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ÖSTERREICHISCHES INSTITUT FÜR WIRTSCHAFTSFORSCHUNG

Pilot Energy Innovation Scoreboard

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Research assistance: Katharina Köberl (WIFO)

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Abstract

A concept for an "Energy Innovation Scoreboard" was developed that presents an overview on energy research indicators and that serves as an input for the "IEA Expert Group on R&D Priority Setting and Evaluation". The study uses the concept of the Innovation Union Scoreboard as well as previous work by ÖGUT as starting point. Based on this input a pilot for a similar Energy Innovation Scoreboard is presented.

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Motivation

This short study commissioned by the Austrian Federal Ministry for Transport, Innovation and Technology to WIFO and ÖGUT aims at delivering an input for discussion in the IEA Expert Group on R&D Priority Setting and Evaluation. The work of WIFO and ÖGUT should stimulate discussion on the feasibility of an energy innovation scoreboard with respect to the conceptual framework and structure as well as the choice of indicators to be included.

The aim is to propose a structure based on an integrated view of the energy innovation process that is embedded in a conceptual framework of the energy system. Internationally comparable databases like the IEA and OECD databases are screened with respect to the availability of relevant indicators for energy innovation. Based on the compiled data sets exemplary energy innovation indicators are proposed and discussed. This is supplemented by an outline of additional indicators that would improve the value of an energy innovation scoreboard.

The short study is divided into two parts:

Part A, carried out by WIFO, discusses the role of energy R&D for a transformation of the energy system and develops a conceptual framework for an energy innovation scoreboard integrated in a broader perspective of the energy system. It aims at providing a setting that illustrates the energy innovation capabilities of countries and that has the potential to be used as benchmarking tool for energy innovation policy.

Part B, carried out by ÖGUT, focuses on extending and complementing the developed framework for an energy innovation scoreboard. Additional indicators are discussed, using proxy data that cover further aspects relevant for energy innovation. This extended indicator system aims at using a broader information base.

Part A: Scoping a feasible structure for an energy innovation scoreboard – WIFO

1 Conceptual Framework

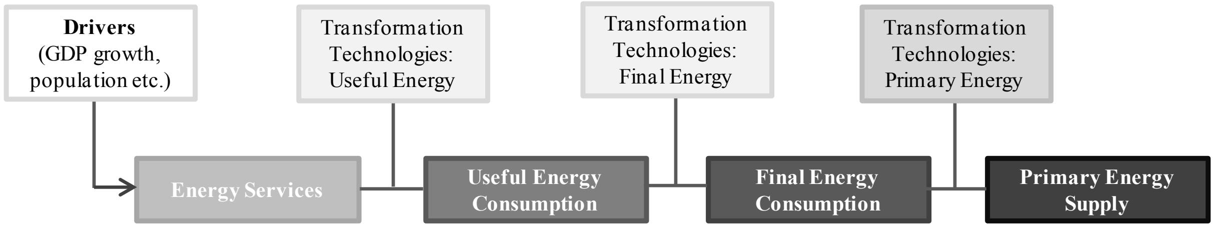
Energy fuels nearly all aspects of our economies and societies . On a global scale, fossil fuels that entail massive detrimental effects on the environment or health have a share in primary energy supply of 81% (IEA, 2013). This goes along with manifold societal challenges like climate change, the aim to increase energy security and the debate on competitiveness due to differing national energy prices, all contributing to the discussion on how to transform energy systems.

There exists no broad consensus on guidelines for a transformation of the energy system and the necessary innovations. The German "Energiewende" for instance is driven by phasing out nuclear energy. This automatically translates into a focus on electricity supply and a change of the energy mix in favour of an increased share of renewables. An alternative perspective e.g. as put forward in the project EnergyTransition (Köppl et al., 2011) puts energy services into the centre of transformation options.

The latter approach perceives the energy system as complex and goes beyond technological aspects of transformation technologies or the energy mix in final energy demand. The final goal and respectively the starting point for a transformation of energy systems are welfare relevant energy services. This perspective offers a wider range of transformation potentials and points of action for targeted research and innovation policy than the usual focus on energy flows and energy supply. It draws the attention to the different use categories of energy, e.g. heating and cooling, lighting, steam production, mobility, and the respective energy sources used in each category. In this system perspective, the transformation of energy is viewed as the end point of the energy chain.

Figure 1 illustrates the whole energy chain highlighting the manifold aspects of energy transformation and starting points for innovation, including demand side as well as supply side technologies.

Figure 1. Structure of the energy chain



Source: Köppl et al. (fc.).

As stated above, it is not the quantity of energy demanded by households and companies that is relevant for welfare and development, but the amount and quality of the energy services consumed. Energy services, such as well-tempered living space, are provided by products (fuel etc.) combined with a wide range of capital stocks (buildings, heating systems, etc.). The range of available transformation and application technologies (incorporated in the capital stocks) and energy sources thus opens up a spectrum of options, which result in different levels of energy flows and greenhouse gas emissions (GHG) for any given quantity of services demanded.

Innovation plays a key role in the transformation process of the energy system. The integrated view of the energy system starting with energy services again offers a broader range of triggers for innovation. Policies stimulating energy R&D would ideally capture the innovation process along the whole energy chain and collect suitable indicators that can be used to monitor innovation progress and serve as input for R&D and innovation policy. R&D and innovation policy are crucial stimuli for innovative activities and a prerequisite for a successful diffusion of new technologies in the energy system. A fundamental restructuring of the energy system requires more than incremental innovation in the areas energy productivity, low-carbon technologies and adequate transformation, distribution and storage systems.

In a globalised world, innovation is more and more perceived as crucial to competitiveness and economic success. Aiginger et al. (2013) introduce a new perspective on competitiveness, identifying among other factors innovation as one of the determinants. Innovation in general is a complex and diverse issue. Innovation activities can refer to product or process innovation as well as to management and organisational innovation. Depending on the focus of innovation, innovation processes can take many different forms. This applies to innovation systems in general and to the energy innovation system as well. In both cases, differentiated information is inevitable for monitoring, steering or comparative analyses.

In order to gain insights into the R&D and innovation system for energy we follow the approach of the Innovation Union Scoreboard[1] (Hollanders and Tarantola, 2011), which is described in more detail in chapter 2. As an underlying theoretical reference system we adhere to the above described perspective of the energy system. The Innovation Union Scoreboard, which is published annually, is a monitoring and benchmarking tool for innovation in the European Union. The scoreboard provides a comparative assessment of general innovation performance of the EU Member States as well as of strength and weaknesses of the national innovation systems. The idea of the IUS is to compile data not only for inputs to the innovation system but also indicators to measure innovation output. The IUS also condenses the information given by the underlying data and provides composite indices.

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[1] Until 2009, the publication was labelled 'European Innovation Scoreboard'.

In general, scoreboards have the advantage that they are more adequate for covering the multidimensional aspects of complex systems compared to a single indicator. In the context of innovation systems this refers e.g. to the measurement of innovation success in terms of output or outcome which describes the diffusion of innovative technologies. Energy innovation typically is targeted to changes in the supply and use of energy. The measurement of innovation success in the context of energy innovation scoreboards thus refers to effects in the energy system as well as to economic effects.

One can observe an increase in available innovation indicators since the mid-1990s. These indicators are complemented by the development of innovation scoreboards (Hollanders, 2009). Prominent examples of innovation scoreboards besides the IUS include the OECD's 'Science, Technology and Industry Scoreboard' (OECD, 2013b) first published in 1995 and the EU Industrial R&D Investment Scoreboard (EC, 2013b) first published in 2004. For 2011 and 2012, also a scoreboard for eco-innovation has been compiled (eco-innovation observatory, 2012, 2013). The main purpose of these scoreboards is to assist policymakers by summarising a range of (diverse) information on innovation performance.

Over a longer time period, scoreboards can highlight the process character of innovations as well as a potential time lag between innovation efforts (inputs, e.g. public subsidies) and innovation outputs (e.g. patents).

Indicator scoreboards are also frequently used in the context of the measurement of sustainable development and well-being due to the inherent complexity and multidimensionality of these phenomena (see e.g. Kettner et al., 2007; Kettner et al., 2012). Dashboards of sustainability indicators e.g. include the EU Sustainable Development Indicators (Eurostat, 2012), the UN Indicators for Sustainable Development (UN, 2007) or the IEA/IAEA Indicators for Sustainable Energy Development (IEA/IAEA, 2001); recent applications of indicator scoreboards for well-being include the OECD Better Life Indicators (OECD, 2011) and the Better Life Index (OECD, 2013a) as well as the Human Development Index (UNDP, 2013) and the Gross National Happiness Index (Centre for Bhutan Studies & GNH Research, 2013) and their respective indicator sets.

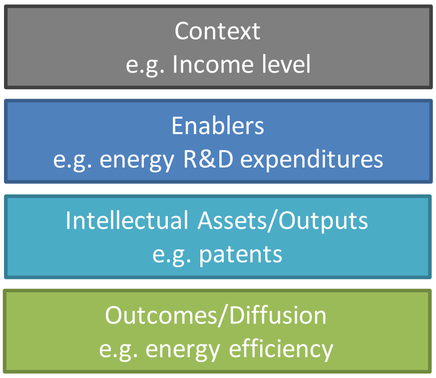
When constructing a data scoreboard, the selection of the indicators included is crucial and should be thoroughly argued for the issue the scoreboard is tailored to. For the area we address in this paper, this is innovation and transformation in the energy system. Hollanders (2009) states that the selection of indicators for a scoreboard should ideally adhere to the following general criteria (Hollanders, 2009): (1) Each indicator should be relevant for medium- and long-term innovation and R&D policy issues; (2) all indicators should be of similar importance for innovation performance; (3) the indicators should be derived from reliable statistics; and (4) hold their value over time. In practice, however, it proves difficult to meet all of these criteria. The OECD also lists basic criteria in the Handbook of Constructing Composite Indicators (OECD, 2008) for the selection of indicators and data quality. These quality criteria are closely linked to user needs and have several dimensions. The handbook discusses six criteria that have a decisive influence on the quality of data scoreboards and the potential construction of composite indices:

- *Relevance* refers to the careful selection of data to cover the relevant dimensions of a scoreboard.
- *Accuracy* is to be seen in the context of the credibility of the data used and the confidence users can place in the objectivity of the data generation.
- *Timeliness* has to be considered, especially if indicators for different dimensions of the scoreboard are published at different points in time.
- *Accessibility* refers to the availability of data included so that they are also accessible to third parties.
- *Interpretability and coherence* are closely related and bring up the issue of definitions and classifications of data and the assessment of comparability over time and across countries.

The selection of indicators for scoreboards or the construction of composite indices is often based on a stakeholder process in order to ensure that all user-relevant aspects are captured. A structured presentation of the selected indicators is inevitable to make the broad information manageable and useful for further analysis and policy.

In line with the IUS, our approach for energy innovation follows a broad coverage with respect to the innovation system. The proposed energy innovation scoreboard is structured according to the four categories as illustrated in Figure 2. Enablers and output indicators for innovation are embedded in a framework that covers also general context indicators, such as GDP per capita, and outcome indicators that describe progress in the transformation of the energy system.

Figure 2. Structure of the Energy Innovation Scoreboard



Source: Own illustration.

The energy system and its required transformation are complex and broad. The aim of an energy innovation scoreboard is to reflect this complexity and to provide useful information for users to understand the innovation process in this area. A good understanding of the innovation process in the energy system would need firm-specific data on innovation activity. This perspective is also reflected in the Oslo Manual for the Measurement of Scientific and Technological Activities (OECD, 1996) that focuses at firm activities as 'From the point of view of current economic development, it is the differential success of firms which shapes economic outcomes and which is of policy significance. It is the subject, the firms, which count, and the [subject approach] has been chosen as the basis for these guidelines.' As to our knowledge, this information is not available in international comparable databases. On an international scale, the IEA is compiling data on public R&D energy expenditure. In a first step we propose to use these data as indicator for an innovation input. They play an important role with respect to stimulating firm activities and shape the scientific basis on the national level. A shortcoming, however, is that it does neither reveal the share of firms receiving public funds nor does this data base allow to gain insight in the share of innovating firms.

