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Monitoring R&I in Low-Carbon Energy Technologies

Methodology for the R&I indicators in the State of the Energy Union Report -2016 edition-

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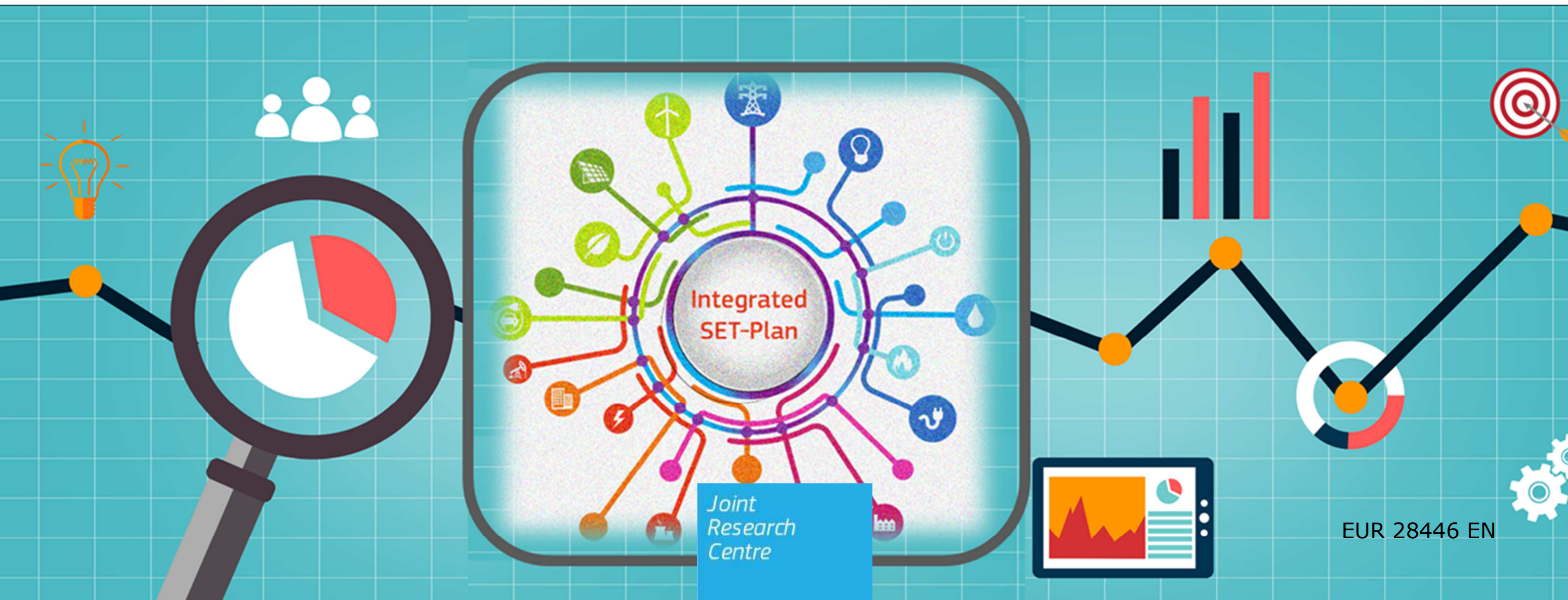

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Title Monitoring R&I in Low-Carbon Energy Technologies

Abstract
The report presents the methodologies that JRC/SETIS applies for the evaluation of selected key performance indicators measuring progress in research and innovation in Europe, and provides the necessary theoretical background to underpin the SETIS contributions to the State of the Energy Union reports. It addresses key conceptual and operational points that are important for the interpretation and use of these results in the policy debate, such as the timing of data availability, information sources, methodological caveats, or the level of disaggregation of reported results.

Contents

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Executive summary

The aim of this report is to present the methodologies that SETIS applies for the evaluation of selected key performance indicators (KPIs) used in the State of the Energy Union report to measure progress in research and innovation (R&I) in Europe and thus provide the necessary theoretical background to underpin the SETIS contributions to the same document.. This report addresses key conceptual and operational points that are important for the interpretation and use of these results in the policy debate, such as the timing of data availability, information sources, methodological caveats, or the level of disaggregation of reported results. The overall aim is to make the work of SETIS on these KPIs fully transparent, with regards to both data and methodology. This would allow stakeholders to review both the methodology used and the outcome, and also trigger feedback to the JRC that would lead to the further improvement of data collection, processing and evaluation mechanisms.

The main methodological points for the key indicators can be summarised as follows:

— **The technology coverage** follows the integrated SET Plan structure, showing the links between the Energy Union R&I and Competitiveness priorities, the SET Plan Integrated Roadmap and the 10 SET Plan actions.

— **Trends in patents**: The data source is PATSTAT, the Worldwide Patent Statistical Database created and maintained by the European Patent Office (EPO). A full dataset for a given year is completed with a 3.5-year delay; thus detailed data have a 4-year delay. Estimates with a 2-year lag are provided at EU28 level. The data specifically address advances in the area of low-carbon energy and climate mitigation technologies (Y02 scheme of the Cooperative Patent Classification). Datasets are processed in-house to eliminate errors and inconsistencies. Patent statistics are based on the priority date, simple patent families and fractional counts of submissions made both to national and international authorities to avoid multiple counting of patents.

— **Private R&I investments**: Data are estimated based on financial information from publicly available company statements and patent data from PATSTAT. As with patent data, complete data series have a 4-year delay. Estimates with a 2-year time lag are made at EU28 level.

— **Public (national) R&I investments**: The International Energy Agency (IEA) statistics are the main source of data. They address 20 of the EU Member States, but both the regularity of reporting and the granularity of technological detail vary. There is a 2-year time delay in reporting for most Member States. Data gaps are supplemented by the Member States through the SET Plan Steering Group and/or through targeted data mining. Additional estimates are provided based on the correlation of macroeconomic indicators such as GBAORD and/or GDP.

Policy context

The Communication 'Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European energy system transformation' called for a further strengthened SETIS, the information system that manages and operates the monitoring and reporting scheme of the SET Plan. SETIS supports the implementation and continuous development of the integrated SET Plan, through a more diligent and intelligent use of available information, data and reporting practices by stakeholders and Member States. In this context, the monitoring and reporting activities of SETIS support the following objectives:

— The Annual State of the Energy Union Report: SETIS monitors and reports on a number of key indicators that are used to measure progress in the implementation of the fifth dimension of the Energy Union, i.e. on research, innovation and competitiveness. Two of these indicators, identified in the Integrated SET Plan Communication are:

- the level of investment in R&I (both in the private and public sectors), and
- trends in patents.

— SET Plan implementation: SETIS will reports as necessary, addressing various aspects of SET Plan implementation, in agreement and collaboration with the Member States.

Related and future JRC work

The SETIS input to the Annual State of the Energy Union Report and the annual report "Energy R&I financing and patenting trends in the EU" in the context of the SET Plan are both outputs of the methodology presented here.

SETIS is constantly exploring options to improve the methodology and address any shortcomings in data quality and timeliness. Any significant methodological advancement will be communicated in subsequent revisions of the present document.

Quick guide

A short introduction sets the context for the work and presents the integrated SET Plan structure, showing the links between the Energy Union R&I and Competitiveness priorities, the SET Plan Integrated Roadmap and the 10 SET Plan key actions. In the following three sections that address methodological issues, the methodology on patent statistics is explained first, as it also forms the basis for the work on private investments described in the following chapter. The last methodological chapter describes the treatment of public R&I investment data. A summary of the main points is provided at the end of each methodological section. Finally, the Annexes provide a detailed breakdown of the input from PATSTAT and IEA in the form of concordance tables between the relevant statistical codes, the Energy Union R&I and Competitiveness priorities and the 10 SET Plan actions.

1 Introduction

The Energy Union framework strategy, COM(2015)80 (European Commission, 2015a), has called for an integrated governance and monitoring process to ensure that energy-related actions at all levels, from European to local, contribute to the Energy Union's objectives. This inter alia includes improved data collection, analysis and intelligence mechanisms that pool the relevant knowledge and make it easily accessible to all stakeholders; and an annual reporting on the state of the Energy Union to address key issues and steer the policy debate. Furthermore, in its Communication 'Towards an Integrated Strategic Energy technology (SET) Plan: Accelerating the European energy system transformation', C(2015)6317 (European Commission, 2015b), the European Commission proposed to develop a set of key performance indicators (KPIs) in order to measure progress in research and innovation (R&I) in Europe. This task was assigned to SETIS, the Strategic Energy Technologies Information System. SETIS manages and operates the monitoring and reporting scheme that supports the implementation and continuous development of the Strategic Energy Technology Plan (SET Plan), through a more diligent and intelligent use of available information, data and reporting practices by stakeholders and Member States.

In this context, SETIS monitors and reports two relevant KPIs that have been identified in the Integrated SET Plan Communication and have been included in the first State of the Energy Union report in 2015, SWD(2015)243 (European Commission, 2015c):

— the level of investment in R&I in terms of both private (expenditure by businesses and industry) and public (Member States' national programmes and instruments)

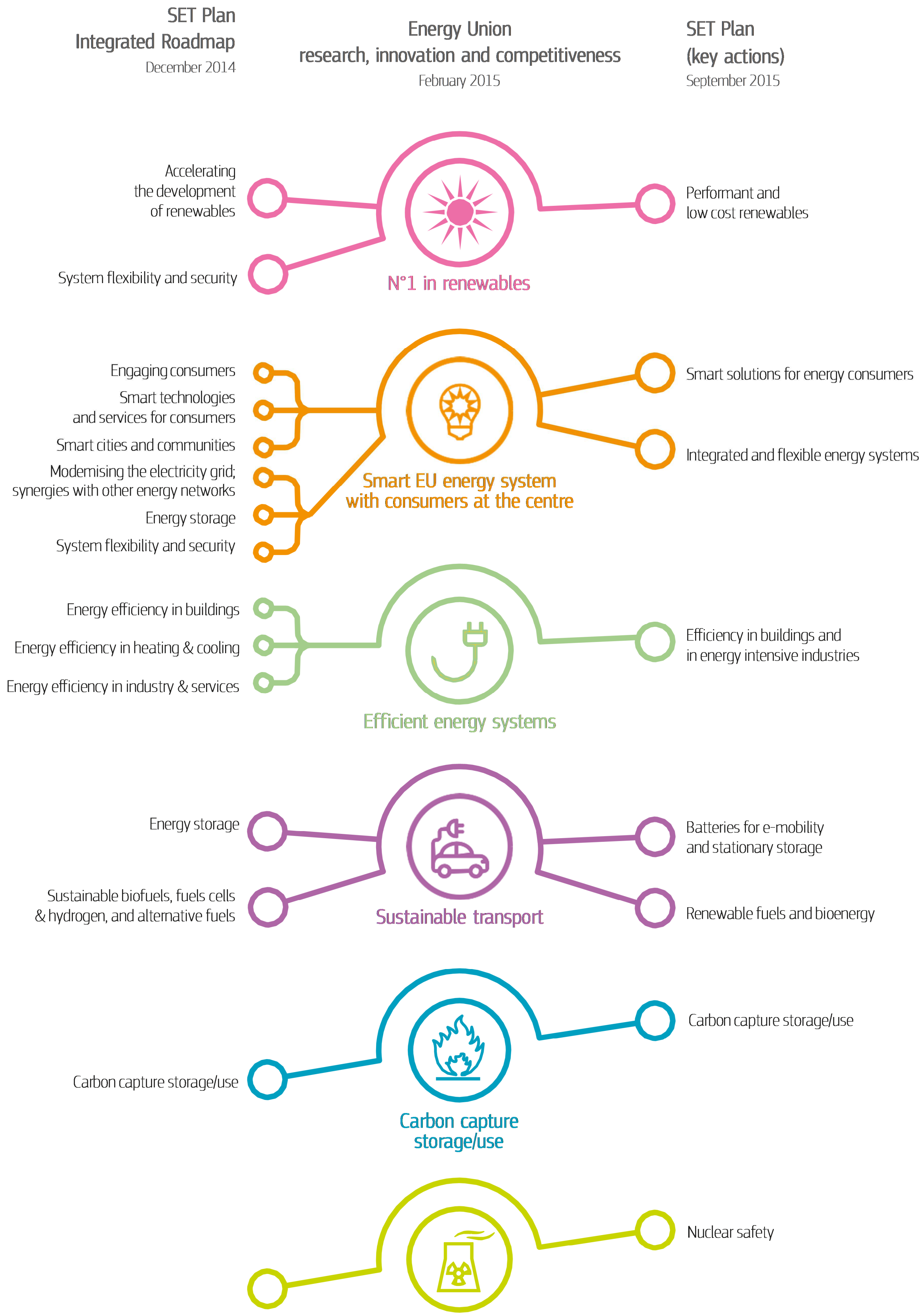
— trends in patents

The aim of this report is to present the scientific methodologies, based on JRC work (Fiorini et al., 2016; Wiesenthal et al., 2012), that SETIS applies for the evaluation of the two KPIs listed above, and provide the necessary theoretical background to underpin the SETIS contributions to the State of the Energy Union reports. This report addresses key conceptual and operational points that are important for the interpretation and use of these results in the policy debate, such as the timing of data availability, information sources, methodological caveats, or the level of disaggregation of reported results. The aim is to make the work of SETIS on these KPIs transparent, with regards to both data and methodology. This will allow stakeholders to review both the outcome and the methodology used, and trigger feedback to the JRC for the further improvement of data collection, processing and evaluation mechanisms.

1.1 Levels of reporting - the integrated SET Plan structure

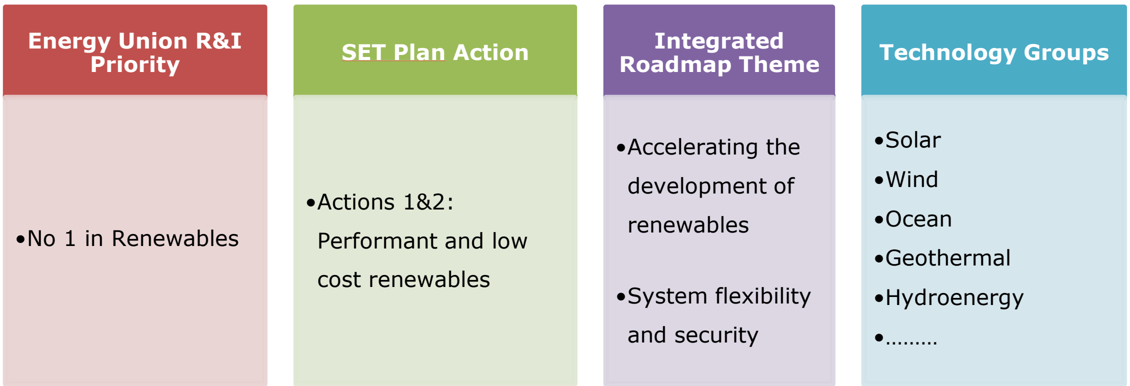
Figure 1 shows a representation of the integrated SET Plan structure, and in particular the links between (i) the Energy Union R&I and Competitiveness priorities, (ii) the SET Plan Integrated Roadmap, and (iii) the 10 SET Plan actions. These links define the levels of reporting addressed by SETIS and thus set the requirements for data granularity.

Further to the level of technological resolution shown in Figure 1, on certain topics, such as renewable energy, it is of interest to extend the analysis further to individual technology groups as shown in Figure 2. An overview of the topics included under each of the Energy Union R&I and Competitiveness priorities is given in Table 1. The detailed concordance between the data sources used and these topics is provided in the respective chapters and Annexes. In order to maintain highest possible degree of transparency, SETIS relies on data that is publicly available and thus traceable. However, the granularity and structure of this data has been defined at an earlier date, to serve a different purpose, and is thus not designed to be fully aligned with the Energy Union R&I and Competitiveness priorities and SET Plan actions. As a result it does not always allow optimal allocation of topics as described in Figure 1 and Table 1. SETIS is working with main data sources, such as the International Energy Agency (IEA) and the European Patent Office (EPO) to address these issues and ensure continuous data validation.



Source: European Commissio (2016a)

Figure 1: The Integrated SET Plan Structure, representing the links between the Energy Union R&I and Competitiveness priorities, the SET Plan Integrated Roadmap and the 10 SET Plan actions.



Source: JRC

Figure 2: Example of technology aggregation levels relevant for reporting according to the different tasks fulfilled by SETIS. For renewables there is further disaggregation by technology.

Table 1: Overview of topics within the Energy Union R&I and Competitiveness priorities, produced by SETIS. This allocation is applied to the extent made possible by the structure and granularity of publicly available data. A more detailed description of topics is provided in Annexes 1&2.

Energy Union R&I priority	**Contents**
No1 in Renewables	Solar energy (photovoltaics, solar heating and cooling, concentrated solar power); wind energy, ocean energy (tidal, wave, salinity gradient power); geothermal energy; hydroelectricity
Smart system - Smart EU energy system with consumers at the centre	Residential and commercial building appliances and equipment; energy management systems (incl. smart meters) and ICT; lighting technologies and control systems; heating, cooling and ventilation technologies; electric power generation; combustion technologies, coal, oil and gas; electricity transmission and distribution; grid communication, control systems and integration; energy storage (non-transport applications); batteries and other stationary electrochemical storage (excl. vehicles); thermal, electromagnetic and mechanical storage; energy system analysis.
Efficient energy systems	Residential and commercial building design and envelope; building integration of renewables; waste heat recovery and utilisation; heat pumps and chillers; industrial techniques and processes, equipment and systems for energy efficiency.
Sustainable transport	Biofuel production and use; hydrogen technology and fuel cell technology; vehicle batteries/storage technologies; advanced power electronics; motors and EV/HEV/FCV systems and combustion engines; electric vehicle infrastructure.
CCUS	CO2 capture, transport, utilisation and storage
Nuclear safety	Nuclear fission reactors, fuel cycle, waste management, plant safety and integrity, environmental protection, decommissioning. Nuclear fusion.

Source: JRC

The report is structured as follows: The methodology on patent trends is explained first (section 2), as it also forms the basis for the work on private investments described in section 3. The last section describes the treatment of public R&I investment data. A summary of the main points is provided at the end of each methodological section. Finally, the Annexes provide a detailed breakdown of the input from PATSTAT and IEA in the form of concordance tables between the relevant statistical codes, the Energy Union R&I and Competitiveness priorities and the 10 SET Plan actions.

2 Patents as an indicator of Research & Innovation

Patent statistics is one of the indicators widely used to assess technological progress. As defined by the OECD Patent Statistics Manual, "patents are means of protecting inventions developed by firms, institutions or individuals, and as such they may be interpreted as indicators of invention" (OECD, 2009). However, patent data are complex and their use as proxy of innovation and technological progress is widely debated among the scientific community between opponents and advocates (OECD, 2009; Watanabe et al., 2001; Desrochers, 1998).

The caveat to using patent statistics as an indicator is that careful consideration and interpretation of the data is needed. Inventors might decide, for instance, not to patent, but to use secrecy, alliances or short lead times to gain a competitive advantage depending on their innovation strategy. The propensity to patent differs across countries and industries and the different standards applied across patent offices and their evolution over time can affect patent statistics (OECD, 2009). In addition, the statistical distribution of patents can frequently be skewed and exhibit peculiar properties as many patents have no industrial application while a certain few can have high technical and economic value. Furthermore, patent applicants do not necessarily retain patent ownership, subsequent to the application or grant of the patent.

On the other hand, constructing indicators from patent data has a number of advantages. As patents protect invention, patent statistics can be used as proxy for inventive performance, despite the fact that the relationship between the two is not a simple one. Moreover, large scale patent databases are broadly available at relatively low cost, which allows interested parties to easily access and analyse patent data, and verify related studies. For example, PATSTAT, the Worldwide Patents Database managed by the European Patent Office, provides access to patent document statistics containing information on the technological context of the invention, geographical location of the applicants, inventors, etc. Such information can be used, for example, to track the diffusion of knowledge, inventor's mobility and networks, alliances between firms, etc. Thus, patent data represent a very rich set of information, suitable to perform extensive and transparent analysis, since they are "commensurable", "quantitative" and "widely available" (Haščič and Moigotto, 2015).

