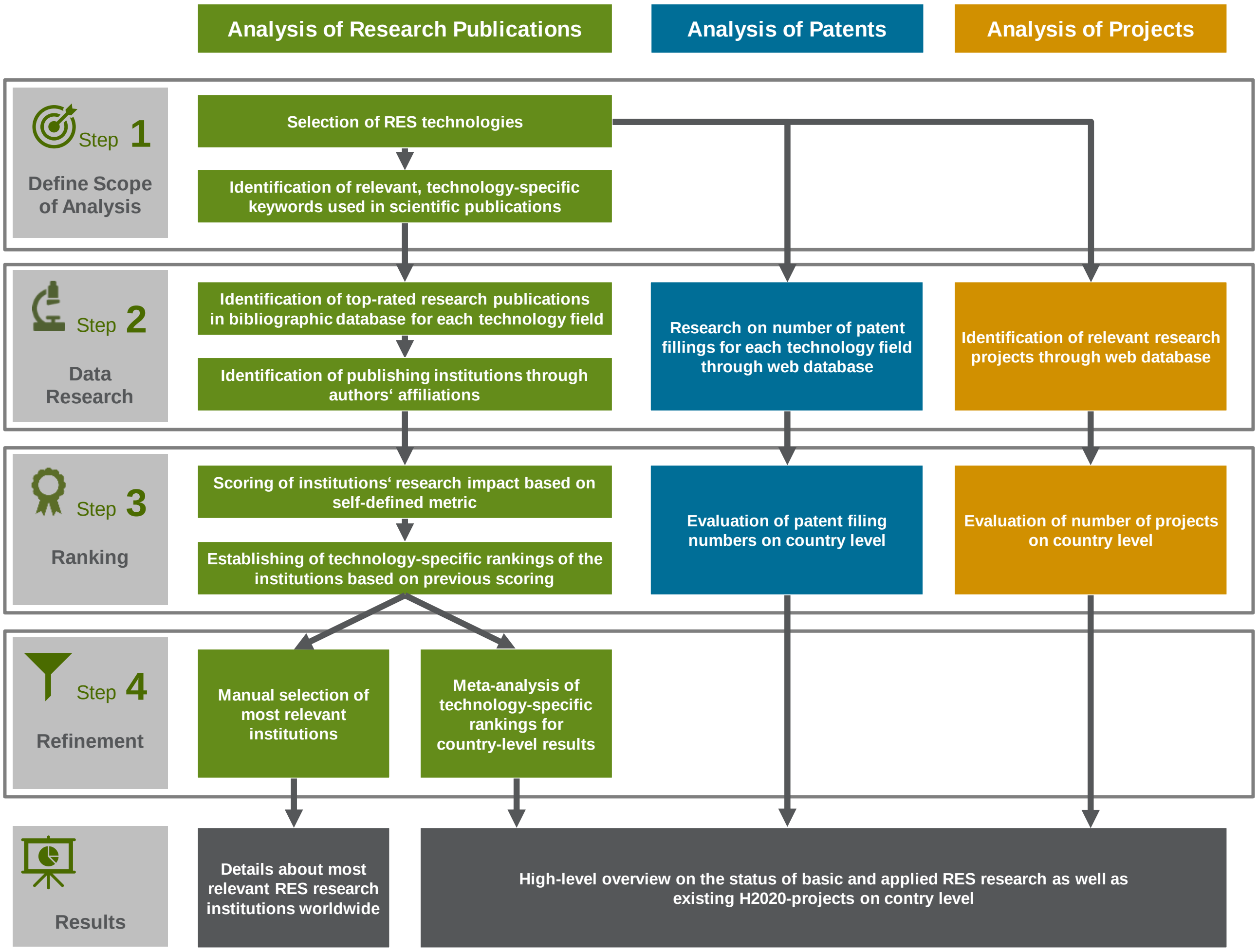
Thereby, we are able to develop complementary insights on technology R&D as well as international collaboration in RES research on a country level. Furthermore, we are able to provide detailed information about RES technology R&D on an institutional level by focusing on the first pillar of this study, the bibliographic analysis of scientific publications.

Underlying assumption of the analysis of scientific publications is that RES R&D leads to findings which are published in the scientific literature. Relevant research institutions can, therefore, be identified through the affiliations of the authors of high-impact publications. Consequently, the analysis of scientific publications consists of four main steps:

1. We define the scope of the analysis by selecting relevant RES technologies and matching keywords to these technologies. Then these keywords can be used to identify relevant and technology-specific publications in scientific literature.
2. We identify high-impact publications for each technology and derive the publishing institutions through the publications' authors and their affiliations.
3. For each technology field, we score and rank the identified institutions based on a self-defined metric, measuring the research impact of an institution's publications.
4. Taking into account the previously established ranking as well as additional information, we select a small set of institutions for each technology as potential partners for an intensified research cooperation. In addition, we perform a meta-analysis of these institution rankings to obtain further insights on a country level.

To analyse RES patents and RES research projects, we use our previously defined scope of RES technologies and employ online data bases[23] to obtain insights about patent filings per technology and existing research projects within the H2020 framework on a country level.

Figure 7: Overall approach for publication analysis



[23] For RES patent filings, we rely on the International Standards and Patents in Renewable Energy (INSPIRE) platform by IRENA. For RES research projects within the H2020-framework, we use the Community Research and Development Information Service (CORDIS) database by the EC.

4 METHODOLOGY

In this chapter, we describe in detail our methodological approach used to identify relevant research institutions in the field of the RES, as well as the assessment of R&D activity on a country level. This chapter starts off with a description of the analysis of RES research publications, continues with the analysis of patents and concludes with the analysis of projects.

4.1 Publication Analysis

Scientific progress – also in the field of RES technologies – is documented and shared in the scientific community through publications in peer reviewed journals. Consequently, we developed an approach to identify relevant research institutions based on research publications in the field of RES.

4.1.1 Step 1: Scope of the Analysis

Numerous papers are published on a weekly basis, covering a plethora of topics. Therefore, we need to define a scope for the analysis, to ensure that only relevant publications are taken into account, enabling us to identify relevant research institutions. In addition, we need to limit the size of the data basis, thus the number of publications taken into account, to keep computational efforts of the Excel-based analysis on an acceptable level. To define the scope we consider three dimensions, each of them further explained in the following:

- the time frame in which the papers have been published;
- the topic of the publications, thus the various types of RES and enabling technologies;
- the impact of the publications.

4.1.1.1 Time Frame

Regarding the time frame, we only consider recent publications from the year 2014 onwards. The reason is that the scientific landscape is changing rapidly, as discussed in the previous chapter, and we want to ensure that these developments are reflected through an up-to date data set.

4.1.1.2 Focused Technologies

We consider 11 technologies, for each of which a technology-specific set of relevant publishing institutions is identified. These technologies comprise 7 RES technologies and 4 enabling technologies, depicted in Figure 8, in alignment with the technologies outlined by the EC’s SET Plan as well as the technology classification used by the IEA.[24]

The 7 RES technologies which we consider in this analysis, describe the entirety of available RES:

- Photovoltaics (PV)
- Concentrated Solar Power (CSP) including thermal energy storage

[24] (European Commission 2017), (IEA 2019)

- Wind Power, on- and offshore
- Hydropower and related topics, such as water turbines and dams
- Ocean Power, such as tidal power or ocean thermal energy conversion
- Geothermal Power
- Bioenergy and Biofuels

In addition, we complement these RES technologies through 4 enabling technologies, which play a crucial role in integrating rising variable renewable energy shares into the energy system and/or facilitate increased electrification:

- Smart grids: comprising research on the topic of transmission and distribution grids, electricity and flexibility markets, management of distributed energy resources and alike.
- Hydrogen, fuel cells and synthetic fuels (synfuels): research on hydrolysis, hydrogen storage, transport and usage, as well as fuel cells or synthetic fuels.
- Storage: comprising research on the wide variety of energy storage, thus electrical, mechanical, chemical and thermal energy storage, with lithium batteries being the most prominent one.
- Heat pumps: research on heat pumps and similar electrical devices used for heating, ventilation and cooling (HVAC).

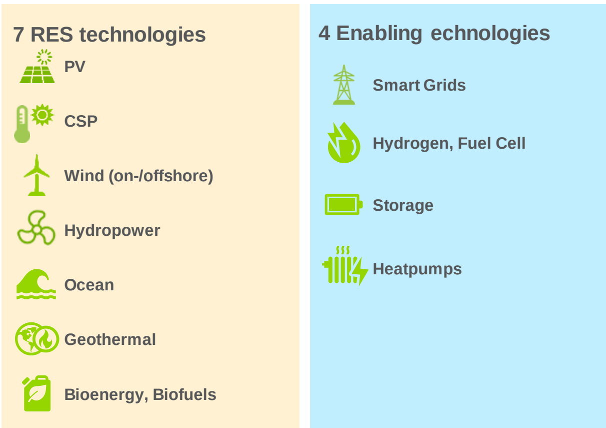


Figure 8: Overview of the analysed technologies

Once the relevant technology fields have been defined, we need to identify publications matching these various topics. To do so, we make use of a technology-specific set of keywords commonly used in relevant publications. For example, the key words 'distribution grid', 'demand side management' or 'distributed energy resource' are commonly used in smart grid related research. We identify these keywords through a short analysis of the keywords used by authors to describe the content of their publications in journals: We summed up all occurrences of a keyword in a technology-specific journal, e.g. Progress in Photovoltaics, within a certain year and took the most frequently used ones into account for our bibliographic analysis. Furthermore, we complemented these keyword lists through expert judgement and derived 11 sets of technology-specific keywords, depicted in Figure 9.

Utilizing these technology-specific keywords for a keyword search in a publication database, we are able to identify relevant publications within the entirety of academic journals. Thus, we are able to include not only technology-specific niche journals into our publication search, but also the most prestigious journals, which usually cover a broad spectrum of topics.

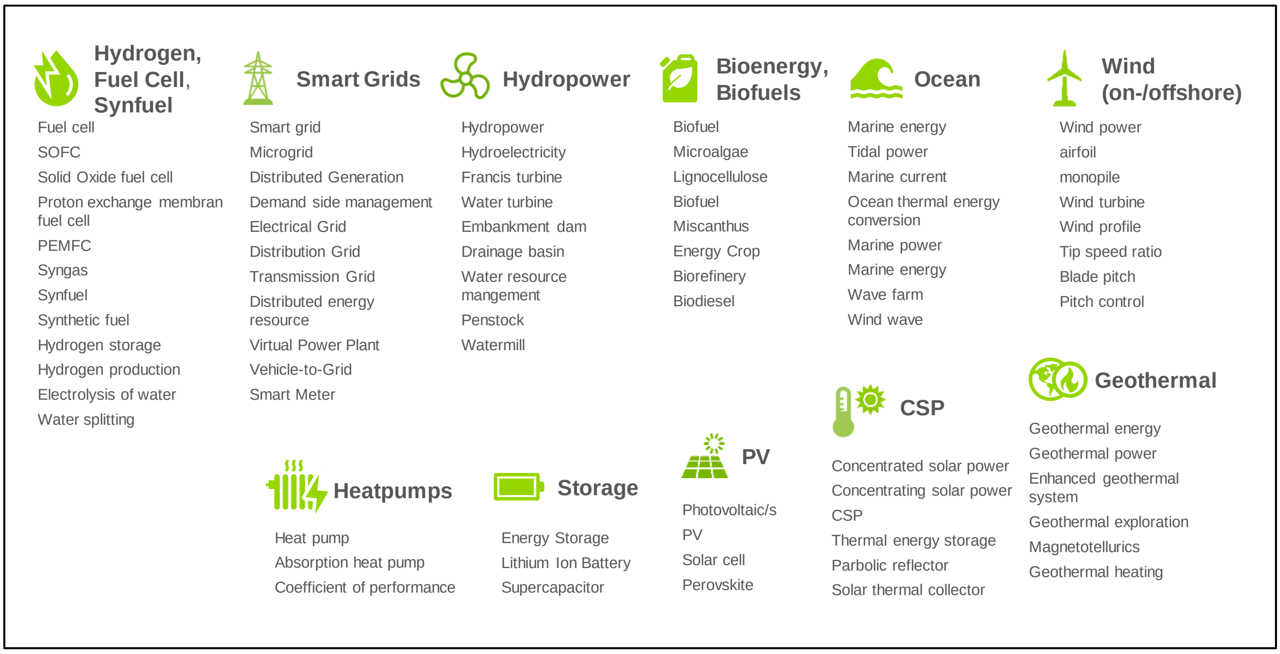


Figure 9: List of technology-specific keywords used to identify relevant scientific publications

4.1.1.3 Research Impact

In addition, we limit the scope of the bibliographic analysis by considering only the most influential publications from each research field. Thereby we want to ensure that the most relevant publishing institutions are identified by means of this analysis. Since the number of citations is a commonly used measure for a publication’s influence and research impact, we limit our analysis to the 500 most cited publications from each research field.

4.1.2 Step 2: Data Research and Identification of Publishing Institutions

Based on the previously defined scope of the analysis we identified the 500 most cited publications for each technology, published within the last five years, by performing a keyword search in a bibliographic database. Several of these bibliographic databases are available online, providing access to the meta data of scientific publications, such as authors and their affiliations, topic, title, journal and publication year. The most common databases are CrossRef (freely available), Google Scholar (freely available), Microsoft Academic (freely available), Scopus (commercial), and Web of Science (commercial).[25] We decided to use MS Academic for our keyword search, since the platform provides an API for data access and export and provides the

[25] See: (Crossref 2020), (Google 2020), (Microsoft 2020), (Elsevier 2020), (Web of Science Group 2020)

most comprehensive freely available database of publications, comparable to the commercial solutions on the market.

Looking at results of our database query, we find that each individual publication is published by a set of authors affiliated with certain research institutions. To derive a clean list of all these publishing institutions for each technology, we used an Excel-based tool and analysed the raw output data from MS Academic.[26] This approach is also depicted in Figure 10.

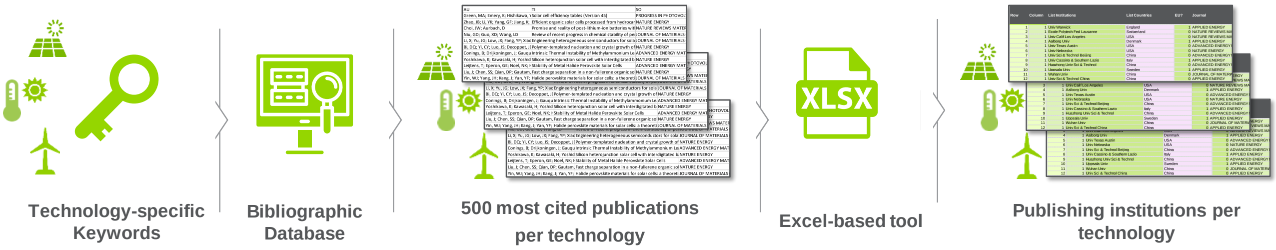


Figure 10: Approach for the identification of publishing institutions

4.1.3 Step 3: Scoring and Institution Ranking

So far, as described in the previous chapters, we identified longlists of several hundred research institutions per RES technology through a technology-specific keyword search in a bibliographic database. In the following, we develop a methodology to score and rank these institutions. Thereby, we are able to pin down the institutions which are most relevant as potential partner institutions for an increased research cooperation between Horizon 2020 member states and other countries.

In a first step, to structure the data set, we mapped the research institutions to the country in which they are located. This country mapping is based on publicly available data, such as university rankings,[27] as well as a manual effort to map the institutions to their countries through desk research. By means of this mapping, we will be able to derive results on a country level later on.

Furthermore, we categorize the countries along two dimensions:

- First, we distinguish between Horizon 2020 countries and other countries. Horizon 2020 countries are the 28 (now 27) EU member states and 16 (now 17) additional countries associated with the EU-funded framework programmes for research and development.[28] Through this differentiation we can establish separate institution rankings for the two groups and identify not only Non-H2020 Countries institutions which are most relevant as potential research partners, but also institutions from Horizon 2020-countries which do not actively cooperate with institutions in the ROW yet, and can therefore be targeted for increased research cooperation.

[26] See appendix for an extract from the tool, highlighting its functionality.
[27] (SCIMAGO 2020); (QS Quacquarelli Symonds 2020), (University Leiden CWTS 2019), (Times Higher Education 2020)
[28] See: (European Commission 2020)

- Second, we divide between developed and emerging countries, according to the categorization used by the IMF.[29] Thereby we are able to give a high-level overview of the distribution of research institutions between long-established and new players in the further analysis.

The resulting categorization of countries is illustrated in Figure 11.

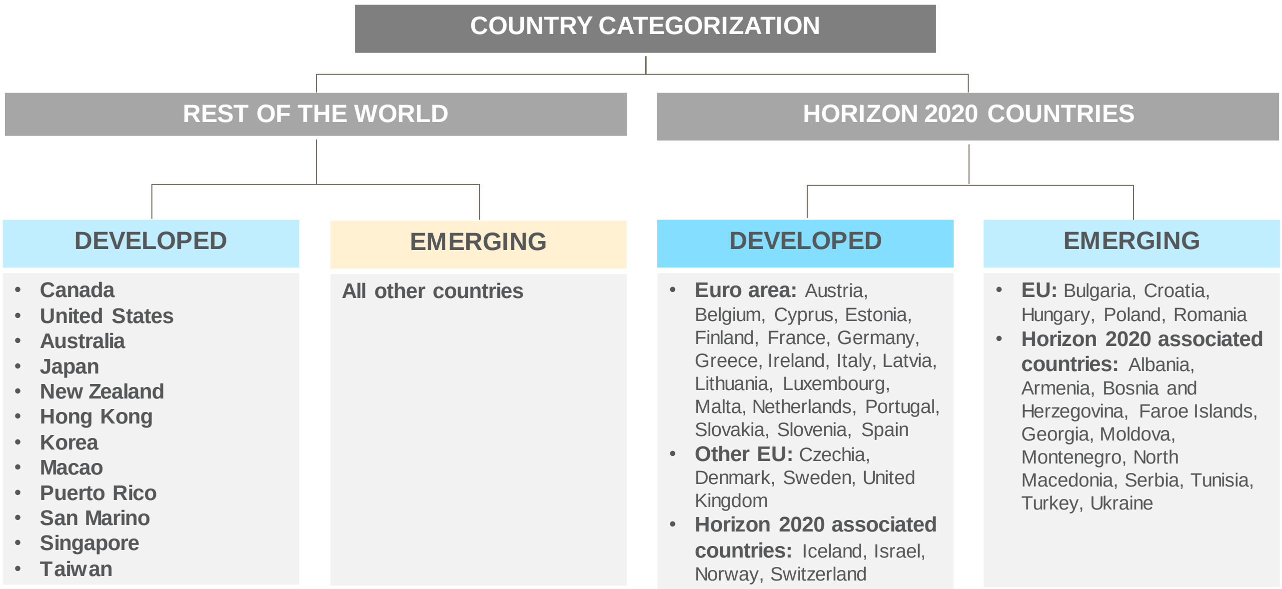


Figure 11: Country classification

By means of a ranking we aim at the identification of the institutions with the highest impact in their respective research fields. To measure the research impact of an institution, we developed a formula based on well accepted metrics in bibliometric studies. These are,

- first, the number of publications as a means to measure the research output quantity,

- and second, to measure the quality of the research output, we take into account the number of citations of a paper and the ranking of the journal in which the respective paper has been published.

The formula and its application are depicted in Figure 12. Input figures for the calculation are taken from the previously built data set, thus Microsoft Academic (number of publications by an institution, number of citations of these publications). In addition, we use the Scimago Journal Rank (SJR), [30] a journal ranking metric provided by Scimago, that is available for almost any scientific journal and measures a journal's prestige. Without going into detail about the application of the formula, it needs to be emphasized that we establish the ranking of an institution relative to all other institutions in the considered research field. Therefore, an institution receives a higher scoring in a certain research field if it published more publications, and/or publications with more citations, and/or publications within highly prestigious journals.

[29] (International Monetary Fund 2019)
[30] Scimago Journal Rank (SJR) indicator is developed by SCImago and measure a journal's scientific prestige. See: (Scimago 2020)

Moreover, a research institution can receive different scorings in different research fields. Finally, all institutions with publications in a certain research field are scored according to the described methodology and receive a score between 0 and 100, with 100 being the best and 0 the worst score. The institutions are then ranked based on their score.

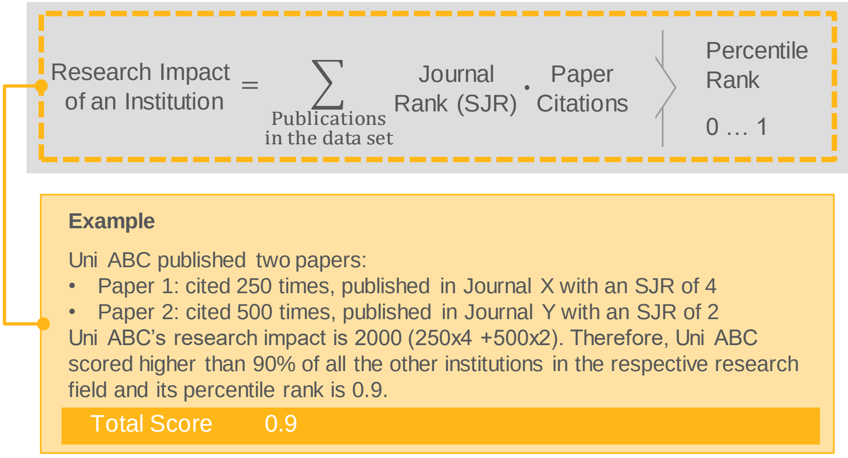


Figure 12: Calculation of the ranking metric (research impact)

4.1.4 Step 4: Result Refinement and Meta-Analysis

Based on the previously described scoring and ranking methodology we derived a ranking of research institutions for each RES technology, providing insights on the research impact of each institution listed. To pick the institutions which are most interesting for an intensified research cooperation, we take into account additional information and complement the ranking through:

- calculation of the share of publications by an institution which have been published in collaboration with another institutions
- calculation of the numbers of institutions with which a certain research institute has been collaborating with
- calculation of the share of publications by an institution which have been published in collaboration with institutions within or outside of H2020 countries
- the Times Higher Education Research Score,[31] a score published by Times Higher Education, which measures an institution's research volume, research reputation, and the amount of research funding (not available for all institutions though)

With these additional measures, we are able to obtain insights about an institution's collaboration efforts – within and outside of H2020 countries – and the overall research quality of an institution, even beyond the considered RES technology field. Taking into account all this information, we use expert judgement to pick three institutions from H2020 countries and the ROW for each technology, which are the resulting most interesting targets for an increased research cooperation.

[31] (Times Higher Education 2020)

Further on, we use the technology-specific rankings as input for a meta-analysis to derive additional insights on a higher level. In particular, we are able to aggregate the results throughout all analysed research fields on a country level based on the country mapping introduced in section 4.1.3. Country-level metrics we calculate are:

- the number of research institutions active in RES research for each country and how many of the institutions are active in a certain research field;
- the number of top-ranked research institutions active in RES research for each country and how many of the institutions are active in a certain research field;
- the overall share of research publications from a country which are published in collaboration with institutions from another country.

Through the publication analysis and the corresponding meta-analysis, we were able to rank countries according to the number of research institutes active in a country. The results unveil, that about 80% of all listed institutions are located in only 21 countries, listed in Figure 13. These 21 countries are further on used as our focus countries, for which we did not only perform a publication analysis, but also additional analyses on patent filings and research projects.

Non-Horizon 2020 countries	Horizon 2020 countries
United States	United Kingdom
China	Germany
India	France
Canada	Turkey
South Korea	Italy
Japan	Spain
Iran	Sweden
Australia	Portugal
Brazil	
Taiwan	
Malaysia	
Pakistan	
South Africa	

Figure 13: List of focus countries

4.2 Patent Analysis

In addition to the publication analysis, which provides insights on basic and applied R&D on institutional as well as country level, we analyse the number of patent filings on a country level. Thereby we gain insights on the intensity of the more advanced phases of technology R&D, from applied R&D to demonstration.