Despite these shortcomings the IEA data base provides detailed information on different aspects of the energy system. Public energy R&D expenditures cover expenditure for basic research, applied research and demonstration projects. The disaggregation of the data compiled by the IEA is illustrated in Figure 3. The database contains fuel specific public R&D expenditure on the one hand, and expenditure targeted at energy productivity captured in the categories energy efficiency and other power and storage technologies on the other hand. This is complemented by the category crosscutting technologies and research.

Figure 3. Disaggregation of IEA data on public energy R&D expenditures

ENERGY EFFICIENCY	FOSSIL FUELS	RENEWABLE ENERGY SOURCES	NUCLEAR	HYDROGEN AND FUEL CELLS	OTHER POWER AND STORAGE TECHNOLOGIES	OTHER CROSS-CUTTING TECHS/RESEARCH
Industry	Oil and gas	Solar energy	Nuclear fission	Hydrogen	Electric power conversion	Energy system analysis
Res. and comm. buildings, appliances and equipment	Coal	Wind energy	Nuclear fusion	Fuel cells	Electricity transmission and distribution	Basic energy research not allocated
Transport	CO2 capture and storage	Ocean energy			Energy storage	Other
Other energy efficiency		Biofuels				
		Geothermal energy				
		Hydroelectricity				
		Other renewable energy sources				

Source: IEA, own illustration.

The outline and discussion of a contextual framework for an energy innovation scoreboard as well as a selection of exemplary indicators for energy innovation should contribute to identifying whether such an approach could be helpful for guiding policy decisions in the area of energy R&D. It should stimulate the discussion on which indicators would be desirable in order to improve the information base and where data gaps hamper conclusions.

In the following chapter we present a short overview of the Innovation Union Scoreboard which provides the guidance for the proposed first set of energy indicators as discussed and presented in chapters 3 and 4.

2 The EU's Innovation Union Scoreboard

The EU's Innovation Union Scoreboard (IUS) serves as role model for an Energy Innovation Scoreboard as aimed for in this short study. The IUS, previously European Innovation Scoreboard (EIS), is a tool for the measurement of the innovation performance of the EU Member States and its major competitors based on a comparative assessment. It has been developed under the Lisbon Strategy in 2000[2] and revised after the adoption of the Europe 2020 Strategy[3]. The objective of the scoreboard is to 'inform policy discussions at national and EU level, by tracking progress in innovation performance within and outside the EU over time' (IUS, 2013).

The European Innovation Scoreboard was developed by Maastricht University (MERIT) and SPRU at University of Sussex. The pilot version published in the year 2000 comprised 16 indicators of innovation performance for 17 European countries. Between 2001 and 2010, ten full versions of the EIS have been published; these updates included minor revisions and extensions of the indicator set on the one hand and an extended number of countries on the other. In 2011, the Innovation Union Scoreboard, that has a slightly modified structure with respect to the dimensions of innovation addressed, has replaced the EIS. A detailed description of the modifications is provided in Hollanders and Tarantola (2011).

The annual EIS / IUS publications provide a comparative assessment of the recent innovation performance of the EU and its Member States including an analysis of the relative strengths and weaknesses of national research and innovation systems as well as an assessment of the development of innovation performance over time. Furthermore, the reports include a comparison of the EU's innovation performance with its main competitors.

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[2] In the Lisbon Process, the European Innovation Scoreboard (EIS) was developed in order to 'track and benchmark the relative innovation performance of EU Member States' (EC, 2009).

[3] The importance of innovation is also mirrored in one of the seven flagship initiatives for achieving the overarching targets of EU 2020 strategy, the Innovation Union Flagship Initiative. It aims at refocusing "R&D and innovation policy on the challenges facing our society, such as climate change, energy and resource efficiency, health and demographic change" and at improving the framework conditions and financing for innovation and R&D. The European Innovation Scoreboard has been adapted in this context to measure progress towards the 2020 targets (see Hollanders and Tarantola, 2011).

2.1 The structure of the Innovation Union Scoreboard

As addressed above, the IUS displays the multidimensional aspects of innovation processes in a structured framework[4]. The version of the Innovation Union Scoreboard for 2013 for example, comprises 25 indicators to measure innovation performance to provide a benchmarking tool of innovation activities in the EU Member States, seven other European countries (Iceland, the Former Yugoslav Republic of Macedonia, Norway, Serbia, Switzerland and Turkey) and ten global competitors (Australia, Brazil, China, India, Russia, South Africa, Canada, Japan, South Korea and the US). As innovation is seen as important determinant for competitiveness the IUS not only illustrates innovation activities within the EU but goes beyond European borders and allows for an international comparison.

Following the methodology of previous editions, the indicators of the 2013 IUS are grouped in three categories – enablers, firm activities and outputs – that are subdivided in eight dimensions of innovation (see Table 1).

Table 1. Structure of the IUS

Category	Dimension
Enablers	Human resources
	Open, excellent and attractive research systems
	Finance and support
Firm activities	Firm investments
	Linkages and entrepreneurship
	Intellectual assets
Outputs	Innovators
	Economic effects

Source: Own illustration.

The list of the 25 indicators included in the 2013 Innovation Union Scoreboard as well as the data sources used is provided in Table 2. The **enablers** describe the key drivers of innovation performance at the national level, differentiating between three dimensions, each of which comprises several indicators. The dimension 'human resources' covers three indicators that measure the availability of a well-educated workforce. In the dimension 'open, excellent and attractive research systems', the focus is directed mainly to scientific publications as a proxy

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[4] The indicators aim at depicting virtually all aspects of the innovation process; this ultimately leads to an (almost arbitrary) eclecticism that is not based on a theoretical foundation (see Schibany et al., 2007): Some indicators refer to narrow, well-defined micro-economic facts like the share of cooperating companies, while other indicators address structural issues on the level of the economy (e.g. orientation of research towards 'societal challenges'). In addition, multicollinearity is an issue, i.e. some indicators might be highly correlated with each other and thus measure the same aspect of innovation, which leads to an overweighting of this aspect. Another point of criticism refers to the question of the optimal level for each indicator. In this respect the IUS uses the principle 'the more, the better' for all indicators, which might not be fully valid for all of them.

for the international competitiveness of science and research. 'Finance and support' measures venture capital investments and R&D expenditures of the public sector.

The core of the innovation system is covered by the category **firm activities.** It is the innovation performance at firm level that is of interest here. The IUS distinguishes between three different innovation dimensions. 'Firm investments' covers firms' R&D expenditures as well as their non-R&D innovation expenditures[5]. 'Linkages & entrepreneurship' provides information on the share of SMEs innovating in-house, collaboration between innovating SMEs and 'research collaboration between the private and public sector', measured by the number of co-publications. In the dimension 'intellectual assets' indicators of different forms of Intellectual Property Rights, i.e. international and European patent applications, are included. In contrast to the categorisation of the IUS, in the literature patents are often used as output indicators for innovation (e.g. Oltra et al., 2010; Johnstone et al., 2010; Furman et al., 2002).

Output indicators as defined by the IUS measure the effects of innovation activities in two innovation dimensions. The first, 'innovators', comprises indicators for the share of firms that has introduced innovations and the presence of high-growth firms[6]. The second dimension, 'economic effects', includes five indicators that measure the economic success of innovative activities, including employment in knowledge-intensive activities, the role of medium and high-tech product in exports, sales due to innovations and license and patent revenues from abroad.

[5] This indicator measures e.g. investment in equipment and machinery as well as the acquisition of patents.

[6] The indicator high-growth firms corresponds to the new EU2020 headline indicator that is currently still under development.

Table 2. The latest IUS indicators

Main type / innovation dimension / indicator	Data source
ENABLERS	
Human resources	
New doctorate graduates (ISCED 6) per 1000 population aged 25-34	Eurostat
Percentage population aged 30-34 having completed tertiary education	Eurostat
Percentage youth aged 20-24 having attained at least upper secondary level education	Eurostat
Open, excellent and attractive research systems	
International scientific co-publications per million population	Science-Metrix (Scopus)
Scientific publications among the top 10% most cited publications worldwide as % of total scientific publications of the country	Science-Metrix (Scopus)
Non-EU doctorate students as a % of all doctorate students	Eurostat
Finance and support	
R&D expenditure in the public sector as % of GDP	Eurostat
Venture capital investment as % of GDP	Eurostat
FIRM ACTIVITIES	
Firm investments	
R&D expenditure in the business sector as % of GDP	Eurostat
Non-R&D innovation expenditures as % of turnover	Eurostat
Linkages & entrepreneurship	
SMEs innovating in-house as % of SMEs	Eurostat
Innovative SMEs collaborating with others as % of SMEs	Eurostat
Public-private co-publications per million population	CWTS (Thomson Reuters)
Intellectual assets	
PCT patents applications per billion GDP (in PPS€)	Eurostat
PCT patent applications in societal challenges per billion GDP (in PPS€) (environment-related technologies; health)	OECD / Eurostat
Community trademarks per billion GDP (in PPS€)	OHIM2 / Eurostat
Community designs per billion GDP (in PPS€)	OHIM / Eurostat
OUTPUTS	
Innovators	
SMEs introducing product or process innovations as % of SMEs	Eurostat
SMEs introducing marketing or organisational innovations as % of SMEs	Eurostat
High-growth innovative firms	N/A
Economic effects	
Employment in knowledge-intensive activities (manufacturing and services) as % of total employment	Eurostat
Contribution of medium and high-tech product exports to the trade balance	UN
Knowledge-intensive services exports as % total service exports	UN / Eurostat
Sales of new to market and new to firm innovations as % of turnover	Eurostat
License and patent revenues from abroad as % of GDP	Eurostat

Source: IUS (2013).

In addition to the detailed data scoreboard the IUS aims at providing condensed information that is easy to communicate. For this purpose the single indicators are aggregated to composite indices.

2.2 Composite indices in the Innovation Union Scoreboard

There exists a trade-off between a detailed database to illustrate the multidimensionality of innovation processes and the ability to communicate overall trends and innovation performance in a condensed manner. This trade-off is also mirrored in the context of the IUS where aggregate innovation performance is measured by a composite index, the 'Summary Innovation Index'. This index aggregates the 25 single indicators using equal weights. The Summary Innovation Index allows a grouping of the Member States, reflecting their innovation performance.

In order not to lose the detailed information completely, sub-indices on the relative strengths and weaknesses in innovation performance of Member States as well as on the respective drivers of innovation are presented[7].

Composite indices are more and more used for comparing countries' performance regarding complex issues. They are considered to be more easily interpreted by policy makers than comprehensive indicator lists. Nevertheless, composite indices may provide poor guidance for policy decisions if the underlying data and indicators are poorly selected and argued (OECD, 2008).

In this short study on an Energy Innovation Scoreboard composite indices are not considered, they might, however, be of interest in a later stage. Therefore, the methodology on which the calculation of the composite Summary Innovation Index is based is summarised here (see IUS, 2013; Hollanders and Tarantola, 2011):

- Positive and negative outliers are replaced by the maximum and minimum values observed over all countries and years (see below).
- Based on the data availability for all countries, a reference year is chosen for each indicator.
- Missing values are imputed.
- Maximum and minimum scores are identified, i.e. for each indicator the highest and respectively the lowest relative score over the whole time period and over all countries is determined (excluding outliers).
- Highly skewed data (e.g. non-EU doctorate students, venture capital investments, public-private co-publications, PCT patent applications) are transformed using a square root transformation[8].