Patenting activity has also been studied as a measure of the intermediate output in the R&I process (Hausman et al., 1984). In this context, this indicator displays a so-called lag structure (Wang and Hagedoorn, 2012), which means that current patenting activity is better explained by recent R&I effort rather than older R&I activity, exhibiting knowledge depreciation over time (Hall et al., 1986). Finally, more R&I investment does not result in more patents, but rather leads to higher quality of inventions (Ernst, 1998).

In constructing indicators on patenting activity and trends in the context of the State of the Energy Union report and the SET Plan, the following points are of importance:

— **Capturing all activities** and not only those deemed worth of protection at the international level. This requires statistics for fillings from national patent offices, as well as the EPO and other international routes of protection.

— **Monitoring inventions not document fillings** through a consistent grouping of documents, indicating whether they relate to the same invention (e.g. supplementary documents or a filing under a different authority), so that there is no multiple counting of the same R&I effort.

— **Relevance to the Energy Union R&I priorities**, the SET Plan Actions and the technological areas, indicated by a detailed and consistent classification of the technical aspects of patents so that they can be allocated to the respective topic.

— **Location of the R&I effort** through information on the country of the applicants, as an indication of the geographical distribution of the R&I effort and the provenance of the funding that supports it.

Existing statistical datasets by OECD and Eurostat address some of the above requirements, but not to the extent required for the needs of SETIS. The main drawbacks have been the coarse level of aggregation in terms of technological detail; the difference in approach concerning coverage of patenting at national level; and working with the concept of inventions (collections of documents) rather than patent applications.

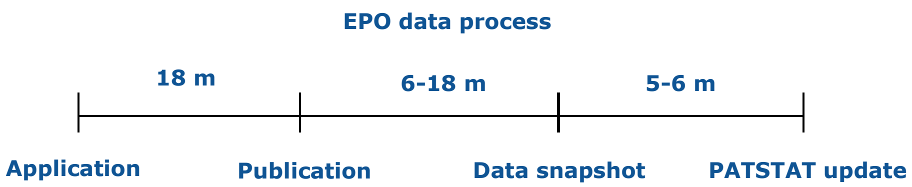
To accommodate the analytical needs underpinning the SETIS work on patenting trends, a bottom-up approach based on detailed raw data has been devised, described in detail in the following sections. As in the case of the Eurostat and OECD datasets, the source data comes from PATSTAT, which provides access to bulk data from a large number of statistical authorities, in a format that can be exported, processed and queried in depth. To address the points raised above, SETIS extracts data on patent applications and their relationships; the applicants and their country of origin; and the coding indicating technological relevance; from all national and international authorities as recorded in the latest PATSTAT release available. Details on the data processing and analysis are provided in the following section.

2.1 Data sourcing (PATSTAT) and management

The European Patent Office (EPO), upon request of the Patent Statistics Task Force led by the Organisation for Economic Co-operation and Development (OECD), has created the "Worldwide Patent Statistical Database", often addressed by its abbreviation PATSTAT. The EPO maintains a database called DOCDB (also known as Patent Information Resource) covering over 90 countries. These include the EU Member States and other European countries as well as the other major investors in energy, such as the USA, Japan, China, Korea, Canada, Australia etc. This statistical database is a 'snapshot' of the source databases of all the contributing patent authorities at a specific point in time (EPO, 2016a).

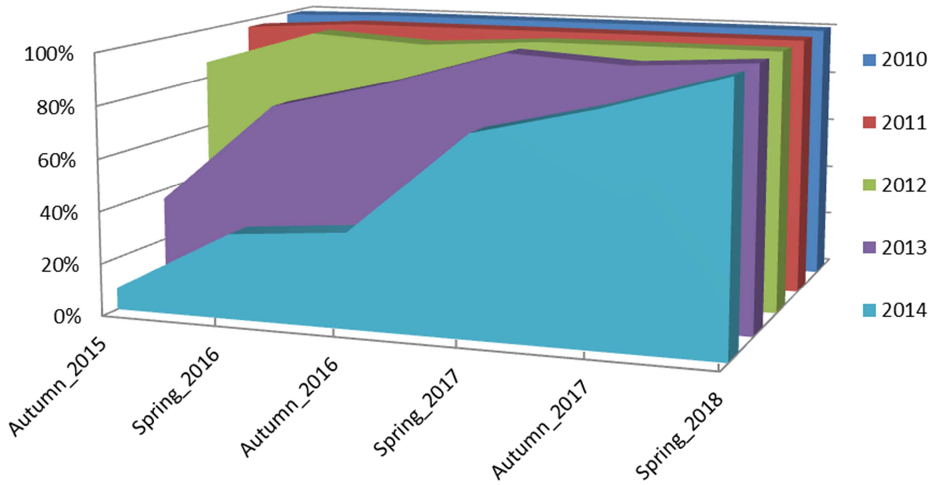
Data is updated twice a year in the so-called Spring- and Autumn-Editions. Typically, the date of data extraction from the source patent office databases is end of January for the Spring Edition and end of July for the Autumn Edition. There is a significant time delay between the filling of an application and its publication in the statistical patent data, which is due both to the time required to process and publish applications and to the time required by EPO to process all the datasets from the reporting national authorities. Figure 3 shows the indicative lead time between a patent filing and the availability of the data in PATSTAT.

Recent experience has shown that this time delay is approximately 3.5 years (EPO, 2016b). This means that the PATSTAT Spring 2016 Edition contains a near complete dataset for 2012, around 75% of the expected 2013 data (estimated on the basis of the availability of data observed on previous Spring and Autumn Editions of the database) and approximately 30% of the data expected for 2014. Figure 4 shows a schematic representation of the JRC estimates of expected lead times for the completion of data on each year.



Source: JRC

Figure 3: Indicative lead time between a patent application being filed, published and recorder in PATSTAT.



Source: JRC

Figure 4: Empirical JRC estimate of data availability in PATSTAT based on the contents of previous releases.

In consultation with the EPO Academy (EPO, 2015a), the JRC concluded that:

— PATSTAT (and in particular the DOCDB database) is, at present, the most appropriate source of data for the SETIS analysis on the KPIs;

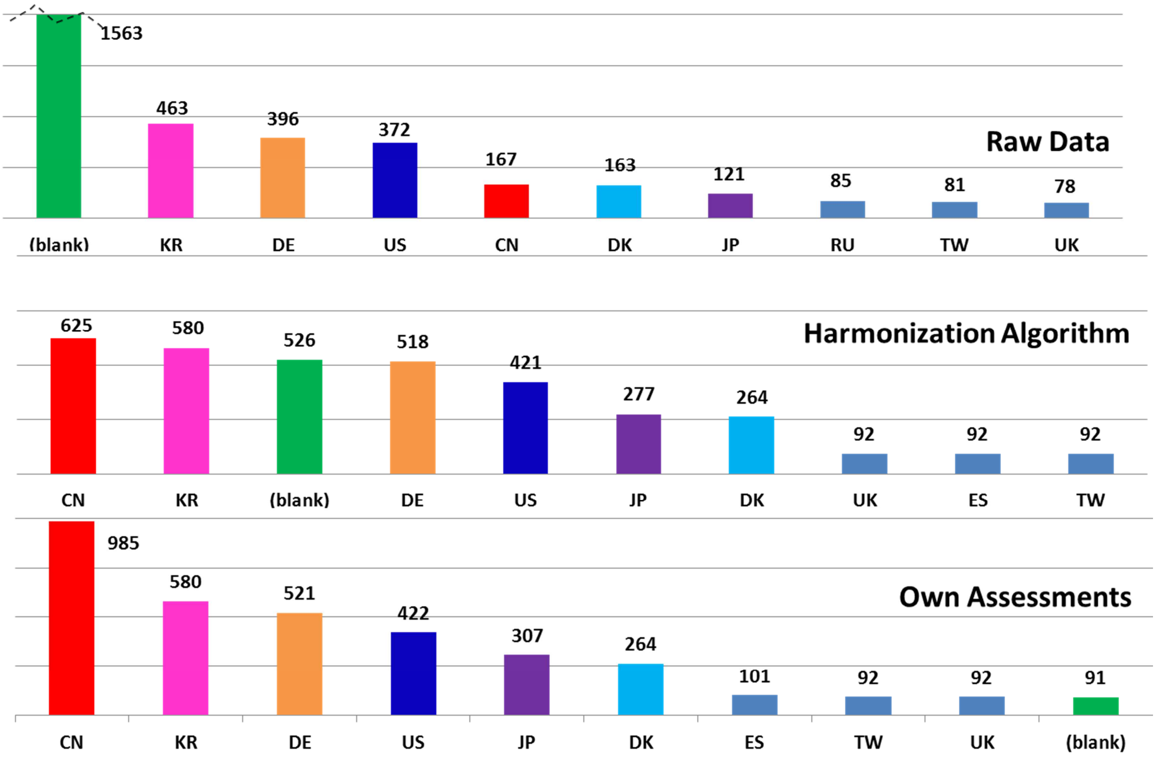
— The lead time cannot be reduced by sourcing data elsewhere (e.g. national offices), as it would entail replicating the EPO work cycle.

The PATSTAT database is maintained by the EPO and contains data provided on a voluntary basis by national and supranational patent authorities. However, there is a caveat with regards to data quality, which is strictly the responsibility of the reporting office, as the EPO does not carry out a subsequent quality control. Both the time of reporting and the volume (fraction of total) of data which the national patent authorities report, as well as the amount of editing and restructuring of previously reported data that may have occurred between each update, is random. This means that there is limited confidence in projections based on incomplete datasets; it also means that if significant 'clean-up' or 'reclassification' exercises take place at a given point in time, either in a national office or in the EPO, this may have retroactive effects on the results of previous analyses or time series.

There is a significant variation in the quality and completeness of the data, as extracted from PATSTAT, relating to the provision of country codes, consistency in the names of entities, spelling errors etc. Before the statistical analysis, the data extracted from PATSTAT need to go through a harmonisation check to eliminate such errors and inconsistencies to the extent possible. This is a necessary, critical step of the process as these issues affect a large share of the data and can thus have a significant impact on the resulting trends.

For example, in the Autumn 2015 Edition, 40% of the applicant companies related to patents in the area of wind energy technologies had no country code associated with them. After data treatment to assign the missing country codes, twice as many companies were assigned to Japan and six times as many to China compared to the original dataset (see Figure 5). Data quality issues are more prevalent for applications and entities originating from non-EU patent authorities. Nonetheless, as seen in Figure 5, the process also has a significant effect on the data for EU Member States. Furthermore, a corrected complete dataset is essential in order to develop an understanding of the EU competitiveness vis-a-vis international trade partners.

To minimise the effect of these shortcomings, similarly to other existing work (Peeters et al., 2009; Magerman et al., 2009; Du Plessis et al., 2009), the JRC carries out the data harmonisation exercise using algorithms and own assessments. This is a time consuming process that has to be repeated every time a new PATSTAT Edition becomes available, i.e. twice a year.



Source: JRC

Figure 5: Indicative example of the effect of data harmonisation on statistics for the top patenting countries in the field of wind energy. (blank) entities are missing country codes. Processing, assigns six times as many entities to China; also having a significant effect on other countries.

In conclusion, although the best resource readily available, PATSTAT has some shortcomings and inconsistencies that – if raw data is used as extracted – can lead to erroneous results. Post-processing of data by the JRC provides a corrected dataset, which is suitable for the analysis of patent trends in the context of SETIS.

2.2 Avoiding double counts: application authority, priority date and patent families

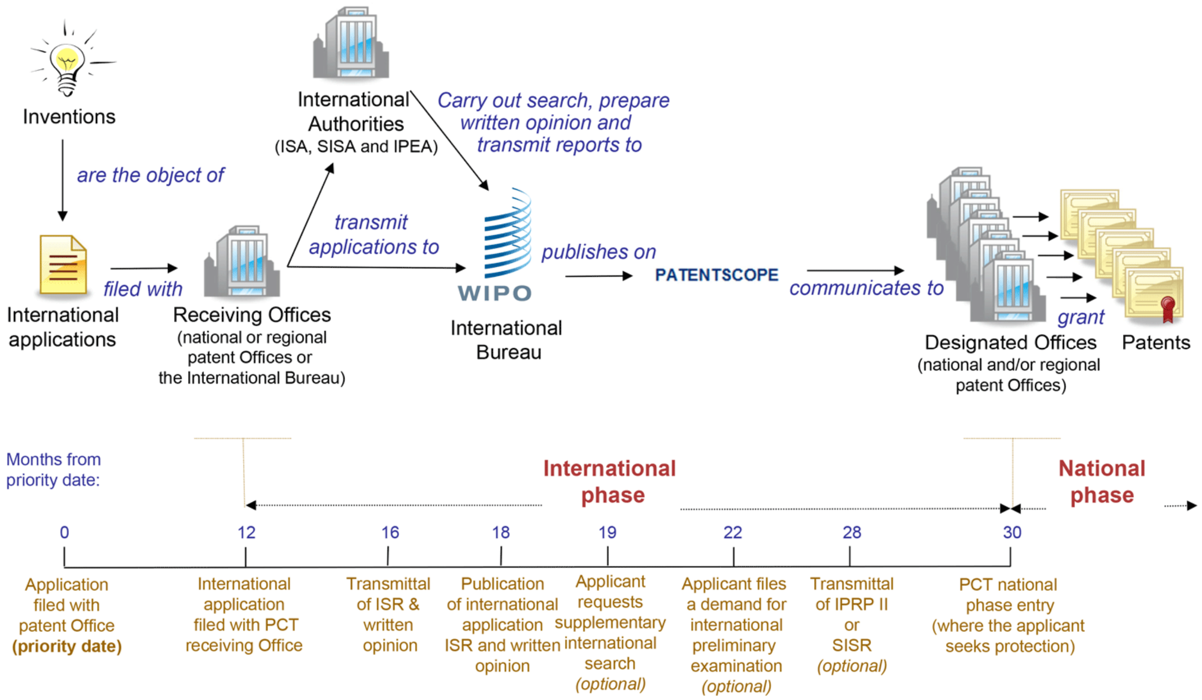
The use of indicators based on patents requires the development of a methodology on data extraction, processing and interpretation. This methodology defines the main patent parameters to be considered based on the needs of the analysis i.e. the question that needs to be answered and on the best available solution for the creation of robust indicators. The main methodological choices to be made concern the statistical population, the reference date, the reference country or authority, and the use or not of fractional counts and patent families. Discussion of these issues requires a general understanding of the patenting process; thus some essential background information is provided early in this section, leading to the explanation of the rationale and choices behind the SETIS methodology.

Different routes for the protection of an invention, via patenting, can be followed to suit the strategy adopted by the inventor/applicant. Depending on the choice of process, patenting time and costs will be different. The protection (OECD, 2009) can be granted through:

— The National route. A direct application to the National Patent Office where protection is requested;

— The Regional route. A single application to a regional patent office can extend the protection across a set of member countries. In case of the European Patent Office (EPO), the protection can be guaranteed in up to 38 countries;

— The International route, under the Patent Cooperation Treaty (PCT) legal framework. In this case, the application first goes through an international phase – lasting between 18 and 30 months – and is subsequently granted in a national phase (see Figure 6).



Source: WIPO (2015)

Figure 6: Overview of the international route for invention protection.

To protect an invention, inventors/applicants usually undertake the national route, because of the geographical proximity to the place of invention. Subsequently, based on the expectation of future commercialisation and market penetration, they can decide to widen the protection to other countries. The regional route reduces these consecutive procedures to a single one. Alternatively, the international route can be selected, whereby after the first filing, the applicant can proceed to the so-called "National phase" and claim protection for the same invention through an application in other countries, based on the same priority date. The latter rule is applied based on the Paris Convention for the Protection of Industrial Property (WIPO, 1983; Dernis, 2004).

Therefore, an invention can be protected in one country or several. Additionally, one invention can have more than one inventor and/or applicant located in different countries, and can be marked as applicable or relevant to one or more technological areas. These characteristics can result in "multiple counting" when attributing patents to one company, technological area, or country as the simple count of patents might not be representative of the research effort, but rather the result of the business strategy of the inventor/applicant. In other terms, multiple distinct patent applications may refer to one single invention.

Multiple counting can be avoided by:

- Using priority date instead of application date
- Using patent 'families'.
- Applying fractional instead of absolute counts – i.e. attributing an equal share of the invention to each applicant and/or technological area;

These approaches are described below:

The priority date is the date of the first filing for a certain patent. It is therefore the closest date to the R&I activity and invention. The priority date is particularly important in order to set the "rights of priority" defined by the Paris Convention for the Protection of Industrial Property (WIPO, 1983). For example, it is possible to modify the basic patent within the first year after application (priority year) and have an additional priority date assigned to the patent document. The very first claimed document sets the so-called "earliest priority date". Also, "continuation applications" may claim priority to an earlier filed parent application. To avoid multiple counting in these cases, analytical approaches (Moed et al., 2005) suggest the choice of the first priority date as the reference date. This first priority date is also considered by the methodology followed by the JRC. This leads to the use of the patent 'family' concept instead of the patent application as statistical unit, by establishing a connection between a distinct invention and all documents referring to it.

Patent families are groups of patent applications, typically filed in different countries, which are related to each other by one or several common priority dates. The consideration of the group of patents as protecting the same invention will depend on the definition of the family. The use of patent families comes with certain caveats, as there is no guarantee that all the corresponding patent documents will be present within the current databases and there are different types of patent families (simple patent family, extended patent family triadic family, etc.) depending on the methodology adopted (EPO, 2016c). Nonetheless, the use of patent families is preferable when the focus of the analysis is on "inventive activity", as they avoid multiple counting, improve the international comparability and eliminate "home country advantage" and the influence of geographical location (Dernis, 2004).

Patent families, rather than patent applications, are considered by the JRC when using patenting activity as a proxy for innovation output, as the focus is on monitoring inventions and not individual documents. This approach is also preferable when the aim is to establish a connection between R&I spending and innovation output.

Fractional rather than simple counts rule out multiple counting of patents during statistical analysis by attributing an "equal fraction of a patent" to each applicant/inventor. Fractional counting is applied in the JRC methodology to attribute a part of a patent family to each of the applicants. The same approach is used for the attribution to more than one technological area.

The methodological approach adopted by the JRC is consistent with the practices widely adopted for the construction of patent statistics. For example, the OECD analysis on patent statistics by country and technology is based on the following (OECD, 2015):

- Statistical population: Triadic patent families, which group patents filed at the European Patent Office, the United States Patent and Trademark Office (USPTO) and the Japan Patent Office for the same invention;
- Priority date as reference date;
- Reference country: inventor's country and/or applicant's country;
- Fractional counting.

In summary, for the purpose of measuring technological innovation and R&I investments, the JRC uses the priority date, simple patent families and fractional counts, based on submissions made both to national and international authorities. SETIS has been consulting with the EPO Academy (EPO, 2015a) and will continue to seek collaboration and advice for the further development of the methodology.

2.3 The CPC classification

The attribution of patents to technological areas of interest can be done through specific classification codes. Several classification systems exist, which are constantly evolving to keep up with technology innovation and ensure a measure of compatibility between them. The Cooperative Patent Classification (CPC) (EPO and USPTO, 2016) system is the result of a joint effort by EPO and USPTO to develop a common, international classification system for technical documents. The first "launch scheme" was released on January 2013. This system is based on the International Patent Classification (IPC) (EPO and USPTO, 2016) and includes three classifications: European Classification System (ECLA), In Computer Only (ICO) and United States Patent Classification (USPC). Therefore, CPC widens the scope of pre-existing systems; it contains approximately 250000 classes, compared to approximately 70000 in IPC.

The use of the IPC, with or without keywords, is broadly employed in patent studies for the definition of a technological area. This approach is not suitable for assessing innovation trends in low-carbon energy technologies in the context of SETIS, for two main reasons:

— Patents relating to low-carbon energy technologies may not fall under a single section or code of the classification or may not be exclusively included in one; this might lead to the inclusion of false positives as well as the exclusion of false negatives;

— Emerging low-carbon energy technologies are developing very quickly and with relevance to several other technological fields, which can lead to them being coded independently along several classification sections. These technologies may not be captured by IPC-based queries (Montecchi et al., 2013; Veefkind et al., 2012).