To do so, we employ the INSPIRE data base by IRENA,[32] which provides patent filing figures on a yearly basis, separated by technology and country in which a patent has been filed. The INSPIRE data base relies on data from the European Patent Office's database PATSTAT, which lists patent filings worldwide. The INSPIRE data base only provides figures up to the year 2016. To be consistent with our publication analysis we choose the same lower bound for the analysed

[32] See: (IRENA 2020)

time span, as of 2014. Consequently, we consider the three-year time span, 2014 to 2016. If data for this time span is not available for a certain technology or country, we take into account data from the latest available three-year time span.

With respect to the technology scope defined in chapter 4.1.1, we notice that the patent database does not provide figures for the technology groups grids, hydrogen/fuel cells/synfuels, and storage. Instead, patents within these technology groups are listed as part of the technology category "RE Enablers". Consequently, we are not able to provide disaggregated figures for these three technology groups, but rather list patent filing numbers for the broad category of enablers, which includes patents in all of these three technology groups. We performed the patent analysis only for the previously defined list of focus countries.

4.3 Project Analysis

Besides the analysis of publications and patents, we also considered existing research cooperation between H2020 and the ROW, by analysing research projects. To do so, we employed the EC's CORDIS database, listing all projects funded by the EU's framework programmes for research and innovation. In particular, we considered projects listed within H2020-3.3. The programme H2020-3.3 "SOCIETAL CHALLENGES - Secure, clean and efficient energy" is H2020's major funding line for RES and other energy-related research.

For all of the previously defined focus countries, which are not H2020 members, we performed a project search within the CORDIS database. Thereby, we are able to identify H2020-3.3 projects with non-H2020 collaboration. In addition, we matched all identified projects to the previously defined RES technology groups. However, we were not able to identify and list all projects in which the H2020 focus countries are involved – the more than 1000 projects could not be manually processed. Therefore, we concentrated on the already identified research projects with non-H2020 participation and checked whether any of the H2020 focus countries are participating in these projects as well. Thereby, we were able to identify and map all H2020-3.3 projects with non-H2020 participation to the list of focus countries.

4.4 Results Aggregation and Country Classification

Based on the previously described publication and patent analysis we derived data on a country-level to evaluate a country's activities in

- early-phase R&D on RES through the number and ranking of research institutions,
- late-phase R&D on RES through the number of patents filled,
- research cooperation on RES through the share of publications from a county's institutions which have been co-published by research institutions from another country.

Building on this data set, we are able to classify the focus countries of this study according to their performance in one of the three categories. We define countries as "front runners" which perform best in the respective category, as "top" which show a significant activity in one of the three categories, and as "intermediate" for the remaining countries of the list, keeping in mind that the set of focus countries represents the most active ones in RES research. The criteria used for the classification are described in Table 3. Therein, also specific values are defined for these criteria to differentiate the three classes, front runners, top, and intermediate.

Table 3: Criteria used for country classification and example

	Early-phase R&D	Late-phase R&D	Research Cooperation	Overall Rating
Data Source	Publication analysis	Patent analysis	Publication analysis	Publication and patent analysis
Criteria	number of (top-ranked) institutions	number of patents	share of internationally co-authored papers	Sum of point rating in all three categories
Front Runners	≥ 180 (=>15) institutions	≥ 10.000 patents	≥ 80%	∑ = 7-9 points
Top	≥ 36 (=>3) institutions	≥ 1.000 patents	≥ 70%	∑ = 5-6 points
Intermediate	< 36 (<3) institutions	< 1.000 patents	< 70%	∑ = 4 or less points
Missing Data	Label used if data is missing in any of the three categories			
Example: Japan	54 institutions in total, 3 top-ranked institutions → Top (2 points)	11.874 patents → Front Runner (3 points)	81% → Front Runner (3 points)	2+3+3=8 points → Front Runner

Front runner countries in the category early-phase R&D represent more than 10% (180 institutions) of all listed institutions from the publication analysis, or more than 10% (15 institutions) of all top 10 ranked institutions. Likewise, front runners in the category late-phase R&D represent more than 5% of all listed patents in the RES patent database. Front runners in the category research cooperation show a share of internationally co-published research papers of at least 80% in their total amount of RES research publications listed in the publication analysis.

Lastly, we combine the country classification in these three categories into one overall rating. If a country got rated as a front runner it gets 3 point. Similarly, 2 points are given for the top rating and 1 point for the intermediate rating. Summing up the point ratings in all three categories a country is labelled as front runner for 7 to 9 points, top for 5 to 6 points and intermediate with 4 or less points. If data is missing in one of the categories, we do not give an overall rating for the respective country. In Table 3, an example is provided on how the country classification is applied.

4.5 Study Limitations

In the course of this study we faced several issues and limitations, mostly connected to the highly data-driven approach. In the following, we want to give a short overview of these limitations to provide transparency and facilitate an evaluation of the study's results. The main limitations are:

- **Language**: The bibliographical database we used lists only publications in English language. Despite English being the primary language in science, a substantial part of all scientific publications is published in third languages. By performing our keyword search for publications in English language, we consequently neglect a substantial part of the scientific landscape, which could be publications from certain emerging countries without strong ties to the rest of the world, or from advanced countries with proud scientific traditions and pride in their language. While e.g. India or Nigeria might not be problems in this respect, Germany, France, Brazil, Iran or China could be.

- **Keywords:** Technology-specific keywords as input for a keyword search in the bibliographic database are necessary to filter for relevant publications. However, since we needed to limit the number of keywords for the database query and keywords in scientific publications are not standardized, we might have missed some relevant publications in our data research.

- **Time frame:** For the publication analyses only publications from the last 5 yrs. have been considered. Thereby, we are able to show the most recent developments in the scientific landscape. However, the R&D process is slow and high-impact publications (i.e. heavily cited) may only be visible in a longer time frame.

- **Data quality:** In the publication analysis, not all of the 2000 institutions we identified could be mapped to a country. The remaining 80 institutions are omitted from our country level results. Furthermore, we have been facing a limited data quality in the patent analysis; first, not all of the countries and technologies have been listed, and second, for some countries the latest available data dated back to years before 2016. Therefore, we've been forced to choose different analysis time spans for different countries, which results in a lack of comparability.

- **Used indicators:** We used the number of publications as well as the number of patents to indicate country activity in technology R&D. However, not all types of activities in research necessarily lead to the publication of scientific papers or the filing of patents. Some research institutions may choose other types of publications to present their findings and new technological developments may not be described and protected through patents. This is usually the case if the application of new technologies is time critical and companies do not want to follow the lengthy process of patent applications.

- **R&D beyond academia:** In the publication analysis, we focused on R&D actors from academia and filtered out non-academic institutions, such as companies if they showed up in the results listing. Reasoning is, that companies or other commercial R&D actors usually do not follow the same publication processes as academic actors. Therefore, other indicators than the ones used in this study may be better suited to assess commercial R&D activity, e.g. a company's R&D spending or its patent filings. Thus, we have not been able to identify individual companies as key players in the RES technology field, although commercial R&D is an important part of the R&D landscape.

5 RESULTS

In this chapter we present the findings of this study, thus the results of the publication, patent, and project analysis. Therein we focus on the aggregated results at country level. Initially, we present an overview of the regional distribution of research institutions and patent filings, then move on to the results of our three-fold analysis at country level. In addition, we present the classification of our focus countries according to their impact in the international RES R&D landscape. Thereafter, we highlight the results of country case studies for Brazil, Canada and Egypt. The detailed results of the publication analysis, however, showing in-depth results on the level of individual institutions are not shown in this chapter, instead they can be found in the appendix.

5.1 Regional Distribution of Research Institutions and Patent Filings

As described in the methodology section of this report, we analysed the 500 most cited research publications per technology, totalling a number of 5500 publications. The analysis revealed more than 1900 authoring research institutions.

Due to the country mapping of these institutions we are able to quantify the distribution of these institutions to different regions of the world, particularly Horizon2020, the developed and emerging world.[33] The results, depicted in Figure 14, show that one third of all listed institutions is located in Horizon 2020-member states, indicating the important role of the EU in RES research. Taking a closer look, we realize that, only a seventh of these institutions are located in emerging, mostly eastern European, countries. In the rest of the world (ROW) however, institutions from emerging countries have outnumbered institutions in the developed world, highlighting the growing importance of emerging economies in the RES research landscape.

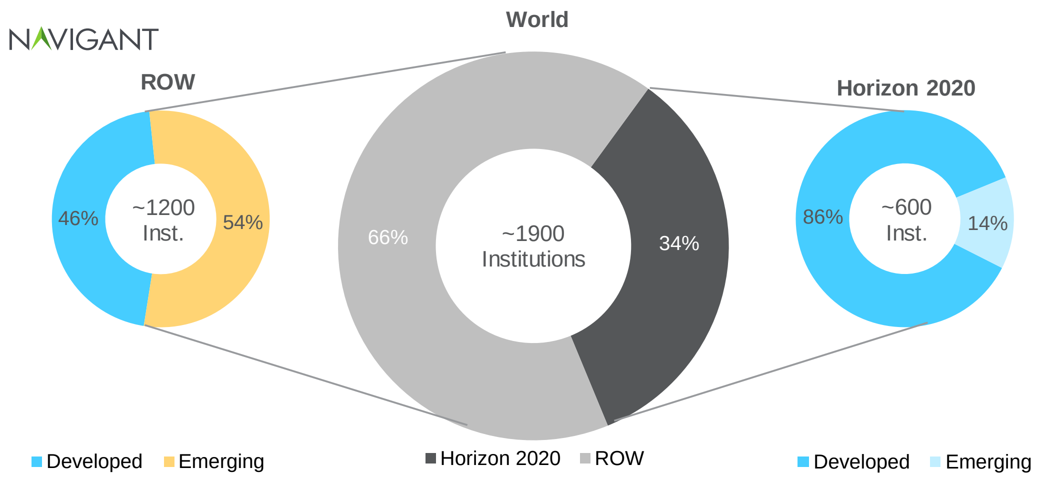


Figure 14: Regional distribution of research institutions

[33] A mapping of the countries to these groups can be found in Figure 11: Country classification.

The distribution of the 1900 RES research institutions onto their about 100 home countries worldwide is shown in the world map, Figure 15. Countries representing the most institutions are highlighted in dark green, clearly pointing out that China and the US take a leading role. More generally speaking, developed countries including Horizon 2020-members are most prominent, but East and South Asia are most active amongst emerging countries. The visibility of Central Asia, Africa and Latin America remains very limited, though.

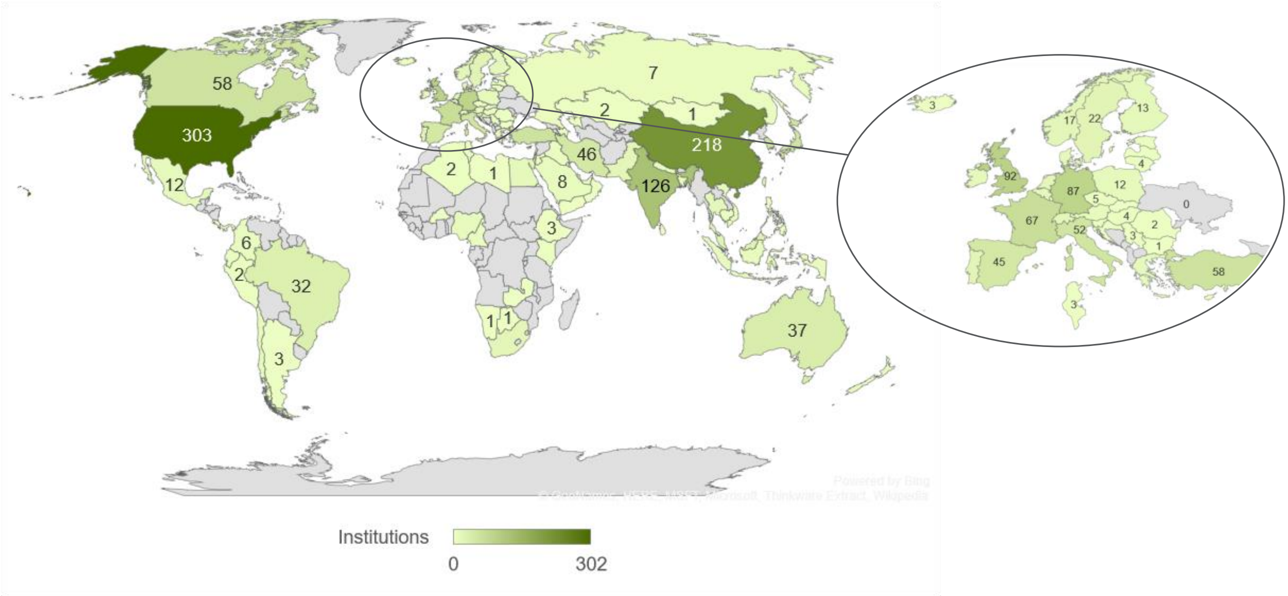


Figure 15: Distribution of research institutions worldwide

In Figure 16, the results of the patent analysis are shown. Once again, countries representing a high number of patent filings are highlighted in dark green. Just as it has been the case for early-phase R&D represented through the number of research institutions, we find that the US and China have a leading role in RES patent filings. Whilst Europe remains with good visibility also on this map, indicating a strong role in late-phase R&D, the lack of data does not allow us to draw further conclusions with regard to other regions of the world.

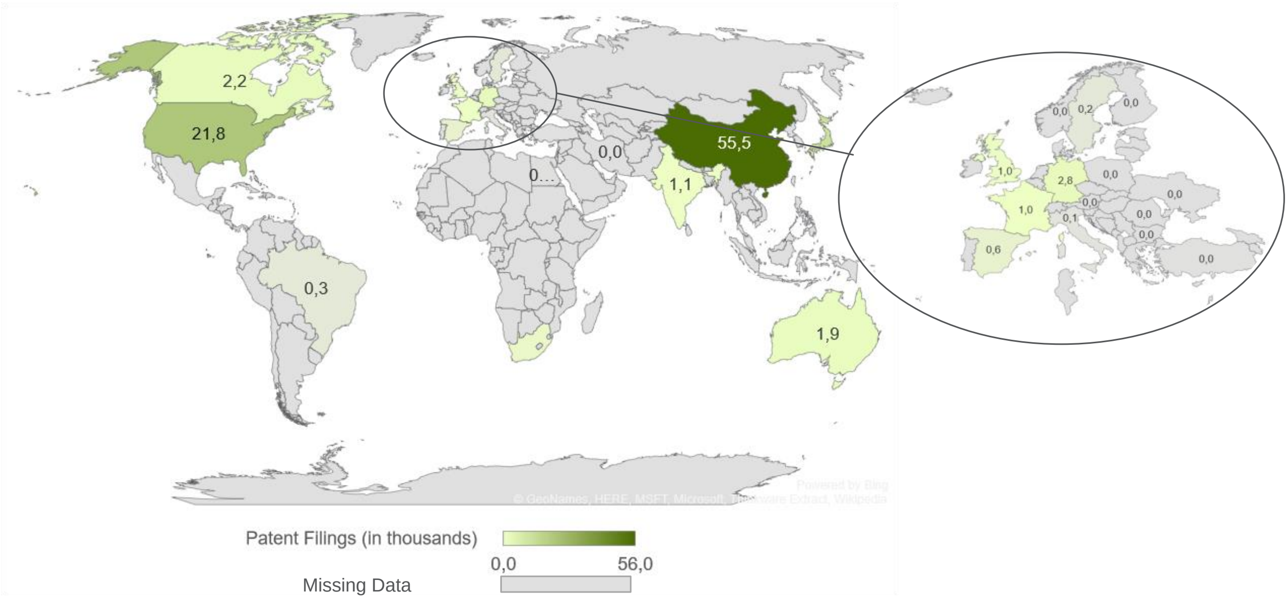


Figure 16: Patent filings on RES technology worldwide (2014 – 2016, or most recent 3-year period)

5.2 Country-Level Results

In the following section, we go into more detail and explore the country-level results from our publication, patent and project analysis for the focus countries of this study.[34]

5.2.1 Results of Publication Analysis

By means of the publication analysis we identified and ranked a high number of relevant institutions active in RES research. Figure 17 presents the number of identified institutions per technology for all focus countries, as well as the number of top 10-ranked institutions in each country, shown in brackets. The green colour coding of the table cells indicates the split of a country's research institutions onto the different research fields and thereby highlights the most prominent research field of a country in dark green. It should be noted, that separate institution rankings have been established for non-H2020 and H2020 countries resulting in separated lists of top 10 institutions, one per country group and technology. Furthermore, it should be noted, that the number of top 10-ranked institutions does not include double counting. If an institution is top 10 ranked for more than one technology, it is counted only once. The colour coding of the countries maps them to a certain country group, as explained in Figure 11. Lastly, the results table in Figure 17 also presents the results of the country classification in the form of the purple bubbles on the left hand side, according to the methodology explained in chapter 4.4.

We notice that the 21 countries shown in the results table already cover 80% of all listed institutions and 80% of the institutions that got top 10-ranked institutions for one of the technologies. Therefore, these focus countries clearly dominate the landscape of RES early-phase research. More specifically, the US and China by far outpace other countries in terms of active research institutions. Yet, Horizon-2020 would be top of the list, if counted as one country. Taking a look at the number of top 10-ranked institutions, we realize that the US and China are

[34] See Figure 13: List of focus countries

leading once again, however, H2020 countries show a high share of top-ranked institutions indicating high quality research within the federation. Interestingly, India which shows a high number of active research institutions does not have a single institution that made it to the top 10 ranks in one of the technology fields. Consequently, there is a contrast between research quantity and quality. Considering the split of institutions onto different technology fields, we realize that almost all top-ranked countries are active in all research fields. Only for a few countries certain research fields stand out, e.g. Bioenergy in Malaysia. These key insights are summarized in Figure 18.

Country	Total No of Institutions listed (No of Top 10 listed*)	No of Institutions per country active in a certain research field (No of Top 10 listed)										
		Bio	CSP	Geo-thermics	Heat-pumps	Hydro-gen	Hydro-power	Net-works	Ocean	PV	Storage	Wind
Non-Horizon 2020 countries												
United States	303 (22)	47 (4)	51 (1)	53 (1)	39 (0)	75 (3)	77 (2)	109 (2)	82 (8)	67 (5)	70 (2)	77 (2)
China	218 (23)	40 (1)	52 (4)	38 (5)	59 (6)	99 (4)	50 (5)	55 (1)	37 (1)	42 (0)	87 (5)	56 (5)
India	126 (0)	57 (0)	20 (0)	7 (0)	7 (0)	19 (0)	13 (0)	23 (0)	9 (0)	4 (0)	15 (0)	16 (0)
Canada	58 (5)	12 (1)	9 (1)	12 (0)	15 (0)	14 (0)	24 (0)	20 (3)	20 (0)	4 (0)	9 (0)	19 (0)
South Korea	57 (3)	14 (0)	12 (0)	4 (0)	16 (0)	16 (0)	4 (0)	15 (1)	8 (0)	24 (2)	17 (1)	14 (0)
Japan	54 (3)	11 (0)	2 (0)	11 (0)	11 (0)	17 (1)	7 (0)	6 (0)	15 (0)	9 (2)	8 (0)	6 (0)
Iran	46 (6)	14 (0)	17 (0)	16 (3)	15 (3)	7 (0)	7 (0)	15 (0)	8 (0)	2 (0)	7 (0)	21 (1)
Australia	37 (4)	12 (0)	14 (0)	17 (0)	6 (0)	12 (1)	10 (0)	20 (0)	22 (1)	14 (1)	12 (0)	16 (1)
Brazil	32 (2)	16 (0)	4 (2)	2 (0)	1 (0)	1 (0)	14 (0)	7 (0)	8 (0)	0 (0)	2 (0)	6 (0)
Taiwan	30 (1)	13 (0)	0 (0)	4 (0)	4 (0)	7 (0)	5 (1)	4 (0)	5 (0)	10 (0)	5 (0)	6 (0)
Malaysia	24 (4)	18 (3)	11 (1)	2 (0)	4 (0)	6 (0)	6 (1)	5 (0)	2 (0)	8 (0)	9 (0)	4 (0)
Pakistan	18 (1)	5 (0)	1 (0)	4 (0)	0 (0)	0 (0)	3 (0)	5 (1)	0 (0)	2 (0)	1 (0)	6 (0)
South Africa	18 (0)	4 (0)	5 (0)	2 (0)	3 (0)	5 (0)	4 (0)	1 (0)	3 (0)	1 (0)	0 (0)	3 (0)
Horizon 2020 countries												
United Kingdom	92 (15)	18 (1)	19 (2)	19 (0)	19 (2)	14 (3)	24 (2)	28 (1)	48 (4)	14 (3)	15 (2)	32 (1)
Germany	87 (10)	8 (1)	9 (0)	21 (2)	20 (0)	20 (3)	28 (3)	18 (0)	16 (0)	14 (3)	14 (2)	18 (0)
France	67 (6)	9 (0)	15 (2)	8 (0)	9 (0)	8 (0)	11 (0)	9 (1)	25 (3)	2 (0)	10 (2)	9 (0)
Turkey	58 (10)	10 (1)	10 (1)	24 (3)	17 (2)	8 (0)	8 (0)	12 (2)	3 (0)	0 (0)	5 (0)	4 (1)
Italy	52 (6)	6 (0)	9 (0)	21 (3)	17 (1)	7 (0)	21 (1)	14 (0)	12 (0)	12 (2)	7 (2)	12 (1)
Spain	45 (6)	16 (0)	8 (1)	9 (0)	11 (1)	5 (1)	21 (1)	7 (0)	14 (1)	10 (0)	10 (1)	12 (1)
Sweden	22 (4)	5 (0)	5 (1)	7 (0)	7 (1)	6 (0)	12 (1)	5 (0)	6 (1)	5 (1)	4 (0)	4 (0)
Portugal	19 (0)	6 (0)	2 (0)	1 (0)	2 (0)	1 (0)	10 (0)	6 (0)	7 (0)	0 (0)	2 (0)	5 (0)

Front Runners Top Intermediate

0% 100%
Share of a country's institutions active in certain research field

Figure 17: Number of research institutions per technology and country

Non-H2020 countries – most active countries

China and USA are by far the most important players in RES research. Both countries prevail in almost all RES research fields.

- USA: 300 research institutions, thereof 20 top-ranked
- China: 200 research institutions, thereof 20 top-ranked

Other active countries include

- Developed countries: Canada, South Korea, Japan, Australia, Taiwan
- Emerging economies: India, Iran, Brazil, Malaysia, Pakistan, South Africa

Other **emerging economies show a diverse picture** – high visibility of south/southeast Asia, limited visibility for Africa and LAC

H2020 countries – most active countries

Europe has an **overall strong position** in RES R&D worldwide with more than 600 research institutions active in the RES field

British and German institutions lead the rankings

CEE countries have a limited visibility and should be stimulated to be more active

Leading countries maintain **strong collaboration with non-European countries**, with Great Britain and Nordics being most active

Non-H2020 countries – focused technologies

Developed economies (USA, Canada, Australia, Japan) specialized in **new technologies**, such as ocean energy, hydrogen and smart grids

Developing economies focus on **bioenergy**; cooperation in this field may be interesting for Taiwan, Iran, India, and Malaysia

Other interesting country/technology matches include:

- China is taking over leadership in global wind research, dominates PV and is very active in smart grids
- Malaysia for CSP
- Brazil and Egypt for hydropower
- Egypt and Canada – hydrogen, networks and ocean energy
- Indonesia and India for geothermal energy
- Saudi Arabia, Japan and Singapore for hydrogen
- Hong-Kong and Nigeria for heat pumps

H2020 countries – focused technologies

Particularly strong in PV, Wind, Ocean

Whilst top-ranked countries are active in all research fields, some have a particularly strong stand in one technology (Ocean – GBR, Hydro – SWE/NLD, Wind – DNK)

Figure 18: Insights from the publication analysis on most active countries and technology field

5.2.2 Results of Patent Analysis

By means of the patent analysis we identified the number of patent filings for RES technology on a country level. Figure 19 presents the number of patent filings per technology for all focus countries. The same green colour coding for the table cells is used as in Figure 17, now indicating the split of a country's research patents onto the different technology fields. Similarly, we use the same colour coding to map countries to a certain country group, as in Figure 17. Likewise, the results table uses the same graphical representation of the country classification, the purple bubbles on the left-hand side.