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[7] The relative strengths and weaknesses of each country are calculated as the difference between the composite index scores for each of the eight dimensions of innovation and the aggregate Summary Innovation Index.

- For each indicator, the scores are normalised using the following formula:
  $\frac{(\text{value to convert} - \text{minimum value})}{(\text{maximum value} - \text{minimum value})}$
  The normalised scores hence range between 0 (for the worst possible outcome) and 1 (for the best possible outcome).
- Finally, the Summary Innovation Index is calculated as the unweighted average of the normalised indicators.

The main advantages of calculating composite indices are that they provide "an easy-to-grasp summary statistic of a country's innovation performance" (Hollanders, 2009). The purpose of the composite index is to reduce the complexity and to provide a useful instrument for policy monitoring and decision making. In addition, the index can serve as a communication tool. Through aggregating single indicators to composite indices, information about specific details (e.g. development in different innovation dimensions), however, can be lost (e.g. OECD, 2008). It is therefore useful to additionally also provide the single indicators containing important information about the different aspects of innovation.

3 Energy Innovation Scoreboard with a focus on renewables

The comprehensive view of the cascade of the energy system as presented above is our theoretical framework and builds– together with the discussion on suitable indicators, indicator selection and indicator scoreboards – the foundation for a pilot version for an energy innovation scoreboard. The pilot version of the scoreboard aims at stimulating a stakeholder discussion on the usefulness of the proposed indicators. It is developed in a way that it could be further extended in the future e.g. with respect to firm level data or the construction of a composite index.

We approach the design of an energy innovation scoreboard by concentrating on the following characteristics:

- Nested structure of the innovation process
- Selection of indicators corresponding to each stage of the innovation process
- Focus on energy innovation in the areas of efficiency, renewable energy sources and cross cutting issues like energy system analysis[9]
- Complementarity to the EU Innovation Scoreboard
- National level
- Public R&D expenditure

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[8] I.e. the square root of the indicator value is used instead of the original value.

[9] The system boundaries for the pilot energy innovation scoreboard do not comprise energy R&D for fossil or nuclear energy, although with respect to energy efficiency and crosscutting issues the boundaries may be blurred. An extension to fossil energy sources or nuclear energy as included in the IEA database could be easily implemented.

This pilot version of an energy innovation scoreboard is strongly influenced by data accessibility. We focus on readily available data; this is the reason why we concentrate on the aggregate national level and public energy R&D expenditure captured by the IEA database. The IEA database is a valuable source on inputs to energy R&D on the national level. For firm level energy R&D and innovation expenditure, however, a comparable international database is not available. This also holds true for other input factors to the research system like energy specific human capital. Using the IEA database on public energy R&D as input measure does not provide insight into energy innovation activities on the firm level and their effects on innovation outputs and outcomes. This has to be kept in mind when discussing the proposed indicators or when arguing for potential next steps.

We depict the overall outline of our proposed energy innovation scoreboard already in Figure 2 in chapter 2. Starting from this aggregate structure, we propose in Figure 4 those dimensions we find important in order to describe the different stages of the energy innovation process. We start with indicators that provide context information like GDP per capita assuming that the wealth level is of relevance for the innovation performance of a country. In order to indicate whether nations specialise in energy R&D compared to other public R&D expenditure we propose the share of energy R&D expenditure in total public R&D as indicator. Ideally, this measure would be complemented by a comparable indicator for the private sector.

The next level in the scoreboard refers to enablers. Enablers are inputs into the innovation process like public or private energy R&D expenditure but also indicators like well-educated workforce or a policy framework that encourages energy innovation.

The success of R&D and innovation is captured on the level of intellectual assets/outputs and energy system and economic outcomes covered on the next two levels. Indicators typically used to measure output are energy related patents, energy related publications or the share of SMEs introducing energy innovations. The debate in the literature about patents as an adequate measure of innovation success is controversial. One shortcoming of patent indicators lies in cultural differences of patenting behaviour between countries and some inventors might chose to keep their inventions secret instead of applying for a patent and disclosing their information. Such a patenting behaviour would result in underestimates of the success of R&D and innovation[10]. Another shortcoming refers to the fact that patents do not capture the quality of an invention, i.e. it is not guaranteed that a patent results in a relevant innovation in technological or economic terms (see e.g. OECD and Eurostat, 2005; Popp, 2006).

Finally we propose indicators that describe the potential impact of energy innovations in the energy and economic system when the diffusion process is successful. The selection of indicators to capture the innovation influence is, however, not as straightforward since it is not

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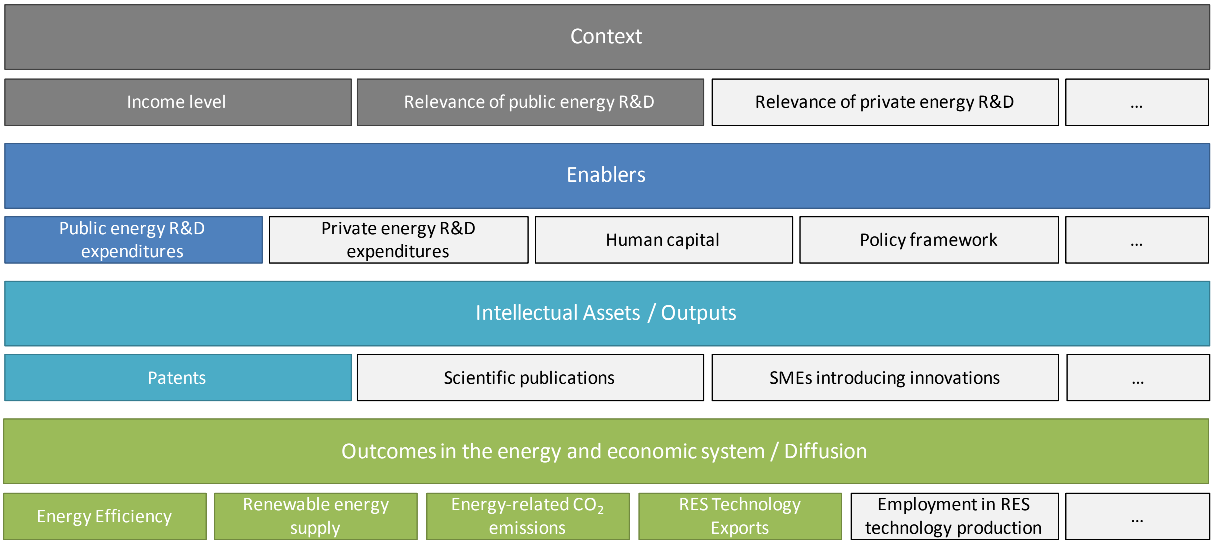
[10] Whether innovations are patented varies e.g. significantly between sectors (see Popp, 2006).

possible to trace back the impacts to innovation activity or other factors like regulation. The indicators proposed here as outcome in the energy and economic system/diffusion (e.g. energy efficiency, share of renewable energy, share of renewable technology exports) focus on changes in the energy system and selected economic impacts.

Figure 4 illustrates the described structure of the energy innovation scoreboard. It indicates for which dimensions data are available and in which areas we are confronted with data gaps, illustrated by the white boxes. In the remainder, we describe in more detail those indicators for which internationally comparable data is available.

Figure 4. Structure of the energy innovation scoreboard



Source: Own illustration.

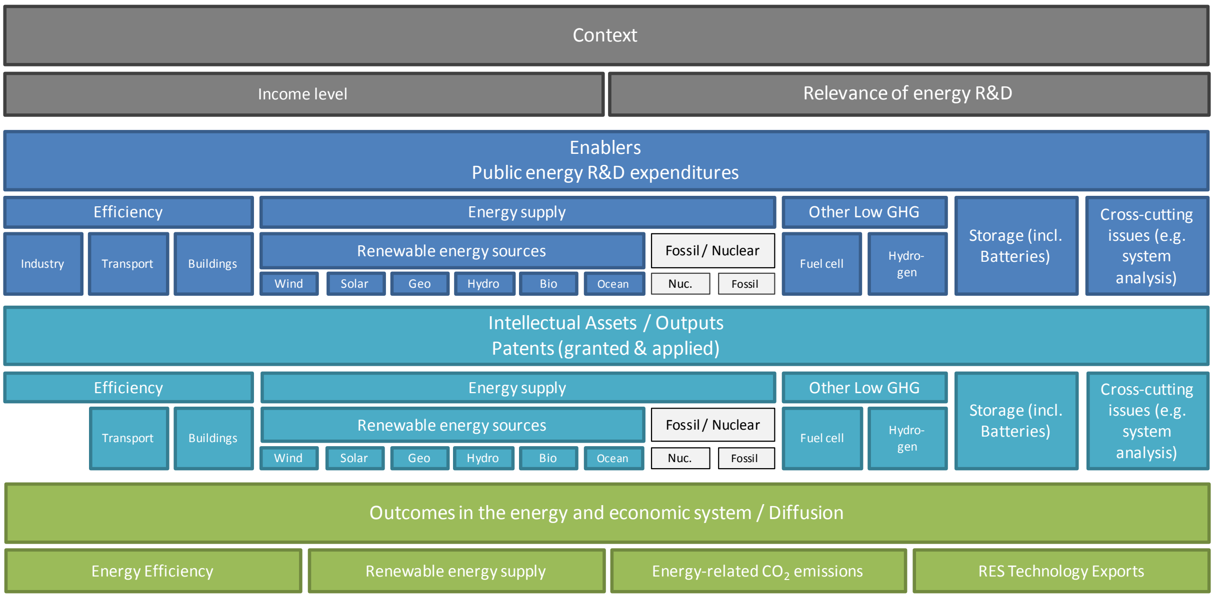
In Figure 5, the pilot energy innovation scoreboard, for which data can be compiled based on international statistics, is illustrated. Compared to Figure 4 it includes a disaggregation level of the energy system for the input and output indicators. The scoreboard concentrates on the following dimensions of the energy system: renewables, energy efficiency, storage and crosscutting issues. This focus corresponds with the perspective of a service-oriented energy system as well as with the longer-term goals of a reduction in GHG emissions of 80-95% in order to restrict global temperature increase to 2°C compared to pre-industrial levels.

In the pilot version, the following databases are used to compile the indicators of the scoreboard:

- **Context indicators:** For 'GDP per capita' the OECD National Accounts Database and OECD population statistics are used; the indicator '% of energy R&D in total public R&D' is based on the IEA Energy R&D Statistics and OCED Research and Development Statistics.
- **Enablers:** All data on public energy R&D expenditures are from the IEA Energy R&D Statistics.

- **Intellectual Assets / Output indicators:** All patent data are derived from OECD Patents Statistics.
- **Outcome in the energy and economic system / Diffusion indicators:** 'Energy efficiency', i.e. GDP per final energy consumption, is derived from the IEA Energy Balances and the OECD National Accounts Statistics. The 'share of renewables' in primary energy supply and energy-related CO_2 emissions are also from the IEA Energy Balances. The share of 'RES Technology Exports' in total exports is derived from the UN COMTRADE Database according to a compilation of relevant export goods as used in Köppl et al. (2013).

Figure 5. Structure of a pilot energy innovation scoreboard with a focus on renewables



Source: Own illustration.

Based on the data sources as listed above and according to the disaggregation as illustrated in Figure 5, Table 3 summarises the proposed indicators including the units. The context indicators reflect the income level given by GDP per capita and the share of public energy R&D expenditure in total public R&D expenditure. The enablers are expressed as sectoral public energy R&D in relation to GDP.

The level of intellectual assets/outputs measures the number of applied and granted energy patents per GDP disaggregated by energy source. Alternatively or additionally, one could include the share of energy patents in total patents as a measure of specialisation in energy innovation. With respect to outcomes in the energy and economic system, we propose the indicators energy efficiency measured as GDP per total final consumption, the share of renewable energy sources in primary energy supply, energy-related CO_2 emissions in million tons and the share of renewable energy technology exports in total goods exports.