The issues mentioned above are not only relevant to the SETIS work, but to all researchers dealing with low-carbon, sustainable and climate change mitigation technologies. As social and policy interest in these fields of research increased, the EPO, in close co-operation with expert partners in the field, developed a dedicated document tagging scheme which enables users to find these technologies in its databases (Hurtado-Albir et al., 2016; Veefkind et al., 2010). This is an additional class used in parallel with the historical IPC and corresponding CPC classes; it addresses specifically clean energy and climate change mitigation technologies. Each time a document relating to a climate change mitigation technology is added to its databases, the EPO now assigns it the code Y02.

An example provided by EPO (Veefkind et al., 2010) and illustrated in Figure 7 shows how the introduction of the Y codes improves the identification of patents relevant to climate change mitigation technologies by reducing the “noise” in any given dataset:

— Capture of greenhouse gases and especially CO2 is not specifically treated in “conventional” classes.

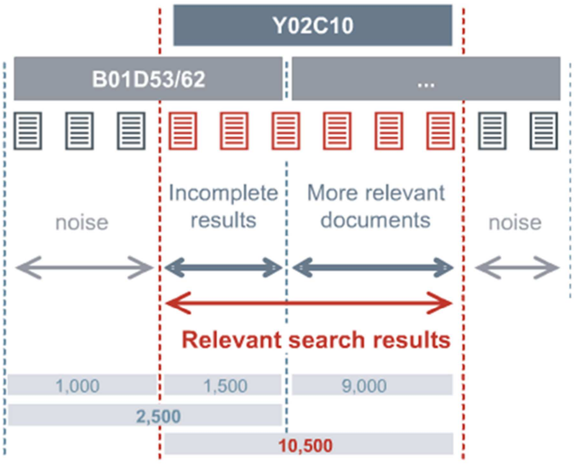
— the closest IPC and ECLA entry is B01D53/62: Separation of gases or vapours - Recovering vapours of volatile solvents from gases - Chemical or biological purification of waste gases - Carbon Oxides.

— In practice, this is not very helpful in retrieving documents on CO2 capture because:

- it relates only to chemical and biological purification and does not include other commonly used separation techniques such as sorption or condensation;
- it relates to carbon oxides in general, which also include carbon monoxide (CO) (CO is a useful, yet highly poisonous substance, thus good separation/removal technologies are important for many industrial sectors);

— The B01D53/62 entry contains many documents relating to CO capture, rather than CO_2 capture.

— Y02C 10 (Capture, storage, sequestration or disposal of greenhouse gases - CO_2 capture or storage) however contains entries directly relating to CO_2 capture characterised by the method of capture or storage.



Source: EPO (2013)

Figure 7: Representation of the selection of relevant data based on the Y02 scheme of the CPC, and the reduction of false positives/negatives versus the use of "conventional" IPC (or CPC) codes.

The use of the Y02 scheme offers the possibility to better monitor the patents related to energy technologies as a result of document tagging performed by expert patent examiners, identifying "…new technological developments; … cross-sectional technologies spanning over several sections of the IPC " (EPO, 2013). Apart from the manual classification, the tagging activity is formalised into algorithms that can be re-run periodically to update the classes. In essence, a patent examiner adds a Y code to the existing technical classification to indicate the energy technology the patent is relevant to.

It follows that the CPC Y02 class and sub-classes are the most appropriate filter for the purpose of monitoring technological progress in low-carbon energy technologies in the context of SETIS. An overview of the main CPC codes used to retrieve patent statistics from PATSTAT as allocated under each Energy Union R&I Priority and SET-Plan Action is shown in Table 2. A detailed list of the CPC Y02 codes that are relevant to the assessment of patent trends along the Energy Union Research Innovation and Competitiveness priorities and the SET Plan Actions is included in Annex 1. The concordance developed between these codes and the different levels of technological groups used for reporting purposes in the State of the Energy Union and SET-Plan reports is also provided therein. The list only includes descriptions to a certain level of detail. For the full description of the codes and the Y02 scheme in general, the original CPC classification should be consulted (EPO and USPTO, 2016).

It is important to stress that it is a challenge to adapt the CPC Y02 scheme to an ever progressing state of art, as technology development advances. Thus, the definition of codes is a work in progress and new types of classifications will arise as new inventions are examined. Consequently, the Y02 section codes are subject to a periodic revision in order to cover all novelties and update the technological state of the art. As a result, a constant reclassification of the documents is in process, which could potentially have an effect on the consistency and reproducibility of time series based on subsequent database versions.

Table 2: Overview of CPC Y02 codes as allocated under each Energy Union R&I Priority and SET Plan action. Codes are given at the first level of detail and may be split along more than one priority or action at a lower level, thus they appear twice in the table below as a main heading. A more detailed breakdown of the codes by topic is provided in Annex 1.

NO 1 IN RENEWABLES	
Actions 1 &2: Performant, low cost renewables	
Y02E 10/ Energy generation through renewable energy sources	
CONSUMERS AND THE ENERGY SYSTEM	
Action 3: Smart solutions for consumers	**Action 4: Integrated and flexible energy systems**
Y02B 20/ Enenrgy efficient lighting technologies Y02B 30/ Energy Efficient HVAC Y02B 40/ Energy efficiency of home appliances Y02B 50/ Energy efficiency of elevators, escalators etc Y02B 60/ ICT for reduction of own-energy use Y02B 70/ Efficient end-user power management Y02B 90/ Enabling applications (network / meters) Y04S 20/ Supporting systems for end-user control	Y02E 20/ Combustion technologies with mitigation Y02E 40/ Efficient power generation / transmission Y02E 60/ Enabling technologies (energy storage) Y02E 70/ Energy conversion or management systems Y04S 10/ Support for power generation / transmission Y04S 40/ ICT for power generation / transmission
EFFICIENT ENERGY SYSTEMS	
Action 5: Energy efficiency in buildings	**Action 6: Energy efficiency in industry**
Y02B 10/ Integration of renewable energy in buildings Y02B 30/ Energy Efficient HVAC Y02B 80/ Thermal performance of buildings	Y02E 20/ Combustion technologies with mitigation Y02P 10/ Technologies for metal processing Y02P 20/ Technologies for chemical industry Y02P 30/ Technologies for oil refining/petrochemicals Y02P 40/ Technologies for processing minerals Y02P 60/ Technologies for agroalimentary industry Y02P 70/ Production of industrial or consumer goods Y02P 80/ Sector-wide applications Y02P 90/ Enabling technologies
SUSTAINABLE TRANSPORT	
Action 7: Batteries and e-mobility	**Action 8: Renewable fuels**
Y02E 60/ Enabling technologies (battery technology) Y02T 10/ Road transport of goods or passengers Y02T 30/ Transport of goods or passengers by railway Y02T 50/ Aeronautics or air transport Y02T 90/ Enabling technologies (e-vehicle charging) Y02W 30/ Waste management (battery recycling)	Y02B 90/ Enabling technologies (fuel cells) Y02E 50/ Fuel of non-fossil origin Y02E 60/ Enabling technologies (hydrogen/fuel cells) Y02E 70/ Energy conversion/management systems Y02T 10/ Road transport of goods or passengers Y02T 50/ Aeronautics or air transport Y02T 90/ Enabling technologies (hydrogen/fuel cells) Y02W 30/ Waste management (fuel cell recycling)
CARBON CAPTURE UTILISATION AND STORAGE	
Action 9: Carbon capture, utilisation and storage	
Y02C 10/ CO2 capture or storage Y02E 20/ Combustion technologies with mitigation Y02P 10/ Technologies for metal processing Y02P 20/ Technologies for chemical industry	Y02P 30/ Technologies for oil refining/petrochemicals Y02P 40/ Technologies for processing minerals Y02P 90/ Enabling technologies (enhanced oil recovery)
NUCLEAR SAFETY	
Action 10: Nuclear safety	
Y02E 30/ Energy generation of nuclear origin	Y02W 30/ Waste management - Nuclear fuel

Source: JRC based on EPO & USPTO (2016)

Box 1. Summary of methodological choices in the construction of the patent dataset

MAIN METHODOLOGY POINTS:

— Relevance to low-carbon energy technologies is based on the CPC Y02 classification

— The priority date is used as reference as it is considered the closest to the invention date

— The location of the applicants is assumed as the location of the R&I effort

— Simple patent families rather than patent applications are considered, to avoid multiple counts of distinct inventions

— Fractional counting is applied for patent families, which have more than one applicant and/or which are tagged with more than one technological field of relevance.

RESULTING DATASET:

Number of patent families (fractional count) per entity and technological area by priority year

2.4 Estimates

The use of estimates is employed to provide an extension of the time series to recent years, in anticipation of complete datasets and thus facilitate the policy making process overcome the hurdle of time-lags in the statistical process. Nonetheless, due to the uncertainties outlined in section 2.1, these can only be carried out at high level of aggregation.

Estimates for patent trends are only carried out at the level of EU28 and major trading partners. The volume and quality of data available for the most recent years, which are partially complete, does not allow for reliable projections at the individual Member State level. The estimates are produced for the two years following the last complete dataset e.g. in year 2016 (last near complete dataset refers to 2012) estimates are generated for the years 2013 and 2014. These are based on the average of the yearly rate of change for the last three complete periods available (e.g. 2009-10; 2010-11; 2011-12). Estimates are calculated at technology level and then summed up at Action or Energy Union R&I Priority level.

All estimates generated for the monitoring and reporting tasks of SETIS, are explicitly marked as such, and the difference from statistical data is clearly indicated.

Box 2. Summary of the SETIS methodology for patent statistics

DATA SOURCE:

PATSTAT, the Worldwide Patents Database managed by the European Patent Office.

DATA QUALITY & MANAGEMENT

Data quality lies with the (supra-)national reporting patent office. EPO does not perform subsequent quality controls. As a result, there is significant variation in the quality and completeness of the data, as extracted from PATSTAT, relating to the provision of country codes, consistency in the names of entities, spelling errors etc. Data extracted from PATSTAT undergo harmonisation check by the JRC to eliminate such errors and inconsistencies to the extent possible.

DATA TIME LAG

PATSTAT is updated twice a year, during spring and autumn. There is a 3.5 year delay in data availability due to the application process and the time required by EPO to integrate datasets from reporting national authorities. It is estimated that the PATSTAT Spring 2016 Edition contains a near complete dataset for 2012, and around 75% and 30% of the expected data for 2013 and 2014 respectively. This implies a 4 year time lag for the SETIS analysis, reduced to 3 years for partial data.

Both the time of reporting and the amount of data reported, edited and restructured by patent offices between PATSTAT updates is random. This means that there is limited confidence in projections based on incomplete datasets.

Estimates can only be provided at a high level of aggregation using the average rate of change for the last three years of complete datasets, extending the available time series for a further 2 years.

Occasional 'clean-up' or 'reclassification' exercises in a national patent office or in EPO, can have retroactive effects on the results of previous analyses or time series.

SETIS APPROACH

Raw data are extracted from PATSTAT using the Y02 scheme of the Cooperative Patent Classification (CPC). This scheme specifically addresses advances in the area of climate mitigation technologies.

A concordance between Energy Union R&I priorities, SET Plan Actions, technology themes and CPC Y02 codes has been developed by the JRC for this purpose (see Annex 1).

PATSTAT dataset extracts go through data harmonisation to eliminate errors and inconsistencies; this is a laborious process that is repeated every time new data becomes available, i.e. twice a year.

Patent statistics are based on the priority date, simple patent families and fractional counts of submissions made both to national and international authorities.

INDICATIVE OUTPUT

— Patenting trends (time series) per Energy Union R&I priority, SET Plan action or technology group for the EU, Member states and major international trading partners

— Number of patents normalised by population or GDP.

3 Private investment in Research and Innovation

Private R&I investments in the context of this report, refer to expenditure made by industry and businesses on R&I programmes. Private R&I efforts play a key role in the innovation process, however, few studies have addressed R&I investments by industry in the field of energy technologies, either from a methodological or from data collection and analysis perspective. This can be attributed to both the lack of mandate to do so, but more importantly to the lack of appropriate and readily accessible data sources.

Availability of private R&I investment data is limited, and data quality is difficult to assess, as dissemination of this information is ruled by corporate strategies and legal constraints. Companies may be reluctant to disclose figures on the amount and target of their R&I spending since this information can unveil strategic choices (Lantz and Sahut, 2005), and is thus treated as confidential. Nevertheless, companies can benefit from announcing an increase in R&I expenditure, in so far as it is perceived as an anticipation of market growth opportunities (Zantout and Tsetsekos, 1994; Sundaram et al., 1996), especially for companies active in high-tech industries (Chan et al., 1990) or in concentrated markets (Doukas and Switzer, 1992).

With the exception of companies listed on the stock-exchange, there is no obligation for public reporting of expenditures in the industry/business sector. As a result, specific data sources on private R&I investments for energy technologies are scarce. Annual reports and financial statements are only available for listed companies, which represent a small (even if significant in terms of level of expenditure) sample of private investors active in low-carbon energy technology R&I. Furthermore, even for the R&I figures published, the specific topics of the R&I activities are not disclosed.

The result of data scarcity is that studies concentrate on specific technologies or pockets of activity, trying to derive insights from best available datasets, rather than building a methodology and information sources to address the entire sector.

There is a clear need to gain insight on private R&I investments, considering the central role of industry in carrying out and financing innovation in the energy sector. Sources like the Community Innovation Survey (Eurostat, 2012) and the European Innovation Scoreboard (European Commission, 2016b), which provide expenditure in the business sector lack both the depth of information and the level of disaggregation needed for the SETIS work on KPIs for R&I in low-carbon energy technologies. Similarly, the use of data structured according to the economic activities classification systems (e.g. Eurostat - NACE) poses difficulties, as the sectors breakdown does not allow for the level of technological detail needed and the necessary allocation of investments along different activities, especially when companies invest in multiple energy technologies (Wiesenthal et al., 2012; Borup et al., 2013; Breyer et al., 2013).

In their new cycle for RD&D statistics 2016-17, the IEA also request participating countries to volunteer data for a new optional table dedicated to "Private Sector & Private Enterprises RD&D budgets" (IEA, 2016a). The questionnaire covers private sector budgets from 2012 onwards and uses the same technological breakdown employed for the statistics on national budgets (see section 4). Should the compilation of these statistics become established as a regular feature that countries report on at a detailed level, it will provide a major step in filling the knowledge gap on private investments in energy R&I. However, it is expected that this will take time, and in the meantime other methods of assessing private R&I investments in energy have to be employed.

The update of the JRC methodology (Fiorini et al., 2016) presented here builds upon- and extends the guidelines drawn in previous work by the institute (Wiesenthal et al., 2012) for the estimation of private R&I investment by country and thematic area. The approach developed previously is strengthened by introducing more quantitative steps based on data derived from patent statistics. In effect, while qualitative information (reports, websites, presentations, speeches, newspaper articles, direct contacts) and/or proxy-indicators (R&I employees, patent applications) had previously been used to assign R&I

investment companies active in more than one technological field, the current approach primarily uses patent statistics for this purpose. This methodology is based on the assumption that there is a relationship between patenting activity and R&I expenditure, in agreement with scientific literature (Schmookler, 1966; Griliches, 1984, 1990) and specific research in the field of energy technology (Margolis and Kammen, 1999; Herzog and Kammen, 2002; Popp, 2005). By assuming the existence of this relationship, the methodology presents a process to assign R&I expenditure to companies active in low-carbon energy technology innovation. The use of patent data allows the identification of the energy technology sectors of activity for each company (through the use of the CPC Y02 codes as described in section 2.3) and, subsequently, the allocation of the R&I expenditure accordingly.

The application of the methodology results in a highly granular and complete dataset of calculated R&I investment estimates. This is a methodological response to the lack of statistical information needed to monitor progress towards the EU energy policy objectives at the desired level of technological detail and geographical coverage. It is thus important to stress that the resulted KPI is a metric that allows relative comparisons rather than an accurate account of private investment figures. The present methodology is an improvement on the approach previously employed in the last editions of the SETIS Capacities Map reports (Wiesenthal et al., 2009; Gnamus, 2011; Corsatea et al., 2015).

The methodological steps can briefly be described as follows:

— Identification, through patent statistics, of relevant companies active in low-carbon energy technology R&I.

— Data collection, based on published statements, of private R&I investments of relevant entities, as identified above.

— Where published data is available, R&I investment effort is allocated to specific technological areas and/or subsidiary companies utilising the link with patenting efforts, to estimate a 'unitary R&I investment effort per invention' for each company and technological area.

— Estimation of R&I expenditure for the remaining entities, for which no R&I statements are published, based on the 'unitary investment effort per invention' as calculated above.

— Aggregation of the collected and estimated R&I information per country and thematic area (Energy Union R&I priority, SET Plan Action or technology).

In summary, the data resulting from the patent analysis in Section 2 are combined with published company statements on R&I investment data, to construct an indicative unitary expenditure per invention and thematic area. This value is then used as a proxy for the expenditure incurred for all entities active in R&I (as identified through their patenting efforts) in the same technological area in a given year. More details for each step of the process are provided in the following sections.

3.1 Data collection

EU-based companies, active in low-carbon energy technology R&I are retrieved from PATSTAT. This dataset is maintained, supplemented and updated by the JRC with information such as:

— ownership;

— energy technology area of activity;

— country of registered office – this may differ from operational or R&I headquarters (Wiesenthal et al., 2012);

— published R&I statements if available;

through consultation with JRC technology experts, and further review of publicly available resources. The list created is non-exhaustive, and could inevitably favour – in terms of data completeness - larger stakeholders for which more information is available in the public domain, and companies with a high-propensity to patent.

The aim is to construct and maintain a dataset of active companies per technology area, based on patenting behaviour. This serves as a guide to check against for developments in R&I for a specific technology, as well as indicate company statements that should be researched in the annual process of data mining.

Data collection on published R&I expenditure, while time consuming and resource intensive, is a necessary step of the dataset construction. A key source of information is the financial (and other) documentation provided by companies either in the form of individual statements or as reported in aggregating studies such as the EU Industrial R&I Investment Scoreboard (latest version Hernández et al., 2016) . Nonetheless, the information available is far from comprehensive, and requires additional effort and harmonisation before it is incorporated in the analysis, as described in the following (Fiorini et al., 2016).

Publicly-traded companies are legally obliged to produce and disclose detailed periodic statements on their economic performance, filed in compliance with specific standards. On the contrary, private companies with limited liability of the shareholders, albeit requested to report their accounts, are subject to different requirements, and small business entities may even be exempt from any obligation.

A number of factors have an impact on the completeness, comparability and quality of data. Firstly, accounts are written up in different currencies and along different financial years. Moreover, facts and figures are published in a variety of formats and languages, there might be limited access to documents, and information may only be published for the latest financial year with no archive or historical data available. Lastly, the current reporting year may be given as a preliminary estimate.

Companies may also be unwilling to report their specific R&I figures. In some cases, this is replaced by generic information as the announcement of the size of a multiannual investment plan or a declaration to keep the overall level of investment constant as a specific share of the internal resources (sales or turnover).

The ownership structure of the potential industrial players of interest is also a factor influencing the construction of the dataset. In case of large Multinational Corporations (MNCs), which hold shares in subordinated entities (also called a parent company-subsidiaries relationship), publications report only the group's consolidated financial statement. Further details, when available, are mostly given at business/industrial line and/or geographical level. Consequently, the economic performance of specific subsidiaries or associated companies lays hidden under the overall group's facts and figures. In order to overcome this difficulty, organisations listed in the JRC dataset resulting from the patent analysis, when possible, are grouped under the respective MNCs. This step is crucial for the analysis described below.

The issues mentioned in the above, make the construction of a complete and sufficiently granular dataset extremely challenging. In particular, the sample could be overly influenced by listed companies because their expenditure is reported, with the relevant financial documents being readily available. Smaller entities remain underrepresented, since data that can be drawn from documentation are discontinuous and require much more effort to decipher and incorporate in the dataset in a harmonised way. Thus the dataset may inevitably underestimate the contribution of SMEs along the innovation process, which is conversely highly recognised in literature (Ortega-Argilés et al., 2009; Voigt and Moncada-Paternò-Castello, 2012; Vervenne et al., 2014).