Taking a look at the results, we notice the limited data quality – for some countries no patent filing figures had been available. Nevertheless, despite limited data quality, the number of patent filings reveals a similar picture as the number of research institutions. This leads to the conclusion that a strong position in early-phase R&D usually correlates well with, or provides a good basis for, a strong position in late-phase R&D and commercialization of new technologies. We see, that similar to the number of research institutions, USA and China by far outpace other countries in terms of patent filings. Japan is third ranked with some distance to the other two front runners, thereby taking a very strong role in late-phase R&D which deviates from the country's intermediate ranking in early-phase R&D. Countries with comparatively strong manufacturing sectors, e.g. China, Japan or Germany, tend to have more patents than countries focusing more on services (e.g. USA, UK). Furthermore, the results show that most countries are active in all research fields. The overall number of patents per technology highlights PV, CSP, Bio and Wind as the technologies with a high level of late-phase R&D.

Institutions	Total No of Patents	Patent Filings (2014 – 2016, or latest three year period) Bio	CSP	Geo-thermics	Heat-pumps	Hydro-power	Ocean	PV	Wind	Enablers
Non-Horizon 2020 countries										
United States	21.806	3.171	2.556	149	46	411	295	6.360	2.588	6.230
China	55.498	6.120	14.983	316	281	3.359	1.186	11.390	7.830	10.033
India	1.117	183	162	1	4	69	27	146	293	232
Canada	2.219	487	220	31	11	123	88	273	472	514
South Korea										
Japan	11.874	729	827	112	270	451	129	4.278	1.007	4.071
Iran										
Australia	1.913	387	381	44	7	76	85	300	262	371
Brazil	313	42	31	3		32	8	33	116	48
Taiwan										
Malaysia	40	8				10		5	6	11
Pakistan										
South Africa	808	230	162	4		13	25	125	80	169
Horizon 2020 countries										
United Kingdom	961	73	148	14	7	122	56	135	202	204
Germany	2.823	160	459	30	14	147	36	440	628	909
France	1.004	91	146	15	17	106	84	155	114	276
Turkey	47		11			6	9	1	13	7
Italy	117	22	15			42		8	21	9
Spain	591	34	216			48	31	47	151	64
Sweden	244	35	70	5	5	11	15	26	53	24
Portugal	47		16			20	18		33	11

Front Runners · Top · Intermediate · Missing Data

0% – 100%
Share of a country's patents filed in a certain technology field

Figure 19: Number of patent filings per country and technology

To put these absolute number of patent filings into perspective, the number of RES patent filings can be compared to a country's GDP. According to EUrobserv'ER, in 2014 the EU filed 109 patents per trillion EUR GDP, thereby lagging behind China (529), Japan (505) and Korea (1676), but surpassing the US (61).[35]

5.2.3 Results of Project Analysis

By means of the patent analysis we identified the research projects within H2020-3.3 where non-H2020 countries are involved. Figure 20 presents the number of international cooperation projects per technology in which the focus countries are involved. In addition, in brackets the volume of these projects is given. As before, the same green colour coding for the table cells is used as in Figure 17, now indicating the split of a country's research projects onto the different technology fields. Similarly, we use the same colour coding to map countries to a certain country group, as in Figure 17. Likewise, the results table uses the same graphical representation of the country classification, the purple bubbles on the left-hand side.

The programme H2020-3.3 "SOCIETAL CHALLENGES - Secure, clean and efficient energy" is H2020's major funding line for RES and other energy-related research. More than 1200 projects

[35] (EURObservER 2018)

are funded through this programme, totalling 5930 Mio. EUR. However, the results of the project analysis highlight, that only very few of these RES research projects - 21 in total - involve non-H2020 countries. In consequence, the RES research projects with non-H2020 cooperation represent only 1% of the overall budget of the H2020-3.3 programme. Thereby, we identify a strong mismatch between the importance of non-H2020 countries in the RES research landscape and their involvement in H2020-funded projects.

Taking a look at individual countries, we find that China and Germany are the most active countries in H2020-funded cooperation projects outside H2020 or within H2020, respectively. Moreover, the research field hydrogen/fuel cells/synfuels is the most prominent topic amongst the existing projects with international collaboration outside of H2020.

Country	Total No of projects (total budget in Mio. EUR)	No of research projects in a certain research field (budget in Mio. EUR)										
		Bio	CSP	Geo-thermics	Heat-pumps	Hydro-gen	Hydro-power	Net-works	Ocean	PV	Storage	Wind
Non-Horizon 2020 countries												
United States												
China	4 (14,9)					3 (10,7)					1 (4,2)	
India	2 (9,5)				1 (2,1)			1 (7,4)				
Canada												
South Korea	2 (27,3)			1 (24,7)		1 (2,6)						
Japan	1 (4,4)					1 (4,4)						
Iran												
Australia	2 (7,9)									1 (5,1)	1 (2,8)	
Brazil												
Taiwan												
Malaysia												
Pakistan												
South Africa	2 (8,9)	1 (3,0)	1 (5,9)									
Horizon 2020 countries												
United Kingdom	5			1 (24,7)		2 (6,3)		1 (7,4)			1 (4,2)	
Germany	10	1 (3,0)	1 (5,9)	1 (24,7)	1 (2,1)	4 (11,8)				1 (5,1)	2 (7,0)	
France	6			1 (24,7)		1 (2,6)		1 (7,4)		1 (5,1)	2 (7,0)	
Turkey	1					1 (4,8)						
Italy	4		1 (5,9)			3 (8,9)						
Spain	4		1 (5,9)		1 (2,1)	2 (4,4)		1 (7,4)				
Sweden	1				1 (2,1)							
Portugal												

0% 100%
Share of H2020-3.3 projects covering a certain research field

Figure 20: H2020-3.3 projects with collaboration of non-H2020 countries

5.2.4 Aggregated Results and Country Classification

In the following results table, Figure 21, we aggregate our findings from the publication, patent and project analysis. Based on the individual rating within the three categories early-phase R&D, late-phase R&D and research cooperation, an overall rating is assigned, and countries are classified as front runners, top or intermediate in the RES research landscape. The individual rating for the three categories is given based on the quantitative results of the study, indicated through the light green arrows in the figure. These individual ratings are, in turn, summed up to the overall rating, as indicated by the dark green arrow in the figure. In addition, the results table shows the leading technology in early- and late-phase R&D for each country, defined as the technology field in which the most research institutions are active, or respectively, the most patents have been filed. Moreover, the number of H2020-3.3 research projects with non-H2020 cooperation are shown as well for each of the countries. However, the leading technologies and the number of H2020 projects are given for informational purposes only and do not feed into the overall rating.

Considering the overall rating, four countries are classified as front runners: the US, China and Japan, plus the UK as the only H2020 country. If all H2020 members would be counted as one country though, it would receive the front runner rating as well, shown in the last row of the table.

Country	Early-phase R&D				Late-phase R&D			Research Cooperation			Overall Rating
	Research Institutions	Top-ranked Institutions	Rating	Leading Technologies	Patents	Rating	Leading Technologies	Internat. Collaboration	Rating	H2020-3.3 Cooperation projects	
Non-H2020 countries											
United States	303	22	Front Runners	Grids, Ocean	21.806	Front Runners	PV, Enablers	74%	Top	-	Front Runners
China	218	23	Front Runners	Hydrogen, Storage	55.498	Front Runners	CSP, PV, Enablers	67%	Intermediate	4	Front Runners
India	126	0	Top	Bioenergy, Grids	1.117	Top	Wind, Enablers	47%	Intermediate	2	Top
Canada	58	5	Top	Hydropower, Grids, Ocean	2.219	Top	Enablers, Wind, Bio	61%	Intermediate	-	Top
South Korea	57	3	Top	PV, Storage		Missing Data		66%	Intermediate	2	Missing Data
Japan	54	3	Top	Hydrogen, Ocean	11.874	Front Runners	PV, Enablers	81%	Front Runners	1	Front Runners
Iran	46	6	Top	Wind, CSP		Missing Data		59%	Intermediate	-	Missing Data
Australia	37	4	Top	Ocean, Grids	1.913	Top	Bio, CSP, Enablers	78%	Top	2	Top
Brazil	32	2	Intermediate	Bio, Hydropower	313	Intermediate	Wind, Enablers, Bio	69%	Intermediate	-	Intermediate
Taiwan	30	1	Intermediate	Bioenergy, PV		Missing Data		71%	Top	-	Missing Data
Malaysia	24	4	Top	Bioenergy, CSP	40	Intermediate	Enablers, Hydro, Bio	65%	Intermediate	-	Intermediate
Pakistan	18	1	Intermediate	Wind, Grids		Missing Data		91%	Front Runners	-	Missing Data
South Africa	18	0	Intermediate	Hydrogen, CSP	808	Intermediate	Bio, Enablers, CSP	61%	Intermediate	2	Intermediate
H2020 countries											
United Kingdom	92	15	Front Runners	Ocean, Wind	961	Top	Enablers, Wind	73%	Top	5	Front Runners
Germany	87	10	Top	Hydropo., Geo., Hydrogen	2.823	Top	Enablers, Wind, CSP	72%	Top	10	Top
France	67	6	Top	Ocean, CSP	1.004	Top	Enablers, PV, CSP	72%	Top	6	Top
Turkey	58	10	Top	Geothermics, Heat pumps	47	Intermediate	Wind, CSP	70%	Top	1	Top
Italy	52	6	Top	Geothermics, Hydropower	117	Intermediate	Hydrop., Bio, Wind	64%	Intermediate	4	Intermediate
Spain	45	6	Top	Hydropower, Bio	591	Intermediate	CSP, Wind	74%	Top	4	Top
Sweden	22	4	Top	Hydrop., Geo., Heat pumps	244	Intermediate	CSP, Wind	76%	Top	1	Top
Portugal	19	0	Intermediate	Hydropower, Ocean	47	Intermediate	Wind, Hydropower	80%	Front Runners	-	Top
All H2020 MS	627	84	Front Runners	Hydrop., Ocean, Geo.	7.040	Top	Enablers, Wind, CSP	70%	Top	22	Front Runners

Front Runners   Top   Intermediate   Missing Data

Figure 21: Country level results for institutions, patents and projects

Country Case Study: Brazil

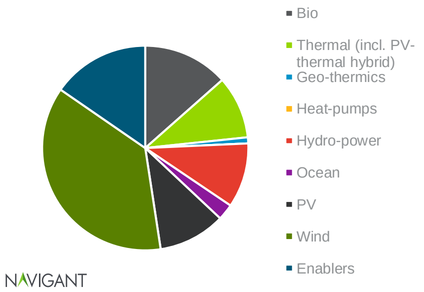
Key findings

- Brazil has most significant experience in biofuels, hydropower and networks. Our knowledge of the Brazilian R&I in these three fields is consistent with leadership roles here.
- Brazil can, therefore, be a strong partner for promoting environmentally friendly hydropower solutions, along with the European know-how. CEPEL br. – an Eletrobras arm, can be one of partners to implement innovative hydropower projects worldwide, building on the Brazilian – and the EU know-how.
- Brazil has also some cooperation with the EU member states on networks and biofuels.
- Brazil is not very strong in other research areas and could benefit from European IP sharing.

Key figures

- Number of institutions listed: 32 (~2% of total number of institutions)
- Number of institutions listed in Top 10: 2 (~1% of total number of institutions ranked amongst top 10)
- Number of patent filings (2014-2016): 313 (<0.1% of total number of patent filings)
- Participation in research projects within H2020-3.3: 0

Distribution of patent filings



Top-ranked institutions

Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively H2020 collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
Universidade Federal do Espirito Santo	BRA	99.1 (CSP)	1	277	22.2	100%	0%	2		Top-ranked in CSP
Federal University of Paraiba	BRA	99.1 (CSP)	1	277	22.2	100%	0%	2		Top-ranked in CSP

Country Case Study: Canada

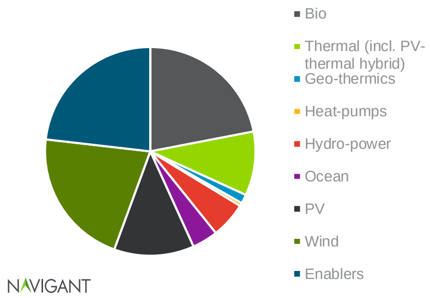
Key findings

- Canada is particularly strong in hydropower, networks, wind power and ocean energy. Our knowledge of Canadian RD&I especially in the first two fields is consistent with leadership roles here.
- Similarly to Brazil, Hydroquebec can be one of partners to implement innovative hydropower projects worldwide, building on the Brazilian – and the EU know-how.
- Canada and Europe have a relatively good cooperation already but further cooperation in the above-mentioned areas may further strengthen the IP flow between the EU and Canada.

Key figures

- Number of institutions listed: 58 (~0,3%% of total number of institutions)
- Number of institutions listed in Top 10: 5 (~0,3% of total number of institutions ranked amongst top 10)
- Number of patent filings: 2,219 (~1.1% of total number of patent filings)
- Participation in research projects within H2020-3.3: 0

Distribution of patent filings



Top-ranked institutions

Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively H2020 collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
University of Toronto	CAN	94,1 (PV)	6	712	11,5	50%	50%	4	89,5	Top-ranked in PV
University of Toronto	CAN	98.0 (Grids)	8	50	3.4	50%	50%	7	89.5	Top-ranked in Grids
Ryerson University	CAN	94.4 (Wind)	4	109	2.4	50%	50%	2	26	Top-ranked in Wind
University of British Columbia	CAN	94.6 (Ocean)	4	30	1.9	75%	50%	10	73.2	Top-ranked in Ocean
University of British Columbia	CAN	96.1 (Grids)	5	83	2.6	60%	40%	5	73.2	Top-ranked in Grids
University of British Columbia	CAN	98.8 (Bio)	1	1459	13.3	100%	100%	4	73.2	Top-ranked in Bio
University of Ottawa	CAN	99.1 (Grids)	6	91	2.5	50%	50%	6	42	Top-ranked in Grids
University of Waterloo	CAN	98.5 (Grids)	13	68	2.0	77%	69%	21	42.1	Top-ranked in Grids

Country Case Study: Egypt

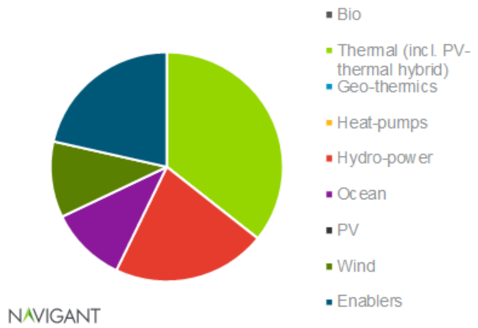
Key findings

- Regarding early-phase research, Egypt shows the highest number of active research institutes in bioenergy and geothermal energy, closely followed by wind and hydropower.
- Even though Egypt's only top-ranked institution achieved a high-score in the hydropower technology field, respective R&D is most likely focused on problems specific to the Egyptian hydro resources, namely the Great Aswan Dam. Therefore, transferability of this knowledge might be limited research cooperation should focus on other R&D fields.
- Egypt develops research in a number of other areas and strengthening cooperation in these fields may contribute to further spreading the European IP, in particular in new technologies (hydrogen, networks and ocean energy).

Key figures

- Number of institutions listed: 13 (0,7% of total number of institutions)
- Number of institutions listed in Top 10: 1 (0,6% of total number of institutions ranked amongst top 10)
- Number of patent filings: 28 (<0,1% of total number of patent filings)
- Participation in research projects within H2020-3.3: 0

Distribution of patent filings



Top-ranked institutions

Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively H2020 collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
Alexandria University	EGY	97.9 (Hydropower)	2	72	2.7	50%	50%	1	13.1	Top-ranked in Hydropower

5.3 Ranking of Research Institutions

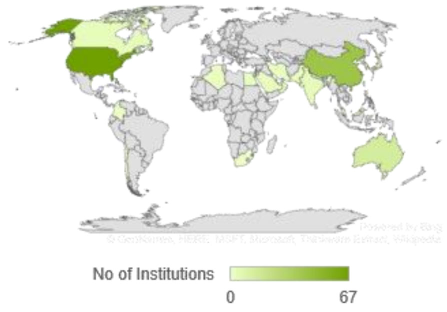
Besides the high-level results presented in the previous sections, we derived in-depth details through the publication analysis on the level of individual research institutions. For each of the technologies, we established a ranking of all listed institutions. However, in this section we will only present an overview of the results for all considered technology fields and give an example of the institution ranking for one technology to provide guidance on how to interpret the results. The institution rankings for all other technology fields can be found in the appendix.

5.3.1 Overview of the Results of the Institution Ranking

As an overview of the institution ranking, we provide some key findings in the table below for each of the 11 technology fields. These key findings are separately listed for non-H2020 and H2020 countries, describing insights for the 11 individual technology fields. Moreover, maps are presented which indicate the regional distribution of institutions active in a certain research field.

Table 4: Key findings from the institution ranking for PV

Technology Field	Key findings for non-H2020 countries	Key findings for H2020 countries
PV	• China and USA lead the way. • Chinese research organizations are very actively cooperating with non-Horizon countries; these may be a target for strengthening cooperation in the field to bring some IP back to Europe.	• Germany and the UK, followed by Italy are European leaders in PV publications. • Most German and Italian universities concentrate on EU collaboration. • No CEE institutions have important publications in the field.



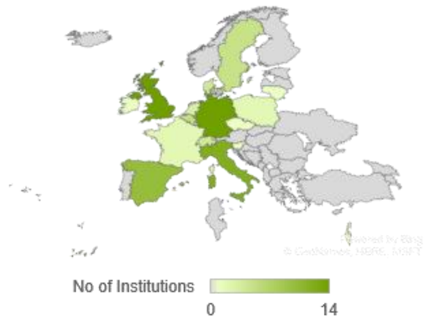
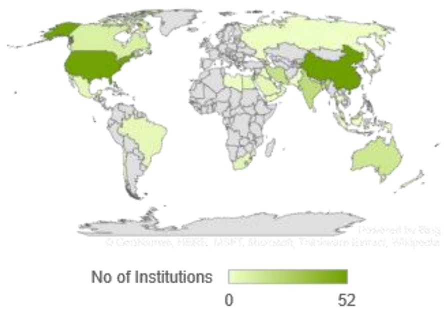


Table 5: Key findings from the institution ranking for CSP

Technology Field	Key findings for non-H2020 countries	Key findings for H2020 countries
CSP	• China, USA lead the way, but interestingly research is done in Brazil, Malaysia and a few other countries, developed and developing ones. • China and Brazil do cooperate with Europe already, Iran and India don't.	• UK, France and Belgium are top active in CSP research. • Emerging economies active too: Poland and Turkey. • Top-scored institutions cooperate mainly outside the EU.



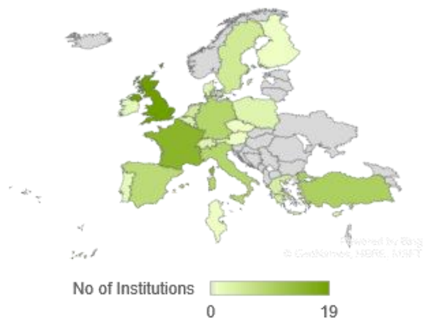


Table 6: Key findings from the institution ranking for wind power

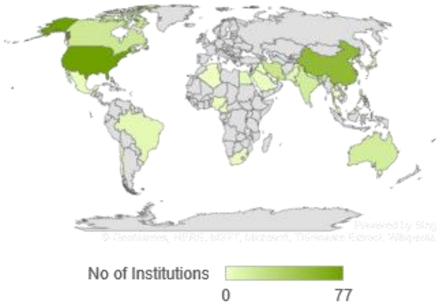
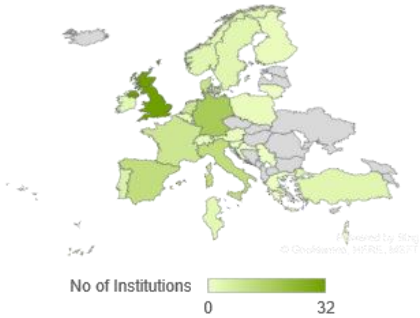
Technology Field	Key findings for non-H2020 countries	Key findings for H2020 countries
Wind power	• Chinese research institutions outpace developed economies. • USA take the lead amongst developed economies. 	• Denmark and UK lead research in wind, followed by Switzerland, and Germany. 

Table 7: Key findings from the institution ranking for hydropower

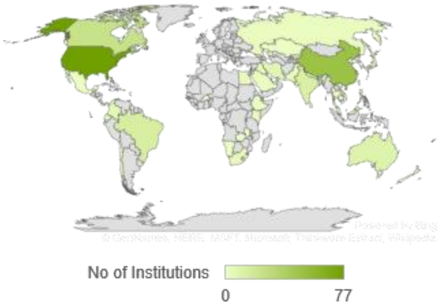
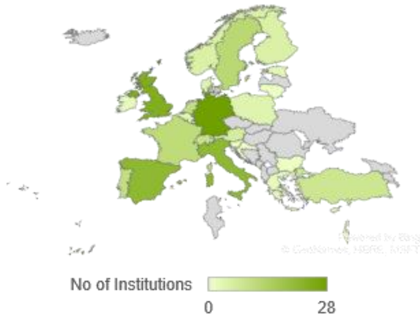
Technology Field	Key findings for non-H2020 countries	Key findings for H2020 countries
Hydropower	• Similar to PV, China and US dominate the hydropower landscape; regarding collaboration with the EU, they show a mixed picture. • Canada and Brazil also take a strong role in this research field, reflecting those countries vast and diverse hydro resources. • Taiwan and Egypt are also high ranked. 	• UK leads the hydropower research, followed by Germany, Spain and the Netherlands. • There is no CEE/emerging country in the ranking. 

Table 8: Key findings from the institution ranking for ocean energy

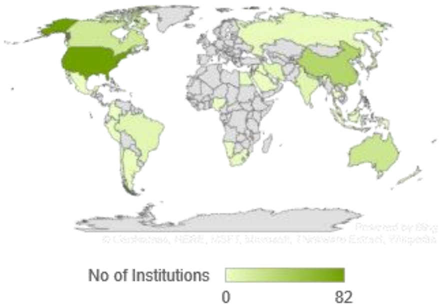
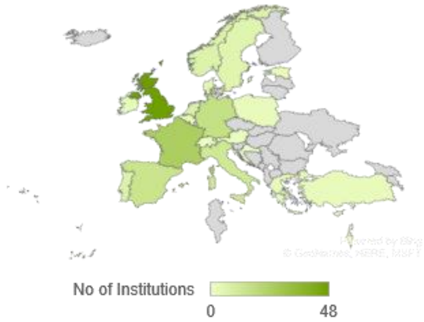
Technology Field	Key findings for non-H2020 countries	Key findings for H2020 countries
Ocean Energy	• Ocean energy research is dominated by developed economies, mainly USA, who often collaborate actively with the EU. • The research also attracts companies and international organizations (not shown in list). 	• France and the UK dominate this research field. • The research also attracts companies and international organizations (not shown in list). 