Table 3. Indicators for the pilot renewable energy innovation scoreboard

Stage of innovation	Dimension / Indicator			Unit
Context	GDP per capita			1000 US$/cap
	Energy R&D in total public R&D			%
Enablers	**Public energy R&D expenditures** Public energy R&D expenditure per GDP	Energy efficiency	Buildings	%
			Transport	%
			Industry	%
		Rewable energy supply	Wind	%
			Solar	%
			Geothermal	%
			Hydro	%
			Biomass	%
			Ocean	%
		Other low GHG technoglogies	Fuel cells	%
			Hydrogen	%
		Storage		%
		Cross cutting issues (incl. energy system analysis)		%
Intellectual Assets / Outputs	**Patents** Number of patents applied or granted per GDP	Energy efficiency	Buildings	Patents/GDP
			Transport	Patents/GDP
		Rewable energy suply	Wind	Patents/GDP
			Solar	Patents/GDP
			Geothermal	Patents/GDP
			Hydro	Patents/GDP
			Biomass	Patents/GDP
			Ocean	Patents/GDP
		Other low GHG technoglogies	Fuel cells	Patents/GDP
			Hydrogen	Patents/GDP
		Storage		Patents/GDP
Outcome in the energy and economic system / Diffusion	Energy efficiency - GDP per total final energy consumption			GDP/TFC
	Share of RES in Primary Energy Supply			%
	Energy-related CO_2 emissions			Mt CO_2/GDP
	Share of RES technology exports in total exports			%

Source: Own illustration.

The choice of the proposed indicators was guided by a preceding data research in order to ensure data availability. The data coverage shows some variation with respect to the time period as well as to the number of countries for which data are available. From Table 4, one can see that the lowest regional coverage is given for the enabler indicators, i.e. public energy R&D expenditure. A broad regional coverage for an energy innovation scoreboard would need some effort to motivate a larger number of countries to provide information on public energy R&D. From twelve EU member states that are also OECD members, data on public energy R&D expenditure are missing. The table also shows that the largest time lag can be observed for patent data.

Table 4. Regional and temporal coverage of indicators

Stage of innovation	Dimension / Indicator			Number of countries	Time period covered
Context	GDP per capita			34	2000-2012
	% of energy R&D in total public R&D			14	2000-2011
Enablers	**Public energy R&D expenditures** Public energy R&D expenditure per GDP	Energy efficiency	Buildings	20	2000-2011
			Transport	20	2000-2011
			Industry	20	2000-2011
		Rewable energy supply	Wind	20	2000-2011
			Solar	20	2000-2011
			Geothermal	20	2000-2011
			Hydro	20	2000-2011
			Biomass	20	2000-2011
			Ocean	19	2000-2011
		Other low GHG technoglogies	Fuel cells	13	2000-2011
			Hydrogen	23	2000-2011
		Storage		20	2000-2011
		Cross cutting issues (incl. energy system analysis)		18	2000-2011
Intellectual Assets / Outputs	**Patents** Number of patents applied or granted per GDP	Energy efficiency	Buildings	34	2000-2010
			Transport	34	2000-2010
		Rewable energy suply	Wind	34	2000-2010
			Solar	34	2000-2010
			Geothermal	34	2000-2010
			Hydro	34	2000-2010
			Biomass	34	2000-2010
			Ocean	34	2000-2010
		Other low GHG technoglogies	Fuel cells	34	2000-2010
			Hydrogen	34	2000-2010
		Storage		34	2000-2010
Outcome in the energy and economic system / Diffusion	Energy efficiency - GDP per total final energy consumption			34	2000-2011
	Share of RES in Primary Energy Supply			34	2000-2011
	Energy-related CO_2 emissions			34	2000-2011
	Share of RES technology exports in total exports			34	2000-2011

Source: Own illustration.

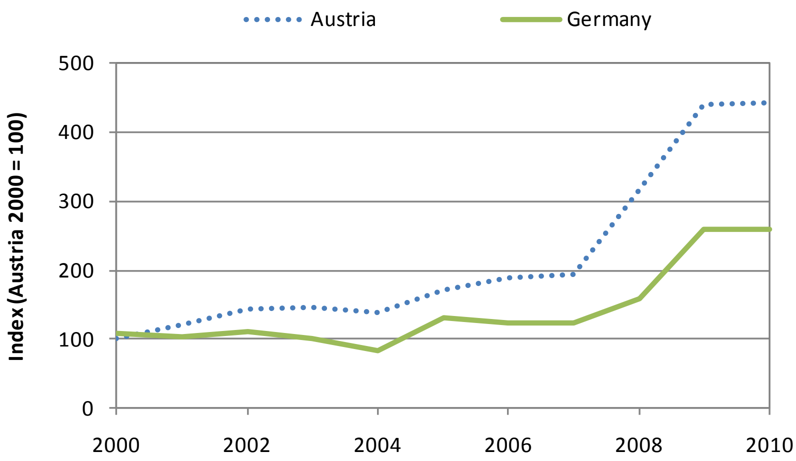
4 Exemplary illustration of energy innovation indicators

In the following, we present illustrations for a selection of indicators included in the pilot renewable energy innovation scoreboard. Principally, the focus in the presentation of the scoreboard indicators can either emphasise the development over time, a cross-country comparison or a combination of both. The examples presented here illustrate the different options.

Enablers

Figure 6 illustrates the development of the share of public renewable energy R&D expenditure relative to GDP in Austria and Germany in the period 2000 to 2010; the figure thus has a time component but also a comparative aspect. The graph illustrates the standardised development of the indicator over time, i.e. all values have been converted to index values calibrated to the share of public renewable energy R&D expenditure relative to GDP in Austria in the year 2000. This indicator shows that in Austria public renewable energy R&D relative to GDP grew more dynamic over the ten year period than in Germany. The graph further displays that it is the development in recent years determining Germany's lower share relative to Austria.

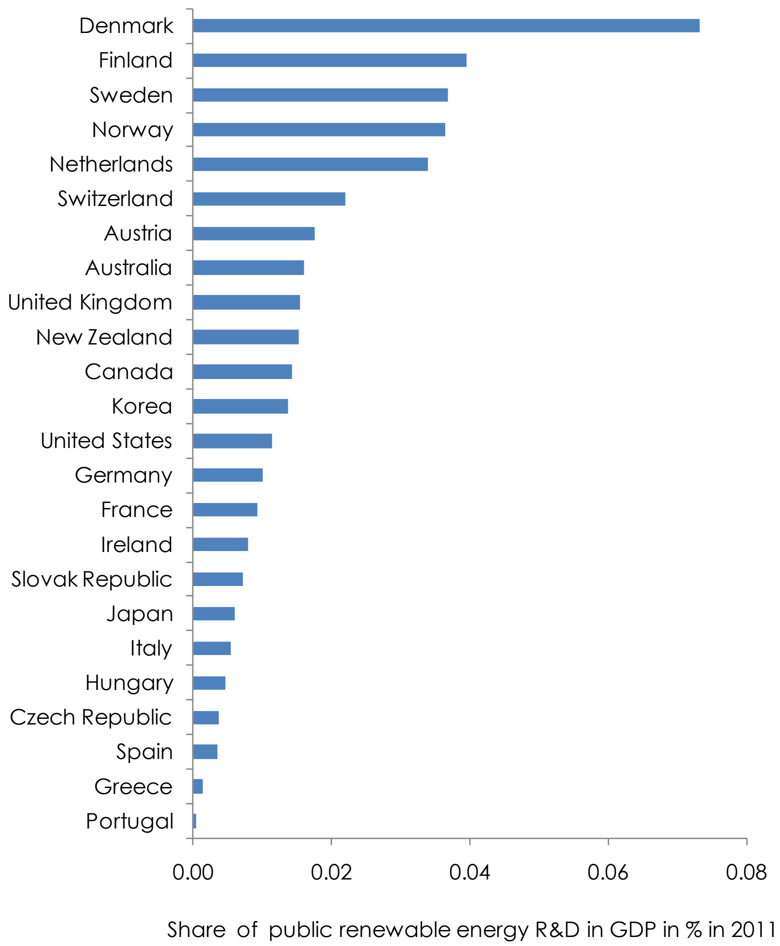
Figure 6. Development of public RES R&D expenditure per GDP in Austria and Germany, 2000-2010



Source: IEA R&D expenditures database (2013).

A cross-country perspective on public renewable energy R&D is given in Figure 7 where the share of renewable public R&D in GDP is ranked according to size. Overall, one has to keep in mind that the share of public energy R&D in GDP is very small. The figure implies that the Scandinavian countries seem to put a stronger emphasis on public renewable energy R&D expenditure in 2010, while public renewable energy R&D expenditures in the Mediterranean countries generally were low.

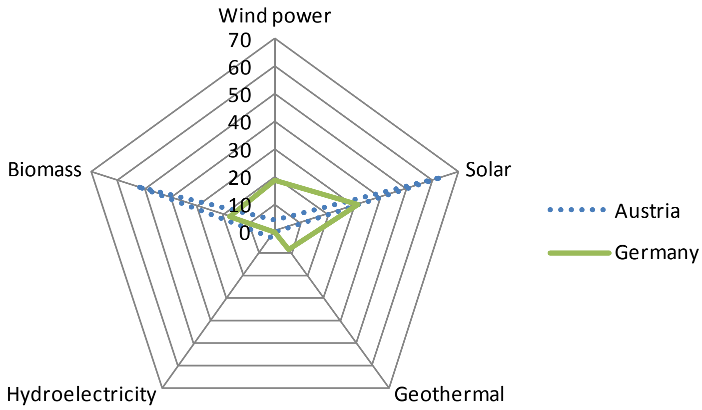
Figure 7. Share of public RES R&D expenditure per GDP in selected OECD countries in 2011



Source: IEA R&D expenditures database (2013).

The third exemplary illustration for the enablers dimension (Figure 8) refers to the structure of public renewable energy R&D expenditure per GDP, that is a disaggregation by energy source, for Austria and Germany. The indicators show a considerably stronger concentration of expenditure on individual RES categories in Austria than in Germany. Solar energy and biomass are by far dominating the sectoral relevance of Austrian public renewable energy R&D, with minor relevance of hydroelectricity and wind power. For Germany, solar energy is the dominating area followed by wind energy and biomass whereas hydroelectricity does not play a role. Public energy R&D expenditure per GDP for geothermal energy is comparable for both countries.

Figure 8. Structure of public RES R&D expenditure in Austria and Germany in 2011 in US$ per Mio US$ GDP

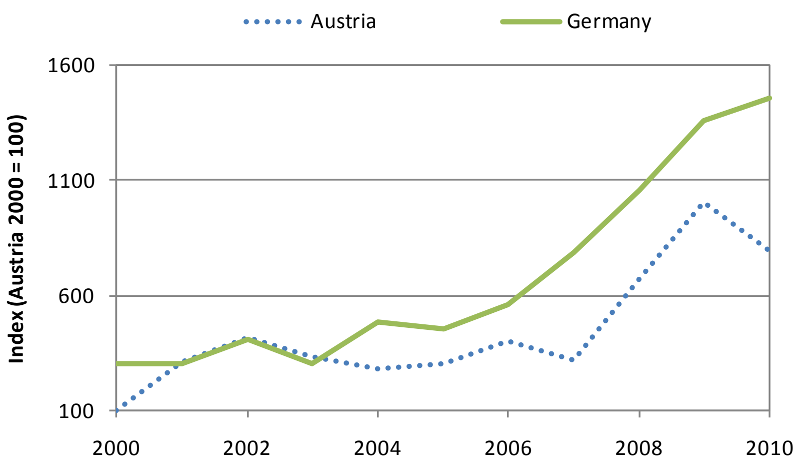


Source: IEA R&D expenditures database (2013).