Annual financial statements generally report the aggregated R&I expenditures, without further breakdown. Following the methodological note developed for the EU Industrial R&I Investment Scoreboard "*…part of or all of R&I costs have been capitalised, the* *additions to the appropriate intangible assets are included to calculate the cash investment and any amortisation eliminated…*" (Hernández et al., 2014). Other systematic differences may also occur, influenced for example by the type of sector or maturity of the technology analysed.

The main routes for data retrieval are:

1. Financial statements (mainly for listed companies). These provide aggregated R&I expenditure and are treated as follows:
    - The data available on financial statements can cover more than one year; in this case an equal split is applied between the years in question.
    - If the company follows an accounting standard not based on the calendar year (e.g. UK), the expenditure for the calendar year is assumed.
    - Alternative currencies are converted to Euro, based on Eurostat exchange rates (Eurostat, 2015).
    - In the case of corporate structures e.g. parent company & country delegations; parent company & sectorial subsidiaries (bioenergy, wind, etc.), where the financial information is reported by business lines, but rarely broken down by sector, data is broken down further based on patenting activity.
2. The EU Industrial R&I Investment Scoreboard (latest version Hernández et al., 2016) – aggregated R&I expenditure (parent company level) and R&I intensity.
3. PATSTAT – patent applications (families) filed per company for the reference year in each technological area using the methodology described in chapter 2. Additionally, for companies for which R&I expenditure is known, total patent (family) numbers are retrieved to provide an indication on how the R&I budget might be split across the different areas of activity.

3.2 Relationship between R&I investment and patent statistics

The causal relationship between R&I investment and number of patents, as indicator of knowledge generation and technological change, has long been explored at firm level (Wang and Hagedoorn, 2012), with specific attention paid to designing indicators based on current patent counts as a function of current and previous R&I expenditure (Hausman et al., 1984; Hall et al., 1986; Pakes and Griliches, 1984). This supposed "long-run effect" of R&I investment productivity is built on the evidence that:

— R&I investment and patents are, respectively, on the input and output side of the innovation system. They are the result of unsynchronised choices along a sequential path.

— The innovation process is of a cumulative nature: early innovations provide a boost for later innovations (Scotchmer, 1991). Existing knowledge stock is the consequence of investment flows evolving over time.

— Legal and procedural aspects of the patenting process differ between application authorities, affecting the timing between research, invention and the filing of a patent application.

The challenge in finding a meaningful model for this relationship lies with the peculiar characteristics which apply to both R&I expenditure and patent data:

— There is no simple direct connection from R&I expenditure to patent; rather the connection is part of the complex framework described by a set of input and output parameters within the knowledge production process.

— Patenting activity is measured as a discrete count and its empirical distributions display some specific features (Wang and Hagedoorn, 2012; Gumru and Pérez-Sebastián, 2008). That is, distributions of patent counts are mainly asymmetric and with high frequencies corresponding to non-patenting (highest) and intensely-patenting firms.

— Even though R&I expenditure data exhibit a very high degree of persistence over time, meaning that historical spending on R&I will influence current behaviour, the mechanism governing R&I expenditure over time is a substantially unpredictable (Wang and Hagedoorn, 2012; Hall et al., 1986).

The main results from the econometric models can be summarized in the following sentence: *".. there is very little direct evidence of anything but simultaneity in the year movements of patents and R&I…*"(Hall et al., 1986). When a patent count is regressed against a distribution of lags of R&I expenditure, the size of parameters of the contemporaneous value appears to be dominant and more stable (Wang and Hagedoorn, 2012; Hall et al., 1986; Gumru and Pérez-Sebastián, 2008). This conclusion holds even in studies where the influence of past R&I expenditure on patents is found to be statistically significant. One study in particular concludes that "*….although results are sensitive to different choices of the estimation method, the contemporaneous relationship between patenting and R&I continues being significant and rather strong, accounting for above 60% of the total R&I elasticity*" (Gumru and Pérez-Sebastián, 2008). Similar results on the strong impact of contemporaneous R&I on patenting activity are also quoted by other studies (Wang and Hagedoorn, 2012).

In conclusion, the methodological choice of a contemporaneous relationship between patent data and R&I investment can be justified by the following observations:

— Setting the priority date as time index means adopting the closest date to the research activity.

— A firm's knowledge is subject to depreciation over time. Thus recent R&I investment is expected to have a greater impact on firm patenting, while the contribution of older R&I has become less valuable (Wang and Hagedoorn, 2012).

— Patent statistics are used as an innovation input indicator. Applications occur at an intermediate stage in the process of transforming research input into benefits from knowledge output. They can be used, therefore, to separate the lag that occurs in that process into two parts: one which produces patents, with past research investments, and another which transforms patents, with the possible addition of more research expenditures (Pakes and Griliches, 1984). Similarly, other literature observes that the patent-R&I relationship is affected by simultaneity (Montalvo, 1997). A successful patent (granted) induces the firm to invest more in R&I in order to transform the patent into a more commercial innovation in order to obtain benefits. From this viewpoint, R&I can be seen as a predetermined variable rather than a strictly exogenous one.

— Due to the peculiarity of the data, contemporaneity is considered a precautionary approach against the (unpredictable) randomness of R&I investment time evolution.

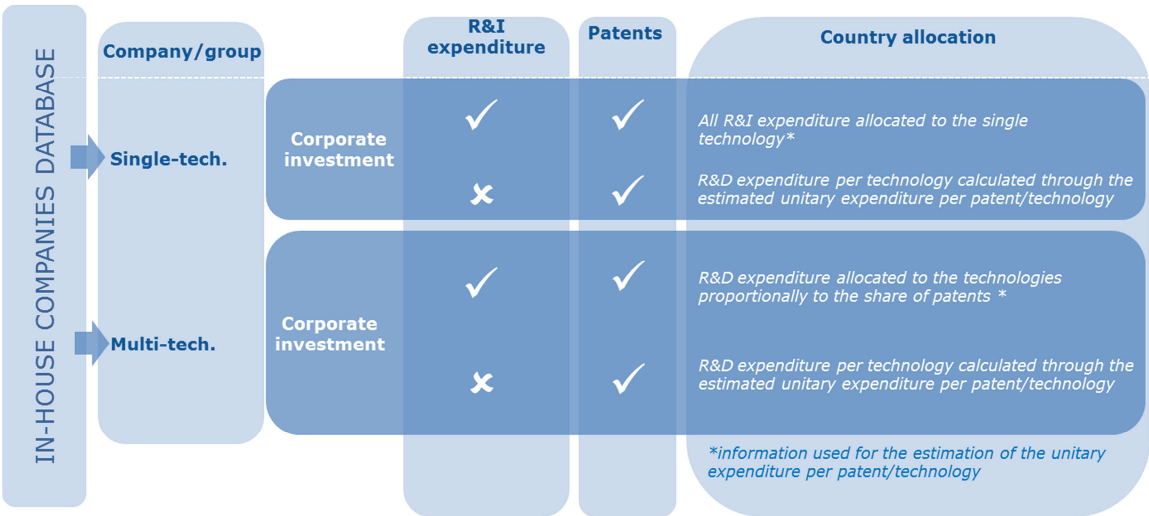
— The relative robustness of a contemporaneous relationship linking patents to R&I investment is widely demonstrated in literature. Main results found in early studies "*The strongest thing one can say is that R and D and patents appear to be dominated by a contemporaneous relationship, rather than leads or lags*" (Hall et al., 1986) are consistent with recent literature as cited in the above.

Taking the above into account, a contemporaneous relationship is assumed in the methodology. In effect, this means that patent statistics for the year *n* are used to estimate R&I for the same year. The SETIS estimations of private R&I are a metric aimed at enabling relative comparisons over time, rather than an accurate account of private investment figures. In this context the effect of the contemporaneous relationship assumed, viewed over long time periods, is not deemed to have an adverse effect to the resulting analysis.

3.3 Estimation of private R&I expenditure

The principles described in Chapter 2 for the construction of the patent statistics, are maintained for the selection of patent data used for the estimation of private R&I. The focus is the use of patent families, irrespective of application authority, rather than patent applications. The reasoning resides with the fact that the focus is on where and when the R&I effort has taken place rather than where and when an applicant seeks protection for the invention. The concept of patent families is associated to the concept of inventions: consequently, the priority date is also the closest date that can be associated to the invention (Hinze and Schmoch, 2004; EPO, 2015b).

Since the objective is to assess private R&I expenditure through patent statistics, only applicant companies are considered; applicants are – at that point – the owners of the patent and, consequently, those that are investing in R&I. Conversely, the inventors are the persons researching and developing the invention. In many cases, an applicant is the organisation, which employs the inventor; however it can happen that the same entity is both the applicant and the inventor. The classification employed in PATSTAT is used to distinguish between different types of applicant (company, individual, university, government, non-profit organisation).



Source: JRC

Figure 8: Allocation of R&I investments for single and multi-technology companies.

Figure 8 shows an overview of the estimation process combining published data on R&I expenditure and patent statistics employed for companies active in a single- or multiple technological areas. If the entity is active in a single technological area, the allocation of known expenditure is straightforward. For firms active in more than one technological area, the distribution of patents across relevant technologies is assumed to be indicative of the spending in the R&I in the respective fields (Wiesenthal et al., 2012). Thus the calculation proceeds as follows:

1. The fractional of the patents relative to all the activities of an entity are computed. This quantifies overall inventive activity. As a reminder, a fractional is the part of an invention (patent family) attributed to a company or technology, given that patents can be filed by more than one applicant, and be associated with more than one technology. All applicants and associated technologies are assumed to have an equal weight, i.e. they are allocated an equal fraction of the invention.
2. In order to address the ownership structure and to disentangle the total R&I across all the subsidiaries (see section 3.1) the R&I expenditure in a specific technological area of one company belonging to a group is assumed proportional of the inventive activity

of that company in that technological sector over the total inventive activity of the group. The procedure enables the allocation of an R&I expenditure figure to any company belonging to a multinational corporation. This methodology is consistent with the knowledge and technology transfer between parent and subsidiaries (Un and Cuervo-Cazurra, 2008) and with the concept of globalisation of R&I through subsidiaries (Iwasa and Odagiri, 2004; Hegde and Hicks, 2008).

The combination of patent analysis and companies' data is necessary to determine the indicative R&I cost per patent family/invention (also referred to in the following as "unitary expenditure"). This is calculated as follows:

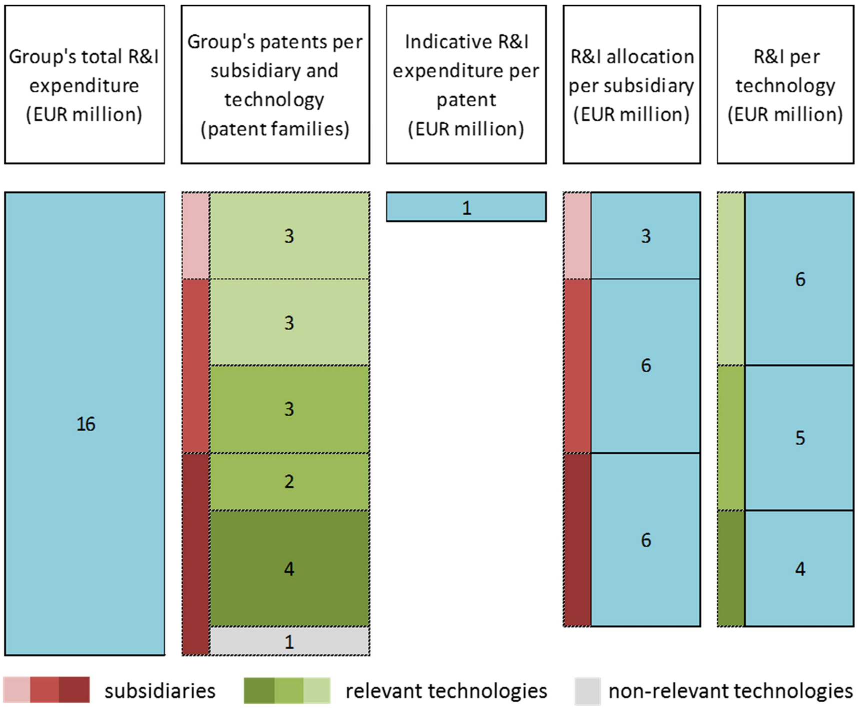
1. The total R&I expenditure allocated to a given technology is summed up for all companies with both patents and published R&I data.
2. The sum of the fractional counts from the patent statistics referring to the same technology for the same sample of companies provides the total fractional for the technology, corresponding to the published R&I data.
3. The unitary expenditure per patent family for the particular technology is calculated by dividing the two figures above.

In accordance with the way in which patent statistics have been constructed (see Chapter 2), these values represent the estimated effort in terms of R&I expenditure by the private sector to produce one invention in a specific technological area.

Figure 9 shows a simplified example of the allocation of R&I expenditure reported by a multinational group of companies to the relevant subsidiaries and technologies. For simplicity, each subsidiary is assumed to also represent a different country and no co-applicants or multiple technologies are assumed for the patent families. The first column shows the level of reported R&I investment. The second column shows the number of patent families identified for each of the subsidiaries of this multinational group (these are the applicants) and the corresponding technological areas addressed (defined through the CPC Y02 codes). Dividing the sums of the two columns provides the value in the third column, which is the indicative R&I expenditure per patent for this particular group. The following two columns visualise the allocation of R&I expenditure per subsidiary and per technology. The principle remains the same when applied to more complex cases with multiple applicants and technologies. The increased complexity is then reflected by fractional counts for the number of patent families per entity or technology.

The overall average R&I expenditure of about EUR 3.2 million per patent family estimated for renewable energy generation technologies (Fiorini et al., 2016), is comparable with other estimates found in literature e.g. for the manufacturing sector in Germany, France and Italy (Johnson, 2002), and the manufacturing, electronics and pharmaceutical sectors in the USA (Berman, 2002). After adjusting for the age and currency of the studies these values range from EUR 3.2 million to EUR 4.1 million. Indicative average R&I expenditure have similarly been calculated for other Energy Union priorities, SET Plan actions or technological areas. The more specific the analysis on the technological details, the greater the difference encountered in terms of unitary expenditure; however on balance, the energy sector R&I is similarly positioned in terms of overall expenditure as the sector results presented for the average indicative expenditure per invention.

This unitary expenditure is used as a proxy to estimate an indicative R&I expenditure for companies, active in patenting, for which published R&I data are not available. The assumption is that their spending is similar to the average value obtained by the analysis performed on the sample of companies with published R&I expenditure.



Source: JRC

Figure 9: Simplified example of the allocation of R&I expenditure reported by a multinational group of companies to the relevant subsidiaries and technologies. Each subsidiary here is assumed to also represent a different country and no co-applicants or multiple technologies are assumed for the patent families.

Using the year 2012 as an indicative example, the following demonstrates in numbers the data availability and samples involved in the construction of the dataset:

— 99000 energy related global entities are featured in PATSTAT (excluding individuals)

— 17000 global entities patented in low-carbon energy technologies, of which in excess of 2500 are EU-based companies

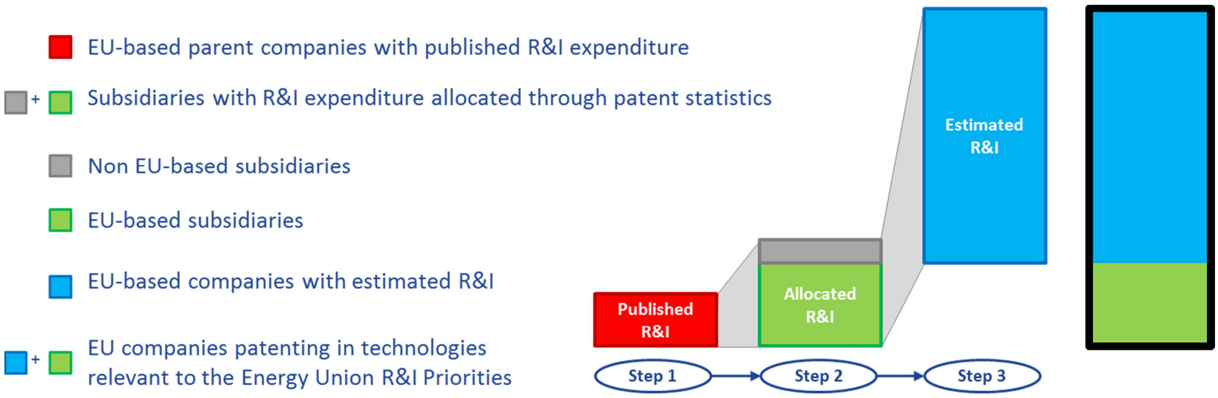
— 150 of the companies based in the EU are "parent" companies with published R&I expenditure

— The published figures for the 150 "parent" companies also cover the activities of subsidiaries, bringing the number of companies to which R&I expenditure can be allocated to geographical location and technological areas up to nearly 460.

— The estimation of indicative unitary R&I expenditure per patent for each technology is thus, following this example, based on these 460 entities

— The indicative unitary R&I expenditure per patent for each technology is used, in turn, to calculate the R&I expenditure for the remaining entities, based in the EU, with patents in the same technology for the same year (see Figure 10).

As noted in Section 2.1, patent data availability has a 3-4 year lag; this is transferred to the estimation of private investments as the methodology relies on patent statistics. Listed companies provide accounts on an annual basis and data could be available up to 2 years before the reporting year (Y-2) or even for the year before, in the case of provisional data. Information based on the listed companies included in the sample can provide an early indicator of R&I investment trends for the years that cannot yet be covered through full estimates due to the lag in the update of patent data; however, due to the low number of reporting companies available, this early trend estimate has a very high uncertainty associated with it.



Source: JRC

Figure 10: Representation of calculation steps and the share of parent and subsidiary companies in the dataset. In the year 2012, published data for over 150 EU-based parent companies (in red) allocated to EU-based subsidiaries, resulted in the sample of 460 companies (in green). The final data set contains in excess of 2500 companies (green & blue).

Box 3. Summary of main points on private R&I investment

DATA SOURCE

Company R&I expenditure is sourced through public documents such as annual reports, financial statements and dedicated studies such as the JRC Innovation Scoreboard. PATSTAT, the Worldwide Patents Database managed by the European Patent Office is the source of patent statistics used for the identification of entities and the calculation of estimates.

DATA QUALITY & MANAGEMENT

A list of EU-based companies is constructed by the JRC based on PATSTAT, and supplemented with information on ownership structure and R&I expenditure through sources in the public domain. Quality issues mentioned in the context of patent statistics also apply here.

DATA TIME LAG

Listed companies provide accounts on an annual basis up to 2 years before the reporting year (year before for provisional data). A full update of PATSTAT is only completed with a 3.5-years delay. Complete estimates based on patent data have a 4 year delay. This can be reduced to 2 years if incomplete patent datasets are used as a proxy, but the same caveats on reduced robustness of the indicators expressed in the previous section also apply here.

Information based on the listed companies included in the sample can provide an early indicator of R&I investment trends. However, this early trend estimate is highly uncertain and not specific to a technological area.

SETIS APPROACH

An updated and adapted version of the Capacities Mapping methodology (JRC, 2009 onwards):

- Relevant companies, not limited to energy industries, involved energy R&I activity, are identified through their patenting activity as listed in PATSTAT
- Data is collected on company R&I investments of relevant EU-based firms.
- R&I investment effort is allocated to specific technologies and subsidiary companies based on patenting activity.
- A 'unitary R&I investment/expenditure effort per patent family/invention' is calculated for each technological area, based on the sum of R&I expenditures as allocated in the previous step and patent statistics.
- R&I expenditure for the remaining identified companies, where published R&I information is not available, is estimated, based on patent data and the 'unitary investment effort per patent' as calculated above.
- Collected and estimated R&I information is aggregated per country and technological area for the EU Member States.

INDICATIVE OUTPUT

- Private investment trends (time series) per Energy Union R&I priority, SET Plan action or technology group for the EU and Member states.
- Private investment normalised by GDP or turnover.

4 Public investment in Research and Innovation

New technologies emerge via intensive innovation processes that start with investment in research, followed by development and deployment. Public financing is extremely important for innovation and growth in any sector. This is more so for the energy sector where, in order to achieve the goals of decarbonisation, the development and deployment of a wide range of low-carbon energy technologies is required. This portfolio diversification, and the inherent structure and functioning of the sector at large, involving high capital requirements, regulatory uncertainties, economies of scale etc. makes the contribution of the public sector essential in the process, especially in the early stages of technology development. Thus, support to energy R&I through public funding is also monitored through SETIS. This section describes the SETIS approach on the collection and assessment of information on R&I investments by national authorities.