Table 9: Key findings from the institution ranking for geothermal energy

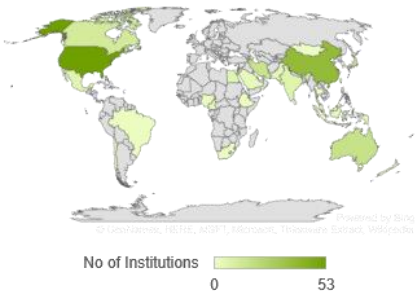
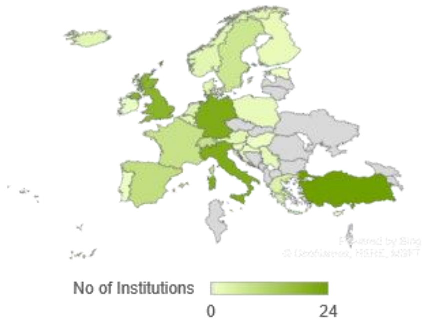
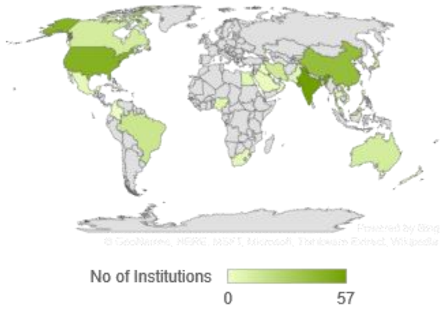
Technology Field	Key findings for non-H2020 countries	Key findings for H2020 countries
Geothermal Energy	• The geothermal research is quite diversified geographically. • Apart from the biggest players (US, China), research is done in Indonesia, India, Iran, Saudi Arabia and Egypt. • Indonesia and Saudi Arabia do not cooperate with the EU yet. 	• In Europe, Italy is the leading country for geothermal research, followed by Germany, Iceland, Switzerland and several CEE countries (Croatia, Serbia and Turkey). 

Table 10: Key findings from the institution ranking for bioenergy/biofuels

Technology Field	Key findings for non-H2020 countries	Key findings for H2020 countries
Bioenergy and Biofuels	• Apart from the global leaders (China, US), there are several interesting emerging players. • A prominent role is taken by India, Malaysia and Brazil.	• UK, Germany, and Denmark are most active. • CEE institutions, e.g. from Serbia and Turkey, are highly scored as well. • All high scored institutions cooperate with non-EU countries.



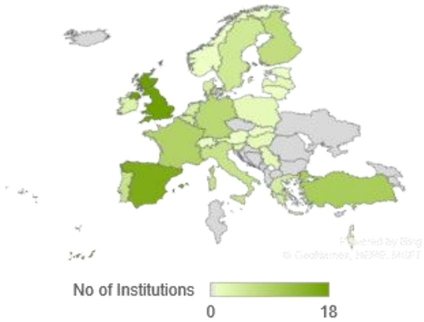
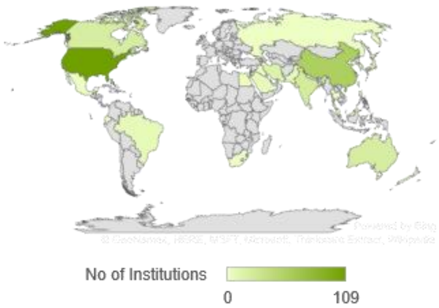


Table 11: Key findings from the institution ranking for smart grids

Technology Field	Key findings for non-H2020 countries	Key findings for H2020 countries
Smart Grids	• In smart grids R&D Canadian and US institutions are most prominent, followed by Singapore and China. • Canada, China and Singapore show only limited cooperation with Europe in the field.	• UK and Denmark are leaders in smart grid research followed by many European states, excluding CEE • Norway and Turkey do not cooperate with EU countries, so strengthening this cooperation could be considered • Great Britain, Denmark and Germany are focusing on partners outside the EU



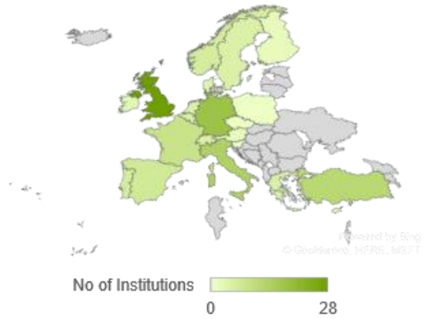


Table 12: Key findings from the institution ranking for hydrogen/fuel cells/synfuels

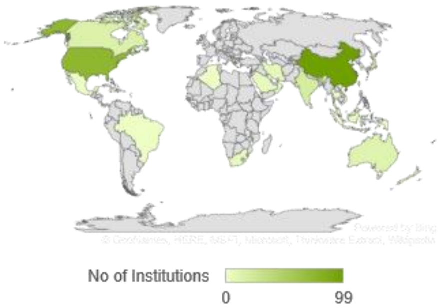
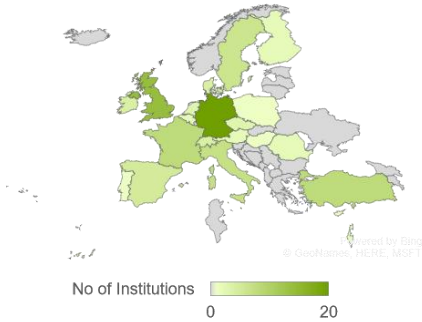
Technology Field	Key findings for non-H2020 countries	Key findings for H2020 countries
Hydrogen, Fuel Cells, Synfuels	• China and US dominate the research field, followed by Saudi Arabia, Singapore, Australia and Japan.  	• Germany and UK lead the research in hydrogen, but they are closely followed by Israel, Sweden, Spain, Switzerland. Netherlands is also pretty active in the field. 

Table 13: Key findings from the institution ranking for storage

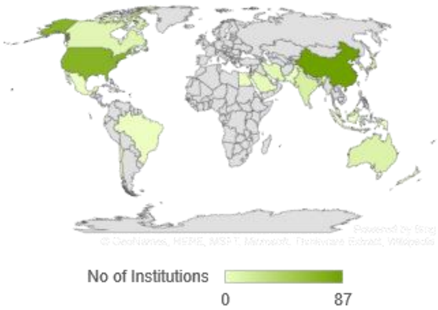
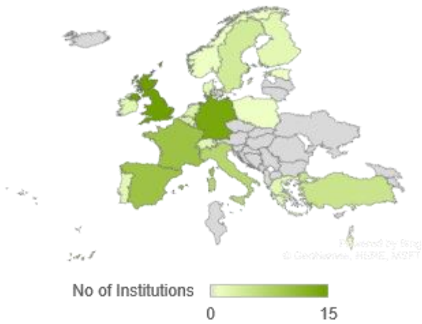
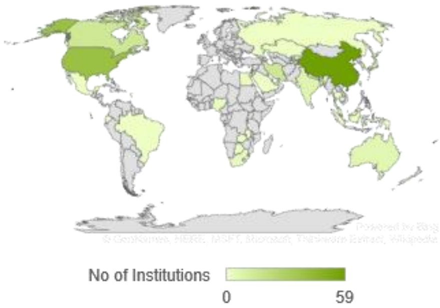
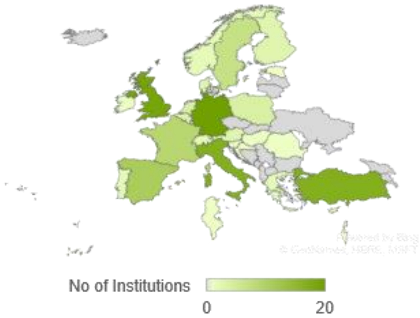
Technology Field	Key findings for non-H2020 countries	Key findings for H2020 countries
Storage	• China and USA dominate storage research, followed by Korea, Singapore, and Japan.  	• France and Italy are leaders in storage research publications, followed by Germany and UK. • Poland represents CEE Member states. • Almost all institutions cooperate beyond the EU, except Poland. 

Table 14: Key findings from the institution ranking for heat pumps

Technology Field	Key findings for non-H2020 countries	Key findings for H2020 countries
Heat pumps	• China leads the research publications in the field, followed by Iran and Hong-Kong, USA and Australia. • Emerging and developing countries are very prominent in this field. • Hong-Kong has little cooperation with Europe so far. 	• Many EU countries publish on the topic of heat pumps, with UK and Italy, Turkey and Slovenia in the lead. • All top-scored institutions already cooperate internationally. 

5.3.2 Detailed Results of the Institution Ranking per Technology Field

We established a ranking of all listed research institutions, one for each of the 11 technology fields. In the results tables – one example given in this chapter, the rest shown in the appendix – we present 40 top-ranking institutions, divided into four top 10 rankings:

- For institutions from Horizon 2020 countries:
    - Top 10 institutions, which primarily collaborate with institutions from non-Horizon 2020 countries (denominated "Institutions with strong non-H2020 collaboration" in the table)
    - Top 10 institutions, which primarily collaborate with institutions from Horizon 2020 countries (denominated "Institutions with strong H2020 collaboration" in the table)
- For institutions from non-Horizon 2020 countries:
    - Top 10 institutions, which primarily collaborate with institutions from non-Horizon 2020 countries (denominated "Institutions with strong non-H2020 collaboration" in the table)
    - Top 10 institutions, which primarily collaborate with institutions from Horizon 2020 countries (denominated "Institutions with strong H2020 collaboration" in the table)

In the results tables we present various indicators for each institution, described in Figure 22. The first four indicators (No. 1-4 in the figure) show the overall score of the institutions in the respective technology field, as well as the indicators on which this score is based. Furthermore, four additional indicators (No. 5-8 in the figure) are presented, which provide information on the institution's research collaboration.

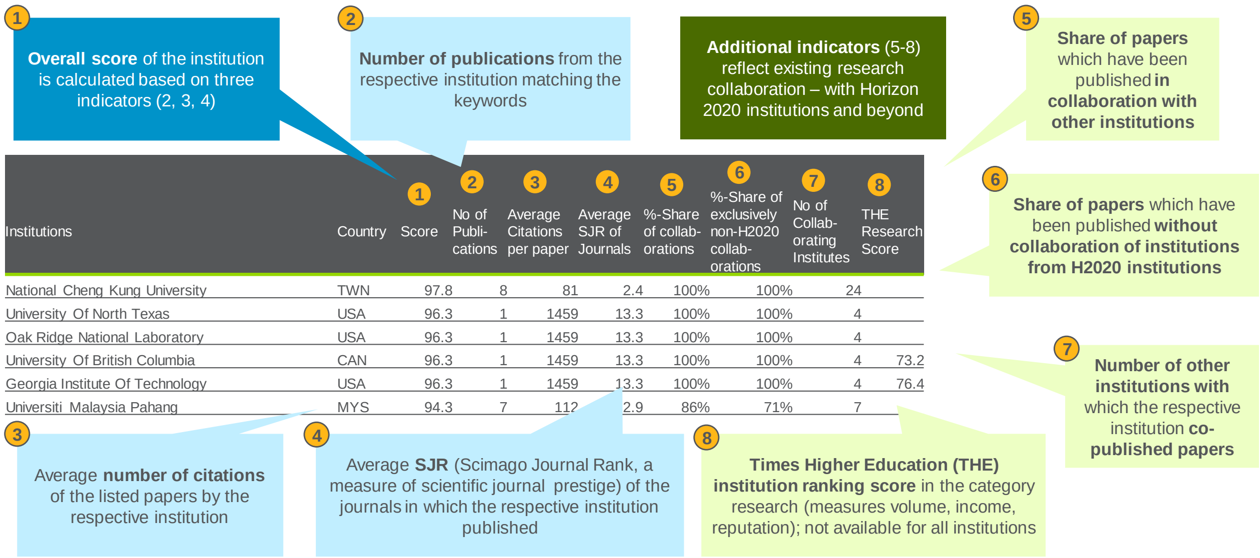


Figure 22: Explanation of result tables for institution rankings

To exemplify the result of the institution ranking, we consider the first institution listed in Figure 22, the National Cheng Kung University, Taiwan. The individual indicators in the table can be interpreted as follows:

1) The university achieves a score of 97.8 points. The score is calculated based on the following three indicators (2, 3, 4).

2) The university published 8 journal articles within the research field, in the considered time span.

3) Each of the 8 publications has been cited 81 times on average.

4) The journals in which the 8 articles have been published achieve a Scimago-Journal-Rank (SJR, the higher the better) value of 2.4 on average. The SJR is a measure of a journal's scientific prestige.

5) All of the National Cheng Kung University's 8 articles have been published together with researchers from other universities. Therefore, the share of collaborations is 100%.

6) Yet, none of the National Cheng Kung University's 8 articles has been published in collaboration with an institution from a Horizon2020 country. Therefore, the share of exclusively non-H2020 collaborations is 100%.

7) The considered articles by the National Cheng Kung University have been published in collaboration with 24 different institutions.

8) For the National Cheng Kung University, no Times-Higher-Education (THE) research score has been reported, therefore the respective table cell is empty. The THE research score ranks universities according to their research performance, measured by the quantity of research output, the monetary income of the institution available as research funding and the reputation of the university. The THE research score, taken from an external source, is reported here complement the original analysis of research publications.

5.3.2.1 *Top-Ranked Institutions – Example PV*

As an example, we present the results for institutions active in PV research here. Due to their extent, the results for all others of the 11 technology fields are moved to the appendix.

Table 15: Top ranked institutions active in PV research

	Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively (non-) H2020 collaborations*	No of Collaborating Institutes	THE Research Score
Non-H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	University of Toronto	CAN	94,1	6	712	11,5	50%	50%	4	89,5
	Korea University	KOR	92,8	2	1581	13,3	100%	50%	6	50,2
	National Institute for Materials Science	JPN	91,8	7	495	9,9	86%	71%	11	
	Shanghai Jiao Tong University	CHN	90,8	6	515	9,7	100%	100%	10	63
	King Abdullah University of Science and Technology	SAU	90,5	4	739	9,4	75%	75%	6	
	University of Rochester	USA	87,6	4	557	10,0	100%	75%	10	30,3
	Central South University	CHN	87,2	4	618	9,2	100%	100%	8	33,9
	Peking University	CHN	85,6	9	294	7,2	78%	56%	16	90
	North Carolina State University	USA	82,4	7	197	9,9	100%	71%	14	35,3
	Colorado School of Mines	USA	81,4	2	451	15,1	100%	50%	5	25,1
	Institutions with strong H2020 collaboration									
	Sungkyunkwan University	KOR	99,0	21	649	9,4	52%	5%	18	
	National Renewable Energy Laboratory	USA	98,6	21	2158	5,1	100%	14%	52	
	University of California Los Angeles	USA	98,3	9	938	8,4	22%	22%	3	
	University of New South Wales	AUS	97,7	17	2546	3,3	76%	12%	33	
	University of Nebraska Lincoln	USA	97,0	16	514	9,6	38%	19%	13	
	National Institute of Advanced Industrial Science and Technology	JPN	96,7	10	4184	1,9	100%	0%	30	
	University of Washington	USA	96,4	15	424	10,6	53%	27%	15	82,2
	Stanford University	USA	95,7	13	530	9,1	54%	15%	14	96,4
	Ulsan National Institute of Science and Technology	KOR	95,4	11	503	10,2	82%	36%	14	
	Huazhong University of Science and Technology	CHN	95,1	9	660	9,5	78%	33%	13	39,1
H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	Ecole Polytechnique Federal De Lausanne	CHE	99,6	42	467	9,1	76%	29%	50	
	University of Oxford	GBR	99,3	30	493	9,8	67%	23%	34	99,6
	University of Cambridge	GBR	98,0	16	488	10,8	75%	31%	21	98,7
	Fraunhofer Society	DEU	97,3	13	3268	3,0	92%	8%	35	
	Imperial College London	GBR	88,9	9	438	7,2	78%	11%	10	87,6
	Uppsala University	SWE	84,0	6	323	8,0	67%	0%	8	56,4
	University of Hasselt	BEL	79,8	2	635	9,5	50%	0%	1	
	Swansea University	GBR	78,8	1	887	13,1	100%	0%	1	24,1
	Weizmann Institute of Science	ISR	78,1	4	344	7,9	50%	0%	4	
	King S College London	GBR	75,2	2	879	3,9	50%	0%	1	
	Institutions with strong H2020 collaboration									
	Helmholtz Zentrum Berlin	DEU	91,2	4	765	13,2	100%	75%	4	
	Polytechnic University Of Milan	ITA	90,2	6	497	11,1	100%	67%	16	35,2
	Istituto Italiano Di Tecnologia	ITA	89,2	7	434	11,9	100%	57%	18	
	Max Planck Society	DEU	83,0	9	305	5,3	56%	56%	7	
	University of Valencia	ESP	81,7	6	228	9,6	83%	50%	10	20,8
	Eth Zurich	CHE	76,2	6	211	7,5	100%	50%	9	92,8
	University of Rome Tor Vergata	ITA	72,9	5	179	8,6	80%	60%	6	
	Delft University of Technology	NLD	72,6	4	225	9,7	75%	75%	6	72,3
	Swiss Federal Laboratories for Materials Science and Technology	CHE	71,9	3	198	12,2	100%	67%	6	
	University of Erlangen Nuremberg	DEU	71,3	4	172	10,5	75%	75%	2	

*For institutions from non-H2020 countries the %-share of exclusively non-H2020 collaborations is reported; for institutions from H2020 countries the %-share of exclusively H2020 collaborations is reported.

5.3.2.2 Most Relevant Institutions

Considering all available information, we hand-picked several institutions, which are the most interesting candidates to be targeted for an increased research cooperation on institutional level. In Table 16 we present the results for the technology field PV.

To exemplify, we consider the Shanghai Jiao Tong University, China, listed first in Table 16. This university is particularly interesting for an increased research cooperation with H2020 institutions in the field of PV R&D. Reasons are:

- The university ranks very high in this research field, due to a high number of heavily cited publications in prestigious journals.
- Moreover, the university is actively collaborating with many different institutions in this research field. Yet, the university so far does not collaborate with H2020 institutions on PV R&D since all relevant publications have been published without H2020 involvement.
- The university achieved a THE research score of 63 which indicates an overall strong position in the international research landscape for this institution.

Table 16: Most relevant institutions active in PV research

Top-ranked Institutions Outside Horizon 2020

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively non-EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
Shanghai Jiao Tong University	CHN	90,8	6	515	9,7	100%	100%	10	63	high number of publications; no EU-collaboration yet; good THE score
King Abdullah University Of Science And Technology	SAU	90,5	4	739	9,4	75%	75%	6		Good publication numbers; Low level of EU-collaboration
Central South University	CHN	87,2	4	618	9,2	100%	100%	8	33,9	Good publication numbers; Low level of EU-collaboration
National Institute For Materials Science	JPN	91,8	7	495	9,9	86%	71%	11		high number of publications; high-impact journals; low level of EU-collaboration
University Of Rochester	USA	87,6	4	557	10,0	100%	75%	10	30,3	Good publication numbers; Low level of EU-collaboration
Korea University	KOR	92,8	2	1581	13.3	100%	100%	6	50.2	no EU-collaboration yet; publications in high-impact journals

Top-ranked Horizon 2020 Institutions

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
Ecole Polytechnique Federale De Lausanne	CHE	99,6	42	467	9,1	76%	29%	50		Outstandingly high number of publications
Polytechnic University Of Milan	ITA	90,2	6	497	11,1	100%	67%	16	35,2	Good publication numbers; low level of non-EU collaboration
Helmholtz Zentrum Berlin	DEU	91,2	4	765	13,2	100%	75%	4		Good publication numbers; low level of non-EU collaboration

An overview of the results for the other technology fields is listed in the table below. Detailed results, including all indicators as well as an explanation why certain institutions have been chosen, can be found in the appendix.

Table 17: Potential target institutions increased research cooperation

R&D field	Institution name and country: Non-H2020 – developed economies		Non-H2020 – emerging economies		H2020	
PV	National Institute for Materials Science	JPN	Shanghai Jiao Tong University	CHN	Ecole Polytechnique Federale De Lausanne	CHE
	University of Rochester	USA	King Abdullah University of Science and Technology	SAU	Polytechnic University of Milan	ITA
	Korea University	KOR	Central South University	CHN	Helmholtz Zentrum Berlin	DEU
CSP	University of Auckland	NZL	Universiti Teknologi Malaysia	MYS	University of Toulouse	FRA
	Arizona State University	USA	Ferdowsi University of Mashhad	IRN	Polytechnic University of Turin	ITA
	City University of Hong Kong	HKG	Tsinghua University	CHN	Centre National De La Recherche Scientifique	FRA
Wind	Deakin University	AUS	Chinese Academy of Sciences	CHN	Technical University of Denmark	DNK
	Electric Power Research Institute	USA	Chongqing University	CHN	Aalborg University	DNK
	National University of Singapore	SGP	Tsinghua University	CHN	Polytechnic University of Catalonia	ESP
Hydropower	Georgia Institute of Technology	USA	Dalian University of Technology	CHN	Wageningen University and Research Centre	NLD
	University of Washington	USA	North China Electric Power University	CHN	University of Padua	ITA
	National Tsing Hua University	TWN	Beijing Normal University	CHN	Spanish National Research Council	ESP
Ocean energy	University of British Columbia	CAN	University of Cape Town	ZAF	Plymouth University	GBR
	Woods Hole Oceanographic Institution	USA	Dalian University of Technology	CHN	University of Santiago De Compostela	ESP
	Oregon State University	USA	Peking University	CHN	Delft University of Technology	NLD
Geothermal energy	Kyushu University	JPN	King Saud University	SAU	Eth Zurich	CHE
	United States Geological Survey	USA	Gadjah Mada University	IDN	University of Iceland	ISL
	Commonwealth Scientific and Industrial Research Organization	AUS	Chinese Academy of Sciences	CHN	Rwth Aachen University	DEU
Bioenergy, Biofuels	University of Southern Queensland	AUS	National Cheng Kung University	TWN	Technical University of Denmark	DNK
	University of Illinois At Urbana Champaign	USA	Chinese Academy of Sciences	CHN	University of Bologna	ITA
	National Renewable Energy Laboratory	USA	University of Malaya	MYS	Ghent University	BEL
Smart Grids	Princeton University	USA	Singapore University of Technology and Design	SGP	Gazi University	TUR
	University of Waterloo	CAN	Peking University	CHN	Aarhus University	DNK
	University of Sydney	AUS	Nanyang Technological University	SGP	Ecole Normale Superieure	FRA
Hydrogen, Fuel Cells, Synfuels	University of Adelaide	AUS	King Abdulaziz University	SAU	Max Planck Society	DEU
	Tohoku University	JPN	Dalian Institute of Chemical Physics	CHN	Ecole Polytechnique Federale De Lausanne	CHE
	California Institute of Technology	USA	Nanyang Technological University	SGP	Centre National De La Recherche Scientifique	FRA
Storage	University of Washington	USA	Nanyang Technological University	SGP	Istituto Italiano Di Tecnologia	ITA
	Griffith University	AUS	Chinese Academy of Sciences	CHN	Centre National De La Recherche Scientifique	FRA
	Pacific Northwest National Laboratory	USA	Tsinghua University	CHN	Karlsruhe Institute of Technology	DEU
Heat pumps	University of Wollongong	AUS	Hong Kong Polytechnic University	HKG	Aalto University	FIN
	University of Tokyo	JPN	Guangdong University of Technology	CHN	University of Padua	ITA
	N/A		Xi An Jiaotong University	CHN	University of Naples Federico Ii	ITA

6 Conclusions and Key Recommendations

In this study, we analysed research publications, patents and Horizon 2020-funded research projects on RES technology to identify potential partners for an increased research cooperation on country- and institutional-level. Moreover, we gained insights on the positioning of the EU (and other Horizon 2020 members) in the global landscape of RES technology R&D, and thereby derived some key recommendations which are presented in the following.

RES research is fundamental in the RES technology life cycle and defines the starting point of the whole RES value chain, especially as much technological, market and systems development is still needed to achieve global climate neutrality in less than 30 years from now. As pointed out by the EC in 2018, **technological leadership is key for commercial success**, since "those who set the standards are also those who later control the markets."[36] So far, the **EU has been benefiting from its early mover competitive advantage**, but is at **risk of losing its position as a front runner through strong challengers worldwide**. To maintain the EU's strong positioning, however, **increased research cooperation** can be one means to strengthen the foundation of the Unions success in the RES sector.