Intellectual Assets/output

As an exemplary indicator for the level of intellectual assets/outputs of the pilot renewable energy innovation scoreboard we display a comparison of Austria and Germany with respect to the development of applied patents for renewable energy technologies in the period 2000 to 2010 in Figure 9. Again, the development is shown relative to the initial value for Austria in the year 2000. The figure shows that Austria has a less active behaviour in patent application. Especially since 2006 German patent applications relative to GDP show a significant dynamic.

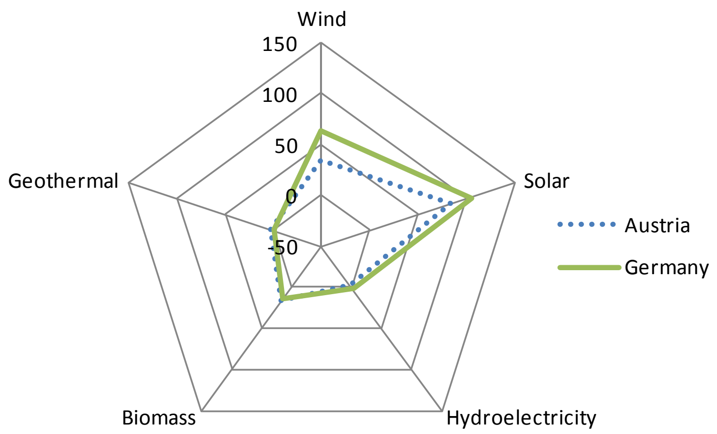
Figure 9. Development of applied RES patents per GDP in Austria and Germany, 2000-2010



Source: OECD patent statistics.

Figure 10 displays the change in applied patents for the disaggregated categories of renewable energy sources between 2000 and 2010 for the two countries. The indicators show a comparable development for Austria and Germany. For both countries, two areas show a stronger dynamic between 2000 and 2010, namely wind and solar, and in both cases the patent activity in Germany is a little stronger than in Austria. Applied biomass patents were somewhat higher in 2010 than in 2000 whereas patent applications in hydroelectricity and geothermal energy in 2010 did not exceed the level in 2000.

Figure 10. Applied RES patents in Austria and Germany in 2010 compared to 2000 in patents per GDP



Source: OECD patent statistics.

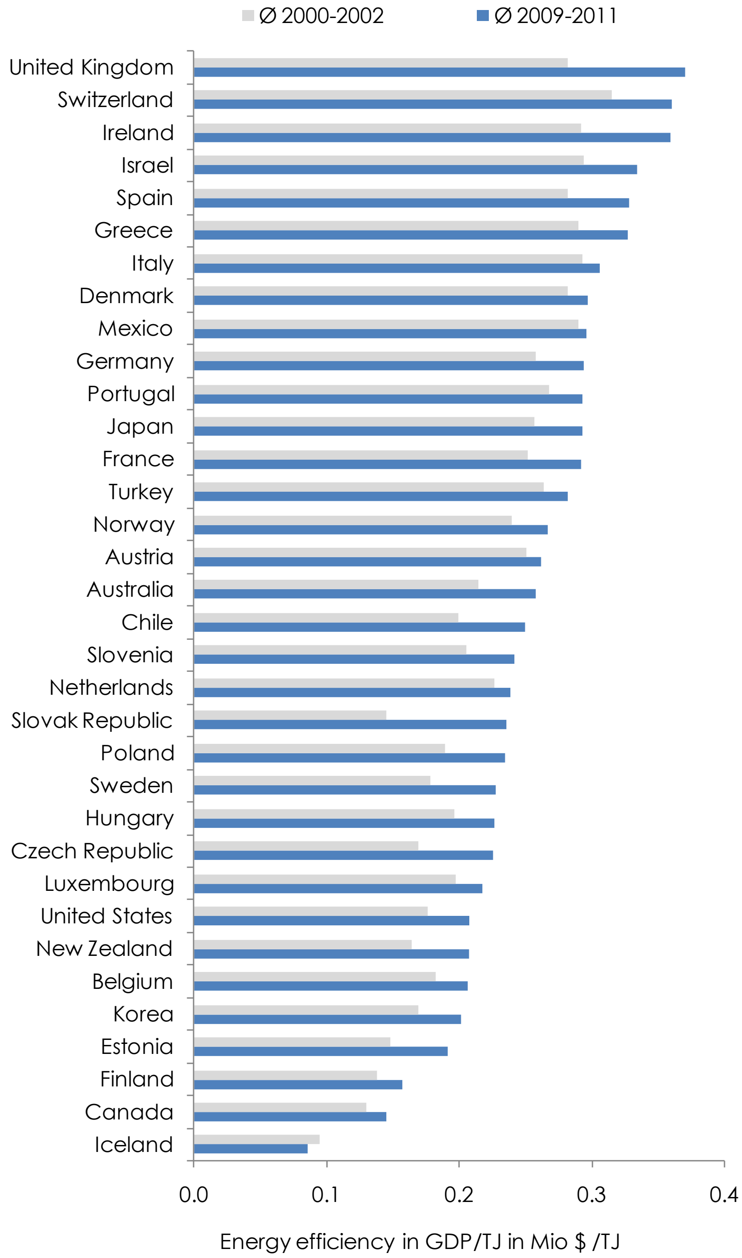
Outcome in the energy and economic system/Diffusion

When interpreting indicators related to outcomes in the energy and economic system one needs to keep in mind that a distinction between energy R&D and innovation and other drivers like regulation, (changes in) economic structure etc. is not feasible. Related indicators to this dimension of the pilot renewable energy innovation scoreboard are energy efficiency and emission intensity for the energy system and the share of renewable energy technologies exports in total goods exports for the economic system. As an illustrative example for these indicators, a cross-country ranking of selected OECD countries is provided.

All three indicators are expressed as averages over three year periods in order to correct for yearly fluctuations in energy efficiency and emission intensity caused for example through cold or mild winters or the export of large energy facilities in a certain year.

A ranking of countries according to energy efficiency for two three year periods (2000-2002 and 2009-2011) puts the United Kingdom on top, with the strongest improvement between the two periods displayed. All countries except Iceland could achieve an improvement of energy efficiency over time (Figure 11).

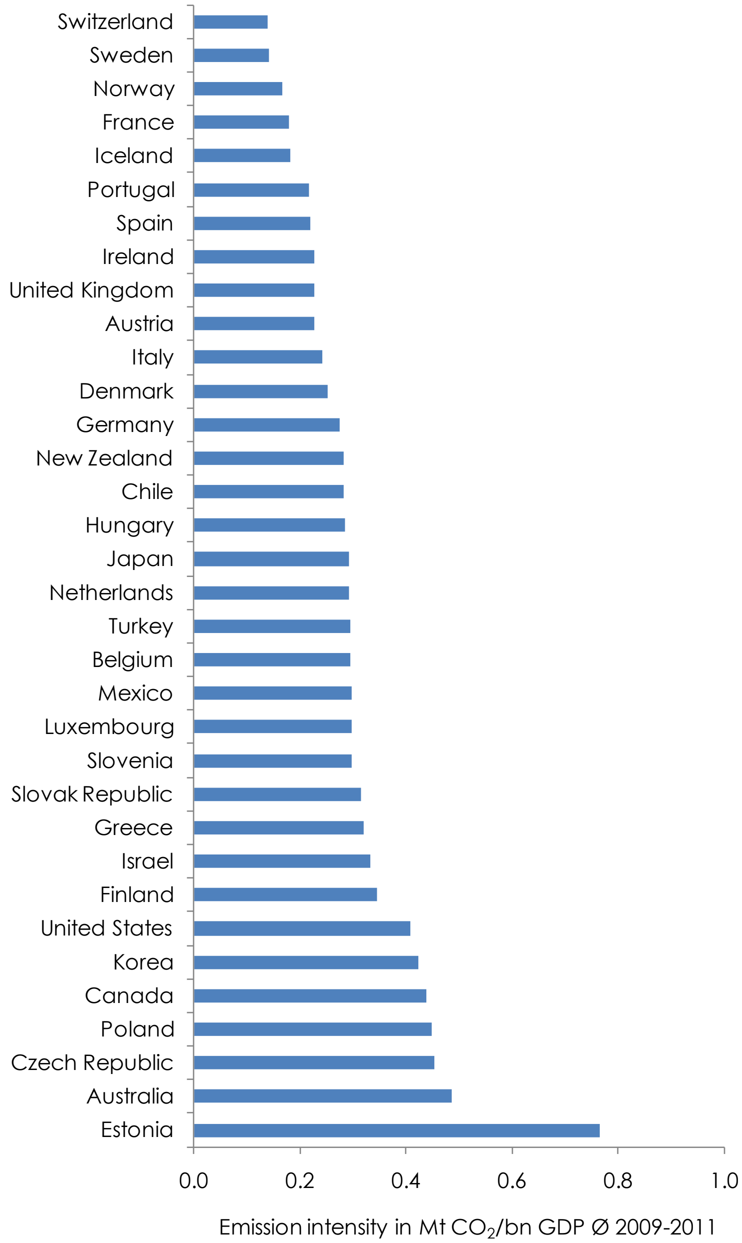
Figure 11. Energy efficiency in selected OECD countries in bn. US$ GDP / TJ total final energy consumption, 2000/2002 and 2009/2011



Source: IEA energy balances (2013).

The emission intensity, measured as energy related CO_2 emissions per GDP, shows considerable variability between countries. Compared to energy efficiency, Austria shows a better performance concerning this indicator (Figure 12).

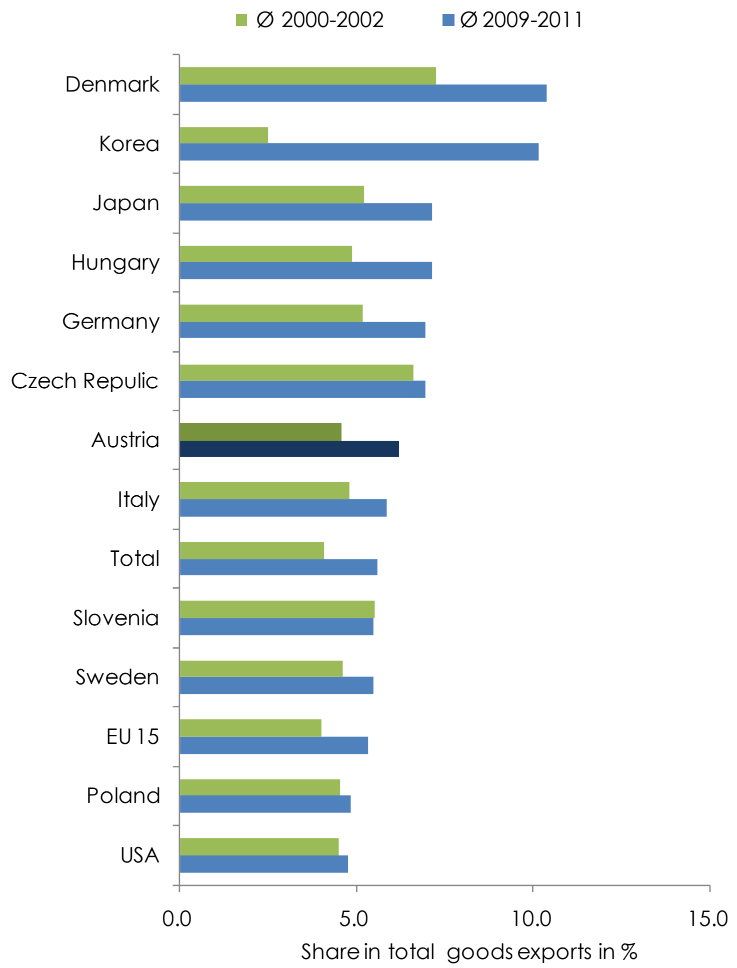
Figure 12. Emission intensity in Mt CO_2 per GDP for selected OECD countries, 2009/2011



Source: IEA CO_2 emissions from fuel combustion 2013.