R&I funding provided at EU level by various programmes and instruments is not addressed in this report. Statistics on public investment at EU level are provided by the respective Commission services.

4.1 Data source and management

The IEA is the main source of data available for national RD&D funding at the level of detail necessary for the analysis of low-carbon energy technologies.

The advantages of using the IEA data are that:

— Information is already collected directly by national authorities, through a well-established reporting process, thus creating no additional reporting burden on the Member States;

— The data and all relevant documentation, such as reporting guidelines (IEA, 2011), are in the public domain and available through the IEA website (IEA, 2016b) ensuring a transparent process.

— If filled in detail – to a large extent – the IEA questionnaire categories permit analysis at both the level of Integrated SET Plan Actions and Energy Union R&I and Competitiveness priorities.

The drawbacks of using the IEA RD&D statistics are that:

— Datasets are not always complete for all the IEA member countries included in the reporting.

— Not all IEA members provide data regularly and not all EU Member States are members of the IEA (non-members: Bulgaria, Cyprus, Croatia, Latvia, Lithuania, Malta, Romania and Slovenia).

— The data reported are not always at the lowest level of granularity available in the questionnaire, which is the level necessary to provide analysis at the level of SET Plan actions; e.g. Member States opting to report total investments in solar energy without a breakdown between photovoltaics and solar thermal or solar heating and cooling; or reporting on investments in biofuel research with no distinction between heat and power or transport applications.

Table 3 shows the main IEA RD&D reporting questionnaire headings and codes allocated under each Energy Union R&I Priority and SET Plan Action. A more detailed concordance table is included in Annex 2. Due to the fact that most submissions are at a low level of disaggregation, the allocation of categories only uses the 2nd level of detail (2-digit code). This has implication on the estimation of public investment for some SET Plan actions or technological areas. For example, at the moment SETIS is not able to report on public investments made specifically on batteries and e-mobility.

SETIS has established a close collaboration with the IEA to improve the understanding of the underlining IEA data collection and analysis. Additionally, in coordination with the

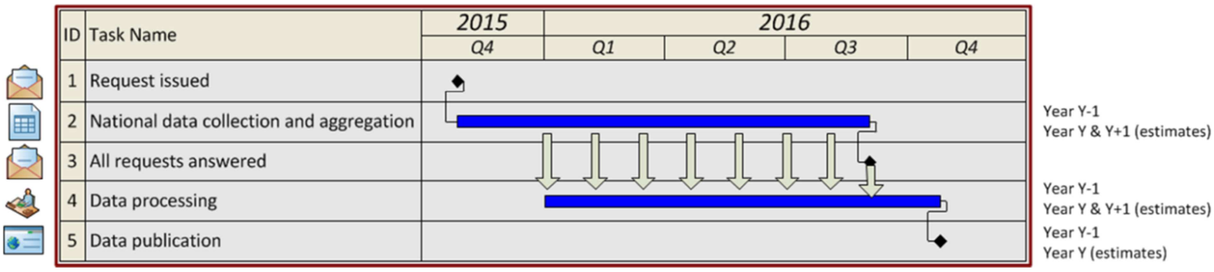
Member States through the SET Plan Steering Group, SETIS is working on improving the data availability, granularity and validation.

The availability of data is dependent on the IEA's workflow and associated timelines, an indicative presentation of which is given in Figure 11. The reporting questionnaires to be filled with national R&I spending for years Y-1, Y (estimates) and Y+1 (estimates) are sent to the IEA members in year Y. The data is then processed, the database is updated and made public on the IEA website during the following year (Y+1). Despite the fact that there are estimates for the year Y (and in certain cases also Y+1) available at publication time, these data are not published. Thus, the latest information that is made available in any given year by the IEA is at least one year old, for very partial data sets, and two years in order to obtain a reasonable picture of R&I expenditure, at least with regards to the major investing countries (see Figure 12 and Figure 13 for an example of data availability in September 2016).

Table 3: Overview of main IEA RD&D reporting questionnaire headings and codes allocated under each Energy Union R&I Priority and SET Plan action. Codes are given at the first two levels of detail and may be split along more than one priority or action at a lower level. A more detailed breakdown of the codes by topic is provided in Annex 2.

<table>
<tr><th colspan="2">NO 1 IN RENEABLES</th></tr>
<tr><td colspan="2">Actions 1 &2: Performant, low cost renewables</td></tr>
<tr><td colspan="2">31 Solar energy, 32 Wind energy, 33 Ocean energy, 35 Geothermal energy, 36 Hydroelectricity</td></tr>
<tr><th colspan="2">CONSUMERS AND THE ENERGY SYSTEM</th></tr>
<tr><td>Action 3: Smart solutions for consumers</td><td>Action 4: Integrated and flexible energy systems</td></tr>
<tr><td>12 Residential and commercial buildings
(operations & appliances)</td><td>21 Oil and gas
22 Coal
6 Other power storage technologies
7 Other cross-cutting technologies or research</td></tr>
<tr><th colspan="2">EFFICIENT ENERGY SYSTEMS</th></tr>
<tr><td>Action 5: Energy efficiency in buildings</td><td>Action 6: Energy efficiency in industry</td></tr>
<tr><td>12 Residential and commercial buildings
(design & envelope)</td><td>11 Industry
14 Other energy efficiency</td></tr>
<tr><th colspan="2">SUSTAINABLE TRANSPORT</th></tr>
<tr><td>Action 7: Batteries and e-mobility</td><td>Action 8: Renewable fuels</td></tr>
<tr><td>allocation not possible at present as it requires data at the 4^{th} level of detail, not often filled in by reporting countries</td><td>13 Transport
38 Biofuels
5 Hydrogen and Fuel cells</td></tr>
<tr><th colspan="2">CARBON CAPTURE UTILISATION AND STORAGE</th></tr>
<tr><td colspan="2">Action 9: Carbon capture, utilisation and storage</td></tr>
<tr><td colspan="2">23 CO2 capture and storage</td></tr>
<tr><th colspan="2">NUCLEAR SAFETY</th></tr>
<tr><td colspan="2">Action 10: Nuclear safety</td></tr>
<tr><td colspan="2">4 Nuclear fission and fusion</td></tr>
</table>

Source: JRC based on IEA (2011)



Source: JRC

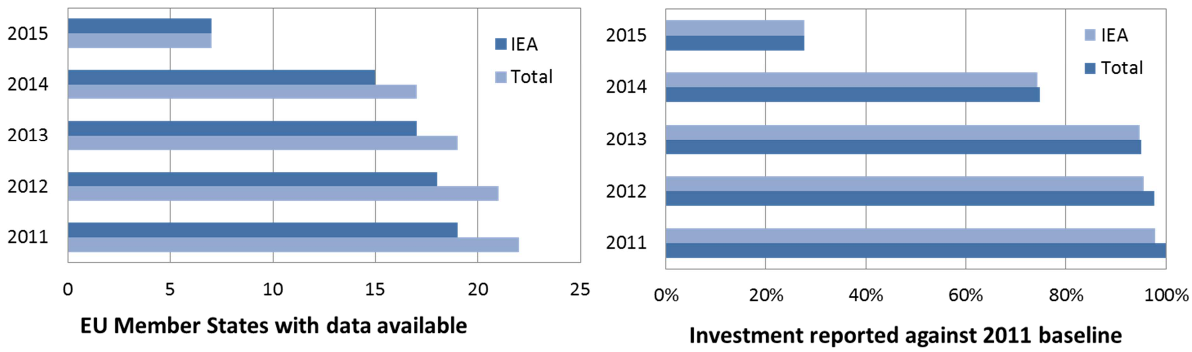
Figure 11: Indicative representation of the workflow for reporting national expenditure in the energy R&I sector, based on observation and bilateral discussions with the IEA.

The number of countries that report to the IEA within the proposed timeframe can vary from year to year. This is shown in Figure 12 that presents the data availability for previous years in September 2016. Nonetheless, comparison with the data availability under the same time-frame for previous years shows that the reporting that has taken place within the timescale given in Figure 11 captures the majority of investments.

Figure 12 reports two values: the one obtained through IEA statistics, and a total, which includes incremental information collected by SETIS and updated/validated investment figures provided to SETIS directly by the Member States in the context of the SET Plan Steering Group (e.g. additional data provided by Austria, Czech Republic, France, Italy, Norway, Poland, Sweden the United Kingdom, Germany and the Netherlands). Figure 13 shows the data availability per Member State in September 2016. Two points should be emphasised based on Figure 12 and Figure 13:

— The timing and quality of the reporting by SETIS is commensurate to the quality (accuracy and granularity) and timeliness of reporting to the IEA. Direct collaboration with the Member States through the SET Plan Steering Group is hugely beneficial in this respect.

— Additional efforts by SETIS to acquire incremental data through complementary data sources have a negligible effect in terms of the total national R&I investment at EU level e.g. sourcing information on the Member States that are not members of the IEA only increases the total R&I reported by 0.5%.



Source: JRC and IEA (2016b)

Figure 12: Available statistics on R&I support for energy technologies through the IEA and additional sources, in terms of number of countries(left) and investment (right), September 2016.

Source: JRC based on IEA (2016b)

Figure 13: Relative availability of national R&I data broken down by Member State (September 2016). Major investors report early to the IEA.

In addition to EU Member States, the IEA reports on national R&I spending for Australia, Canada, Japan, Norway, New-Zealand, South Korea, Switzerland, Turkey and the United States. SETIS supplements this information through data collection on the R&I activities of China and India, in order to report on the major international trading partners in low-carbon energy technology R&I. Although significant activity seems to be taking place in Brazil on biomass/biofuels (also signified through EU projects) there is no reliable publicly available information to allow the inclusion of this country in the analysis.

4.2 Data gaps

Where data are not available, data gaps can be filled using several alternative methods and/or data sources depending on the type of data missing. This is only applied if necessary, on a case-by-case basis and explicitly stated in the resulting data set. As a rule, the following principles are employed:

— For countries or technological areas of reporting for which historical information is available, the same trend (e.g. percentage change) can be assumed for the year for which information is missing.

— If additional information (e.g., percentage change compared to other countries or technological areas of reporting, public organisations' investments as participants in EU funded projects) is available, it is taken into consideration to obtain a more complete picture of the national funding for the year in question.

4.3 Estimates based on other macro-economic indicators

In addition to the assumptions described for gap-filling in the above, SETIS has developed a methodology to provide estimates of national investments based on their relationship with macroeconomic indicators, as listed in Table 4.

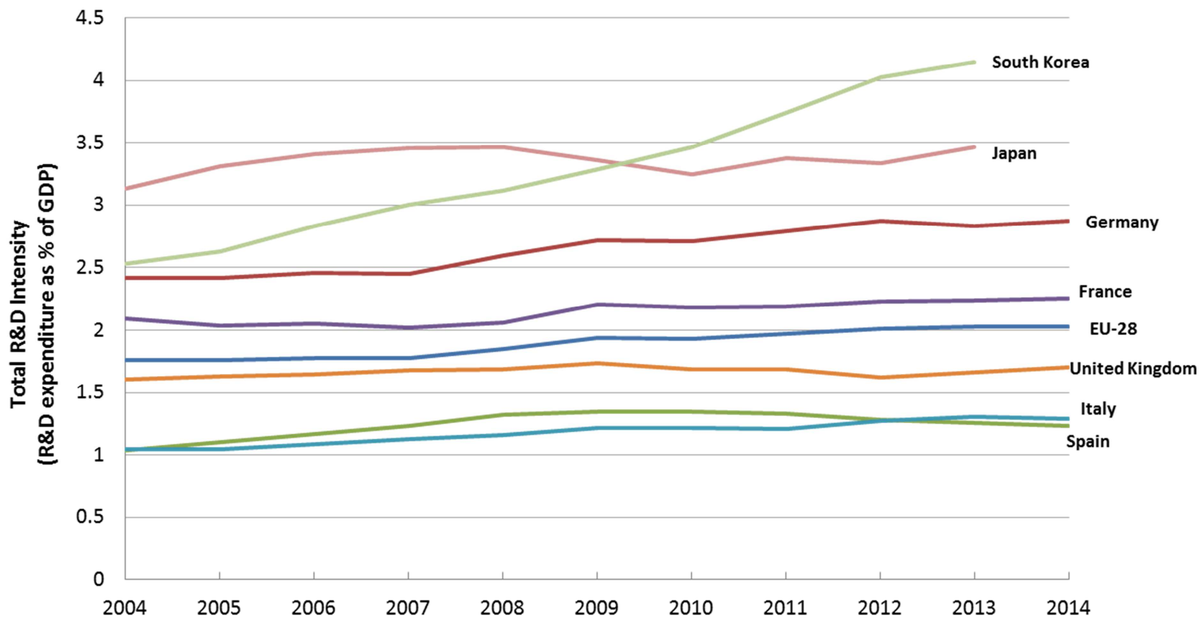
The main concept of this methodology is to exploit the link between R&I expenditure and macro-economic variables, which are frequently reported in national statistics accounts. Such estimates can be generated by two methods: either a regression-based or an indicator-based extrapolation. SETIS analysis has shown that the second option yields better results and is also simpler to apply and report.

The indicator-based approach examines the ratio of IEA reported investments over Government Budget Appropriations or Outlays on R&D (GBAORD) and Gross Domestic Product (GDP) statistics. These indicators are selected as being country specific and stable, on average, over time. This is particularly true for indicators constructed using R&I investment and GDP. Figure 14 shows that the R&I intensity of the GDP, although different in terms of magnitude, is relatively stable over a 3-5 year time period in major economies. This means that the time average of the intensity indicators represents the joint behaviour of the variables and that a smoothing average can be used to estimate the target values.

Table 4: Target values to be estimated and macro-economic variables used for the implementation of the methodology.

	Description	Source	Unit	Latest year
Target R&I values				
IEA-AG	Public R&I expenditure – All technologies	IEA	m EUR	2014
IEA-EU	Public R&I expenditure – Energy Union priorities	IEA	m EUR	2014
Macroeconomic indicators				
GBAORD-T	GBAORD – All NABS 2007 socio economic objectives	Eurostat	m EUR	2014
GBAORD-E	GBAORD – NABS 2007 energy objective	Eurostat	m EUR	2014
GDP	Gross Domestic Product	Eurostat	m EUR	2015

Source: IEA (2015), Eurostat (2016a, b)



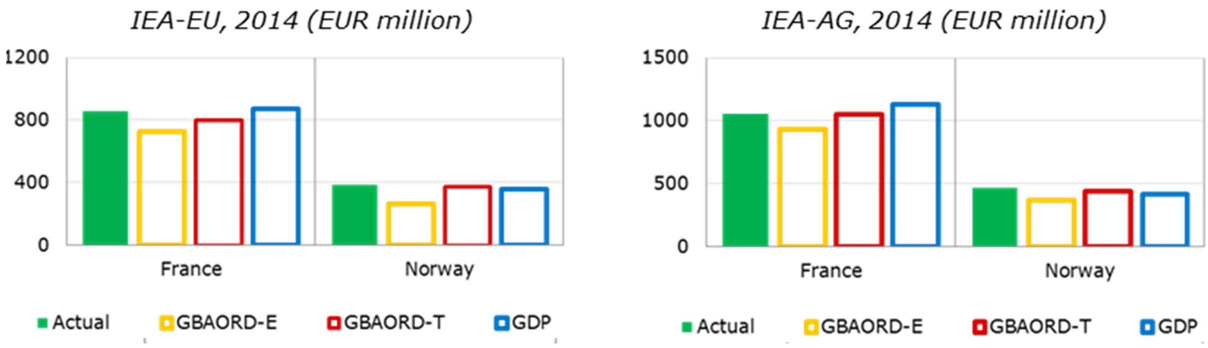
Source: JRC analysis of Eurostat data (Eurostat, 2016c).

Figure 14: R&D intensity over time for major investors, over all socio-economic objectives of science and technology/research and development.

Figure 15 shows a comparison of reported vs. estimated values - using three different variables - for national R&I expenditure, applied to 4 examples: Energy Union relevant (left) and all IEA categories (right) for France and Norway with reference to the year 2014. Ratios over GBAORD-T yield the closest estimate to the actual value; at worst the values are underestimated by 7%. Figure 16 reports average estimates, with corresponding maximum and minimum (upper and lower bound) of the same values for a number of countries for same year. Estimates are consistent between the three variables for most cases; the most notable variation is that of the UK, where the use of the GDP returns a high estimate. Figure 17 shows the time series of aggregated values at EU level for national R&I expenditure in Energy Union R&I priorities, and all IEA categories, for the EU members of the IEA between 2010 and 2014. The value given for 2014 is an estimate with a low and high bound (as in Figure 16) accompanied by the values reported at the time of the estimate – containing reports from 10 out of 28 Member States.

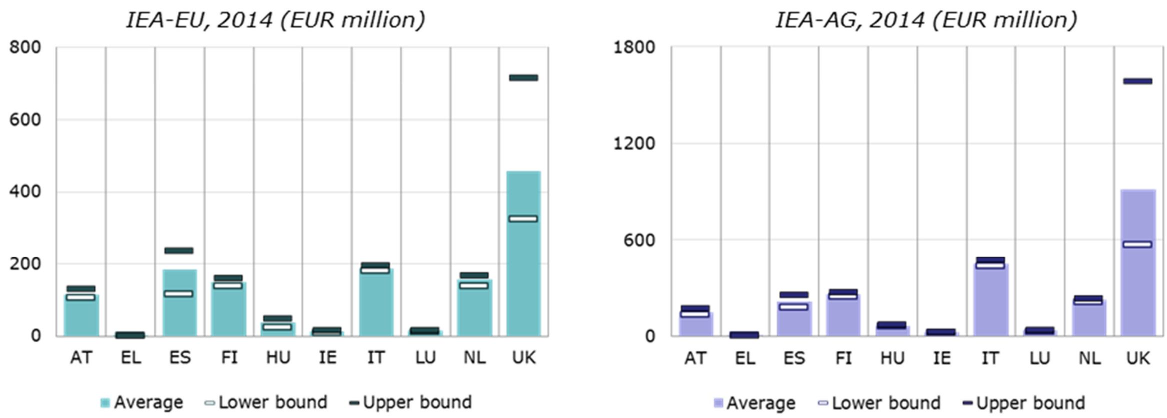
The results show that the approach provides reasonable estimates, in the absence of reported data. The estimation method is easy and consistent to apply on a case by case basis, using existing, regularly updated data sets, but should not be used to draw generic conclusions, or for the generation of estimates over a longer time frame.

The use of gap-filling and estimates is employed to provide a better indication of the time series and of expected datasets and thus facilitate the policy making process overcome the hurdle of time-lags in the statistical process. All estimates generated for the monitoring and reporting tasks of SETIS, are explicitly be marked as such, and the difference from statistical data is clearly indicated.



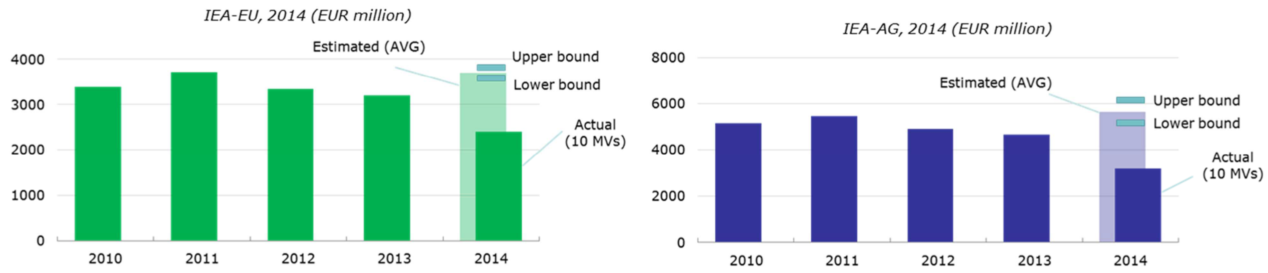
Source: JRC analysis of data from IEA (2015), Eurostat (2016a, b)

Figure 15: Comparison of reported (green filled shapes) vs. estimated (hollow shapes) values for national R&I expenditure in Energy Union relevant (left) and all IEA categories (right) using three different variables.