Regarding early-phase RES technology R&D, represented through high quality research publications and their publishing institutions, we notice that **only 21 countries (incl. 8 Horizon 2020 members) already represent 80%** of the 1900 research institutions which have been identified in the course of this analysis. Consequently, the impact of increased R&I cooperation can be maximized by aiming at these 13 Non-H2020-countries for bilateral innovation alliances, as presented in Figure 23.

[36] (European Commission 2018)

Country	Early-phase R&D: Research Institutions	Early-phase R&D: Top-ranked Institutions	Early-phase R&D: Rating	Early-phase R&D: Leading Technologies	Late-phase R&D: Patents	Late-phase R&D: Rating	Late-phase R&D: Leading Technologies	Research Cooperation: Internat. Collaboration	Research Cooperation: Rating	Research Cooperation: H2020-3.3 Cooperation projects	Overall Rating
Non-H2020 countries											
United States	303	22	Front Runners	Grids, Ocean	21.806	Front Runners	PV, Enablers	74%	Top	-	Front Runners
China	218	23	Front Runners	Hydrogen, Storage	55.498	Front Runners	CSP, PV, Enablers	67%	Intermediate	4	Front Runners
India	126	0	Top	Bioenergy, Grids	1.117	Top	Wind, Enablers	47%	Intermediate	2	Top
Canada	58	5	Top	Hydropower, Grids, Ocean	2.219	Top	Enablers, Wind, Bio	61%	Intermediate	-	Top
South Korea	57	3	Top	PV, Storage		Missing Data		66%	Intermediate	2	Missing Data
Japan	54	3	Top	Hydrogen, Ocean	11.874	Front Runners	PV, Enablers	81%	Front Runners	1	Front Runners
Iran	46	6	Top	Wind, CSP		Missing Data		59%	Intermediate	-	Missing Data
Australia	37	4	Top	Ocean, Grids	1.913	Top	Bio, CSP, Enablers	78%	Top	2	Top
Brazil	32	2	Intermediate	Bio, Hydropower	313	Intermediate	Wind, Enablers, Bio	69%	Intermediate	-	Intermediate
Taiwan	30	1	Intermediate	Bioenergy, PV		Missing Data		71%	Top	-	Missing Data
Malaysia	24	4	Top	Bioenergy, CSP	40	Intermediate	Enablers, Hydro, Bio	65%	Intermediate	-	Intermediate
Pakistan	18	1	Intermediate	Wind, Grids		Missing Data		91%	Front Runners	-	Missing Data
South Africa	18	0	Intermediate	Hydrogen, CSP	808	Intermediate	Bio, Enablers, CSP	61%	Intermediate	2	Intermediate
H2020 countries											
United Kingdom	92	15	Front Runners	Ocean, Wind	961	Top	Enablers, Wind	73%	Top	5	Front Runners
Germany	87	10	Top	Hydropo., Geo., Hydrogen	2.823	Top	Enablers, Wind, CSP	72%	Top	10	Top
France	67	6	Top	Ocean, CSP	1.004	Top	Enablers, PV, CSP	72%	Top	6	Top
Turkey	58	10	Top	Geothermics, Heat pumps	47	Intermediate	Wind, CSP	70%	Top	1	Top
Italy	52	6	Top	Geothermics, Hydropower	117	Intermediate	Hydrop., Bio, Wind	64%	Intermediate	4	Intermediate
Spain	45	6	Top	Hydropower, Bio	591	Intermediate	CSP, Wind	74%	Top	4	Top
Sweden	22	4	Top	Hydrop., Geo., Heat pumps	244	Intermediate	CSP, Wind	76%	Top	1	Top
Portugal	19	0	Intermediate	Hydropower, Ocean	47	Intermediate	Wind, Hydropower	80%	Front Runners	-	Top
All H2020 MS	627	84	Front Runners	Hydrop., Ocean, Geo.	7.040	Top	Enablers, Wind, CSP	70%	Top	22	Front Runners

Front Runners Top Intermediate Missing Data

Figure 23: Country classification according to publication, patent and project analysis

Not surprisingly, the **US and China** by far outpace other countries not only in terms of numbers and ranking of research institutions but also in terms of patent filings. These two countries **should be one particular focus for strategic partnerships in RES technology research**. However, noting that these two countries are quite different from each other, European cooperation with them would need to take different approaches. Countries with strong political ties to the EU can be targeted for a research cooperation through top-down approaches, i.e. aligning research agendas and priorities on national level and designing research cooperation programs which connect already existing research networks within the EU and third countries. For research cooperation with countries, however, where political relations are less stable and potentially strained, a bottom-up approach is more appropriate; i.e. research cooperation on institutional level can be fostered through setting the right framework conditions and bringing together institutions with similar research foci. The institutions identified in this analysis are a first starting point for this type of matchmaking.

Other countries that achieve a high rating due to their activities in early- and late-phase R&D, as well as their active international research collaboration are **Japan, India, Canada and Australia**. These countries should provide a second area of focus, again noting the differences among them and correspondingly differentiated cooperation approaches.

On a global level, the growing importance of emerging economies as markets for RES technologies is also reflected in the RES research landscape, where institutions from emerging countries have outnumbered institutions in the developed world. Therefore, **research cooperation needs to put a stronger focus on emerging countries and their respective**

RES market needs. Potential partner countries, which have been emphasized by this analysis through their performance in RES technology R&D are besides the already mentioned ones **Iran, Brazil, Malaysia, Pakistan, and South Africa**. Amongst emerging economies, **China and India** stand out due to their patenting activities and high numbers of active research institutions. Interestingly, the share of international research collaboration is lower for emerging economies than for developed economies – a chance for the EU to step in and fill the gap.

Comparing Horizon 2020 members amongst each other, we realize that **only a seventh of all H2020 institutions are located in emerging, mostly eastern European, countries** – almost none of the top-ranked institution amongst them. **To develop stronger RES research capabilities in eastern European countries** can therefore be a useful step to strengthen RES value chains in these countries and thereby drive inclusive growth on a European level. Policy measures to increase research cooperation should therefore consider regional differences and specifically target research cooperation between countries with strong RES sectors and countries with development potential.

Our results highlight, that a **high level of research cooperation exists between different H2020 members** but also H2020 and third countries, apparent through significant numbers of research publications on RES with co-authors from several countries. Therefore, the EU succeeds at building the right framework conditions for international collaborations, which are according to literature: expertise, funds and research infrastructure. [37] Nevertheless, there are **only very few RES research projects funded by H2020-3.3 which involve non-H2020 countries**. Consequently, **the EU misses out on an opportunity to intensify this type of cooperation through EU-funded research**, and more importantly to align the goals of these research projects with the EU's strategic goals defined in the SET Plan. Thus, it is advisable to put a higher emphasis on international collaboration beyond EU-borders in the H2020 successor.

Furthermore, the results of the publication analysis listed not only research institutions and universities, but also research associations, governmental entities and companies – although only in small numbers compared to the "conventional" research institutions[38]. This reflects a greater diversification in the research landscape but also raises the question which role these "non-conventional" actors play in the RES research landscape. Despite further need for investigation, it should be considered if research cooperation schemes should be more open to participation of "non-conventional" actors in the research landscape. More specifically, results of this study suggest that the EU – whilst being a front runner in early-phase R&D – performs only moderate compared to other developed economies in bridging the gap between innovation and commercialization of new RES technologies. Therefore, **funding schemes on EU level may put a higher emphasis on late-phase technology R&D and the collaboration between research institutions and industry, in particular**. Thereby, **public funding can** not only cover gaps in the R&D landscape but even more so, **steer private investments**. Likewise, **public research funding can be interlinked with other financing instruments, e.g. venture capital, needed at later stages in the technology life cycle**. According to IRENA, a strategic collaboration between research institutions and the RES industry enables the incubation of knowledge, ensures the industry relevance of public research, and brings the needs

[37] (Fraunhofer ISI 2009)
[38] Such as CEBEL in Brazil or Hydroquebec in Canada

and opportunities of local production to attention in the research landscape – and thereby strengthens supply chains for the RES sector.[39]

Even though international research cooperation on RES provides various benefits, it needs to be embedded in strong political frameworks guaranteeing access to RES markets, compliance with IPR regulation and knowledge transfer in both directions. Otherwise, knowledge drain from H2020 members in combination with third countries' aggressive industrial strategies might pose a significant challenge to the EU's positioning as a RES technology leader in the long-term.

Finally, international collaborations, in research and beyond, have the potential to accelerate the energy transition by sharing knowledge and engaging various actors, from developed and developing countries.

[39] (IRENA 2020)

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APPENDIX

List of H2020-3.3 projects with non-H2020 cooperation

Grant agreement ID	Project Name	Start date	End date	Partnering Country (non-H2020 country)	Coordinating Country (H2020 country)	Overall budget (Mio. EUR)	Research Focus (RES in bold)
696081	Digi-Label	01.04.2016	31.03.2019	United States	United Kingdom	1,7	Energy efficiency
640896	SHEER	05.01.2015	30.04.2018	United States	Germany	0,3	Shale gas exploration
837733	COZMOS	01.05.2019	30.04.2023	China	Norway	4,8	**Hydrogen**
864496	ComBioTES	01.11.2019	31.10.2023	China	France	4,2	**Storage**
838077	eCOCO2	01.05.2019	30.04.2023	China	Spain	4,4	**Hydrogen**
764697	CHEERS	01.10.2017	30.09.2022	China	Norway	16,8	CCS
764816	CLEANKER	01.10.2017	30.09.2021	China	Italy	9,2	CCS
671461	HySEA	01.09.2015	30.11.2018	China	Norway	1,5	**Hydrogen**
649796	OPTi	03.01.2015	30.04.2018	India	Sweden	2,1	**Heatpumps**
824386	MERLON	01.01.2019	31.12.2021	India	Greece	7,4	**Networks**
875118	NEWELY	01.01.2020	31.12.2022	South Korea	Germany	2,6	**Hydrogen**
837975	MOF4AIR	01.07.2019	30.06.2023	South Korea	Belgium	11,1	CCS
727503	ROLINCAP	10.01.2016	30.09.2019	South Korea	Greece	3,2	CCS
727619	GRAMOFON	10.01.2016	31.03.2020	South Korea	Spain	4,3	CCS
691728	DESTRESS	03.01.2016	30.11.2020	South Korea	Germany	24,7	**Geothermal**
838077	eCOCO2	05.01.2019	30.04.2023	Japan	Spain	4,4	**Hydrogen**
654465	LEILAC	01.01.2016	31.12.2020	Australia	France	21,0	CCS
850937	PERCISTAND	01.01.2020	31.12.2022	Australia	Belgium	5,1	**PV**
875489	SONAR	01.01.2020	31.12.2023	Australia	Germany	2,8	**Storage**
857804	DiBiCoo	10.01.2019	30.06.2022	South Africa	Germany	3,0	**Bio**
815264	PRE-LEAP-RE	07.01.2018	31.08.2019	South Africa	France	1,0	RES research partnerships
654443	MnWaterCSP	01.01.2016	31.12.2018	South Africa	Germany	5,9	**CSP**

List of Institutions for Country Case Studies

Brazil

Institution	Ranking Score per Research Field											THE Research Score
	Bio	CSP	Geo-thermal	Heat-pumps	Hydro-gen	Hydropower	Networks	Ocean	PV	Storage	Wind	
Brazilian institute of geography and statistics						49.4						
Cemig						37.4						
coordenadoria de aperfeicoamento de pessoal de nivel superior								88.3				
federal fluminense university	86.6	20.9			6.2			13.9				
federal university of amazonas											10.8	
federal university of bahia	0.6						62.0	3.5				13.7
federal university of ceara	71.8										42.8	
federal university of maranhao								16.6				
federal university of paraiba	0.6	99.1										
federal university of parana	77.4						72.6	88.3		65.1	68.0	
federal university of pernambuco											81.0	9.2
federal university of rio de janeiro	78.1	55.0				89.2		24.4				22
federal university of sao carlos										65.1		
federal university of uberlandia						73.1						
Inatel							50.2					
national institute for space research						73.7		10.1				
oswaldo cruz foundation	56.0											
pontifical catholic university of rio de janeiro	58.7											
rio de janeiro state university	50.0					49.4	55.0					
sao paulo state university	18.0											
state university of campinas	18.9					89.6						
universidade federal de lavras						27.0						
universidade federal de mato grosso						55.1						
universidade federal de minas gerais	33.9		4.9	8.9			55.0				10.8	
universidade federal de ouro preto							55.0					
universidade federal de santa Catarina	19.8					31.5	51.2					
universidade federal de santa maria	0.6											
universidade federal de sao joao del rei						8.3						
universidade federal do espirito santo		99.1										
universidade federal do rio grande do sul	77.0					78.8		72.1				

Institution	Ranking Score per Research Field											THE Research Score
	Bio	CSP	Geo-thermal	Heat-pumps	Hydro-gen	Hydropower	Networks	Ocean	PV	Storage	Wind	
university of brasilia			28.1			63.5						
university of sao paulo	33.0					52.9					67.8	

Canada

Institution	Bio	CSP	Geo-thermal	Heat-pumps	Hydro-gen	Hydro-power	Net-works	Ocean	PV	Storage	Wind	THE Research Score
	Ranking Score per Research Field											
acadia university								91.0				
agriculture and agri food canada	17.1					23.4						
alcan inc						21.1						
bc hydro							39.6					
bedford institute of oceanography								60.4				
bombardier aerospace											16.2	
canadian real estate association		96.2		86.2						42.3		
carleton university				62.3			43.2	53.4				27.2
concordia university		80.2				25.2				20.3	63.4	25.9
dalhousie university	8.2	50.7		60.6		31.1	46.3	59.3				29.6
defence research and development Canada											34.0	
ecole de technologie superieure		25.5	67.7	66.0		21.1					65.2	
ecole polytechnique de montreal				14.3		50.3						
environment canada								52.3				
fisheries and oceans canada						40.7		43.1				
geological survey of canada			5.7					19.5				
golder associates			80.2									
health canada											7.6	
hydro quebec				4.8	57.2							
institut national de la recherche scientifique			29.4				37.2					
lakehead university	65.1											19.5
lambton college					14.4							
laval university			73.9	71.2	51.9			33.4				31.8
marine institute of memorial university of newfoundland								84.4				
mcgill university	74.1		79.9	13.5	72.7	83.9	93.8					71.9
mcmaster university							32.6		47.5	62.6		50.1
memorial university of newfoundland	12.5				1.6			76.6				19.9
national institute for nanotechnology										92.4		
natural resources canada				79.3								
ocad university							47.0					
public works and government services canada		40.6										
queen s university								42.0				
ryerson university		24.6		91.6			55.7				94.4	26
simon fraser university					13.2	83.5	67.5	28.0			83.1	35.5
universite de moncton					27.0							
universite de montreal	37.9								61.2			
universite de sherbrooke	19.1					36.2						
universite du quebec					27.0	33.8					16.2	
universite du quebec a montreal					42.9							
universite du quebec a rimouski	19.1							47.6				
universite du quebec a trois rivieres					5.0						47.4	
university of alberta			57.2			81.6	0.0	4.7		92.7		48.8
university of british columbia	98.8		32.0			86.5	96.1	94.6				73.2
university of Calgary			33.0								86.1	34.2
university of guelph	6.4	14.3				52.3					41.6	29.4
university of manitoba	90.8					21.9					71.0	30.8
university of new brunswick						73.5	28.8					
university of ontario institute of technology		20.9	92.7	87.0	60.1		88.1	39.1		1.9	55.7	
university of ottawa		42.1				84.3	99.1				85.8	42
university of saskatchewan	93.5		0.2	27.5	27.7	93.4	61.4	65.6	22.4		47.9	26.9

Institution	Bio	CSP	Geo-thermal	Heat-pumps	Hydro-gen	Hydro-power	Net-works	Ocean	PV	Storage	Wind	THE Research Score
	Ranking Score per Research Field											
university of toronto				18.6		41.5	98.0	80.6	94.1	79.6		89.5
university of victoria					13.2		91.1	79.5			76.8	15.9
university of waterloo			12.5	59.7		72.3	98.5			83.0	34.0	42.1
university of western ontario				49.7		32.7	54.8			84.6	54.3	
university of windsor						37.0	9.3					26.6
york university					18.1			16.4			34.0	37.6

Egypt

Institution	Bio	CSP	Geo-thermal	Heat-pumps	Hydro-gen	Hydro-power	Net-works	Ocean	PV	Storage	Wind	THE Research Score
	Ranking Score per Research Field											
ain shams university			0.0								64.8	10.1
alexandria university	65.6					97.9		15.2				13.1
banha university	65.4		86.1			22.1					7.1	
cairo university	52.4			27.0			2.3			53.2	9.9	13.7
helwan university	24.7			16.6			29.8				17.1	8.6
kafrelsheikh university		60.1				22.1						7.9
mansoura university				35.3					8.1			9.2
minia university			83.0						8.1			7.2
port said university			65.1									
suez canal university			2.8									8.7
tanta university	45.3	63.0	73.1			22.1						7.3
university of sadat city	34.8											
zagazig university		22.6						23.3			17.8	7.7

Most Relevant Research Institutions per Technology

PV

Top-ranked Institutions Outside Horizon 2020

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively non-EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
shanghai jiao tong university	CHN	90,8	6	515	9,7	100%	100%	10	63	high number of publications; no EU-collaboration yet; good THE score
king abdullah university of science and technology	SAU	90,5	4	739	9,4	75%	75%	6		Good publication numbers; Low level of EU-collaboration
central south university	CHN	87,2	4	618	9,2	100%	100%	8	33,9	Good publication numbers; Low level of EU-collaboration
national institute for materials science	JPN	91,8	7	495	9,9	86%	71%	11		high number of publications; high-impact journals; low level of EU-collaboration
university of rochester	USA	87,6	4	557	10,0	100%	75%	10	30,3	Good publication numbers; Low level of EU-collaboration
korea university	KOR	92,8	2	1581	13.3	100%	100%	6	50.2	no EU-collaboration yet; publications in high-impact journals

Top-ranked Horizon 2020 Institutions

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
ecole polytechnique federale de lausanne	CHE	99,6	42	467	9,1	76%	29%	50		Outstandingly high number of publications
polytechnic university of milan	ITA	90,2	6	497	11,1	100%	67%	16	35,2	Good publication numbers; low level of non-EU collaboration
helmholtz zentrum berlin	DEU	91,2	4	765	13,2	100%	75%	4		Good publication numbers; low level of non-EU collaboration

CSP

Top-ranked Institutions Outside Horizon 2020

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively non-EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
universiti teknologi malaysia	MYS	94.8	4	172	2.8	100%	75%	6	25.2	medium publication number; low level of EU-collaboration
ferdowsi university of mashhad	IRN	83.9	6	74	1.5	100%	100%	9	18.5	medium publication number; no EU-collaboration yet
tsinghua university	CHN	89.1	3	125	3.1	67%	67%	4	94	Medium level of EU collaboration leaves room for improvement; very high THE score
university of auckland	NZL	95.7	3	217	3.3	100%	100%	5	43.9	no EU-collaboration yet; good THE research score
arizona state university	USA	92.8	4	120	2.9	100%	75%	6		low level of EU-collaboration
city university of hong kong	HKG	87.3	6	61	2.6	100%	83%	9	48.9	medium publication number; good THE research score; low level of EU-collaboration

Top-ranked Horizon 2020 Institutions

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
university of toulouse	FRA	91.1	3	147	2.4	100%	67%	6		High citation umbers; relatively low share of non-EU collaborations
polytechnic university of turin	ITA	81.6	3	68	2.9	67%	67%	2	25.4	relatively low share of collaborations in general; low share of non-EU collaborations
centre national de la recherche scientifique	FRA	97.1	11	90	2.5	73%	27%	10		High publication number; already cooperates regularly with non-EU countries, but has some improvement potential

Wind Power

Top-ranked Institutions Outside Horizon 2020

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively non-EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
chinese academy of sciences	CHN	99.5	7	111	3.5	57%	29%	11		Relatively low level of collaboration in general; improvement potential for EU collaborations
chongqing university	CHN	95.8	6	73	2.7	83%	50%	5	21.3	Medium publication number; medium level of existing EU collaboration
tsinghua university (CHN)	CHN	99.3	10	86	2.9	50%	30%	9	94	High publication number; very high THE score
deakin university (AUS)	AUS	97.4	5	97	3.0	100%	100%	5	29.6	No EU collaboration yet
electric power research institute (USA)	USA	95.3	5	77	2.8	100%	80%	11		Low level of EU collaboration
national university of singapore (SGP)	SGP	98.3	5	109	3.0	80%	80%	4	90.4	Low level of EU collaboration; very high THE score

Top-ranked Horizon 2020 Institutions

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
technical university of denmark	DNK	99.7	17	88	2.1	71%	35%	17	40.2	Outstandingly high number of publications; improvemnt potential for non-EU collaborations
aalborg university	DNK	98.8	18	69	1.9	39%	17%	11	39.1	Outstandingly high number of publications; low level of collaborations in general
polytechnic university of catalonia	ESP	94.9	3	108	3.4	67%	67%	4	17.2	Low level of non-EU collaboration

Hydropower

Top-ranked Institutions Outside Horizon 2020

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively non-EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
dalian university of technology	CHN	99.3	17	24	1.9	82%	18%	25	23.7	Very high publication number; medium level of EU collaboration
north china electric power university	CHN	94.5	8	23	2.1	88%	63%	9	11.9	high publication number; medium level of EU collaboration
beijing normal university	CHN	98.3	12	21	2.0	42%	17%	5	39.6	Very high publication number; medium THE score
georgia institute of technology	USA	98.9	2	71	5.3	100%	100%	4	76.4	no EU collaboration yet; good THE score
university of Washington	USA	95.5	5	34	2.8	80%	20%	11	82.2	Good THE score
national tsing hua university	TWN	97.1	1	79	5.3	100%	100%	2	46.2	No EU collaboration yet; good THE score

Top-ranked Horizon 2020 Institutions

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
wageningen university and research centre	NLD	98.1	7	50	1.3	86%	57%	18		High publication numbers; medium level of non-EU collaboration
university of padua	ITA	97.3	4	41	2.2	75%	75%	7	30.9	Medium publication numbers; low level of non-EU collaboration
spanish national research council	ESP	94.0	4	53	1.5	100%	50%	15		Medium publication numbers; Low level of non-EU collaboration

Ocean Energy

Top-ranked Institutions Outside Horizon 2020

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively non-EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
university of cape town	ZAF	95.0	8	20	1.2	88%	63%	22	42.8	High number of publications; medium level of EU collaboration; medium THE score
dalian university of technology	CHN	93.0	2	30	2.5	100%	50%	2	23.7	Very high number of publications; medium level of EU collaboration
peking university	CHN	89.4	6	9	2.1	100%	67%	16	90	Low level of EU collaboration; very high THE score
university of british columbia	CAN	94.6	4	30	1.9	75%	50%	10	73.2	Medium level of EU collaboration; High THE score
woods hole oceanographic institution	USA	88.9	3	34	1.0	100%	100%	11		no EU collaboration yet
oregon state university	USA	92.5	6	16	2.0	100%	50%	18	30.1	Medium level of EU collaboration

Top-ranked Horizon 2020 Institutions

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
plymouth university	GBR	99.7	17	36	2.1	88%	82%	18		High publication numbers; Low level of of non-EU collaboration
university of santiago de compostela	ESP	99.5	20	27	1.8	100%	65%	20	16.6	High publication numbers; low level of of non-EU collaboration
delft university of technology	NLD	79.7	3	17	1.5	100%	100%	4	72.3	No non-EU collaboration; good THE score