Finally the relevance of renewable energy technologies in the economic system is illustrated in Figure 13, ranking Denmark first. Most of the countries show an increasing relevance of renewable energy technologies in their goods exports.

Figure 13. Share of renewable energy goods exports in total goods export for selected countries, 2000/2002 and 2009/2011



Source: UN-Comtrade.

In this chapter, we presented exemplary illustrations for a selection of indicators proposed for the pilot renewable energy innovation scoreboard. In addition to the illustration of single indicators, a more aggregate representation of energy innovation performance might be useful in the future in order to improve the ease of perception. Examples include the development of composite indices as used in the IUS and cluster analysis.

The purpose of composite indices is to reduce the complexity, and to provide a useful instrument for policy monitoring and decision making. In addition, the indices can serve as a communication tool. Energy innovation indicators could be aggregated into one overall composite index or into several sub-indices representing the different dimensions of innovation. Through aggregating single indicators to composite indices, information about specific details (e.g. sectoral developments), however, can be lost (e.g. OECD 2002, 2008).

Therefore, a composite index can be thought of as a complement to the single indicators instead of a substitute.

Cluster analysis can be defined as "the art of finding groups in data" (Kaufmann and Rousseuw, 1990). Objects within one group identified by the cluster analysis on the one hand show a high degree of similarity ("internal cohesion") and on the other hand differ significantly from objects in other groups ("external isolation"), at least with respect to some characteristics (Everitt et al., 2001). The groups of similar objects identified by the cluster analysis are called clusters; the group assignment is called clustering. Cluster analysis techniques are widely used exploratory data-analysis techniques. In contrast to other statistical approaches they are, however, "intended largely for generating rather than testing hypotheses" (Everitt, 1993). With respect to an energy innovation scoreboard, cluster analysis could be used to identify countries with a similar energy innovation performance. The analysis could either focus on a wide range of innovation dimensions or investigate certain aspects like the structure of energy-related intellectual assets in more detail.

5 Conclusions

Part A of this short study assesses the feasibility of an energy innovation scoreboard with a focus on renewables. This is a first step in order to stimulate discussion on the national and international level. The approach taken rests on an integrated view of the energy system that places energy services at the centre. We propose this perspective as it highlights the challenges of an energy transition at different stages of the energy system and illustrates the manifold options for energy innovation along the energy chain. The pilot energy innovation scoreboard as presented here focuses on energy efficiency and renewables. The structure and set up could, however, be extended to other areas like fossil or nuclear energy.

Two other guiding principles shape our work: First, we use the EU's Innovation Union Scoreboard as role model and distinguish between different levels of the innovation system, starting from context indicators and enablers and including output and outcome indicators. Second, data availability in internationally comparable databases like the IEA or OECD databases guides indicator selection for the proposed pilot energy innovation scoreboard.

The indicators suggested so far rely on the conceptual framework as outlined above, but should be seen as input for discussion. In the development of the pilot scoreboard we faced a number of challenges that would need to be kept in mind in case of the implementation of such an indicator system. Firm level activities are at the core of the innovation process. For energy innovation, however, firm-specific data are not available. So far, the data compiled thus refer to public energy R&D expenditure. These data are compiled in the IEA Public Energy R&D Database, but so far they are only available for a limited number of countries. Other dimensions that are central to the innovation process like human capital would also need to be tackled.

Part B: Complementary indicators for an energy innovation scoreboard – ÖGUT

6 Data availability and suitability of potential complementary indicators

As discussed in Part A, for some relevant aspects of the energy innovation system internationally comparable databases are missing (see also Figure 4 on page 14). For example, human capital specific for energy innovation, SMEs introducing energy innovations and private energy R&D expenditures are important factors in terms of introducing energy innovations and are thus highly relevant for an energy innovation scoreboard. Therefore the complementary approach followed in Part B of this study aims at proposing and selecting additional indicators. The research is based on an existing indicator screening, which was carried out for Austria in 2012 and investigates its adaptability for the use in a broader energy innovation scoreboard. In 2012 the Austrian Society for Environment and Technology (ÖGUT) gathered indicators for an improved energy innovation monitoring concept (Cerveny et al., 2013). This took the form of literature research, expert interviews and workshops to finally consolidate the large number of possible indicators to a shortlist of seven indicators. Here it is analysed whether the shortlist indicators are suitable and interpretable in the context of an energy innovation scoreboard.

In the study carried out by ÖGUT in 2012 it was concluded by the experts involved that compiling a list of desirable indicators it not sufficient. Any indicator set and / or scoreboard needs to be supplemented by an expert panel. In principle, it should be stressed that indicators without corresponding data knowledge and interpretation are often not useful. This is especially true when it comes to complex chains of causality in a dynamic environment. Energy innovations can be interpreted as such an environment. Thus, the involvement of an expert panel to interpret the key figures of an energy innovation scoreboard (EIS) would be highly recommended. At international level, this could be carried out by experts and existing working groups of the IEA. On a national level, for example, a working group with representatives from national organizations (e.g. Austrian Council for Research and Technology Development) could be established.

The indicator shortlist proposed by Cerveny et al. (2013) consists of the following seven indicators:

- Content and development of market and technology research related to energy technologies and carried out by the aws (Austria Wirtschaftsservice Gesellschaft – an Austrian federal development bank)
- Number of company start-ups in the field of sustainable energy technologies
- Structure and evolution of the share of energy technology-related graduations
- Content and development of the number of vocational trainings programmes with a focus on energy technologies

- Share of private energy related R&D expenditure in GDP
- Share of SMEs conducting energy-related in-house research
- Share of SMEs involved in cooperative energy related research projects

In the study at hand additional research and interviews for these seven indicators in order to assess their usability for an energy innovation scoreboard were conducted. In particular, further research was carried out with respect to data availability, international comparability and significance for an international scoreboard. This was done by identifying the underlying question behind each indicator, analysing available data for Austria, evaluating international data availability and / or determining internationally comparable databases and discussing whether the underlying question could still be answered in an appropriate way. The underlying question behind each indicator provides the rationale for choosing a particular indicator, e.g. the indicator "Number of company start-ups in the field of sustainable energy technologies" should answer the question of how many new energy relevant markets have been developed in order to illustrate market dynamics of the energy sector. Finally, these results lead to suggestions and / or adaption for the seven indicators of this research approach.

In the following, key findings and conclusions from the interviews for each of the originally suggested indicators are described.

6.1 Market and technology researches

Market and technology research projects indicate "knowledge gaps" and can, therefore, help identify future R&D topics as well as market trends. This information – as a quantitative key figure or qualitative statement – could be of essential use for interpreting scoreboard results more accurately. An important aspect of these "knowledge gaps" is for which innovation and technology fields publicly available data is missing (according to the expert interviews and workshops carried out in 2012). aws (Austria Wirtschaftsservice Gesellschaft – an Austrian federal development bank) was identified to be able to provide data from their market and technology research.

If market and technology data are publicly available, companies can base their research on this which reduces knowledge-based barriers for innovation. If no data are publicly available, companies can ask aws-experts to carry out studies and research related to specific innovation efforts of the companies. In this case aws provides an indication for relevant fields of R&D, as well as market trends alongside "mainstream" R&D programs.

According to this consideration, the underlying question to this indicator is phrased as follows:

- Which energy technologies have to be supported with publicly available data?

From 2011 to 2013 aws [11]carried out 42 energy-related studies that differed considerably regarding the technologies covered and the level of detail. This means that summarising technology clusters is not viable in terms of providing useful context information for an energy innovation scoreboard. A specific classification system, which differentiates between many applicable technologies, leads to a handful of studies per cluster. This means low numbers of studies per cluster which cannot be analysed by statistical methods in a reasonable way. A general classification system, which provides statistically meaningful data, lacks qualitative statements. This means that a satisfactory interpretation of the results is not possible because too many different technologies and topics have to be summarised within one cluster (e.g. mixing mobility and storage studies without ensuring that storage results are mobility-related and vice versa).

Topics and development of completed market and technology research is an important source of context information for an energy innovation scoreboard. Due to the unresolved challenges described above it is recommended not to pursue this indicator at the moment. Establishing an energy innovation scoreboard and focussing workload on the other indicators seems more productive. It is very likely that after the initial introduction of an energy innovation scoreboard, further work to sharpen and develop the chosen indicators will be ongoing. It is recommended to take up market and technology research as indicators in a more advanced state of an energy innovation scoreboard.

6.2 Related company start-ups per year

- Number of energy related start-ups according to an energy related economy basket (by NACE classification) per total start-ups per year [%]

Start-ups and spin-offs are established in those areas where a relevant market is expected or already exists. Thus, start-ups are directly connected to new market opportunities – assuming that these new markets differ from previous core businesses. Start-ups and spin-offs hence indicate innovative market trends with newly designed products and services. It should also be noted that the respective national business start-up culture is reflected in this context. Therefore, the total number of start-ups is recommended to be used as a reference, so that the focus of the start-ups is illustrated.

According to this consideration the underlying question with respect to this indicator is as follows:

- How many new energy relevant markets have been developed?

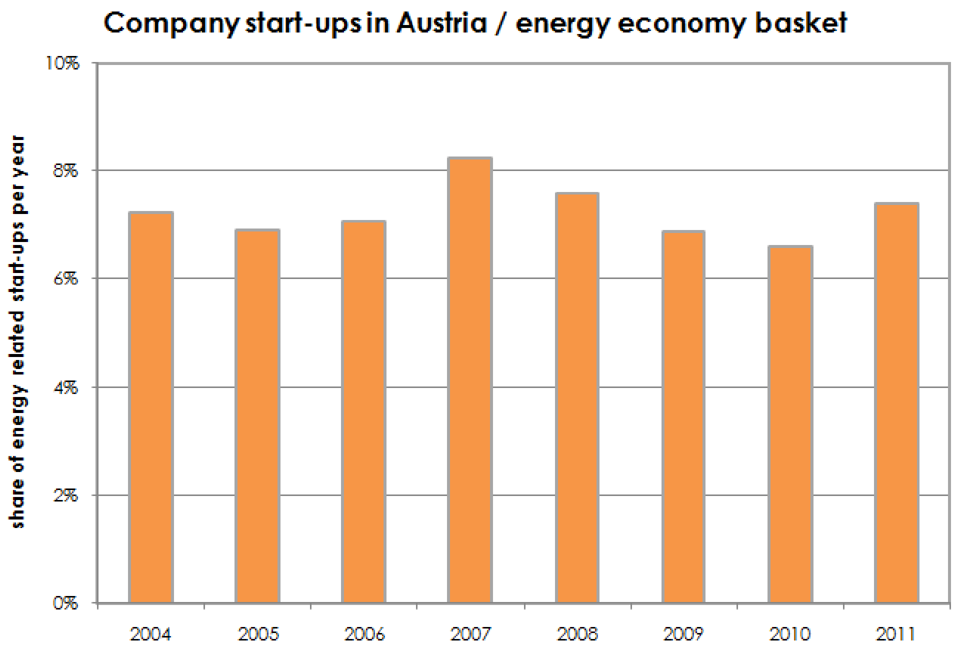
[11] Federal development banks with similar missions such as the aws are located in nearly every IEA country (e.g. “KfW – Kreditanstalt für Wiederaufbau” in Germany, “CDC – Caisse des Dépôts Group” in France, “CDP – Cassa Depositi e Prestiti” in Italy as well as “EIB – European Investment Bank”). This means that in general internationally comparable data is available and data sources are available in a manageable number for data gathering.