Source: JRC analysis of data from IEA (2015), Eurostat (2016a, b)

Figure 16: Average and range of estimated values using the three variables for national R&I expenditure in Energy Union relevant (left) and all IEA categories (right) for a sample of countries.



Source: JRC analysis of data from IEA (2015), Eurostat (Eurostat, 2016a, b)

Figure 17: Average and range of estimated values using the three variables for 2014. Investments in R&I for EU member states, reported values from 10 Member States plus estimates.

Box 4. Summary of main points on public R&I investment

DATA SOURCE

The IEA statistics are the main source of data for national R&I investments. These statistics are supplemented by additional data provided and/or validated by the Member States through the SET Plan Steering Group and/or targeted data mining by SETIS.

DATA QUALITY & MANAGEMENT

The IEA statistics address 20 of the Member States with varying regularity and granularity of technology detail. There are data gaps for certain countries and technologies. Supplementary information from sources in the public domain is used along with estimates based on macro-economic indicators.

DATA TIME LAG

Timing depends on the IEA workflow, and the frequency/diligence of reporting by IEA-members. A 2-year time delay is to be expected for the majority of Member States. This time-lag could be reduced by closer collaboration between SETIS, the Member States and the IEA.

SETIS APPROACH

SETIS engages with both the IEA and the Member States for the collection and validation of data. Data gaps are filled by assuming that historical trends and their correlation with macroeconomic indicators are maintained and the level of investment is unchanged across sectors/ sub-technologies.

PROJECTIONS

Additionally, SETIS has developed a methodology to provide estimates of national investments up to the previous year of reporting, based on the correlation of macroeconomic indicators such as the GDP.

All estimates generated for the monitoring and reporting tasks of SETIS, are explicitly marked as such, and the difference from statistical data is clearly indicated.

INDICATIVE OUTPUT

— Public investment trends (time series) per Energy Union R&I priority, SET Plan action or technology group for the EU and Member states and major international trading partners.

— Public investment normalised by GDP or GBAORD.

5 Concluding remarks

The report provides a summary of the work behind the R&I indicators produced by the JRC/SETIS for the State of the Energy Union Report. This consists of the application of a robust and transparent methodology for the construction of statistics on R&I investments and patenting trends. The methodology is an update of existing practice, building on previous work of the JRC in this area, and relies on publicly available information.

The JRC has already established a number of relationships with relevant actors, such as the EPO and IEA among others, to obtain advice and explore ways to validate and improve the methodology and resulting data. To this extent, all inputs and opportunities to collaborate, both on data collection and methodological issues, are welcome.

The development and improvement of the methodology is ongoing, while respecting the need to preserve consistency and continuity in the provision of R&I statistics for policy support.

Further major methodological changes will be reported in subsequent editions of this report.

The resulting statistics from the application of the methodology in support of the State of the Energy Union Report are reported separately in the JRC report "Energy R&I financing and patenting trends in the EU".

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List of abbreviations and definitions

CPC	Cooperative Classification system
ECLA	European Classification System
EPO	European Patent Office
Eurostat	Thee statistical office of the European Union
GBAORD	Government Budget Appropriations or Outlays on R&D
GDP	Gross Domestic Product
HVAC	Heating Ventilation or Air-conditioning
ICO	In Computer Only
ICT	Information and Communication Technologies
IEA	International Energy Agency
IPC	International Patent Classification
JRC	European Commission Joint Research Centre
KPI	Key Performance Indicator
MS	Member State (EU28)
PATSTAT	The Worldwide Patent Statistical Database maintained by EPO
PCT	Patent Cooperation Treaty, the international patent system
R&D	Research and Development
R&I	Research and Innovation
RD&D	Research, Development and Demonstration
SET Plan	Strategic Energy Technologies Plan
SETIS	Strategic Energy Technologies Information System
USPC	United States Patent Classification
USPTO	United States Patent and Trademark Office

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Annexes

Annex 1. CPC codes used for the selection of patents for statistical analysis per Energy Union R&I Priority and SET Plan Action

Patent codes are only listed to the 3rd level of detail and do not include all the sub-sections. The CPC is an evolving scheme; for up to date description of the structure and classes please consult the online records:

http://www.cooperativepatentclassification.org/index.html .

Table 5: CPC codes selected under the Energy Union R&I and Competitiveness Priority: **Number 1 in Renewables** and corresponding Integrated SET Plan Actions.

SET Plan Action	CPC Technology details			CPC Codes
Performant renewable technologies integrated in the system - Reduce technology costs	Geothermal energy			Y02E 10/10
		Earth coil heat exchangers		Y02E 10/12
			Compact tube assemblies, e.g. geothermal probes	Y02E 10/125
		Systems injecting medium directly into ground, e.g. hot dry rock system, underground water		Y02E 10/14
		Systems injecting medium into a closed well		Y02E 10/16
		Systems exchanging heat with fluids in pipes, e.g. fresh water or waste water		Y02E 10/18
	Hydro energy			Y02E 10/20
		Conventional, e.g. with dams, turbines and waterwheels		Y02E 10/22
			Turbines or waterwheels, e.g. details of the rotor	Y02E 10/223
			Other parts or details	Y02E 10/226
		Tidal stream or damless hydropower, e.g. sea flood and ebb, river, stream		Y02E 10/28
	Energy from sea (tidal stream Y02E10/28)			Y02E 10/30
		Oscillating water column [OWC]		Y02E 10/32
		Ocean thermal energy conversion [OTEC]		Y02E 10/34
		Salinity gradient		Y02E 10/36
		Wave energy or tidal swell, e.g. Pelamis-type		Y02E 10/38
	Solar thermal energy			Y02E 10/40
		Tower concentrators		Y02E 10/41
		Dish collectors		Y02E 10/42
		Fresnel lenses		Y02E 10/43
		Heat exchange systems		Y02E 10/44
		Trough concentrators		Y02E 10/45
		Conversion of thermal power into mechanical power, e.g. Rankine, Stirling solar thermal engines		Y02E 10/46
			Thermal updraft	Y02E 10/465
		Mountings or tracking		Y02E 10/47
	Photovoltaic [PV] energy			Y02E 10/50
		PV systems with concentrators		Y02E 10/52
		Material technologies		Y02E 10/54
			CuInSe2 material PV cells	Y02E 10/541
			Dye sensitized solar cells	Y02E 10/542
			Solar cells from Group II-VI materials	Y02E 10/543
			Solar cells from Group III-V materials	Y02E 10/544
			Microcrystalline silicon PV cells	Y02E 10/545
			Polycrystalline silicon PV cells	Y02E 10/546
			Monocrystalline silicon PV cells	Y02E 10/547
			Amorphous silicon PV cells	Y02E 10/548
			organic PV cells	Y02E 10/549
		Power conversion electric or electronic aspects		Y02E 10/56
			for grid-connected applications	Y02E 10/563
			concerning power management inside the plant , e.g. battery charging/discharging, economical operation, hybridisation with other energy sources	Y02E 10/566
			Maximum power point tracking [MPPT] systems	Y02E 10/58
	Thermal-PV hybrids			Y02E 10/60
	Wind energy			Y02E 10/70

		Wind turbines with rotation axis in wind direction		Y02E 10/72
			Blades or rotors	Y02E 10/721
			Components or gearbox	Y02E 10/722
			Control of turbines	Y02E 10/723
			Generator or configuration	Y02E 10/725
			Nacelles	Y02E 10/726
			Offshore towers	Y02E 10/727
			Onshore towers	Y02E 10/728
		Wind turbines with rotation axis perpendicular to the wind direction		Y02E 10/74
		Power conversion electric or electronic aspects		Y02E 10/76
			for grid-connected applications	Y02E 10/763
		Power conversion electric or electronic aspects	concerning power management inside the plant, e.g. battery charging/discharging, economical operation, hybridisation with other energy sources	Y02E 10/766

Table 6: CPC codes selected under the Energy Union R&I and Competitiveness Priority: **Smart EU energy system, with the consumer at the centre** and corresponding Integrated SET Plan Actions.

SET Plan Action	CPC Technology details			CPC Codes
New technologies & services for consumers	Energy efficient lighting technologies	Energy saving technologies for incandescent lamps		Y02B 20/10
			Halogen lamps	Y02B 20/12 Y02B 20/125
			Specially adapted circuits	Y02B 20/14 Y02B 20/142 Y02B 20/144 Y02B 20/146 Y02B 20/148
		Gas discharge lamps, e.g. fluorescent lamps, high intensity discharge lamps [HID] or molecular radiators		Y02B 20/16
			Low pressure and fluorescent lamps	Y02B 20/18 Y02B 20/181 Y02B 20/183 Y02B 20/185 Y02B 20/186 Y02B 20/188
			Mechanical details of compact fluorescent lamps	Y02B 20/19
			High pressure [UHP] or high intensity discharge lamps [HID]	Y02B 20/20 Y02B 20/202 Y02B 20/204 Y02B 20/206 Y02B 20/208
			Other discharge lamps	Y02B 20/22
		Semiconductor lamps, e.g. solid state lamps [SSL] light emitting diodes [LED] or organic LED [OLED]		Y02B 20/30
			Electroluminescent panels	Y02B 20/32 Y02B 20/325
			inorganic LEDs	Y02B 20/34 Y02B 20/341 Y02B 20/342 Y02B 20/343 Y02B 20/345 Y02B 20/346 Y02B 20/347 Y02B 20/348
			Organic LEDs, i.e. OLEDs for general illumination	Y02B 20/36
			Constructional details	Y02B 20/38 Y02B 20/383 Y02B 20/386
		Control techniques providing energy savings		Y02B 20/40
			timing means or schedule	Y02B 20/42
			detection of the user	Y02B 20/44 Y02B 20/445
			detection of the illumination level	Y02B 20/46
			Smart controllers	Y02B 20/48
		Used in particular applications		Y02B 20/70
			in street lighting	Y02B 20/72
	Energy efficient heating, ventilation or air conditioning [HVAC]	relating to domestic heating, space heating or domestic hot water heating or supply systems [DHW]		Y02B 30/08
			using boilers	Y02B 30/10 Y02B 30/102 Y02B 30/104 Y02B 30/106 Y02B 30/108
			Hot water central heating systems using heat pumps	Y02B 30/12 Y02B 30/123 Y02B 30/126
			Central heating systems having more than one heat source	Y02B 30/14
			Central heating systems using steam or condensate extracted or exhausted from steam engine plants	Y02B 30/16
			Domestic hot-water supply systems using recuperated or waste heat	Y02B 30/18
			Heat consumers: i.e. devices to provide the end user with heat	Y02B 30/20 Y02B 30/22 Y02B 30/24 Y02B 30/26 Y02B 30/28

		Systems profiting of external/internal conditions		Y02B 30/50
			Heat recovery pumps, i.e. heat pump based systems improving the overall efficiency	Y02B 30/52
			Free-cooling systems	Y02B 30/54 Y02B 30/542 Y02B 30/545 Y02B 30/547
			Heat recovery units	Y02B 30/56 Y02B 30/563 Y02B 30/566
		Other technologies for heating or cooling		Y02B 30/60
			Absorption based systems	Y02B 30/62 Y02B 30/625 Y02B 30/64
			Magnetic cooling	Y02B 30/66
		Efficient control or regulation technologies		Y02B 30/70
			Electric or electronic refrigerant flow control	Y02B 30/72
			Technologies based on motor control	Y02B 30/74 Y02B 30/741 Y02B 30/743 Y02B 30/745 Y02B 30/746 Y02B 30/748
			Centralised control	Y02B 30/76 Y02B 30/762 Y02B 30/765 Y02B 30/767
			Ventilation adapted to air quality	Y02B 30/78
		Ultrasonic humidifiers		Y02B 30/80
	Technologies aiming at improving the efficiency of home appliances	Relating to domestic cooking		Y02B 40/10
			Induction cooking in kitchen stoves	Y02B 40/12 Y02B 40/123 Y02B 40/126
			Microwave ovens	Y02B 40/14 Y02B 40/143 Y02B 40/146
			Improved cooking stoves	Y02B 40/16 Y02B 40/163 Y02B 40/166
			Solar cooking stoves or furnaces	Y02B 40/18
		Relating to refrigerators or freezers		Y02B 40/30
			Motor speed control of compressors or fans	Y02B 40/32
			Thermal insulation	Y02B 40/34
		Relating to dish-washers		Y02B 40/40
			Motor speed control of pumps	Y02B 40/42
			Heat recovery	Y02B 40/44
			Optimisation of water quantity,	Y02B 40/46
		Relating to washing machines		Y02B 40/50
			Motor speed control of drum or pumps	Y02B 40/52
			Heat recovery	Y02B 40/54
			Optimisation of water quantity	Y02B 40/56
			Solar heating	Y02B 40/58
		Relating to laundry dryers		Y02B 40/70
			Motor speed control of drum or fans	Y02B 40/72
			Solar heating	Y02B 40/74
		Related to vacuum cleaners		Y02B 40/80
			Motor speed or motor power consumption control	Y02B 40/82
			Motor overheating or overloading prevention	Y02B 40/84
		Energy efficient batteries, ultracapacitors, supercapacitors or double-layer capacitors charging or discharging systems or methods specially adapted for portable applications		Y02B 40/90
	Energy efficient technologies in elevators, escalators and moving walkways	in elevators		Y02B 50/10
			Energy saving technologies	Y02B 50/12 Y02B 50/122 Y02B 50/125

				Y02B 50/127
			Energy recuperation technologies	Y02B 50/14 Y02B 50/142 Y02B 50/144 Y02B 50/146 Y02B 50/148
		in escalators and moving walkways		Y02B 50/20
			Energy saving technologies	Y02B 50/22 Y02B 50/225
			Energy recuperation technologies	Y02B 50/24
	Information and communication technologies [ICT] aiming at the reduction of own energy use	Energy efficient computing		Y02B 60/10
			Reducing energy-consumption at the single machine level, e.g. processors, personal computers, peripherals, power supply	Y02B 60/12 Y02B 60/1203 Y02B 60/1207 Y02B 60/121 Y02B 60/1214 Y02B 60/1217 Y02B 60/1221 Y02B 60/1225 Y02B 60/1228 Y02B 60/1232 Y02B 60/1235 Y02B 60/1239 Y02B 60/1242 Y02B 60/1246 Y02B 60/125 Y02B 60/1253 Y02B 60/1257 Y02B 60/126 Y02B 60/1264 Y02B 60/1267 Y02B 60/1271 Y02B 60/1275 Y02B 60/1278 Y02B 60/1282 Y02B 60/1285 Y02B 60/1289 Y02B 60/1292 Y02B 60/1296
			Reducing energy-consumption by means of multiprocessor or multiprocessing based techniques, other than acting upon the power supply	Y02B 60/14 Y02B 60/142 Y02B 60/144 Y02B 60/146 Y02B 60/148
			Reducing energy-consumption in distributed systems	Y02B 60/16 Y02B 60/162 Y02B 60/165 Y02B 60/167
			Reducing energy consumption at software or application level	Y02B 60/18 Y02B 60/181 Y02B 60/183 Y02B 60/185 Y02B 60/186 Y02B 60/188
		Techniques for reducing energy-consumption in wire-line communication networks		Y02B 60/30
			using reduced link rate	Y02B 60/31
			using subset functionality	Y02B 60/32
			by selective link activation in bundled links	Y02B 60/33
			by operating in low-power or sleep mode	Y02B 60/34 Y02B 60/35 Y02B 60/36
		High level techniques for reducing energy-consumption in communication networks		Y02B 60/40
			by proxying	Y02B 60/41
			by energy-aware routing	Y02B 60/42
			by signaling and coordination, e.g. signaling reduction, link layer discovery protocol [LLDP	Y02B 60/43 Y02B 60/44 Y02B 60/45
			Application modification for reducing energy-consumption	Y02B 60/46
		Techniques for reducing energy-consumption in wireless communication networks		Y02B 60/50
	Technologies for an efficient end-user side electric power management and	Technologies improving the efficiency by using switched-mode power supplies [SMPS], i.e. efficient power		Y02B 70/10
			Power factor correction technologies for power supplies	Y02B 70/12 Y02B 70/123 Y02B 70/126

	consumption	electronics conversion	Reduction of losses in power supplies	Y02B 70/14 Y02B 70/1408 Y02B 70/1416 Y02B 70/1425 Y02B 70/1433 Y02B 70/1441 Y02B 70/145 Y02B 70/1458 Y02B 70/1466 Y02B 70/1475 Y02B 70/1483 Y02B 70/1491
			Efficient standby or energy saving modes	Y02B 70/16
		Systems integrating technologies related to power network operation and communication or information technologies for improving the carbon footprint of the management of residential or tertiary loads, i.e. smart grids as climate change mitigation technology in the buildings sector, including also the last stages of power distribution and the control, monitoring or operating management systems at local level		Y02B 70/30
			End-user application control systems	Y02B 70/32 Y02B 70/3208 Y02B 70/3216 Y02B 70/3225 Y02B 70/3233 Y02B 70/3241 Y02B 70/325 Y02B 70/3258 Y02B 70/3266 Y02B 70/3275 Y02B 70/3283 Y02B 70/3291
			Smart metering supporting the carbon neutral operation of end-user applications in buildings	Y02B 70/34 Y02B 70/343 Y02B 70/346
	Enabling technologies or technologies with a potential or indirect contribution to GHG emissions mitigation	Systems integrating technologies related to power network operation and communication or information technologies mediating in the improvement of the carbon footprint of the management of residential or tertiary loads, i.e. smart grids as enabling technology in buildings sector		Y02B 90/20
			Systems characterised by the monitored, controlled or operated end-user elements or equipment	Y02B 90/22 Y02B 90/222 Y02B 90/224 Y02B 90/226 Y02B 90/228
			Smart metering mediating in the carbon neutral operation of end-user applications in buildings	Y02B 90/24 Y02B 90/241 Y02B 90/242 Y02B 90/243 Y02B 90/244 Y02B 90/245 Y02B 90/246 Y02B 90/247 Y02B 90/248
			Communication technology specific aspects	Y02B 90/26 Y02B 90/2607 Y02B 90/2615 Y02B 90/2623 Y02B 90/263 Y02B 90/2638 Y02B 90/2646 Y02B 90/2653 Y02B 90/2661 Y02B 90/2669 Y02B 90/2676 Y02B 90/2684 Y02B 90/2692
	Systems supporting the management or operation of end-user stationary applications, including also the last stages of power distribution and the control, monitoring or operating management systems at local level	System characterised by the monitored, controlled or operated end-user elements or equipment		Y04S 20/10
			energy storage units, uninterruptible power supply [UPS] systems or standby or emergency generators involved in the last power distribution stages	Y04S 20/12
			protection elements, switches, relays or circuit breakers	Y04S 20/14
			power plugs, sockets, adapters or power strips	Y04S 20/16
			direct current power network, grid or distribution line	Y04S 20/18
		End-user application control systems		Y04S 20/20
			characterised by the aim of the control	Y04S 20/22 Y04S 20/221 Y04S 20/222 Y04S 20/224 Y04S 20/225 Y04S 20/227 Y04S 20/228
			characterised by the end-user application	Y04S 20/24 Y04S 20/242 Y04S 20/244 Y04S 20/246