Geothermal Energy

Top-ranked Institutions Outside Horizon 2020

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively non-EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
king saud university	SAU	90.1	7	12	1.5	100%	100%	15	25.8	High publication numbers; no EU collaboration
gadjah mada university	IDN	92.4	4	21	1.6	100%	100%	7		High publication numbers; no EU collaboration
chinese academy of sciences	CHN	95.5	13	12	1.5	77%	15%	21		Very high number of publications; medium level EU collaboration
kyushu university	JPN	94.2	9	14	1.8	100%	67%	12	39.2	High publication numbers; medium level of EU collaboration; medium THE score
united states geological survey	USA	89.3	6	16	1.7	83%	50%	9		Medium publication numbers; medium level of EU collaboration
commonwealth scientific and industrial research organization	AUS	86.9	8	8	1.4	75%	63%	16		High publication numbers; low level of EU collaboration

Top-ranked Horizon 2020 Institutions

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
eth zurich	CHE	98.4	11	20	1.7	82%	18%	17	92.8	High publication numbers
university of iceland	ISL	97.6	13	13	1.9	31%	8%	6	30	High publication numbers; low level of collaboration in general; medium level of non-EU collaboration
rwth aachen university	DEU	93.7	5	20	2.4	60%	0%	4	61.5	low level of collaboration in general; no non-EU collaboration yet

Bioenergy and Biofuels

Top-ranked Institutions Outside Horizon 2020

Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively non-EU collaborations	No of Collaborating Institutes	THE Research Score	Explanation
national cheng kung university	TWN	96.4	8	81	2.4	100%	88%	24		High number of publications; no EU-collaboration yet
chinese academy of sciences	CHN	97.9	13	81	2.2	62%	8%	13		High number of publications; medium level of EU-collaboration
university of malaya	MYS	98.6	39	112	2.5	46%	26%	31	30.5	Outstanding high number publications; level of EU-collaboration can still be increased; representative for many Malaysian institutions listed
university of southern queensland	AUS	90.1	4	78	2.1	100%	100%	7	19.8	average number of publications; no EU-collaboration yet
university of illinois at urbana champaign	USA	94.8	6	87	1.9	83%	50%	17		average number of publications; medium level of EU-collaboration
national renewable energy laboratory	USA	99.7	4	422	4.4	50%	50%	5		average number of publications; medium level of EU-collaboration; high citation numbers

Top-ranked Horizon 2020 Institutions

Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively EU collaborations	No of Collaborating Institutes	THE Research Score	Explanation
technical university of denmark	DNK	92.6	5	109	2.0	100%	40%	6	40.2	Average number of publications; medium level of non-EU collaboration; good THE score
university of bologna	ITA	76.5	5	57	1.6	100%	80%	8	34.8	Average number of publications; low level of non-EU collaboration
ghent university	BEL	76.7	3	77	2.0	100%	67%	5	55.5	Average number of publications; medium level of non-EU collaboration; good THE score

Smart Grids

Top-ranked Institutions Outside Horizon 2020

Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively non-EU collaborations	No of Collaborating Institutes	THE Research Score	Explanation
singapore university of technology and design	SGP	99.3	11	70	2.4	100%	91%	24		High publication number; low level of EU-collaboration
peking university	CHN	95.7	5	76	2.2	100%	100%	15	90	No EU-collaboration yet; great THE score
nanyang technological university	SGP	95.9	16	63	1.2	81%	81%	22	70.4	High publication number; low level of EU-collaboration; very high THE score
princeton university	USA	99.5	7	93	3.3	100%	57%	17	96.3	low level of EU-collaboration; perfect THE score
university of waterloo	CAN	98.5	13	68	2.0	77%	69%	21	42.1	High publication number; medium level of EU-collaboration
university of Sydney	AUS	95.1	5	77	2.1	100%	60%	13	61.5	Medium publication number; medium level of EU-collaboration; good THE score

Top-ranked Horizon 2020 Institutions

Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively EU collaborations	No of Collaborating Institutes	THE Research Score	Explanation
gazi university	TUR	95.5	5	56	3.3	60%	20%	6	10.6	medium level of non-EU collaboration; low level of collaborations in general
aarhus university	DNK	95.3	5	76	2.3	60%	40%	6	54	medium level of non-EU collaboration; low level of collaborations in general
ecole normale superieure	FRA	93.0	2	140	1.9	50%	50%	1		medium level of non-EU collaboration; low level of collaborations in general

Hydrogen, Fuel Cell, Synfuels

Top-ranked Institutions
Outside Horizon 2020

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively non-EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
king abdulaziz university	SAU	97.1	15	283	3.6	100%	100%	35	16.5	High publication number; no EU-collaboration
dalian institute of chemical physics	CHN	91.3	9	121	5.4	78%	11%	9	23.7	High publication number; low level of EU-collaboration; publications in high-impact journals
nanyang technological university	SGP	98.5	20	176	6.7	85%	70%	25	70.4	High publication number; low level of EU-collaboration; very good THE score
university of Adelaide	AUS	97.3	5	378	9.8	100%	100%	9	41.6	medium publication number; no EU-collaboration; good THE score
tohoku university	JPN	94.2	8	156	8.6	100%	88%	13	54.4	medium publication number; low level of EU-collaboration; good THE score
california institute of technology	USA	98.0	10	277	9.6	90%	40%	16	97.2	high publication number; medium level of EU-collaboration; perfect THE score

Top-ranked
Horizon 2020 Institutions

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
max planck society	DEU	95.1	17	180	4.8	59%	12%	17		Outstandingly high number of publications; low level of collaborations in general
ecole polytechnique federale de lausanne	CHE	94.9	6	270	5.7	50%	33%	3		medium level of non-EU collaboration; low level of collaborations in general
centre national de la recherche scientifique	FRA	77.0	4	116	6.3	75%	50%	8		Medium level of non-EU collaboration

Storage

Top-ranked Institutions
Outside Horizon 2020

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively non-EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
nanyang technological university	SGP	98.8	27	215	6.5	63%	63%	28	70.4	Very high publication number; low level of EU-collaboration; good THE score
chinese academy of sciences	CHN	99.7	50	245	6.5	74%	34%	59		Extremely high publication number
tsinghua university	CHN	99.1	30	208	6.3	67%	30%	28	94	Very high publication number; very good THE score
university of Washington	USA	94.9	5	322	7.7	100%	80%	7	82.2	low level of EU-collaboration; good THE score
griffith university	AUS	93.0	3	401	9.4	100%	100%	5	32.7	No EU-collaboration; good THE score
pacific northwest national laboratory	USA	93.5	4	292	12.0	75%	50%	4		Low level of EU cooperation; publications in high impact journals

Top-ranked
Horizon 2020 Institutions

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
istituto italiano di tecnologia	ITA	97.2	3	707	8.3	100%	67%	7		low level of non-EU collaboration
centre national de la recherche scientifique	FRA	97.7	7	453	5.2	86%	43%	8		medium level of non-EU collaboration
karlsruhe institute of technology	DEU	88.0	3	171	14.0	100%	33%	9	47.8	medium level of non-EU collaboration

Heat pumps

Top-ranked Institutions
Outside Horizon 2020

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively non-EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
hong kong polytechnic university (HKG)	HKG	99.4	15	29	2.8	93%	93%	35	46.6	High publication number; low level of EU collaboration; medium THE score
guangdong university of technology (CHN)	CHN	97.7	11	26	2.6	100%	100%	34	13.1	High publication number; no EU collaboration
xi an jiaotong university (CHN)	CHN	99.7	38	23	2.2	50%	45%	32		Very high publication number; medium level of EU collaboration
university of wollongong (AUS)	AUS	84.4	6	18	2.0	100%	100%	12	35	No EU collaboration
university of tokyo (JPN)	JPN	90.2	7	17	2.7	86%	43%	10		Medium level of EU collaboration
N/A										

Top-ranked
Horizon 2020 Institutions

Institutions	Country	Score	No of Publi-cations	Average Citations per paper	Average SJR of Journals	%-Share of collab-orations	%-Share of exclusively EU collaborations	No of Collab-orating Institutes	THE Research Score	Explanation
aalto university	FIN	88.5	3	32	2.3	67%	33%	2	39.4	medium level of non-EU collaboration
university of padua	ITA	93.1	8	19	2.3	13%	0%	2	30.9	Low level of collaboration in general
university of naples federico ii	ITA	87.3	4	29	2.3	25%	0%	2	23.4	Low level of collaboration in general

Top-Ranked Research Institutions per Technology

PV

Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively (non-) EU collaborations*	No of Collaborating Institutes	THE Research Score
Non-H2020 Countries									
Institutions with strong non-H2020 collaboration									
university of toronto	CAN	94,1	6	712	11,5	50%	50%	4	89,5
korea university	KOR	92,8	2	1581	13,3	100%	50%	6	50,2
national institute for materials science	JPN	91,8	7	495	9,9	86%	71%	11	
shanghai jiao tong university	CHN	90,8	6	515	9,7	100%	100%	10	63
king abdullah university of science and technology	SAU	90,5	4	739	9,4	75%	75%	6	
university of rochester	USA	87,6	4	557	10,0	100%	75%	10	30,3
central south university	CHN	87,2	4	618	9,2	100%	100%	8	33,9
peking university	CHN	85,6	9	294	7,2	78%	56%	16	90
north carolina state university	USA	82,4	7	197	9,9	100%	71%	14	35,3
colorado school of mines	USA	81,4	2	451	15,1	100%	50%	5	25,1
Institutions with strong H2020 collaboration									
sungkyunkwan university	KOR	99,0	21	649	9,4	52%	5%	18	
national renewable energy laboratory	USA	98,6	21	2158	5,1	100%	14%	52	
university of california los angeles	USA	98,3	9	938	8,4	22%	22%	3	
university of new south wales	AUS	97,7	17	2546	3,3	76%	12%	33	
university of nebraska lincoln	USA	97,0	16	514	9,6	38%	19%	13	
national institute of advanced industrial science and technology	JPN	96,7	10	4184	1,9	100%	0%	30	
university of washington	USA	96,4	15	424	10,6	53%	27%	15	82,2
stanford university	USA	95,7	13	530	9,1	54%	15%	14	96,4
ulsan national institute of science and technology	KOR	95,4	11	503	10,2	82%	36%	14	
huazhong university of science and technology	CHN	95,1	9	660	9,5	78%	33%	13	39,1
H2020 Countries									
Institutions with strong non-H2020 collaboration									
ecole polytechnique federale de lausanne	CHE	99,6	42	467	9,1	76%	29%	50	
university of oxford	GBR	99,3	30	493	9,8	67%	23%	34	99,6
university of cambridge	GBR	98,0	16	488	10,8	75%	31%	21	98,7
fraunhofer society	DEU	97,3	13	3268	3,0	92%	8%	35	
imperial college london	GBR	88,9	9	438	7,2	78%	11%	10	87,6
uppsala university	SWE	84,0	6	323	8,0	67%	0%	8	56,4
university of hasselt	BEL	79,8	2	635	9,5	50%	0%	1	
swansea university	GBR	78,8	1	887	13,1	100%	0%	1	24,1
weizmann institute of science	ISR	78,1	4	344	7,9	50%	0%	4	
king s college london	GBR	75,2	2	879	3,9	50%	0%	1	
Institutions with strong H2020 collaboration									
helmholtz zentrum berlin	DEU	91,2	4	765	13,2	100%	75%	4	
polytechnic university of milan	ITA	90,2	6	497	11,1	100%	67%	16	35,2
istituto italiano di tecnologia	ITA	89,2	7	434	11,9	100%	57%	18	
max planck society	DEU	83,0	9	305	5,3	56%	56%	7	
university of valencia	ESP	81,7	6	228	9,6	83%	50%	10	20,8
eth zurich	CHE	76,2	6	211	7,5	100%	50%	9	92,8
university of rome tor vergata	ITA	72,9	5	179	8,6	80%	60%	6	
delft university of technology	NLD	72,6	4	225	9,7	75%	75%	6	72,3
swiss federal laboratories for materials science and technology	CHE	71,9	3	198	12,2	100%	67%	6	
university of erlangen nuremberg	DEU	71,3	4	172	10,5	75%	75%	2	

*For institutions from non-H2020 countries the %-share of exclusively non-H2020 collaborations is reported; for institutions from H2020 countries the %-share of exclusively H2020 collaborations is reported.

CSP

	Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively (non-) EU collaborations*	No of Collaborating Institutes	THE Research Score
Non-H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	king fahd university of petroleum and minerals	SAU	96.8	12	86	2.3	83%	50%	20	15.9
	university of auckland	NZL	95.7	3	217	3.3	100%	100%	5	43.9
	universiti teknologi malaysia	MYS	94.8	4	172	2.8	100%	75%	6	25.2
	university of south australia	AUS	93.1	6	96	2.6	83%	67%	5	39.4
	arizona state university	USA	92.8	4	120	2.9	100%	75%	6	
	tsinghua university	CHN	89.1	3	125	3.1	67%	67%	4	94
	tarbiat modares university	IRN	87.9	1	319	3.3	100%	100%	1	
	city university of hong kong	HKG	87.3	6	61	2.6	100%	83%	9	48.9
	centre for policy research	IND	84.2	1	279	2.7	100%	100%	2	
	ferdowsi university of mashhad	IRN	83.9	6	74	1.5	100%	100%	9	18.5
	Institutions with strong H2020 collaboration									
	universidade federal do espirito santo	BRA	99.1	1	277	22.2	100%	0%	2	
	federal university of paraiba	BRA	99.1	1	277	22.2	100%	0%	2	
	beijing university of chemical technology	CHN	98.5	6	150	3.4	17%	0%	2	
	university of texas at austin	USA	98.2	3	115	5.9	33%	33%	1	76.2
	south china university of technology	CHN	97.9	16	76	2.5	44%	19%	9	29.1
	xi an jiaotong university	CHN	97.7	18	67	2.4	39%	11%	13	
	shanghai jiao tong university	CHN	97.4	14	85	2.6	43%	7%	7	63
	university of malaya	MYS	96.5	14	75	2.4	79%	29%	17	30.5
	sandia national laboratories	USA	95.9	6	131	2.8	50%	0%	3	
	nanjing university	CHN	95,4	9	92	2,5	0%	0%	1	48
H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	universite libre de bruxelles	BEL	99.1	1	277	22.2	100%	0%	2	
	agh university of science and technology	POL	98.8	1	748	7.6	0%	0%	0	13.5
	centre national de la recherche scientifique	FRA	97.1	11	90	2.5	73%	27%	10	
	katholieke universiteit leuven	BEL	95.1	3	131	4.3	100%	0%	6	
	gaziosmanpasa university	TUR	93.6	9	87	2.2	22%	0%	7	
	university of nottingham	GBR	91.4	5	93	2.4	60%	0%	11	42.6
	royal institute of technology	SWE	89.6	5	77	3.0	80%	0%	6	
	loughborough university	GBR	88.8	1	317	3.5	0%	0%	0	34.3
	university of barcelona	ESP	88.5	6	68	2.6	83%	17%	7	32.5
	university of birmingham	GBR	87.6	5	77	2.6	80%	20%	10	45.6
	Institutions with strong H2020 collaboration									
	university of toulouse	FRA	91.1	3	147	2.4	100%	67%	6	
	polytechnic university of turin	ITA	81.6	3	68	2.9	67%	67%	2	25.4
	democritus university of thrace	GRC	68.7	1	123	3.5	100%	100%	1	11.6
	university of perugia	ITA	56.1	2	68	2.1	100%	100%	2	22.8
	brunel university london	GBR	45.5	2	52	2.0	100%	50%	4	26.9
	technical university of denmark	DNK	38.3	2	45	1.7	50%	50%	1	40.2
	university of padua	ITA	37.5	2	46	1.6	50%	50%	3	30.9
	university of castilla la mancha	ESP	34.0	1	70	1.9	100%	100%	2	
	university of western Macedonia	GRC	30.3	2	65	1.0	50%	50%	1	
	university of innsbruck	AUT	27,7	1	72	1,6	100%	100%	1	21.8

*For institutions from non-H2020 countries the %-share of exclusively non-H2020 collaborations is reported; for institutions from H2020 countries the %-share of exclusively H2020 collaborations is reported.

Wind Power

	Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively (non-) EU collaborations*	No of Collaborating Institutes	THE Research Score
Non-H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	national university of singapore	SGP	98.3	5	109	3.0	80%	80%	4	90.4
	deakin university	AUS	97.4	5	97	3.0	100%	100%	5	29.6
	university of sydney	AUS	96.7	4	132	2.1	100%	50%	9	61.5
	hong kong polytechnic university	HKG	96.5	7	62	3.1	57%	57%	6	46.6
	chongqing university	CHN	95.8	6	73	2.7	83%	50%	5	21.3
	electric power research institute	USA	95.3	5	77	2.8	100%	80%	11	
	ryerson university	CAN	94.4	4	109	2.4	50%	50%	2	26
	georgia institute of technology	USA	94.2	5	48	3.8	80%	60%	8	76.4
	university of tennessee	USA	93.2	5	66	2.8	100%	80%	6	
	texas a m university	USA	92.8	4	71	3.2	75%	50%	4	
	Institutions with strong H2020 collaboration									
	chinese academy of sciences	CHN	99.5	7	111	3.5	57%	29%	11	
	tsinghua university	CHN	99.3	10	86	2.9	50%	30%	9	94
	north china electric power university	CHN	99.0	14	72	2.4	43%	21%	20	11.9
	huazhong university of science and technology	CHN	98.6	14	75	1.9	64%	21%	15	39.1
	xi an jiaotong university	CHN	98.1	10	75	2.0	30%	20%	5	
	national renewable energy laboratory	USA	97.6	14	81	1.7	93%	7%	21	
	sharif university of technology	IRN	97.2	7	73	2.9	43%	14%	5	36.7
	university of colorado boulder	USA	96.9	7	86	2.5	86%	14%	17	45.6
	university of western australia	AUS	96.2	3	152	2.4	100%	33%	7	43.9
	university of tehran	IRN	96.0	8	70	2.1	25%	0%	3	23.5
H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	technical university of denmark	DNK	99.7	17	88	2.1	71%	35%	17	40.2
	aalborg university	DNK	98.8	18	69	1.9	39%	17%	11	39.1
	university of copenhagen	DNK	97.9	4	147	2.7	75%	0%	7	44.1
	ecole polytechnique federale de lausanne	CHE	95.1	7	93	1.7	14%	14%	1	
	university college dublin	IRL	93.7	4	84	2.8	75%	25%	6	36.5
	university of strathclyde	GBR	93.0	3	96	3.2	67%	33%	3	31.6
	yildiz technical university	TUR	91.2	1	251	3.3	0%	0%	0	
	uppsala university	SWE	90.7	3	80	2.8	67%	33%	8	56.4
	university of liverpool	GBR	90.0	5	64	2.5	100%	0%	11	37.5
	university of beira interior	PRT	88.6	4	72	2.4	100%	25%	6	16.5
	Institutions with strong H2020 collaboration									
	polytechnic university of catalonia	ESP	94.9	3	108	3.4	67%	67%	4	17.2
	polytechnic university of milan	ITA	91.8	5	78	1.9	60%	60%	5	35.2
	eth zurich	CHE	88.8	4	74	2.4	75%	50%	9	92.8
	fraunhofer society	DEU	87.2	2	115	2.2	100%	50%	3	
	technische universitat munchen	DEU	87.0	2	169	1.6	50%	50%	2	
	imperial college london	GBR	86.8	2	131	2.6	50%	50%	1	87.6
	royal institute of technology	SWE	79.8	3	64	2.4	67%	67%	2	
	rwth aachen university	DEU	79.1	2	89	2.5	50%	50%	1	61.5
	coventry university	GBR	75.9	1	118	3.3	100%	100%	1	12.7
	university of groningen	NLD	72,2	2	96	1,6	100%	50%	3	55.6

*For institutions from non-H2020 countries the %-share of exclusively non-H2020 collaborations is reported; for institutions from H2020 countries the %-share of exclusively H2020 collaborations is reported.

Hydropower

	Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively (non-) EU collaborations*	No of Collaborating Institutes	THE Research Score
Non-H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	georgia institute of technology	USA	98.9	2	71	5.3	100%	100%	4	76.4
	alexandria university	EGY	97.9	2	72	2.7	50%	50%	1	13.1
	national tsing hua university	TWN	97.1	1	79	5.3	100%	100%	2	46.2
	universiti teknologi malaysia	MYS	96.9	1	127	3.3	100%	100%	1	25.2
	north china electric power university	CHN	94.5	8	23	2.1	88%	63%	9	11.9
	xiamen university	CHN	94.2	1	63	5.3	100%	100%	2	22.9
	xinjiang university	CHN	91.6	2	66	2.5	50%	50%	2	
	hong kong polytechnic university	HKG	90.4	1	71	3.3	100%	100%	1	46.6
	university of florida	USA	89.6	1	65	3.3	100%	100%	1	53.8
	state university of campinas	BRA	89.6	1	65	3.3	100%	100%	1	
	Institutions with strong H2020 collaboration									
	chinese academy of sciences	CHN	99.7	24	25	1.8	67%	25%	24	
	huazhong university of science and technology	CHN	99.5	19	24	1.8	58%	5%	17	39.1
	dalian university of technology	CHN	99.3	17	24	1.9	82%	18%	25	23.7
	beijing normal university	CHN	98.3	12	21	2.0	42%	17%	5	39.6
	wuhan university	CHN	96.5	13	15	2.0	77%	23%	23	34
	university of washington	USA	95.5	5	34	2.8	80%	20%	11	82.2
	northwest a f university	CHN	95.3	5	37	1.9	60%	40%	3	
	university of pretoria	ZAF	95.1	4	13	6.6	50%	0%	7	30.1
	sichuan university	CHN	94.7	12	15	1.8	58%	8%	11	24.8
	national institute of technology hamirpur	IND	93.8	6	20	2.1	0%	0%	0	
H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	university of oxford	GBR	99.1	1	436	2.0	0%	0%	0	99.6
	technical university of madrid	ESP	98.7	8	28	2.2	50%	25%	6	14.9
	norwegian university of science and technology	NOR	98.5	18	21	1.5	61%	0%	19	28.3
	university of east anglia	GBR	96.7	4	39	5.1	100%	25%	13	30.1
	leibniz association	DEU	95.9	1	522	0.8	100%	0%	3	
	comillas pontifical university	ESP	95.7	3	41	2.5	100%	33%	5	
	aalto university	FIN	94.9	4	59	1.9	75%	25%	5	39.4
	netherlands environmental assessment agency	NLD	93.2	1	17	16.9	100%	0%	2	
	university of geneva	CHE	93.0	7	31	1.4	57%	43%	9	43.7
	university college london	GBR	92.4	3	13	6.5	67%	0%	5	
	Institutions with strong H2020 collaboration									
	wageningen university and research centre	NLD	98.1	7	50	1.3	86%	57%	18	
	free university of berlin	DEU	97.5	2	279	1.0	100%	50%	5	63.3
	university of tubingen	DEU	97.5	2	279	1.0	100%	50%	5	
	university of padua	ITA	97.3	4	41	2.2	75%	75%	7	30.9
	university of osnabruck	DEU	96.3	2	266	0.9	100%	50%	4	
	university of gothenburg	SWE	96.1	2	115	1.8	100%	50%	7	41.5
	spanish national research council	ESP	94.0	4	53	1.5	100%	50%	15	
	utrecht university	NLD	93.6	2	22	9.0	100%	50%	6	61.2
	london school of economics and political science	GBR	92.2	2	17	9.0	100%	50%	6	83
	university of liverpool	GBR	92.0	2	82	1.7	100%	50%	7	37.5

*For institutions from non-H2020 countries the %-share of exclusively non-H2020 collaborations is reported; for institutions from H2020 countries the %-share of exclusively H2020 collaborations is reported.