In Austria, company start-up data is publicly available at Statistics Austria dating back to the year 2004 – at the level of NACE divisions. The NACE classification (Nomenclature statistique des activités économiques dans la Communauté européenne; Statistical Classification of Economic Activities in the European Community[12]) provides international comparability and easy access to data due to international harmonization of the classification system through the ISIC classification (International Standard Industrial Classification of All Economic Activities by the United Nations). In general, the NACE classification enables data gathering for economic activities. One of the relevant economic sectors in the context of an energy innovation scoreboard is "D 35 Electricity, gas, steam and air conditioning supply", but it is not possible to extract relevant data (e.g. energy or – more specific – photovoltaic) from the existing classification system. This means that an energy relevant economy basket would have to be defined, validated and established to develop this data source for an energy innovation scoreboard.

As an illustrative example of time series for Austria and for a hypothetical "energy economy basket", the NACE divisions "E37 Sewerage", "H 52 Warehousing and support activities for transportation", "D 35 Electricity, gas, steam and air conditioning supply", "B 06 Extraction of crude petroleum and natural gas", "F 41 Construction of buildings", "C 19 Manufacture of coke and refined petroleum products", "H 49 Land transport and transport via pipelines", "H 51 Air transport", "H 50 Water transport", "F 42 Civil engineering" and "C 36 Water collection, treatment and supply" have been summarised. Figure 14 shows the time series of the share of energy related company start-ups based on this hypothetical energy economy basket in comparison to all company start-ups in Austria in the period 2004-2011.

[12] Further considerations on the NACE classification can be found in the appendix.

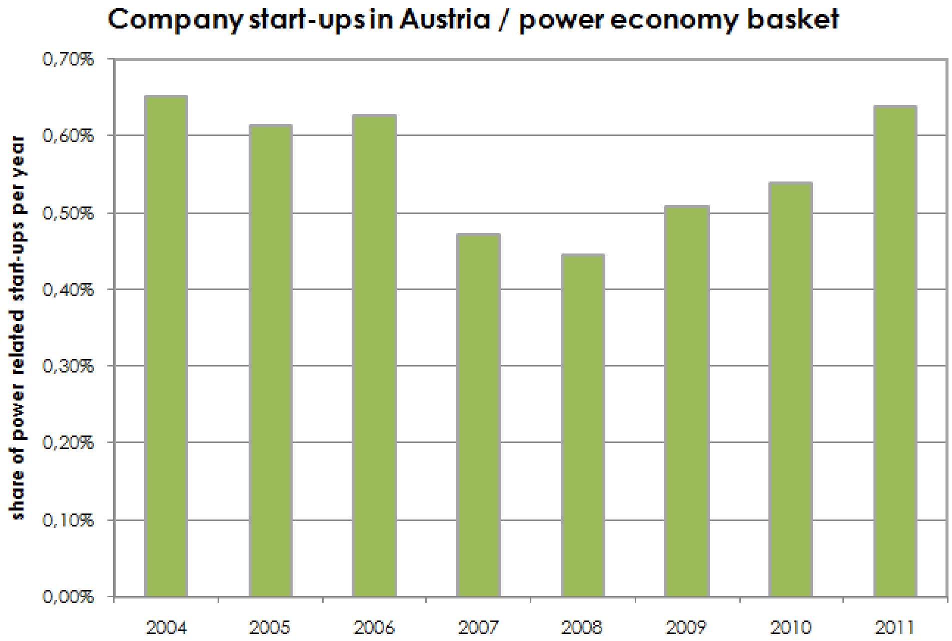
Figure 14. Company start-ups in Austria – hypothetical energy economy basket (2004-2011)



Source: Statistics Austria.

Another example, a hypothetical "power economy basket", is shown in Figure 15. Initially it was planned to subdivide the power economy basket into four NACE groups – "C 27.1 Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus", "C 27.2 Manufacture of batteries and accumulators", "C 27.3 Manufacture of wiring and wiring devices" and "D 35.1 Electric power generation, transmission and distribution". However, this level of detail is not published by Statistics Austria. Looking at a more aggregate level of the related groups ("D 35 Electricity, gas, steam and air conditioning supply" and "C 27 Manufacture of electrical equipment"), an average of nearly 150 company start-ups in these areas can be identified of which about 85% accrue to the sector "C 27 Manufacture of electrical equipment". Figure 15 shows the estimated share of power related start-ups in Austria.

Figure 15. Company start-ups in Austria – hypothetical power economy basket (2004-2011)



Source: Statistics Austria.

Figure 14 and Figure 15 illustrate that the selection of potentially relevant economic sectors for an economy basket according to the NACE classification would be crucial for an accurate and meaningful measurement. There are, however, many caveats with respect to the identification and argumentation of specific sectors. Nevertheless, both figures demonstrate that as soon as a viable economy basket is established data gathering can be easily done.

The NACE classification can provide a first indication on how many (possibly) energy related new markets have been developed. It should be noted that the approach to use the NACE classification lacks accuracy due to the given (not energy focused) system of economic activities, but has the advantage of data availability. Insufficient accuracy can be balanced by a reasonable selection of involved NACE divisions, groups and classes.

In terms of an energy innovation scoreboard the share of related company start-ups per year could be classified as an outcome indicator.

6.3 Secondary and tertiary education

- Matriculation and diploma exams as well as university degrees in technical, industrial and natural scientific fields per exams and degrees per year (acc. to ISCED Levels 3 to 6) [%]

Human capital and the ability of people to innovate is an essential foundation for innovative development. Innovations can be initiated at all levels of an organization, not only in the R&D

department. When it comes to measure the availability of energy-relevant human capital it is therefore important to capture all relevant levels of education. Therefore the ISCED-Levels 3 to 6 should be taken into account. One challenge here is which curricula and degrees are energy-relevant and which are not. In consideration of different national educational systems and available statistical data, a broad approach should be taken. Two main areas of educational content have to be mentioned: first, the key areas such as electronics / electrical engineering, chemical engineering, process technologies, mechanical engineering, specific renewable energy technologies, etc., and, second, the line from pure natural sciences to specific technical and technological applications such as physics, technical physics, engineering science, mechanical engineering etc. Therefore, a clear boundary would be required in order to collect internationally comparable data.

According to this consideration, the underlying question to this indicator is phrased as follows:

- What proportion of human capital with established education is available for energy innovation?

Exact data on energy-related graduations and degrees are currently not available. A first approximation for Austria is provided by the "Master plan to ensure human resources in "Renewable Energies"" ("Masterplan zur Sicherstellung der Humanressourcen im Bereich "Erneuerbare Energie""; Geiger et al., 2013). In this project, training and further education in the field of renewable energy was identified. In the segment of professional qualifications (apprenticeships, secondary schools, colleges, etc.) 26 education opportunities were identified and at university level (universities of applied sciences, university degree programmes and courses) 63 courses. However, in both fields no concrete numbers on the actual, annual graduations and degrees have been determined due to the limited project budget. For Austria, a funding of about € 50,000 would be needed to finance a single investigation. Due to the dynamic field of training opportunities, this sum would be needed to cover every entrusted data collecting project.

As an alternative to this resource intensive method, statistical data on a less detailed level is available. Statistics Austria publishes graduations and degrees by type of school and study; apprenticeships are not listed separately. On the level of secondary schools, the types of schools distinguish between general, technical / industrial, commercial, business, agriculture and forestry as well as teaching. In 2011, in Austria 10,154 matriculation and diploma exams in technical / industrial secondary schools were passed (out of 42,754). Time series back to 1960 are available. Degrees at universities reaching back to 1996 and respectively 1972 (for universities of applied sciences) are also available. In 2011/2012 a total of 14,569 studies (natural and engineering sciences) were completed in Austria (in comparison to a total of 46,415 completed studies in all fields of study). More detailed – in terms of fields of study – data is only available for degrees at universities and would exclude the important field of secondary schools, which are relevant for industrial R&D efforts.

Because of the high costs involved in detailed studies on the energy-related educational sector in each country, missing available data on a detailed level (e.g. secondary schools) and limited comparability of different education systems (e.g. insufficient restriction of fields of study), a “snapshot” using available statistical data seems adequate and easier to compare in an international scoreboard. Gathering comparable data is another argument to fall back on highly aggregated data for use in an international scoreboard due to huge differences between national education systems and to avoid tailoring data selection to a specific country or group of countries.

The advantages of a broad coverage of relevant study areas have to be set against the disadvantages. The suggested definition of the indicator includes types of school and study areas that are not energy relevant at first sight, e.g. only a few biologists are ultimately involved in energy innovation, but the indicator would include all graduated biologists. No estimates of the specific energy relevance of different fields of natural / engineering science and technical / industrial studies are available in the literature.

Secondary education could be located as an enabler indicator within an energy innovation scoreboard.

6.4 Vocational training

Aside from school and university courses, vocational training is another cornerstone for the formation of qualified human capital. It is assumed that vocational training is offered before the same content finds its way into the educational system. Thus a further important indicator for the area of human capital could be the evaluation of vocational training. Because data collection takes place in a very heterogeneous and dynamic field of training providers, it seems sensible to simplify data collection by focussing on large and representative training institutes, possibly added to data from national research, technology and innovation programmes and / or representation of relevant industry sectors.

Given that the structure of the vocational training sector in an international comparison is very heterogeneous, uniform data collection is difficult. If representative training institutes could be found in all countries, data gathering would be within a manageable framework.

According to this consideration the underlying question to this indicator is phrased as follows:

- How does energy related vocational training develop and what are the topics for future educational programmes?

Exact data on vocational training courses in the energy sector are not available at the moment. Geiger et al. (2013) provide a list of 83 identified training courses with a focus on renewable energy in Austria but not an exact number of trained persons.

At the moment more detailed data is not available for Austria and it is highly doubtful that there is a better database in other IEA countries. Due to this lack of data availability and the need to define a clear methodology for gathering data, there is no suggestion to include this indicator in a first draft of an energy innovation scoreboard.

Vocational training could be classified in the context of an energy innovation scoreboard as an enabler indicator, if quantitative data is available. Otherwise a qualitative indication would also be acceptable to provide target routes for future educational opportunities. In this case vocational training should be labelled as a context indicator.

6.5 Private R&D expenditures

- Share of energy-related private R&D expenditure according to a hypothetical energy-related economy basket (by NACE classification) in comparison to total private R&D expenditure per year [%]

Private R&D expenditures are a particularly relevant factor in terms of the market transfer of inventions. Thus, this indicator complements public energy R&D expenditure as already included in the pilot version of an energy innovation scoreboard to a substantial degree. Displaying the share of private energy related R&D expenditure in comparison to the total private R&D expenditure has the advantage that influences of the economic cycle are considered.

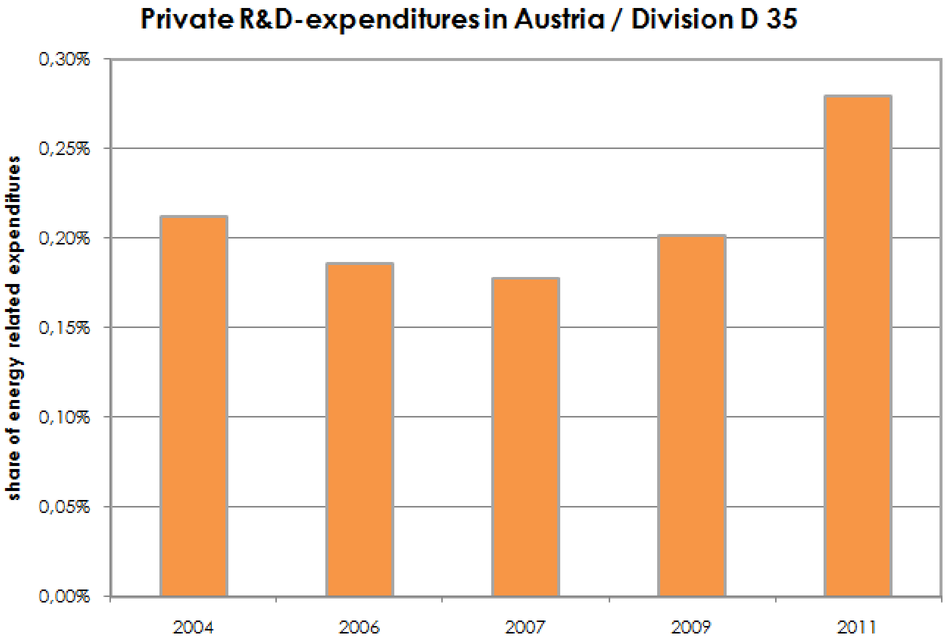
According to this consideration the underlying question to this indicator is phrased as follows:

- What is the level of private, energy-related R&D expenditure?