				Y04S 20/248
		Smart metering		Y04S 20/30
			Systems characterised by remote reading	Y04S 20/32 Y04S 20/322 Y04S 20/325 Y04S 20/327
			Systems which determine the environmental impact of user behaviour	Y04S 20/34
			Methods or devices for detecting or reporting abnormalities	Y04S 20/36
			Identification of individual loads by analysing current or voltage waveforms	Y04S 20/38
			Displaying of usage with respect to time	Y04S 20/40
			Utility meters which are networked together	Y04S 20/42
			Displaying utility price or cost	Y04S 20/44
			Remote display of meters readings	Y04S 20/46
			Methods for determining the topology of meters in a network	Y04S 20/48
			Retrofitting of installed meters	Y04S 20/50
			Systems oriented to metering of generated energy or power	Y04S 20/52
			Systems oriented to metering of generated energy or power	Y04S 20/525
	Systems supporting specific end-user applications in the sector of transportation	Systems supporting the interoperability of electric or hybrid vehicles		Y04S 30/10
			Remote or cooperative charging	Y04S 30/12
			Details associated with the interoperability	Y04S 30/14
	Market activities related to the operation of systems integrating technologies related to power network operation and communication or information technologies	Energy trading, including energy flowing from end-user application to grid		Y04S 50/10
		Billing, invoicing, buying or selling transactions or other related activities		Y04S 50/12
		Marketing, i.e. market research and analysis, surveying, promotions, advertising, buyer profiling, customer management or rewards		Y04S 50/14
Resilience & security of the energy system	Combustion technologies with mitigation potential	Combined combustion		Y02E 20/10
			Heat utilisation in combustion or incineration of waste	Y02E 20/12
			Combined heat and power generation [CHP]	Y02E 20/14
			Combined cycle power plant [CCPP], or combined cycle gas turbine [CCGT]	Y02E 20/16 Y02E 20/18
		Technologies for a more efficient combustion or heat usage		Y02E 20/30
			Direct CO2 mitigation	Y02E 20/32 Y02E 20/322 Y02E 20/324 Y02E 20/326 Y02E 20/328
			Indirect CO2 mitigation, i.e. by acting on non CO2 directly related matters of the process, e.g. more efficient use of fuels	Y02E 20/34 Y02E 20/342 Y02E 20/346 Y02E 20/348
	Technologies for an efficient electrical power generation, transmission or distribution	Flexible AC transmission systems [FACTS]		Y02E 40/10
			Static VAR compensators [SVC], static VAR generators [SVG] or static VAR systems [SVS], including thyristor-controlled reactors [TCR], thyristor-switched reactors [TSR] or thyristor-switched capacitors [TSC]	Y02E 40/12
			Thyristor-controlled series capacitors [TCSC]	Y02E 40/14
			Static synchronous compensators [STATCOM]	Y02E 40/16
			Unified power flow controllers [UPF] or controlled series voltage compensators	Y02E 40/18

		Active power filtering [APF]		Y02E 40/20
			Non-specified or voltage-fed active power filters	Y02E 40/22
			Current-fed active power filters	Y02E 40/24
			using a multilevel or multicell converter	Y02E 40/26
		Reactive power compensation		Y02E 40/30
			using synchronous generators	Y02E 40/32
			for voltage regulation	Y02E 40/34
		Arrangements for reducing harmonics		Y02E 40/40
		Arrangements for eliminating or reducing asymmetry in polyphase networks		Y02E 40/50
		Superconducting electric elements or equipment or power systems integrating superconducting elements or equipment		Y02E 40/60
			Superconducting generators	Y02E 40/62 Y02E 40/622 Y02E 40/625 Y02E 40/627
			Superconducting transmission lines or power lines or cables or installations thereof	Y02E 40/64 Y02E 40/641 Y02E 40/642 Y02E 40/644 Y02E 40/645 Y02E 40/647 Y02E 40/648
			Superconducting transformers or inductors	Y02E 40/66
			Superconducting energy storage for power networks	Y02E 40/67
			Protective or switching arrangements for superconducting elements or equipment	Y02E 40/68
			Current limitation using superconducting elements, including multifunctional current limiters	Y02E 40/69
		Systems integrating technologies related to power network operation and communication or information technologies for improving the carbon footprint of electrical power generation, transmission or distribution, i.e. smart grids as climate change mitigation technology in the energy generation sector		Y02E 40/70
			Systems characterised by the monitoring, control or operation of energy generation units, e.g. distributed generation [DER] or load-side generation	Y02E 40/72
			Systems characterised by the monitoring, control or operation of flexible AC transmission systems [FACTS] or power factor or reactive power compensating or correcting units	Y02E 40/74
			Computing methods or systems for efficient or low-carbon management or operation of electric power systems	Y02E 40/76
	Enabling technologies or technologies with a potential or indirect contribution to GHG emissions mitigation	Energy storage	Ultracapacitors, supercapacitors, double-layer capacitors	Y02E 60/13
			Thermal storage	Y02E 60/14 Y02E 60/142 Y02E 60/145 Y02E 60/147
			Pressurised fluid storage	Y02E 60/15
			Mechanical energy storage	Y02E 60/16
			Pumped storage	Y02E 60/17
		Arrangements for transfer of electric power between AC networks via a high-tension DC link, HVDC transmission		Y02E 60/60
		Systems integrating technologies related to power network operation and communication or information technologies mediating in the improvement of the carbon footprint of electrical power generation, transmission or distribution, i.e. smart grids as enabling technology in the energy generation sector	characterised by the monitored, controlled or operated power network elements or equipment	Y02E 60/72 Y02E 60/721 Y02E 60/722 Y02E 60/723 Y02E 60/724 Y02E 60/725 Y02E 60/726 Y02E 60/727 Y02E 60/728
			characterised by state monitoring	Y02E 60/74
			Computer aided design [CAD]; Simulation; Modelling	Y02E 60/76

			Communication technology specific aspects	Y02E 60/78 Y02E 60/7807 Y02E 60/7815 Y02E 60/7823 Y02E 60/783 Y02E 60/7838 Y02E 60/7846 Y02E 60/7853 Y02E 60/7861 Y02E 60/7869 Y02E 60/7876 Y02E 60/7884 Y02E 60/7892
	Other energy conversion or management systems reducing GHG emissions	combining energy storage with energy generation of non-fossil origin		Y02E 70/30
		Energy efficient batteries, ultracapacitors, supercapacitors or double-layer capacitors charging or discharging systems or methods		Y02E 70/40
	Systems supporting electrical power generation, transmission or distribution	characterised by the monitored, controlled or operated power network elements or equipment		Y04S 10/10
			energy generation units, including distributed generation [DER] or load-side generation	Y04S 10/12 Y04S 10/123 Y04S 10/126
			energy storage units	Y04S 10/14
			electric power substations	Y04S 10/16
			switches, relays or circuit breakers	Y04S 10/18
			protection elements, arrangements or systems	Y04S 10/20
			flexible AC transmission systems [FACTS] or power factor or reactive power compensating or correcting units	Y04S 10/22
			voltage regulating units	Y04S 10/24
			measuring units	Y04S 10/26 Y04S 10/265
		characterised by state monitoring		Y04S 10/30
		characterised by the display of information		Y04S 10/40
		supporting the power network operation or management, involving a certain degree of interaction with the load-side end user applications		Y04S 10/50
			Outage or fault management	Y04S 10/52 Y04S 10/522 Y04S 10/525 Y04S 10/527
			Management of operational aspects	Y04S 10/54 Y04S 10/545
			Supply chain or logistics	Y04S 10/56
			Financial aspects	Y04S 10/58
			Reporting; Information providing; Statistics or analysis	Y04S 10/60
	Communication or information technology specific aspects supporting electrical power generation, transmission, distribution or end-user application management	Communication technology specific aspects		Y04S 40/10
			Transmission structure or support between the monitoring, controlling or managing units and monitored, controlled or operated electrical equipment	Y04S 40/12 Y04S 40/121 Y04S 40/122 Y04S 40/123 Y04S 40/124 Y04S 40/125 Y04S 40/126 Y04S 40/127 Y04S 40/128
			Aspects related to the treatment or conditioning of data or signals	Y04S 40/14 Y04S 40/143 Y04S 40/146
			Management of the overlaying communication network between the monitoring, controlling or managing units and monitored, controlled or operated electrical equipment	Y04S 40/16 Y04S 40/162 Y04S 40/164 Y04S 40/166 Y04S 40/168
		Information technology specific aspects		Y04S 40/20
			Computer aided design [CAD]; Simulation; Modelling	Y04S 40/22
			Arrangements for network security or for protecting computers or computer systems against unauthorised activity	Y04S 40/24

Table 7: CPC codes selected under the Energy Union R&I and Competitiveness Priority: **Efficient Energy Systems** and corresponding Integrated SET Plan Actions

SET Plan Action	CPC Technology details			CPC Codes
New materials & technologies for buildings	Integration of renewable energy sources in buildings	Photovoltaic [PV]		Y02B 10/10
			Roof systems for PV cells	Y02B 10/12
			PV hubs	Y02B 10/14
		Solar thermal		Y02B 10/20
			Evacuated solar collectors	Y02B 10/22
			Air conditioning or refrigeration systems	Y02B 10/24
		Wind power		Y02B 10/30
		Geothermal heat-pumps		Y02B 10/40
		Hydropower in dwellings		Y02B 10/50
		Use of biomass for heating		Y02B 10/60
		Hybrid systems		Y02B 10/70
			Uninterruptible or back-up power supplies integrating renewable energies	Y02B 10/72
	Energy efficient heating, ventilation or air conditioning [HVAC]	Passive houses; Double facade technology		Y02B 30/90
			with air flow into the conditioned premises or facilities	Y02B 30/92
			Improving the thermodynamic properties of the premises or facilities	Y02B 30/94
	Architectural or constructional elements improving the thermal performance of buildings	Insulation		Y02B 80/10
			Slab shaped vacuum insulation	Y02B 80/12
			Slab shaped aerogel insulation	Y02B 80/14
		Windows or doors		Y02B 80/20
			Glazing	Y02B 80/22 Y02B 80/24 Y02B 80/26
			Wooden or plastic frames with extra insulation	Y02B 80/28
		Roofs		Y02B 80/30
			Roof garden systems	Y02B 80/32
			Roof coverings with high solar reflectance	Y02B 80/34
		Floors specially adapted for storing heat or cold		Y02B 80/40
		Light dependent control systems for sun shading		Y02B 80/50
Energy efficiency in industry	Combustion technologies with mitigation potential	Technologies for a more efficient combustion or heat usage	Heat recovery other than air pre-heating	Y02E 20/36 Y02E 20/363 Y02E 20/366
	Technologies related to metal processing	Reduction of greenhouse gas [GHG] emissions	CO2	Y02P 10/134 Y02P 10/136 Y02P 10/138
			Greenhouse gases [GHG] other than CO2	Y02P 10/14 Y02P 10/143 Y02P 10/146
		Process efficiency		Y02P 10/20
			by recovering materials	Y02P 10/21 Y02P 10/212 Y02P 10/214 Y02P 10/216 Y02P 10/218 Y02P 10/22 Y02P 10/224 Y02P 10/226 Y02P 10/228 Y02P 10/23 Y02P 10/232 Y02P 10/234 Y02P 10/236 Y02P 10/238 Y02P 10/24 Y02P 10/242
			by increasing the energy efficiency of the process	Y02P 10/25 Y02P 10/253 Y02P 10/256 Y02P 10/259 Y02P 10/262 Y02P 10/265 Y02P 10/268 Y02P 10/271 Y02P 10/274 Y02P 10/277

				Y02P 10/28 Y02P 10/283 Y02P 10/286 Y02P 10/29 Y02P 10/292 Y02P 10/295
			characterised by the energy source	Y02P 10/30 Y02P 10/32 Y02P 10/34
	Technologies relating to chemical industry	General improvement of production processes causing greenhouse gases [GHG] emissions		Y02P 20/10
			Energy input	Y02P 20/12 Y02P 20/121 Y02P 20/122 Y02P 20/123 Y02P 20/124 Y02P 20/125 Y02P 20/126 Y02P 20/127 Y02P 20/128 Y02P 20/129 Y02P 20/13 Y02P 20/131 Y02P 20/132 Y02P 20/133 Y02P 20/134 Y02P 20/135 Y02P 20/136
			Reagents; Educts; Products	Y02P 20/14 Y02P 20/141 Y02P 20/143 Y02P 20/144 Y02P 20/145 Y02P 20/146 Y02P 20/147 Y02P 20/148 Y02P 20/149 Y02P 20/15 Y02P 20/151 Y02P 20/152 Y02P 20/153 Y02P 20/154 Y02P 20/155 Y02P 20/156
		Improvements relating to chlorine production		Y02P 20/20
			Optimization of Deacon process	Y02P 20/22 Y02P 20/224 Y02P 20/228
		Improvements relating to adipic acid or caprolactam production		Y02P 20/30
			Technologies aiming at reducing N2O emissions	Y02P 20/32 Y02P 20/324 Y02P 20/328
		Improvements relating to chlorodifluoromethane [HCFC-22] production		Y02P 20/40
			Reducing fluoroform [HFC-23] emissions	Y02P 20/42 Y02P 20/424
		Improvements relating to the production of products other than chlorine, adipic acid, caprolactam, or chlorodifluoromethane, e.g. bulk or fine chemicals or pharmaceuticals		Y02P 20/50
			Bulk chemicals	Y02P 20/51 Y02P 20/514 Y02P 20/518
			using catalysts	Y02P 20/52
			characterised by the solvent	Y02P 20/54 Y02P 20/542 Y02P 20/546
			Synthetic design	Y02P 20/55
			Efficient separation techniques	Y02P 20/57 Y02P 20/572
			Recycling	Y02P 20/58 Y02P 20/582 Y02P 20/584 Y02P 20/586 Y02P 20/588
			Biological synthesis; Biological purification	Y02P 20/59
	Technologies relating to oil refining and petrochemical industry	Reduction of greenhouse gas [GHG] emissions during production processes		Y02P 30/10
		Bio-feedstock		Y02P 30/20
		Ethylene production		Y02P 30/40
			using bio-feedstock	Y02P 30/42
			Cracking, e.g. steam cracking	Y02P 30/44 Y02P 30/442

				Y02P 30/444 Y02P 30/446
			Separation	Y02P 30/46 Y02P 30/462 Y02P 30/464
			Compression	Y02P 30/48
	Technologies relating to the processing of minerals	Production of cement		Y02P 40/10
			Clinker production	Y02P 40/12 Y02P 40/121 Y02P 40/123 Y02P 40/125 Y02P 40/126 Y02P 40/128
			Reduction of clinker content in cement	Y02P 40/14 Y02P 40/141 Y02P 40/143 Y02P 40/145 Y02P 40/146 Y02P 40/148
			Non-limestone based cements	Y02P 40/16 Y02P 40/165
		Cement grinding		Y02P 40/20
		Manufacturing or processing of sand or stone		Y02P 40/30
		Production or processing of lime		Y02P 40/40
			Limestone calcination	Y02P 40/42
			Regeneration of lime in pulp and sugar mills	Y02P 40/44
			using fuels from renewable energy sources	Y02P 40/45
			Reduction of lime consumption	Y02P 40/47 Y02P 40/49
		Glass production		Y02P 40/50
			Producing or shaping of glass	Y02P 40/51
			Use of cullet or other waste	Y02P 40/52
			Reusing waste heat during processing or shaping	Y02P 40/53 Y02P 40/535
			Oxy-fuel	Y02P 40/55
			Batch or cullet pre-heating	Y02P 40/56
			Reduction of reject rates; Improving the yield	Y02P 40/57
			Fuels from renewable energy sources	Y02P 40/58
		Production of ceramic materials or ceramic elements		Y02P 40/60
			Manufacturing of materials for construction	Y02P 40/61 Y02P 40/615
			Improving processing, storage or transport systems	Y02P 40/63
			Improving kilns	Y02P 40/65
			Fuels from renewable energy sources	Y02P 40/67
			Substitution of clay or shale by alternative raw materials	Y02P 40/69
	Technologies relating to agriculture, livestock or agroalimentary industries	Food processing		Y02P 60/80
			Use of renewable energies or variable speed drives in handling, conveying or stacking	Y02P 60/81
			Warming or cooking	Y02P 60/83 Y02P 60/831 Y02P 60/833 Y02P 60/835
			Food storage or conservation	Y02P 60/85 Y02P 60/851 Y02P 60/853 Y02P 60/855
			Re-use of by-products of food processing for fodder production	Y02P 60/87 Y02P 60/871 Y02P 60/873 Y02P 60/875 Y02P 60/877
			characterised by the product	Y02P 60/89 Y02P 60/891
	Climate change mitigation technologies in the production process for final industrial or consumer products	Greenhouse gas [GHG] capture, material saving, heat recovery or other energy efficient measures, characterised by manufacturing processes		Y02P 70/10
			Improving processes or machines for shaping products	Y02P 70/12 Y02P 70/121 Y02P 70/123 Y02P 70/125 Y02P 70/127 Y02P 70/129

				Y02P 70/131 Y02P 70/133 Y02P 70/135 Y02P 70/137 Y02P 70/139 Y02P 70/141 Y02P 70/143 Y02P 70/145
			Metal working by removing or adding material	Y02P 70/16 Y02P 70/161 Y02P 70/163 Y02P 70/167 Y02P 70/169 Y02P 70/171 Y02P 70/173 Y02P 70/175 Y02P 70/177 Y02P 70/179 Y02P 70/181 Y02P 70/183 Y02P 70/185 Y02P 70/187
			Printing, lining or stamping machines	Y02P 70/20
			Technologies for working on wood, veneer or plywood	Y02P 70/22
			saving energy and raw materials during the production of paper or paper articles	Y02P 70/24
			Working on or processing of plastics	Y02P 70/26 Y02P 70/261 Y02P 70/263 Y02P 70/265 Y02P 70/267 Y02P 70/269 Y02P 70/271 Y02P 70/273 Y02P 70/275 Y02P 70/277 Y02P 70/279 Y02P 70/281
			Conveying, packing or storing of goods or handling thin or filamentary material	Y02P 70/30
			Relating to mixing	Y02P 70/32
			Relating to separation, flotation or differential sedimentation	Y02P 70/34
			Recycling or reuse of a liquid sprayed or atomised	Y02P 70/36
			Apparatus or processes for applying liquids or other fluent materials	Y02P 70/38
			Drying by removing liquid	Y02P 70/40 Y02P 70/405
		Manufacturing or production processes characterised by the final manufactured product		Y02P 70/50
			Manufacturing of products or systems for producing renewable energy	Y02P 70/52 Y02P 70/521 Y02P 70/523 Y02P 70/525 Y02P 70/527
			Manufacturing of lithium-ion, lead-acid or alkaline secondary batteries	Y02P 70/54
			Manufacturing of fuel cells	Y02P 70/56
			Manufacturing or assembling of vehicles	Y02P 70/58 Y02P 70/585
			Production or assembly of electric or electronic components or products	Y02P 70/60 Y02P 70/601 Y02P 70/603 Y02P 70/605 Y02P 70/607 Y02P 70/609 Y02P 70/611 Y02P 70/613
			Production or treatment of textile or flexible materials or products thereof, including footwear	Y02P 70/62 Y02P 70/621 Y02P 70/623 Y02P 70/625 Y02P 70/627 Y02P 70/629 Y02P 70/631 Y02P 70/633

				Y02P 70/635 Y02P 70/637 Y02P 70/639 Y02P 70/641 Y02P 70/643 Y02P 70/645 Y02P 70/647 Y02P 70/649 Y02P 70/651 Y02P 70/653
			Manufacturing or preparation of tobacco products	Y02P 70/66
	Climate change mitigation technologies for sector-wide applications	Efficient use of energy		Y02P 80/10
			of electric energy	Y02P 80/11 Y02P 80/112 Y02P 80/114 Y02P 80/116
			using compressed air as energy carrier, e.g. for pneumatic systems	Y02P 80/12
			using pressurized fluid as energy carrier, e.g. for hydraulic systems	Y02P 80/13
			District level solutions, i.e. local energy networks	Y02P 80/14
			On-site combined power, heat or cool generation or distribution,	Y02P 80/15 Y02P 80/152 Y02P 80/154
			in fluid distribution systems	Y02P 80/156 Y02P 80/158
		Sector-wide applications using renewable energy		Y02P 80/20
			Biomass as fuel	Y02P 80/21
			Wind energy	Y02P 80/22
			Solar energy	Y02P 80/23 Y02P 80/24 Y02P 80/25
		Reducing waste in manufacturing processes; Calculations of released waste quantities		Y02P 80/30
		Minimising material used in manufacturing processes		Y02P 80/40
	Enabling technologies with a potential contribution to greenhouse gas [GHG] emissions mitigation	Total factory control, e.g. smart factories, flexible manufacturing systems [FMS] or integrated manufacturing systems [IMS]		Y02P 90/02
			assembly processes	Y02P 90/04
			direct numerical control [DNC]	Y02P 90/06
			cooperation between machine tools, manipulators or work piece supply systems	Y02P 90/08 Y02P 90/083 Y02P 90/087
			identification, e.g. of work pieces or equipment	Y02P 90/10
			programme execution	Y02P 90/12
			fault tolerance, reliability of production system	Y02P 90/14
			system universality, i.e. configurability or modularity of production units	Y02P 90/16
			network communication	Y02P 90/18 Y02P 90/185
			job scheduling, process planning or material flow	Y02P 90/20 Y02P 90/205
			quality surveillance of production	Y02P 90/22
			computer integrated manufacturing [CIM], planning or realisation	Y02P 90/24
			modelling or simulation of the manufacturing system	Y02P 90/26 Y02P 90/265
			transport systems	Y02P 90/28 Y02P 90/285
		Computing systems specially adapted for manufacturing		Y02P 90/30
		Fuel cell technologies in production processes		Y02P 90/40
		Hydrogen technologies in production processes		Y02P 90/45
		Energy storage in industry with an added climate change mitigation effect		Y02P 90/50
		Electric or hybrid propulsion means for production processes		Y02P 90/60
		Management or planning		Y02P 90/80

			Energy audits or management systems therefor	Y02P 90/82
			Greenhouse gas [GHG] management systems	Y02P 90/84 Y02P 90/845
			Maintenance planning	Y02P 90/86
		Financial instruments for climate change mitigation		Y02P 90/90
			CO2 emission certificates or credits trading	Y02P 90/95

Table 8: CPC codes selected under the Energy Union R&I and Competitiveness Priority: **Sustainable transport** and corresponding SET Plan Actions.