Ocean Energy

	Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively (non-) EU collaborations*	No of Collaborating Institutes	THE Research Score
Non-H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	university of california santa cruz	USA	97.0	2	65	2.9	100%	50%	12	
	university of cape town	ZAF	95.0	8	20	1.2	88%	63%	22	42.8
	james cook university	AUS	94.8	4	36	1.3	100%	50%	10	28.4
	university of british columbia	CAN	94.6	4	30	1.9	75%	50%	10	73.2
	dalian university of technology	CHN	93.0	2	30	2.5	100%	50%	2	23.7
	oregon state university	USA	92.5	6	16	2.0	100%	50%	18	30.1
	national university of singapore	SGP	91.9	1	48	3.5	100%	100%	1	90.4
	peking university	CHN	89.4	6	9	2.1	100%	67%	16	90
	woods hole oceanographic institution	USA	88.9	3	34	1.0	100%	100%	11	
	secretariat of the pacific community	AUS	86.2	1	78	1.4	100%	100%	7	
	Institutions with strong H2020 collaboration									
	plymouth state university	USA	99.3	21	27	1.5	81%	10%	36	
	stanford university	USA	98.2	4	24	4.6	75%	25%	9	96.4
	national oceanic and atmospheric administration	USA	97.9	5	25	2.7	80%	20%	12	
	university of massachusetts amherst	USA	97.5	8	23	1.7	88%	25%	9	
	university of hawaii at manoa	USA	96.8	2	67	1.9	0%	0%	0	
	shanghai jiao tong university	CHN	96.6	13	14	1.2	46%	23%	11	63
	australian maritime college	AUS	96.4	3	50	1.7	67%	0%	6	
	monterey bay aquarium research institute	USA	95.2	1	52	4.3	100%	0%	5	
	university of california santa barbara	USA	95.2	1	52	4.3	100%	0%	5	
	university of massachusetts boston	USA	95.2	1	52	4.3	100%	0%	5	
H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	centre national de la recherche scientifique	FRA	99.1	14	31	1.7	86%	21%	20	
	ifremer	FRA	98.8	6	58	1.6	100%	17%	9	
	institut national des sciences appliquees de rouen	FRA	98.6	2	151	1.9	100%	0%	4	
	uppsala university	SWE	98.4	5	32	1.4	20%	0%	3	56.4
	university of edinburgh	GBR	97.7	11	18	1.6	55%	9%	12	74.1
	norwegian university of science and technology	NOR	97.3	20	14	1.3	40%	5%	8	28.3
	university of the highlands and islands	GBR	96.1	6	15	2.0	100%	0%	14	
	royal holloway university of london	GBR	95.9	1	64	3.7	0%	0%	0	
	university of exeter	GBR	93.4	10	11	1.6	70%	10%	17	38.9
	cranfield university	GBR	93.2	3	30	2.3	100%	0%	13	
	Institutions with strong H2020 collaboration									
	plymouth university	GBR	99.7	17	36	2.1	88%	82%	18	
	university of santiago de compostela	ESP	99.5	20	27	1.8	100%	65%	20	16.6
	university college dublin	IRL	89.2	2	36	1.6	100%	50%	3	36.5
	ecole normale superieure de cachan	FRA	87.6	1	60	1.9	100%	100%	2	
	ecole centrale de nantes	FRA	83.1	2	36	1.5	100%	50%	7	
	university of bologna	ITA	81.3	2	22	2.0	100%	50%	6	34.8
	ghent university	BEL	80.8	4	13	1.4	75%	50%	8	55.5
	hellenic naval academy	GRC	80.0	2	20	1.9	100%	50%	3	
	delft university of technology	NLD	79.7	3	17	1.5	100%	100%	4	72.3
	university of amsterdam	NLD	78,6	2	17	1,8	100%	50%	7	63,4

*For institutions from non-H2020 countries the %-share of exclusively non-H2020 collaborations is reported; for institutions from H2020 countries the %-share of exclusively H2020 collaborations is reported.

Geothermal Energy

	Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively (non-) EU collaborations*	No of Collaborating Institutes	THE Research Score
Non-H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	stanford university	USA	95.0	4	24	2.2	75%	75%	3	96.4
	kyushu university	JPN	94.2	9	14	1.8	100%	67%	12	39.2
	gadjah mada university	IDN	92.4	4	21	1.6	100%	100%	7	
	king saud university	SAU	90.1	7	12	1.5	100%	100%	15	25.8
	united states geological survey	USA	89.3	6	16	1.7	83%	50%	9	
	university college of engineering	IND	88.8	3	20	2.7	100%	100%	8	
	king fahd university of petroleum and minerals	SAU	88.2	2	45	1.6	100%	50%	4	15.9
	universiti tenaga nasional	MYS	87.7	1	40	3.3	100%	100%	1	
	university of indonesia	IDN	87.7	1	40	3.3	100%	100%	1	19.2
	commonwealth scientific and industrial research organisation	AUS	86.9	8	8	1.4	75%	63%	16	
	Institutions with strong H2020 collaboration									
	xi an jiaotong university	CHN	99.7	13	23	1.9	31%	15%	7	
	university of tehran	IRN	99.2	9	28	1.9	56%	11%	7	23.5
	oregon institute of technology	USA	98.9	1	367	1.5	0%	0%	0	
	university of tabriz	IRN	98.6	9	31	1.6	56%	33%	7	19.9
	urmia university of technology	IRN	97.9	6	29	2.2	50%	0%	9	
	tianjin university	CHN	96.8	12	14	1.7	58%	0%	12	35.7
	university of auckland	NZL	96.3	9	23	1.6	22%	11%	3	43.9
	china university of petroleum	CHN	96.0	8	15	2.4	38%	0%	5	26.1
	china university of geosciences	CHN	95.8	7	17	1.5	57%	29%	8	17.2
	chinese academy of sciences	CHN	95.5	13	12	1.5	77%	15%	21	
H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	eth zurich	CHE	98.4	11	20	1.7	82%	18%	17	92.8
	university of naples federico ii	ITA	98.1	3	50	2.7	67%	33%	2	23.4
	university of iceland	ISL	97.6	13	13	1.9	31%	8%	6	30
	university of gaziantep	TUR	97.3	7	30	1.5	29%	0%	2	
	polytechnic university of milan	ITA	97.1	4	43	1.8	50%	0%	10	35.2
	mugla university	TUR	96.6	9	16	2.1	67%	0%	7	
	suleyman demirel university	TUR	94.7	8	17	1.5	100%	0%	13	
	rwth aachen university	DEU	93.7	5	20	2.4	60%	0%	4	61.5
	university of palermo	ITA	93.2	2	42	3.1	50%	0%	1	17.9
	university of florence	ITA	92,1	2	36	2,7	50%	0%	1	25,1
	Institutions with strong H2020 collaboration									
	university of tubingen	DEU	95.3	1	86	3.5	100%	100%	1	
	university of zagreb	HRV	90.6	2	35	2.8	50%	50%	1	12.9
	university of nis	SRB	85.9	1	54	2.0	100%	100%	1	
	university of salzburg	AUT	71.8	1	31	1.9	100%	100%	1	
	university of erlangen nuremberg	DEU	71.8	1	31	1.9	100%	100%	1	
	delft university of technology	NLD	69.0	2	8	3.4	100%	50%	3	72.3
	technical university of denmark	DNK	63.8	2	9	2.8	50%	50%	1	40.2
	utrecht university	NLD	63.5	3	7	1.7	100%	67%	4	61.2
	tallinn university of technology	EST	52.8	1	13	1.9	100%	100%	1	13.2
	aalto university	FIN	52.8	1	13	1.9	100%	100%	1	39.4

*For institutions from non-H2020 countries the %-share of exclusively non-H2020 collaborations is reported; for institutions from H2020 countries the %-share of exclusively H2020 collaborations is reported.

Bioenergy and Biofuels

	Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively (non-) EU collaborations*	No of Collaborating Institutes	THE Research Score
Non-H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	national renewable energy laboratory	USA	99.7	4	422	4.4	50%	50%	5	
	oak ridge national laboratory	USA	98.8	1	1459	13.3	100%	100%	4	
	university of north texas	USA	98.8	1	1459	13.3	100%	100%	4	
	university of british columbia	CAN	98.8	1	1459	13.3	100%	100%	4	73.2
	georgia institute of technology	USA	98.8	1	1459	13.3	100%	100%	4	76.4
	universiti malaysia pahang	MYS	97.7	7	112	2.9	86%	71%	7	
	national cheng kung university	TWN	96.4	8	81	2.4	100%	88%	24	
	university of illinois at urbana champaign	USA	94.8	6	87	1.9	83%	50%	17	
	jilin university	CHN	94.4	3	106	3.9	100%	67%	6	16.2
	purdue university	USA	93.9	3	135	2.4	67%	67%	3	
	Institutions with strong H2020 collaboration									
	university of malaya	MYS	98.6	39	112	2.5	46%	26%	31	30.5
	national university of singapore	SGP	98.2	14	63	2.9	43%	36%	6	90.4
	chinese academy of sciences	CHN	97.9	13	81	2.2	62%	8%	13	
	universiti putra malaysia	MYS	97.5	13	71	2.4	46%	15%	9	31.4
	anna university	IND	97.0	8	100	2.2	38%	25%	4	14.1
	indian institute of technology roorkee	IND	96.6	10	63	2.6	0%	0%	0	28.2
	universiti teknologi malaysia	MYS	96.2	7	72	2.6	14%	0%	1	25.2
	indian institute of technology kanpur	IND	95.9	5	103	2.4	60%	40%	3	24.5
	northeast normal university	CHN	95.5	2	166	5.0	50%	0%	2	10.3
	kaist	KOR	95.3	6	89	2.4	50%	33%	5	
H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	aston university	GBR	98.4	2	231	8.7	0%	0%	0	24.2
	max planck society	DEU	97.3	1	139	16.1	0%	0%	0	
	university of nis	SRB	96.8	6	94	3.3	50%	0%	4	
	university of belgrade	SRB	95.7	3	125	3.3	100%	0%	4	
	erciyes university	TUR	94.6	4	88	3.1	100%	0%	4	16.3
	technical university of denmark	DNK	92.6	5	109	2.0	100%	40%	6	40.2
	university of jyvaskyla	FIN	89.5	1	214	3.5	100%	0%	1	
	norwegian university of life sciences	NOR	87.5	2	117	2.1	0%	0%	0	10.5
	aarhus university	DNK	87.0	3	85	2.0	67%	0%	9	54
	aalto university	FIN	86.8	2	115	2.5	0%	0%	0	39.4
	Institutions with strong H2020 collaboration									
	centre national de la recherche scientifique	FRA	78.3	2	109	1.9	50%	50%	1	
	spanish national research council	ESP	77.2	2	74	2.8	100%	50%	4	
	ghent university	BEL	76.7	3	77	2.0	100%	67%	5	55.5
	university of bologna	ITA	76.5	5	57	1.6	100%	80%	8	34.8
	wageningen university and research centre	NLD	70.7	4	54	1.7	75%	50%	6	
	university of manchester	GBR	69.1	2	91	2.0	100%	100%	3	63.8
	university of cordoba	ESP	68.7	2	119	1.4	50%	50%	2	
	institut national de la recherche agronomique	FRA	68.0	2	139	1.3	50%	50%	1	
	university of nantes	FRA	62.0	2	71	1.9	50%	50%	1	21
	karlsruhe institute of technology	DEU	56.9	2	68	1.7	50%	50%	2	47.8

*For institutions from non-H2020 countries the %-share of exclusively non-H2020 collaborations is reported; for institutions from H2020 countries the %-share of exclusively H2020 collaborations is reported.

Networks

	Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively (non-) EU collaborations*	No of Collaborating Institutes	THE Research Score
Non-H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	zhejiang university	CHN	99.7	15	63	2.6	80%	67%	27	64.7
	princeton university	USA	99.5	7	93	3.3	100%	57%	17	96.3
	singapore university of technology and design	SGP	99.3	11	70	2.4	100%	91%	24	
	university of ottawa	CAN	99.1	6	91	2.5	50%	50%	6	42
	university of waterloo	CAN	98.5	13	68	2.0	77%	69%	21	42.1
	university of toronto	CAN	98.0	8	50	3.4	50%	50%	7	89.5
	university of houston	USA	97.2	6	90	1.7	83%	50%	9	25.9
	university of illinois at urbana champaign	USA	96.8	4	101	2.9	100%	50%	15	
	tsinghua university	CHN	96.3	8	58	2.7	75%	75%	7	94
	nanyang technological university	SGP	95.9	16	63	1.2	81%	81%	22	70.4
	Institutions with strong H2020 collaboration									
	north carolina state university	USA	98.9	6	91	2.4	50%	33%	11	35.3
	comsats institute of information technology	PAK	98.7	8	65	2.2	75%	38%	8	
	dongguk university	KOR	98.3	1	415	3.3	0%	0%	0	
	hong kong polytechnic university	HKG	97.8	11	52	2.2	55%	36%	13	46.6
	universiti tenaga nasional	MYS	97.0	2	178	3.3	50%	0%	1	
	iran university of science and technology	IRN	96.6	6	68	2.6	50%	17%	6	33
	university of british columbia	CAN	96.1	5	83	2.6	60%	40%	5	73.2
	university of miami	USA	93.4	3	101	2.3	100%	33%	8	25.2
	guangdong university of technology	CHN	93.2	5	68	2.3	100%	40%	12	13.1
	indian institute of technology kharagpur	IND	92.7	7	71	1.9	43%	14%	4	38.9
H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	gazi university	TUR	95.5	5	56	3.3	60%	20%	6	10.6
	aarhus university	DNK	95.3	5	76	2.3	60%	40%	6	54
	ghent university	BEL	94.9	1	162	5.1	0%	0%	0	55.5
	nevsehir university	TUR	94.4	3	80	3.3	67%	33%	2	
	delft university of technology	NLD	94.2	3	82	3.2	67%	33%	2	72.3
	simula research laboratory	NOR	94.0	4	59	3.4	100%	0%	7	
	university of copenhagen	DNK	91.7	2	100	2.7	0%	0%	0	44.1
	aalborg university	DNK	91.5	8	53	2.1	63%	0%	8	39.1
	university of oxford	GBR	90.8	3	76	2.6	33%	0%	2	99.6
	aristotle university of thessaloniki	GRC	88.5	3	79	1.8	67%	33%	2	16.8
	Institutions with strong H2020 collaboration									
	university of cyprus	CYP	97.4	1	239	5.1	100%	100%	1	24.6
	city university london	GBR	97.4	1	239	5.1	100%	100%	1	
	ecole normale superieure	FRA	93.0	2	140	1.9	50%	50%	1	
	frankfurt institute for advanced studies	DEU	86.8	2	118	2.0	100%	50%	3	
	university of seville	ESP	74.5	2	58	2.6	50%	50%	1	18.7
	technische universitat darmstadt	DEU	69.7	1	134	2.0	100%	100%	2	
	university of bamberg	DEU	69.7	1	134	2.0	100%	100%	2	
	eth zurich	CHE	69.7	1	134	2.0	100%	100%	2	92.8
	university of luxembourg	LUX	67.7	1	84	3.1	100%	100%	1	36.5
	university of cyprus	CYP	97.4	1	239	5.1	100%	100%	1	24.6

*For institutions from non-H2020 countries the %-share of exclusively non-H2020 collaborations is reported; for institutions from H2020 countries the %-share of exclusively H2020 collaborations is reported.

Hydrogen

	Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively (non-) EU collaborations*	No of Collaborating Institutes	THE Research Score
Non-H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	jilin university	CHN	99.7	11	328	6.1	91%	55%	20	16.2
	soochow university	CHN	99.0	7	386	8.6	100%	86%	14	20.8
	nanyang technological university	SGP	98.5	20	176	6.7	85%	70%	25	70.4
	university of adelaide	AUS	97.3	5	378	9.8	100%	100%	9	41.6
	king abdulaziz university	SAU	97.1	15	283	3.6	100%	100%	35	16.5
	wuhan university of technology	CHN	96.8	6	403	5.7	67%	67%	14	13.4
	kent state university	USA	96.3	1	1048	16.1	100%	100%	3	19
	rutgers university	USA	94.6	5	292	8.1	80%	80%	6	
	shandong university	CHN	94.4	4	322	6.6	100%	75%	12	29.1
	tohoku university	JPN	94.2	8	156	8.6	100%	88%	13	54.4
	Institutions with strong H2020 collaboration									
	university of tokyo	JPN	99.5	10	318	7.2	50%	20%	11	
	chinese academy of sciences	CHN	99.2	36	168	6.1	86%	36%	56	
	beihang university	CHN	98.7	6	386	7.8	67%	33%	9	34.2
	stanford university	USA	98.3	10	364	7.3	70%	40%	14	96.4
	california institute of technology	USA	98.0	10	277	9.6	90%	40%	16	97.2
	university of wisconsin madison	USA	97.8	3	662	7.7	67%	33%	5	
	dalian institute of chemical physics	CHN	96.6	11	170	9.5	91%	18%	17	
	lawrence berkeley national laboratory	USA	96.1	8	239	8.8	75%	25%	17	
	university of science and technology of china	CHN	95.8	20	153	5.0	40%	10%	13	59.5
	tianjin university	CHN	95.4	7	209	10.1	57%	43%	9	35.7
H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	technion israel institute of technology	ISR	97.5	3	676	5.8	33%	0%	1	31.5
	university college london	GBR	95.6	5	328	7.2	60%	0%	5	
	max planck society	DEU	95.1	17	180	4.8	59%	12%	17	
	ecole polytechnique federale de lausanne	CHE	94.9	6	270	5.7	50%	33%	3	
	dresden university of technology	DEU	92.5	3	287	10.6	33%	0%	3	
	technical university of denmark	DNK	91.0	5	149	9.4	60%	0%	7	40.2
	university of cambridge	GBR	90.3	5	147	7.4	80%	20%	9	98.7
	eth zurich	CHE	87.9	3	130	14.1	67%	0%	2	92.8
	university of graz	AUT	86.9	1	199	26.0	100%	0%	2	18.3
	uppsala university	SWE	85.5	1	349	13.1	0%	0%	0	56.4
	Institutions with strong H2020 collaboration									
	university of nottingham	GBR	92.9	2	393	8.2	50%	50%	2	42.6
	spanish national research council	ESP	92.7	2	376	7.1	50%	50%	3	
	technische universitat munchen	DEU	89.8	2	445	4.7	100%	50%	5	
	ludwig maximilian university of munich	DEU	85.2	4	218	5.3	100%	50%	10	
	palacký university olomouc	CZE	77.5	1	176	16.1	100%	100%	2	
	institute of chemical technology in prague	CZE	77.5	1	176	16.1	100%	100%	2	
	university of erlangen nuremberg	DEU	77.5	1	176	16.1	100%	100%	2	
	centre national de la recherche scientifique	FRA	77.0	4	116	6.3	75%	50%	8	
	paul scherrer institute	CHE	71.9	2	108	9.3	100%	50%	6	
	augsburg college	DEU	62.8	1	225	5.6	100%	100%	3	

*For institutions from non-H2020 countries the %-share of exclusively non-H2020 collaborations is reported; for institutions from H2020 countries the %-share of exclusively H2020 collaborations is reported.

Storage

	Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively (non-) EU collaborations*	No of Collaborating Institutes	THE Research Score
Non-H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	nanyang technological university	SGP	98.8	27	215	6.5	63%	63%	28	70.4
	university of california los angeles	USA	98.0	4	591	10.5	75%	50%	5	
	university of washington	USA	94.9	5	322	7.7	100%	80%	7	82.2
	pacific northwest national laboratory	USA	93.5	4	292	12.0	75%	50%	4	
	wuhan university of technology	CHN	93.3	8	227	6.6	88%	50%	21	13.4
	griffith university	AUS	93.0	3	401	9.4	100%	100%	5	32.7
	zhejiang university	CHN	92.2	13	195	4.8	69%	62%	14	64.7
	university of pennsylvania	USA	91.6	1	865	13.3	100%	100%	2	90.4
	national institute of advanced industrial science and technology	JPN	90.8	2	522	7.6	50%	50%	1	
	soochow university	CHN	90.5	2	188	25.1	100%	50%	6	20.8
	Institutions with strong H2020 collaboration									
	chinese academy of sciences	CHN	99.7	50	245	6.5	74%	34%	59	
	university of texas at austin	USA	99.4	9	404	11.0	56%	33%	13	76.2
	tsinghua university	CHN	99.1	30	208	6.3	67%	30%	28	94
	fudan university	CHN	98.6	16	263	7.6	31%	13%	5	58.6
	ulsan national institute of science and technology	KOR	97.4	5	483	7.5	80%	20%	12	
	peking university	CHN	96.9	6	390	7.9	67%	33%	5	90
	nankai university	CHN	96.6	5	265	17.5	80%	40%	16	21.8
	sun yat sen university	CHN	95.5	12	214	6.7	42%	33%	7	
	university of central florida	USA	94.7	3	496	11.1	0%	0%	0	28.7
	rutgers university	USA	94,4	1	1037	17,0	0%	0%	0	
H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	university of cambridge	GBR	98.3	2	1057	14.7	100%	0%	9	98.7
	centre national de la recherche scientifique	FRA	97.7	7	453	5.2	86%	43%	8	
	scuola normale superiore di pisa	ITA	96.1	1	1685	13.3	100%	0%	5	38.1
	paul sabatier university	FRA	95.8	2	881	7.5	100%	0%	5	
	university of nottingham	GBR	91.3	3	303	9.3	67%	33%	2	42.6
	karlsruhe institute of technology	DEU	88.0	3	171	14.0	100%	33%	9	47.8
	universite de namur	BEL	86.9	1	429	16.1	100%	0%	4	
	max planck society	DEU	82.7	3	271	5.8	100%	0%	6	
	agh university of science and technology	POL	82.4	1	748	7.6	0%	0%	0	13.5
	university of warwick	GBR	81.3	1	1463	3.5	0%	0%	0	52.7
	Institutions with strong H2020 collaboration									
	istituto italiano di tecnologia	ITA	97.2	3	707	8.3	100%	67%	7	
	spanish national research council	ESP	95.2	2	677	14.6	50%	50%	1	
	bar ilan university	ISR	72.1	2	247	5.4	50%	50%	2	
	ecole normale superieure	FRA	55.4	2	328	2.4	50%	50%	1	
	royal institute of technology	SWE	51.8	2	179	3.4	100%	50%	4	
	university of toulouse	FRA	48.7	1	329	3.3	100%	100%	1	
	dresden university of technology	DEU	43.1	1	171	5.2	100%	100%	1	
	democritus university of thrace	GRC	42.0	2	124	3.4	100%	50%	2	11.6
	ruhr university bochum	DEU	40.9	1	229	3.5	100%	100%	3	45
	malardalen university college	SWE	40.9	1	229	3.5	100%	100%	3	

*For institutions from non-H2020 countries the %-share of exclusively non-H2020 collaborations is reported; for institutions from H2020 countries the %-share of exclusively H2020 collaborations is reported.