SET Plan Action	CPC Technology details			CPC Codes
Competitive in the global battery sector (e-mobility)	Enabling technologies or technologies with a potential or indirect contribution to GHG emissions mitigation	Energy storage	Battery technology	Y02E 60/12 Y02E 60/122 Y02E 60/124 Y02E 60/126 Y02E 60/128
	Road transport of goods or passengers	Other road transportation technologies with climate change mitigation effect		Y02T 10/60
			Hybrid vehicles	Y02T 10/62 Y02T 10/6204 Y02T 10/6208 Y02T 10/6213 Y02T 10/6217 Y02T 10/6221 Y02T 10/6226 Y02T 10/623 Y02T 10/6234 Y02T 10/6239 Y02T 10/6243 Y02T 10/6247 Y02T 10/6252 Y02T 10/6256 Y02T 10/626 Y02T 10/6265 Y02T 10/6269 Y02T 10/6273 Y02T 10/6278 Y02T 10/6282 Y02T 10/6286 Y02T 10/6291 Y02T 10/6295
			Electric machine technologies for applications in electromobilty	Y02T 10/64 Y02T 10/641 Y02T 10/642 Y02T 10/643 Y02T 10/644 Y02T 10/645 Y02T 10/646 Y02T 10/647 Y02T 10/648 Y02T 10/649
			Energy storage for electromobility	Y02T 10/70 Y02T 10/7005 Y02T 10/7011 Y02T 10/7016 Y02T 10/7022 Y02T 10/7027 Y02T 10/7033 Y02T 10/7038 Y02T 10/7044 Y02T 10/705 Y02T 10/7055 Y02T 10/7061 Y02T 10/7066 Y02T 10/7072 Y02T 10/7077 Y02T 10/7083 Y02T 10/7088 Y02T 10/7094
			Electric energy management in electromobility	Y02T 10/72 Y02T 10/7208 Y02T 10/7216 Y02T 10/7225 Y02T 10/7233 Y02T 10/7241 Y02T 10/725 Y02T 10/7258 Y02T 10/7266 Y02T 10/7275 Y02T 10/7283 Y02T 10/7291
		Technologies aiming to reduce greenhouse gasses emissions common to all road transportation technologies	Energy harvesting concepts as power supply for auxiliaries' energy consumption	Y02T 10/90
			Energy efficient charging or discharging systems for batteries, ultracapacitors, supercapacitors or double-layer capacitors specially adapted for vehicles	Y02T 10/92
	Transportation of goods or passengers via railways	Energy recovery technologies concerning the propulsion system in locomotives or motor railcars	Specific power storing devices	Y02T 30/18
	Aeronautics or air transport	Efficient propulsion technologies		Y02T 50/60
			Electrical	Y02T 50/62
			Hybrid	Y02T 50/64
	Enabling technologies or	Technologies related to		Y02T 90/10

	technologies with a potential or indirect contribution to GHG emissions mitigation	electric vehicle charging	Electric charging stations	Y02T 90/12 Y02T 90/121 Y02T 90/122 Y02T 90/124 Y02T 90/125 Y02T 90/127 Y02T 90/128
			Plug-in electric vehicles	Y02T 90/14
			Information or communication technologies improving the operation of electric vehicles	Y02T 90/16 Y02T 90/161 Y02T 90/162 Y02T 90/163 Y02T 90/164 Y02T 90/165 Y02T 90/166 Y02T 90/167 Y02T 90/168 Y02T 90/169
	Technologies for solid waste management	Reuse, recycling or recovery technologies	Recycling of batteries	Y02W 30/84
Renewable fuels	Enabling technologies or technologies with a potential or indirect contribution to GHG emissions mitigation	Applications of fuel cells in buildings		Y02B 90/10
			Cogeneration of electricity with other electric generators	Y02B 90/12
			Emergency, uninterruptible or back-up power supplies integrating fuel cells	Y02B 90/14
			Cogeneration or combined heat and power generation	Y02B 90/16
			Fuel cells specially adapted to portable applications	Y02B 90/18
	Technologies for the production of fuel of non-fossil origin	Biofuels		Y02E 50/10
			CHP turbines for biofeed	Y02E 50/11
			Gas turbines for biofeed	Y02E 50/12
			Bio-diesel	Y02E 50/13
			Bio-pyrolysis	Y02E 50/14
			Torrefaction of biomass	Y02E 50/15
			Cellulosic bio-ethanol	Y02E 50/16
			Grain bio-ethanol	Y02E 50/17
			Bio-alcohols produced by other means than fermentation	Y02E 50/18
		Fuel from waste		Y02E 50/30
			Synthesis of alcohols or diesel from waste including a pyrolysis and/or gasification step	Y02E 50/32
			Methane	Y02E 50/34 Y02E 50/343 Y02E 50/346
	Enabling technologies or technologies with a potential or indirect contribution to GHG emissions mitigation	Hydrogen technology		Y02E 60/30
			Hydrogen storage	Y02E 60/32 Y02E 60/321 Y02E 60/322 Y02E 60/324 Y02E 60/325 Y02E 60/327 Y02E 60/328
			Hydrogen distribution	Y02E 60/34
			Hydrogen production from non-carbon containing sources	Y02E 60/36 Y02E 60/362 Y02E 60/364 Y02E 60/366
		Hydrogen technology	Hydrogen production from non-carbon containing sources	Y02E 60/368
		Fuel cells		Y02E 60/50
			characterised by type or design	Y02E 60/52 Y02E 60/521 Y02E 60/522 Y02E 60/523 Y02E 60/525 Y02E 60/526 Y02E 60/527 Y02E 60/528
			integrally combined with other energy production systems	Y02E 60/56 Y02E 60/563 Y02E 60/566
	Other energy conversion or management systems reducing GHG emissions	Hydrogen from electrolysis with energy of non-fossil origin		Y02E 70/10
		Systems combining fuel cells with production of fuel of non-fossil origin		Y02E 70/20
	Road transport of goods or passengers	Internal combustion engine [ICE] based vehicles	Use of alternative fuels	Y02T 10/30 Y02T 10/32 Y02T 10/34 Y02T 10/36 Y02T 10/38
	Aeronautics or air transport	Enabling use of sustainable fuels		Y02T 50/70
			Synthetic fuels	Y02T 50/72
			Bio fuels	Y02T 50/74
	Enabling technologies or technologies with a potential or indirect contribution to	Application of fuel cell technology to transportation		Y02T 90/30
			Fuel cells specially adapted to transport applications	Y02T 90/32

	GHG emissions mitigation		Fuel cell powered electric vehicles [FCEV]	Y02T 90/34
			Fuel cells as on-board power source in aeronautics	Y02T 90/36
			Fuel cells as on-board power source in waterborne transportation	Y02T 90/38
		Application of hydrogen technology to transportation		Y02T 90/40
			Hydrogen as fuel for road transportation	Y02T 90/42
			Hydrogen as fuel in aeronautics	Y02T 90/44
			Hydrogen as fuel in waterborne transportation	Y02T 90/46
	Technologies for solid waste management	Reuse, recycling or recovery technologies	Recycling of fuel cells	Y02W 30/86

Table 9: CPC codes selected under the Energy Union R&I and Competitiveness Priority: **Carbon Capture Utilisation and Storage** and corresponding Integrated SET Plan Action.

SET Plan Action	CPC Technology details			CPC Codes
Carbon Capture Utilisation and Storage	CO_2 capture or storage	Capture by biological separation		Y02C 10/02
		Capture by chemical separation		Y02C 10/04
		Capture by absorption		Y02C 10/06
		Capture by adsorption		Y02C 10/08
		Capture by membranes or diffusion		Y02C 10/10
		Capture by rectification and condensation		Y02C 10/12
		Subterranean or submarine CO_2 storage		Y02C 10/14
	Combustion technologies with mitigation potential	Combined combustion	Combined cycle power plant [CCPP], or combined cycle gas turbine [CCGT]	Y02E 20/185
		Technologies for a more efficient combustion or heat usage	Indirect CO_2 mitigation, i.e. by acting on non CO_2 directly related matters of the process	Y02E 20/344
	Technologies related to metal processing	Reduction of greenhouse gas [GHG] emissions		Y02P 10/10
		Reduction of greenhouse gas [GHG] emissions	CO_2	Y02P 10/12 Y02P 10/122 Y02P 10/124 Y02P 10/126 Y02P 10/128 Y02P 10/13 Y02P 10/132
	Technologies relating to chemical industry	General improvement of production processes causing greenhouse gases [GHG] emissions	Reagents; Educts; Products	Y02P 20/142
		Improvements relating to the production of products other than chlorine, adipic acid, caprolactam, or chlorodifluoromethane	characterised by the solvent	Y02P 20/544
	Technologies relating to oil refining and petrochemical industry	Carbon capture or storage [CCS] specific to hydrogen production		Y02P 30/30
	Technologies relating to the processing of minerals	Production of cement	Carbon capture and storage [CCS]	Y02P 40/18
		Glass production	CO_2 capture, e.g. for large oxy-fuel furnaces	Y02P 40/59
	Enabling technologies with a potential contribution to greenhouse gas [GHG] emissions mitigation	Combining sequestration of CO_2 and exploitation of hydrocarbons by injecting CO_2 or carbonated water in oil wells		Y02P 90/70

Table 10: CPC codes selected under the Energy Union R&I and Competitiveness Priority: **Nuclear Safety** and corresponding Integrated SET Plan Action.

SET Plan Action	CPC Technology details			CPC Codes
Nuclear Safety	Energy generation of nuclear origin	Fusion reactors		Y02E 30/10
			Magnetic plasma confinement [MPC]	Y02E 30/12 Y02E 30/122 Y02E 30/124 Y02E 30/126 Y02E 30/128
		Nuclear fission reactors		Y02E 30/30
			Boiling water reactors	Y02E 30/31
			Pressurized water reactors	Y02E 30/32
			Gas cooled reactors	Y02E 30/33
			Fast breeder reactors	Y02E 30/34
			Liquid metal reactors	Y02E 30/35
			Accelerator driven reactors	Y02E 30/37
			Fuel	Y02E 30/38
			Control of nuclear reactions	Y02E 30/39
			Other aspects relating to nuclear fission	Y02E 30/40
	Technologies for solid waste management	Reuse, recycling or recovery technologies	Nuclear fuel reprocessing	Y02W 30/88 Y02W 30/881 Y02W 30/882 Y02W 30/883 Y02W 30/884

Annex 2: Concordance of IEA questionnaire with Energy Union R&I Priorities and SET Plan Actions

Table 11: Concordance of IEA questionnaire (IEA, 2011) with Energy Union R&I Priorities and Integrated SET Plan Actions

IEA level 1	IEA level 2	IEA level 3	IEA level 4	SET Plan Action	Energy Union R&I Priority
1 ENERGY EFFICIENCY	11 Industry	111 Industrial techniques and processes		Energy efficiency in industry	Efficient Energy Systems
		112 Industrial equipment and systems			
		113 Other industry			
		119 Unallocated industry			
	12 Residential and commercial buildings, appliances and equipment	121 Building design and envelope	1211 Building envelope technologies	New materials & technologies for buildings	
			1212 Building design		
			1219 Unallocated building design and envelope		
		122 Building operations and efficient building equipment	1221 Building energy management systems (incl. smart meters) and efficient internet and communication technologies	New technologies & services for consumers	Smart EU Energy System with consumers at the centre
			1222 Lighting technologies and control systems		
			1223 Heating, cooling and ventilation technologies		
			1224 Other building operations and efficient building equipment		
			1229 Unallocated building operations and efficient building equipment		
		123 Appliances and other residential/commercial	1231 Appliances		
			1232 Batteries for portable devices		
			1233 Other residential/commercial		
			1239 Unallocated appliances and other residential/commercial		
		129 Unallocated residential and commercial buildings, appliances and equipment		Split equally between technologies for buildings and services for consumers	Split equally between Smart System and Efficient Systems
	13 Transport	131 On-road vehicles	1311 Vehicle batteries/storage technologies	Renewable fuels	Sustainable transport
			1312 Advanced power electronics, motors and EV/HEV/FCV systems		
			1313 Advanced combustion engines		
			1314 Electric vehicle infrastructure (incl. smart chargers and grid communications)		
			1315 Use of fuels for on-road vehicles (excl. hydrogen)		
			1316 Materials for on-road vehicles		
			1317 Other on-road transport		
			1319 Unallocated on-road vehicles		
		132 Off-road transport and transport systems			
		133 Other transport			
		139 Unallocated			

		transport			
	14 Other energy efficiency	141 Waste heat recovery and utilisation		Energy efficiency in industry	Efficient Energy Systems
		142 Communities			
		143 Agriculture and forestry			
		144 Heat pumps and chillers			
		145 Other energy efficiency			
		149 Unallocated other energy efficiency			
	19 Unallocated energy efficiency			Split equally between energy efficiency in buildings and industry	
2 FOSSIL FUELS: OIL, GAS and COAL	21 Oil and gas	211 Enhanced oil and gas production		Resilience & security of the energy system	Smart EU Energy System with consumers at the centre
		212 Refining, transport and storage of oil and gas			
		213 Non-conventional oil and gas production			
		214 Oil and gas combustion			
		215 Oil and gas conversion			
		216 Other oil and gas			
		219 Unallocated oil and gas			
	22 Coal	221 Coal production, preparation and transport			
		222 Coal combustion (incl. IGCC)			
		223 Coal conversion (excl. IGCC)			
		224 Other coal			
		229 Unallocated coal			
	23 CO2 capture and storage	231 CO2 capture/separation		Carbon Capture Utilisation and Storage	Carbon Capture Utilisation and Storage
		232 CO2 transport			
		233 CO2 storage			
		239 Unallocated CO2 capture and storage			
3 RENEWABLE ENERGY SOURCES	31 Solar energy	311 Solar heating and cooling		Performant renewable technologies integrated in the system - Reduce technology costs	No 1 in Renewables
		312 Solar photovoltaics			
		313 Solar thermal power and high-temp. applications			
		319 Unallocated solar energy			
	32 Wind energy	321 Onshore wind technologies			
		322 Offshore wind technologies (excl. low wind speed)			
		323 Wind energy systems and other technologies			
		329 Unallocated wind energy			
	33 Ocean energy	331 Tidal energy			
		332 Wave energy			
		333 Salinity gradient power			
		334 Other ocean energy			
		339 Unallocated ocean energy			
	34 Biofuels (incl. liquid biofuels, solid biofuels	341 Production of liquid biofuels	3411 Gasoline substitutes (incl. ethanol)	Renewable fuels	Sustainable transport
			3412 Diesel, kerosene and		

	and biogases)		jet fuel substitutes		
			3413 Algal biofuels		
			3414 Other liquid fuel substitutes		
			3419 Unallocated production of liquid biofuels		
		343 Production of biogases	3431 Thermochemical		
			3432 Biochemical (incl. anaerobic digestion)		
			3433 Other biogases		
			3439 Unallocated production of biogases		
		344 Applications for heat and electricity			
		345 Other biofuels			
		349 Unallocated biofuels			
	35 Geothermal energy	351 Geothermal energy from hydrothermal resources		Performant renewable technologies integrated in the system - Reduce technology costs	No 1 in Renewables
		352 Geothermal energy from hot dry rock (HDR) resources			
		353 Advanced drilling and exploration			
		354 Other geothermal energy (incl. low-temp. resources)			
		359 Unallocated geothermal energy			
	36 Hydroelectricity	361 Large hydroelectricity (capacity of 10 MW and above)			
		362 Small hydroelectricity (capacity less than 10 MW)			
		369 Unallocated hydroelectricity			
	37 Other renewable energy sources				
	39 Unallocated renewable energy sources				
4 NUCLEAR FISSION and FUSION	41 Nuclear fission	411 Light water reactors (LWRs)	412 Other converter reactors	Nuclear Safety	Nuclear Safety
			4121 Heavy water reactors (HWRs)		
			4122 Other converter reactors		
			4129 Unallocated other converter reactors		
		413 Fuel cycle	4131 Fissile material recycling / reprocessing		
			4132 Nuclear waste management		
			4133 Other fuel cycle		
			4139 Unallocated fuel cycle		
		414 Nuclear supporting technologies	4141 Plant safety and integrity		
			4142 Environmental protection		
			4143 Decommissioning		
			4144 Other nuclear supporting technologies		
			4149 Unallocated nuclear supporting technologies		
		415 Nuclear breeder			
		416 Other nuclear fission			
		419 Unallocated nuclear fission			

	42 Nuclear fusion	421 Magnetic confinement			
		422 Inertial confinement			
		423 Other nuclear fusion			
		429 Unallocated nuclear fusion			
	49 Unallocated nuclear fission and fusion				
5 HYDROGEN and FUEL CELLS	51 Hydrogen	511 Hydrogen production		Renewable fuels	Sustainable transport
		512 Hydrogen storage			
		513 Hydrogen transport and distribution			
		514 Other infrastructure and systems			
		515 Hydrogen end-uses (incl. combustion; excl. fuel cells and vehicles)			
		519 Unallocated hydrogen			
	52 Fuel cells	521 Stationary applications			
		522 Mobile applications			
		523 Other applications			
		529 Unallocated fuel cells			
	59 Unallocated hydrogen and fuel cells				
6 OTHER POWER and STORAGE TECHNOLOGIES	61 Electric power generation	611 Power generation technologies		Resilience & security of the energy system	Smart EU Energy System with consumers at the centre
		612 Power generation supporting technologies			
		613 Other electric power generation			
		619 Unallocated electric power generation			
	62 Electricity transmission and distribution	621 Transmission and distribution technologies	6211 Cables and conductors (superconducting, conventional, composite core)		
			6212 AC/DC conversion		
			6213 Other transmission and distribution technologies		
			6219 Unallocated transmission and distribution technologies		
		622 Grid communication, control systems and integration	6221 Load management (incl. renewable integration)		
			6222 Control systems and monitoring		
			6223 Standards, interoperability and grid cyber security		
			6229 Unallocated grid communication, control systems and integration		
		629 Unallocated electricity transmission and distribution			
	63 Energy storage (non-transport applications)	631 Electrical storage	6311 Batteries and other electrochemical storage (excl. vehicles and general public portable devices)		
		631 Electrical storage	6312 Electromagnetic storage		
		631 Electrical storage	6313 Mechanical storage		
		631 Electrical storage	6314 Other storage (excl. fuel cells)		
		631 Electrical storage	6319 Unallocated electrical storage		
		632 Thermal energy			

		storage			
		639 Unallocated energy storage			
	69 Unallocaated other power and storage technologies				
7 OTHER CROSS-CUTTING TECHNOLOGIES or RESEARCH	71 Energy system analysis			Resilience & security of the energy system	Smart EU Energy System with consumers at the centre
	72 Basic energy research that cannot be allocated to a specific category				
	73 Other				

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