Heat pumps

	Institutions	Country	Score	No of Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively (non-) EU collaborations*	No of Collaborating Institutes	THE Research Score
Non-H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	hong kong polytechnic university	HKG	99.4	15	29	2.8	93%	93%	35	46.6
	china university of petroleum	CHN	98.8	12	34	2.6	67%	67%	26	26.1
	guangdong university of technology	CHN	97.7	11	26	2.6	100%	100%	34	13.1
	city university of hong kong	HKG	91.3	3	38	2.7	100%	100%	3	48.9
	the university of nottingham ningbo china	CHN	89.3	4	23	3.3	100%	75%	13	
	university of texas at dallas	USA	85.9	3	28	2.4	67%	67%	2	29.3
	university of wollongong	AUS	84.4	6	18	2.0	100%	100%	12	35
	purdue university	USA	82.7	2	42	2.2	100%	50%	3	
	university of kwazulu natal	ZAF	79.8	1	62	2.7	100%	100%	2	
	university of tasmania	AUS	78.4	5	17	1.7	100%	100%	5	33.7
	Institutions with strong H2020 collaboration									
	xi an jiaotong university	CHN	99.7	38	23	2.2	50%	45%	32	
	university of tehran	IRN	98.5	9	41	2.6	67%	22%	11	23.5
	tsinghua university	CHN	98.2	21	19	2.2	19%	10%	4	94
	islamic azad university	IRN	97.9	6	53	2.5	83%	0%	11	
	harbin institute of technology	CHN	97.4	11	29	2.2	27%	18%	4	36.8
	tianjin university	CHN	97.1	18	16	2.1	33%	11%	7	35.7
	petroleum university of technology	IRN	96.8	4	60	2.7	100%	25%	9	
	university of pretoria	ZAF	96.2	8	28	2.5	25%	13%	4	30.1
	indian institute of technology roorkee	IND	95.9	6	33	2.7	17%	0%	1	28.2
	north china electric power university	CHN	95.6	4	57	2.7	25%	0%	1	11.9
H2020 Countries	**Institutions with strong non-H2020 collaboration**									
	university of ljubljana	SVN	99.1	2	84	9.3	0%	0%	0	18.7
	university of nottingham	GBR	96.5	4	59	2.5	75%	0%	18	42.6
	yasar university	TUR	95.4	5	42	2.1	100%	20%	8	
	university of hull	GBR	95.1	7	23	2.9	71%	0%	10	23
	university of padua	ITA	93.1	8	19	2.3	13%	0%	2	30.9
	ege university	TUR	89.9	3	41	2.1	100%	33%	6	10.2
	chalmers university of technology	SWE	89.6	1	96	3.3	0%	0%	0	42.1
	national technical university of athens	GRC	89.0	4	36	1.8	0%	0%	0	12.8
	aalto university	FIN	88.5	3	32	2.3	67%	33%	2	39.4
	polytechnic university of valencia	ESP	88.2	3	32	2.4	0%	0%	0	11.8
	Institutions with strong H2020 collaboration									
	dalarna university	SWE	80.1	3	17	3.4	67%	67%	2	
	graz university of technology	AUT	79.0	3	18	2.9	67%	67%	2	17.5
	edinburgh napier university	GBR	71.5	1	62	1.9	100%	100%	1	13.9
	university of granada	ESP	71.5	1	62	1.9	100%	100%	1	20.9
	delft university of technology	NLD	67.8	2	18	2.7	50%	50%	1	72.3
	university of calabria	ITA	65.2	2	22	1.9	100%	100%	2	17.5
	politehnica university of bucharest	ROU	62.6	2	45	0.8	100%	50%	4	
	university of twente	NLD	62.6	2	45	0.8	100%	50%	4	46.8
	gediz university	TUR	56.0	1	24	2.7	100%	100%	3	
	technical university of berlin	DEU	56.0	1	24	2.7	100%	100%	3	53.9

*For institutions from non-H2020 countries the %-share of exclusively non-H2020 collaborations is reported; for institutions from H2020 countries the %-share of exclusively H2020 collaborations is reported.

Excel-based Tool for Publication Analysis

The publication analysis was conducted with a VBA- and Excel-based tool. In the following, some snippets of the tool are shown, to highlight its main functionalities.

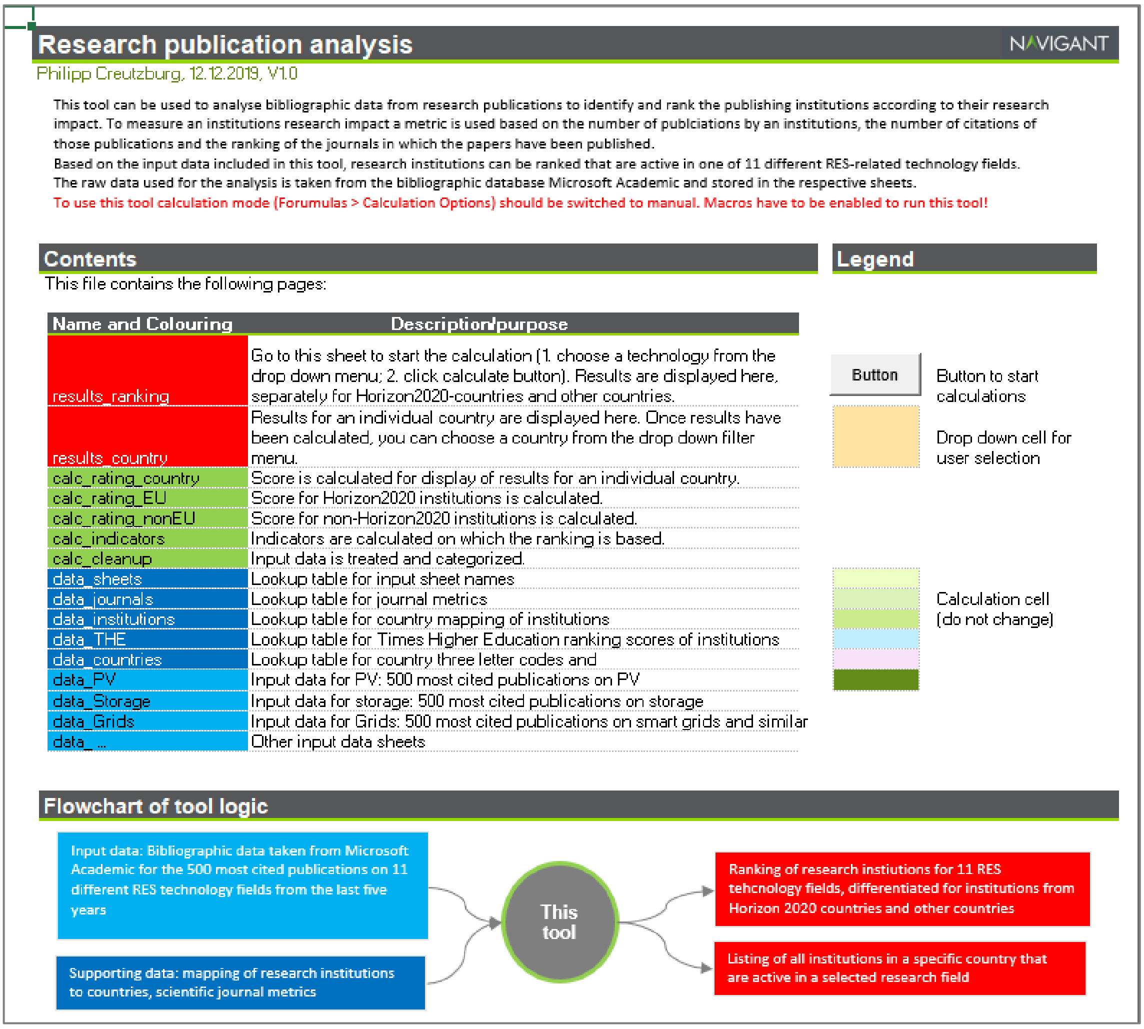


Figure 24: Tool description

logprob	prob	Id	Ti	Y	ECC	J.JN	J.JId	J.JFN
-15,634	1,6E-07	2,1E+09	solar cell	2015	8074	prog phc	1,5E+08	Progress
-17,185	3,4E-08	2,5E+09	solar cell	2016	8021	prog phc	1,5E+08	Progress
-17,057	3,9E-08	2E+09	solar cell	2014	7944	prog phc	1,5E+08	Progress
-16,787	5,1E-08	2E+09	solar cell	2014	7943	prog phc	1,5E+08	Progress
-16,744	5,3E-08	2,2E+09	solar cell	2016	7635	prog phc	1,5E+08	Progress
-15,347	2,2E-07	2E+09	interface	2014	4292	science	3880285	Science
-15,444	2E-07	1,6E+09	high perf	2015	3886	science	3880285	Science
-16,112	1E-07	2,7E+09	iodide m	2017	2645	science	3880285	Science
-16,215	9,1E-08	2,3E+09	cesium c	2016	2522	energy e	1,2E+08	Energy a
-16,238	8,9E-08	2E+09	low trap	2015	2286	science	3880285	Science
-16,162	9,6E-08	2,1E+09	a hole cc	2014	2282	science	3880285	Science
-16,143	9,8E-08	2,1E+09	high effi	2015	1921	science	3880285	Science
-16,316	8,2E-08	2,1E+09	formami	2014	1836	energy e	1,2E+08	Energy a
-16,207	9,1E-08	2,1E+09	bright lig	2014	1827	nat nano	7822423	Nature Nanotechnology
-16,652	5,9E-08	1,9E+09	efficient	2015	1627	science	3880285	Science
-15,906	1,2E-07	2,1E+09	morphol	2014	1581	adv func	1,4E+08	Advance
-16,818	5E-08	2,2E+09	improve	2016	1491	nat nano	7822423	Nature N
-16,536	6,6E-08	2,5E+09	incorpor	2016	1457	science	3880285	Science
-16,755	5,3E-08	2,4E+09	a vacuun	2016	1432	science	3880285	Science
-16,764	5,2E-08	2E+09	efficient	2014	1421	energy e	1,2E+08	Energy a
-16,618	6,1E-08	2E+09	water ph	2014	1368	science	3880285	Science
-16,634	6E-08	2E+09	lead free	2014	1341	nat phot	1,2E+08	Nature P
-16,598	6,2E-08	2,1E+09	atomisti	2014	1319	nano lett	1,4E+08	Nano Letters
-16,938	4,4E-08	2,1E+09	a fast de	2014	1253	angew cl	6,7E+07	Angewar
-16,668	5,8E-08	2,2E+09	a mixed	2016	1194	science	3880285	Science

logprob	AfN1	AfN2	AfN3	AfN4	AfN5	AfN6	AfN7	AfN8	AfN9	AfN10
-15,634	universit	national	national	fraunhofer society						
-17,185	universit	national	national	fraunhofer society						
-17,057	universit	national	national	fraunhofer society						
-16,787	universit	national	national	fraunhofer society						
-16,744	universit	national	national	fraunhofer society						
-15,347	universit	universit	universit	universit	universit	universit	universit	universit	universit	universit
-15,444							sungkyunkwan university			
-16,112	ulsan na	ulsan national institute of science a				sk hynix			hanyang	korea un
-16,215	ecole po	panason	ecole po	ecole po	ecole po	ecole po	ecole po	ecole po	ecole po	ecole po
-16,238	king abd	universit	universit	universit	king abd	universit	king abd	universit	king abd	king abd
-16,162	huazhon	huazhon	huazhon	huazhon	huazhon	huazhon	huazhon	huazhon	huazhon	huazhon
-16,143	los alam	los alam	purdue u	los alam	los alam	los alam	los alam	rutgers u	los alam	purdue u
-16,316	universit	universit	universit	universit	universit	university of oxford				
-16,207						university of cambridge				
-16,652	huazhon	national	national	national	national	huazhon	shanghai	shanghai	shanghai	national
-15,906	universit	universit	universit	universit	university of oxford					
-16,818	universit	universit	university of califi		universit	universit	universit	universit	universit	universit
-16,536	ecole po	ecole po	panason	ecole po	ecole po	ecole po	ecole po	ecole po	ecole po	ecole po
-16,755	ecole po	ecole po	ecole po	ecole po	ecole po	ecole po	ecole po	ecole po	ecole polytechnique feder	
-16,764	universit	universit	universit	universit	universit	universit	universit	universit	central s	universit
-16,618	ecole po	nanyang	sungkyu	ecole po	ecole po	ecole po	ecole po	sungkyu	ecole po	nanyang
-16,634	northwe	northwe	northwe	northwe	northwestern university					
-16,598					king s college london					
-16,938	monash	monash	monash	monash	monash	monash	universit	monash	common	melbour
-16,668	universit	universit	universit	universit	universit	universit	universit	universit	helmhol	helmhol

logprob	AfId1	AfId2	AfId3	AfId4	AfId5	AfId6	AfId7	AfId8	AfId9	AfId10
-15,634	3,2E+07	1,3E+09	73613424	4923324						
-17,185	3,2E+07	1,3E+09	73613424	4923324						
-17,057	3,2E+07	1,3E+09	73613424	4923324						
-16,787	3,2E+07	1,3E+09	73613424	4923324						
-16,744	3,2E+07	1,3E+09	73613424	4923324						
-15,347	1,6E+08	1,6E+08	161318765	1,6E+08	1,6E+08	1,6E+08	1,6E+08	1,6E+08	1,6E+08	1,6E+08
-15,444							848706			
-16,112	4,9E+07	4,9E+07				1,1E+07			4575257	2E+08
-16,215	5124864	1,3E+09	5124864	5124864	5124864	5124864	5124864	5124864	5124864	5124864
-16,238	7,2E+07	1,9E+08	185261750	1,9E+08	7,2E+07	1,9E+08	7,2E+07	1,9E+08	7,2E+07	7,2E+07
-16,162	4,8E+07	4,8E+07	47720641	4,8E+07	4,8E+07	4,8E+07	4,8E+07	4,8E+07	4,8E+07	4,8E+07
-16,143	1,3E+09	1,3E+09	219193219	1,3E+09	1,3E+09	1,3E+09	1,3E+09	1E+08	1,3E+09	2,2E+08
-16,316	4E+07	4E+07	40120149	4E+07	4E+07	4E+07				
-16,207						241749				
-16,652	4,8E+07	2,1E+08	205401836	2,1E+08	2,1E+08	4,8E+07	1,8E+08	1,8E+08	1,8E+08	2,1E+08
-15,906	4E+07	4E+07	40120149	4E+07	4E+07					
-16,818	1,6E+08	1,6E+08	161318765		1,6E+08	1,6E+08	1,6E+08	1,6E+08	1,6E+08	1,6E+08
-16,536	5124864	5124864	1,283E+09	5124864	5124864	5124864	5124864	5124864	5124864	5124864
-16,755	5124864	5124864	5124864	5124864	5124864	5124864	5124864	5124864		
-16,764	1,1E+08	1,1E+08	114395901	1,1E+08	1,1E+08	1,1E+08	5388228	5388228	1,4E+08	1,1E+08
-16,618	5124864	1,7E+08	848706	5124864	5124864	5124864	5124864	848706	5124864	1,7E+08
-16,634	1,1E+08	1,1E+08	111979921	1,1E+08	1,1E+08					
-16,598					1,8E+08					
-16,938	5,7E+07	5,7E+07	56590836	5,7E+07	5,7E+07	5,7E+07	1,7E+08	5,7E+07	1,3E+09	2,8E+09
-16,668	4E+07	4E+07	40120149	4E+07	4E+07	4E+07	4E+07	4E+07	2,8E+09	2,8E+09

Figure 25: Input data – journal articles

Lookup table to match journal name with SJR score

Source:

https://www.scopus.com/sources?zone=&origin=sbrowse

CiteScore metrics calculated using data from **30 April, 2019.** SNIP and SJR calculated using data from **30 April, 2019**

Scopus Source ID	Title	CiteScore	Percentile	Citation Count	Scholarly Output	Percent Cited	SNIP	SJR	RANK	Rank Out Of
28773	Ca-A Cancer Journal for Clinicians	160,19	99	20184	126	77	100,014	72,576	1	122
28773	Ca-A Cancer Journal for Clinicians	160,19	99	20184	126	77	100,014	72,576	1	321
19434	MMWR. Recommendations and reports : Morbidity and mortal	87,75	99	1053	12	100	42,774	48,894	1	89
19434	MMWR. Recommendations and reports : Morbidity and mortal	87,75	99	1053	12	100	42,774	48,894	1	246
19434	MMWR. Recommendations and reports : Morbidity and mortal	87,75	99	1053	12	100	42,774	48,894	1	117
19434	MMWR. Recommendations and reports : Morbidity and mortal	87,75	97	1053	12	100	42,774	48,894	1	24
23340	Chemical Reviews	54,26	99	46227	852	97	12,162	22,157	1	371
23350	Chemical Society Reviews	41,35	99	40522	980	98	8,015	16,116	2	371
29719	Reviews of Modern Physics	39,2	99	4979	127	95	14,721	17,337	1	215
58530	National vital statistics reports : from the Centers for Disease C	38,91	98	1245	32	100	23,015	27,31	1	46
21100812243	Nature Reviews Materials	37,75	99	7362	195	65	13,957	34,171	1	225
21100812243	Nature Reviews Materials	37,75	99	7362	195	65	13,957	34,171	1	83
21100812243	Nature Reviews Materials	37,75	99	7362	195	65	13,957	34,171	1	116
21100812243	Nature Reviews Materials	37,75	99	7362	195	65	13,957	34,171	1	271
21100812243	Nature Reviews Materials	37,75	97	7362	195	65	13,957	34,171	1	19
24212	Proceedings of the IEEE Computer Society Conference on Comp	37,26	99	46427	1246	95	22,499	8,073	1	360
24212	Proceedings of the IEEE Computer Society Conference on Comp	37,26	99	46427	1246	95	22,499	8,073	1	75
17900156715	IEEE Communications Surveys and Tutorials	33,62	99	11129	331	95	13,026	5,123	1	661
17500155114	Energy and Environmental Science	32,34	99	29396	909	98	4,622	13,103	1	100

Figure 26: Input data – journal metrics

Ranking of a selected country's institutions

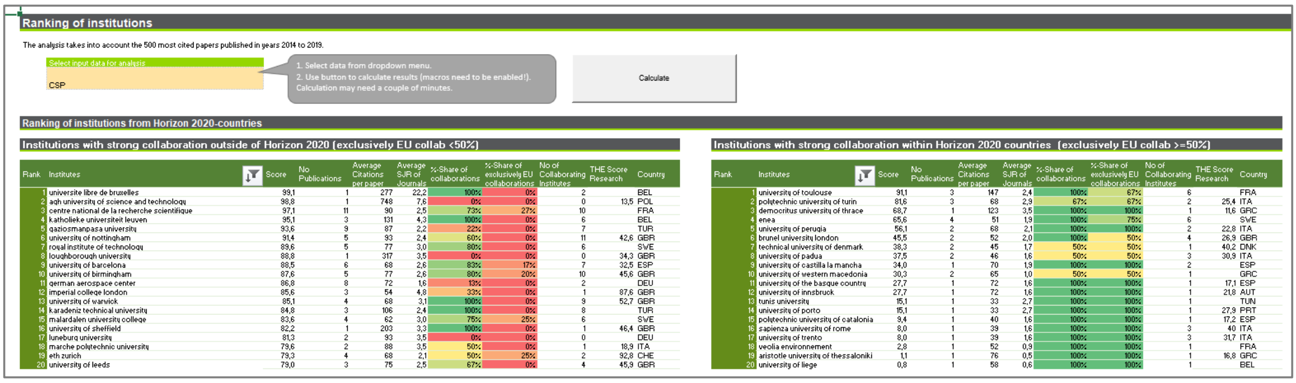
RES technology field: CSP

Select country for analysis: CAN

Select country from dropdown menu (if a country is not listed, there are no institutions listed in this research

Rank	Institutes	Score	No Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	only for non-Horizon2020 institutions: %-Share of exclusively non-EU collaborations	only for Horizon2020 institutions: %-Share of exclusively EU collaborations	No of Collaborating Institutes	THE Score Research	Top Collaborating Institute
1	canadian real estate association	96,2	13	77	2	54%	0%	0%	13		university of barcelona
2	concordia university	80,2	3	107	2	67%	0%	0%	2	25,9	royal institute of technology
3	dalhousie university	50,7	2	74	2	0%	0%	0%	0	29,6	
4	university of ottawa	42,1	1	51	3	0%	0%	0%	0	42	
5	public works and government services canada	40,6	1	84	2	100%	0%	0%	1		concordia university
6	ecole de technologie superieure	25,5	1	58	2	100%	0%	0%	3		university of lille
7	ryerson university	24,6	1	33	3	0%	0%	0%	0	26	
8	university of ontario institute of technology	20,9	1	52	2	100%	0%	0%	3		azarbaijan shahid madani university
9	university of guelph	14,3	1	63	1	0%	0%	0%	0	29,4	
10	**Grand Total**	**395,1**	**24**	**598**	**20**	**421%**	**0%**	**0%**	**22**		#N/A

Figure 27: Results display - institution ranking for an individual country



Ranking of institutions

The analysis takes into account the 500 most cited papers published in years 2014 to 2019.

Select input data for analysis

CSP

1. Select data from dropdown menu.
2. Use button to calculate results (macros need to be enabled!).
Calculation may need a couple of minutes.

Calculate

Ranking of institutions from Horizon 2020-countries

Institutions with strong collaboration outside of Horizon 2020 (exclusively EU collab <50%)

Rank	Institutes	Score	No Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively EU collaborations	No of Collaborating Institutes	THE Score Research	Country
1	universite libre de bruxelles	99,1	1	277	22,2	100%	0%	2		BEL
2	agh university of science and technology	98,8	1	748	7,6	0%	0%	0	13,5	POL
3	centre national de la recherche scientifique	97,1	11	90	2,5	73%	27%	10		FRA
4	katholieke universiteit leuven	95,1	3	131	4,3	100%	0%	6		BEL
5	gaziosmanpasa university	93,6	9	87	2,2	22%	0%	7		TUR
6	university of nottingham	91,4	5	93	2,4	60%	0%	11	42,6	GBR
7	royal institute of technology	89,6	5	77	3,0	80%	0%	6		SWE
8	loughborough university	88,8	1	317	3,5	0%	0%	0	34,3	GBR
9	university of barcelona	88,5	6	68	2,6	83%	17%	7	32,5	ESP
10	university of birmingham	87,6	5	77	2,6	80%	20%	10	45,6	GBR
11	german aerospace center	86,8	8	72	1,6	13%	0%	2		DEU
12	imperial college london	85,6	3	54	4,8	33%	0%	1	87,6	GBR
13	university of warwick	85,1	4	68	3,1	100%	0%	9	52,7	GBR
14	karadeniz technical university	84,8	3	106	2,4	100%	0%	8		TUR
15	malardalen university college	83,6	4	62	3,0	75%	25%	6		SWE
16	university of sheffield	82,2	1	203	3,3	100%	0%	1	46,4	GBR
17	luneburg university	81,3	2	93	3,5	0%	0%	0		DEU
18	marche polytechnic university	79,6	2	88	3,5	50%	0%	1	18,9	ITA
19	eth zurich	79,3	4	68	2,1	50%	25%	2	92,8	CHE
20	university of leeds	79,0	3	75	2,5	67%	0%	4	45,9	GBR

Institutions with strong collaboration within Horizon 2020 countries (exclusively EU collab >=50%)

Rank	Institutes	Score	No Publications	Average Citations per paper	Average SJR of Journals	%-Share of collaborations	%-Share of exclusively EU collaborations	No of Collaborating Institutes	THE Score Research	Country
1	university of toulouse	91,1	3	147	2,4	100%	67%	6		FRA
2	polytechnic university of turin	81,6	3	68	2,9	67%	67%	2	25,4	ITA
3	democritus university of thrace	68,7	1	123	3,5	100%	100%	1	11,6	GRC
4	enea	65,6	4	51	1,9	100%	75%	6		SWE
5	university of perugia	56,1	2	68	2,1	100%	100%	2	22,8	ITA
6	brunel university london	45,5	2	52	2,0	100%	50%	4	26,9	GBR
7	technical university of denmark	38,3	2	45	1,7	50%	50%	1	40,2	DNK
8	university of padua	37,5	2	46	1,6	50%	50%	3	30,9	ITA
9	university of castilla la mancha	34,0	1	70	1,9	100%	100%	2		ESP
10	university of western macedonia	30,3	2	65	1,0	50%	50%	1		GRC
11	university of the basque country	27,7	1	72	1,6	100%	100%	1	17,1	ESP
12	university of innsbruck	27,7	1	72	1,6	100%	100%	1	21,8	AUT
13	tunis university	15,1	1	33	2,7	100%	100%	1		TUN
14	university of porto	15,1	1	33	2,7	100%	100%	1	27,9	PRT
15	polytechnic university of catalonia	9,4	1	40	1,6	100%	100%	1	17,2	ESP
16	sapienza university of rome	8,0	1	39	1,6	100%	100%	3	40	ITA
17	university of trento	8,0	1	39	1,6	100%	100%	3	31,7	ITA
18	veolia environnement	2,8	1	52	0,9	100%	100%	1		FRA
19	aristotle university of thessaloniki	1,1	1	76	0,5	100%	100%	1	16,8	GRC
20	university of liege	0,8	1	58	0,6	100%	100%	1		BEL

Figure 28: Results display - institution ranking

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