Statistical data for private R&D expenditure is available, but e.g. in Austria, not published on a sufficiently disaggregated level for an energy innovation scoreboard. It is, however, possible to build a (hypothetical) energy related economy basket using the NACE classification as described above. For this purpose, a separate data analysis would be necessary as was done by Bointner et al. (2013) who found that private R&D expenditure exceeded public R&D expenditure for renewable energy technologies by a factor of 3.2 in Austria in 2009.

The available statistical databases provide data for the years 2004, 2006, 2007, 2009 and 2011 for NACE divisions (e.g. "D 35 Electricity, gas, steam and air conditioning supply" or "C 27 Manufacture of electrical equipment").

Figure 16. Private R&D expenditures in Austria / NACE-division D 35



Source: Statistics Austria.

Figure 16 shows a time series of private R&D expenditure in Austria for the NACE division "D 35 Electricity, gas, steam and air conditioning supply" in comparison to the total private R&D expenditure of all divisions. Still, one has to keep in mind that innovation expenditure in this sector can also accrue to non-energy-related innovation.

For using this indicator within an energy innovation scoreboard, an annual analysis based on the suggested economy basket would be needed. Due to the fact that these data are statistically available, the additional costs for data provision would be in a very limited range.

It has to be stressed that using economy baskets cannot provide R&D expenditure with a compelling energy focus. It is only possible to display R&D efforts of economic activities which are close and / or part of the energy economy. This lack of accuracy might be acceptable due to missing data for energy related R&D expenditure for all branches and industries, but underlines the need for a reasonable selection of NACE divisions, groups and classes to provide numbers that are as accurate as possible.

Within an energy innovation scoreboard, private R&D expenditure could be classified as an enabler indicator like public R&D expenditure.

6.6 SMEs with product or process innovations

- The number of technological innovations according to a hypothetical energy-related economy basket (by NACE classification) per GDP per capita per year [no./US$]

This indicator is already collected for the IUS every three years, but at a rather aggregate level, i.e. no energy specific data are available. The IUS data, which is provided by the national statistical agencies, are aggregated according to the NACE classification.

According to this consideration the underlying question to this indicator is phrased as follows:

- What is the actual output of all energy related R&D expenditures?

For the years 2008 to 2010 a total of 146 companies (not only SMEs) were recorded within the NACE division "D 35 Electricity, gas, steam and air conditioning supply" in Austria – in comparison to a total of 15,968 companies – of which 94 have declared innovation activities – in comparison to 9,016. However, for the energy innovation scoreboard the whole questionnaire for the IUS was screened to identify possibilities to include an energy focus. Energy innovation specific aspects which could provide an easy indication for further analysis are, however, not addressed in this survey. Including energy-specific questions is highly unlikely, due to the EU-wide harmonization requirement for this questionnaire and the expectation that other industry sectors in this case would claim a similar additional question. This would lead to an even more comprehensive questionnaire which is already too extensive for private companies (Schiefer, 2013).

Because of the high aggregation of published data, no further analysis is possible at this point. As mentioned above, Bointner et al. (2013) already analyzed private R&D expenditure in Austria. For this analysis, 244 Austrian companies within the fields of solid, liquid and gaseous biomass, solar thermal collectors, heat storage manufacturers, photovoltaic, heat pumps, hydro power, wind power, e-mobility and fossil fuels have been identified. This company list could be a starting point for further analysis of IUS questionnaires and a meaningful reference for an evaluation of the suggested economy basket.

For an international energy innovation scoreboard the suggested economy basket should be compared with relevant companies of each country. It should be assessed and documented whether all relevant companies are covered by the selected NACE divisions, groups and classes. This should be done by national statistical offices and is a necessary step to achieve reasonable accuracy for this indicator.

SMEs with product or process innovations could be located within the pilot energy innovation scoreboard as an output indicator according to classification of the IUS.

6.7 SMEs involved in cooperative research

- Share of cooperative, technological innovations in comparison to total, technological innovations according to an energy-related economy basket (by NACE classification) per year [%]

Cooperative researching SMEs can be seen as a supplementary indicator to SMEs with product and process innovations. Availability and aggregation of data is similar to the latter.

According to this consideration the underlying question to this indicator is phrased as follows:

- How are the energy related innovations achieved?

In Austria, 73 companies with technological innovations (product and process innovations) were reported within the NACE division "D 35 Electricity, gas, steam and air conditioning supply" in the years 2008 to 2010 – in comparison to a total of 94 innovation activities (including technological and non-technological) in this division and a total of 7,012 companies with technological innovations in Austria within this time span. 69 of these 73 technological innovations have been achieved by cooperative research (resp. 3,576 of 7,012 in all branches). Thus, the statement that the energy sector tends towards very cooperative research behaviour in comparison to the average Austrian business is valid.

All other conclusions to the indicator "SMEs with product or process innovations" apply also to "cooperative researching SMEs" because of the similar availability and aggregation of data.

Cooperative researching SMEs are – according to the IUS (EC, 2013a) – a firm activity. In the context of an energy innovation scoreboard SME research cooperation could be classified as an enabler indicator, because it more likely represents the research behaviour of the energy sector than the output "achieved innovations".

7 Conclusions

The investigations carried out by ÖGUT have shown that data for five out of seven suggested indicators could be provided with a maintainable effort and are available for most OECD countries, due to the use of NACE or other internationally harmonized classifications. These indicators are, however, only meaningful if a reasonable selection of NACE sectors can be achieved. Even in that case that would imply the use of quite inaccurate proxy data. The suggested indicators can contribute to "fill" data gaps according to the structure of the pilot energy innovation scoreboard as proposed in Part A of this study (white boxes in Figure 4 on page 14), but further research is needed to achieve this in an appropriate and reasonable way.

The seven complementary indicators can be summarized as following:

- **Market and technology research**
  discarded for now, but relevant for future development of an energy innovation scoreboard [no specific unit (yet)] → context indicator
- **Related company start-ups per year**
  number of energy-related start-ups according to an energy-related economy basket (NACE) per total start-ups per year [%] → outcome indicator
- **Secondary and tertiary education**
  matriculation and diploma exams as well as university degrees in technical, industrial and natural scientific fields per exams and degrees in total per year (acc. to ISCED Levels 3 to 6) [%] → enabler indicator

- **Vocational training**
  needs further investigation on an international basis to identify representative training institutes [no specific unit (yet)]→ enabler indicator.
- **Private R&D expenditure**
  share of energy-related private R&D expenditure according to an energy-related economy basket (NACE) in comparison to total private R&D expenditure per year [%] → enabler indicator
- **SMEs with product or process innovations**
  number of technological innovations according to an energy-related economy basket (NACE) per GDP per capita per year [no./US$] → output indicator
- **Cooperative researching SMEs**
  share of cooperative, technological innovations in comparison to total, technological innovations according to an energy-related economy basket (NACE) per year [%] → enabler indicator

It should be mentioned that the first suggested step is to develop and verify an internationally-reasonable energy-related economy basket. This should be performed by comparing a pre-selection of NACE divisions, groups and classes with energy related companies in representative countries. This verification has to answer the question of whether all relevant companies have been covered and therefore the link between energy related companies and energy innovation is given in an appropriate way. This provides more accuracy of future data gathering but cannot close the gap between innovation in the energy economy and energy innovation in all economies. As a second step, national statistical agencies should be entrusted to compile data for this pre-selection of NACE divisions, groups and classes as well as the suggested range of educational data. The third suggested step involves an international discussion of the gathered data. Key inputs for this discussion should be: (1) accessibility of relevant data in all participating countries and (2) actual accuracy of the gathered data (resp. NACE classification and education system). The discussion itself should sharpen the developed indicators in terms of international comparability and reasonable accuracy.

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Appendix

A.1 Notes according NACE classification

The European NACE classification of economic activities is based on the internationally agreed ISIC classification hence it is a promising approach to ensure data comparability for an international scoreboard. Following the idea of the consumer basket to define the consumer price index, a so-called "economy basket" consisting of relevant NACE divisions, groups and classes has to be identified. It is highly recommended to examine this suggestion on an international level to ensure that the chosen divisions, groups and classes – especially the herewith summarised companies – have a significant correlation with the overall output "energy". To achieve this it is necessary to illustrate the real supply and value chains of possible relevant companies and / or industries to derive "technology development chains". The results of this study could improve the selection for the final economy basket. Due to limited time and financial resources, the suggestion at hand is based on rough investigations to provide a first sketch as a basis for further discussions and developments.

Two main factors are directly attached to the method of using an economy basket. First of all, finding a reasonable scale according to which economic activities can be described as energy-related, mainly energy-related and not energy-related. Secondly, accuracy is a main factor for the usability of an energy innovation scoreboard. Therefore an international study should be undertaken to compare potential NACE classifications with representative industry structures and expert opinions. Output of this study should be an energy economy basket based on studies of the energy economy in representative countries complemented by expert interviews and workshops.

As a first suggestion for a starting point of an **"energy economy basket"** the following NACE divisions, groups and classes have been identified. This suggestion focuses on relevant industries and supplying industries for electrical and thermal energy, their distribution as well as mobility in general. Subcategories of seven sections have been chosen – in detail: 12 divisions, 16 groups and 5 classes.

- A 02.2 – Logging
- B 05 – Mining of coal and lignite
- B 06 – Extraction of crude petroleum and natural gas
- B 07.21 – Mining of uranium and thorium ores
- C 19 – Manufacture of coke and refined petroleum products
- C 25.1 – Manufacture of structural metal products
- C 25.2 – Manufacture of tanks, reservoirs and containers of metal
- C 25.3 – Manufacture of steam generators, except central heating hot water boilers
- C 26.3 – Manufacture of communication equipment
- C 26.51 – Manufacture of instruments and appliances for measuring, testing and navigation

- C 27.1 – Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus
- C 27.2 – Manufacture of batteries and accumulators
- C 27.3 – Manufacture of wiring and wiring devices
- C 27.4 – Manufacture of electric lighting equipment
- C 27.5 – Manufacture of domestic appliances
- C 28.1 – Manufacture of general-purpose machinery
- C 28.21 – Manufacture of ovens, furnaces and furnace burners
- C 28.22 – Manufacture of lifting and handling equipment
- C 28.25 – Manufacture of non-domestic cooling and ventilation equipment
- C 29.1 – Manufacture of motor vehicles
- C 29.2 – Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
- C 30.1 – Building of ships and boats
- C 30.2 – Manufacture of railway locomotives and rolling stock
- C 30.3 – Manufacture of air and spacecraft and related machinery
- D 35 – Electricity, gas, steam and air conditioning supply
- E 36 – Water collection, treatment and supply
- E 37 – Sewerage
- F 41 – Construction of buildings
- F 42 – Civil engineering
- H 49 – Land transport and transport via pipelines
- H 50 – Water transport
- H 51 – Air transport
- H 52 – Warehousing and support activities for transportation

It has to be stressed that this suggestion for a starting point for further investigation should provide an overview of which economic activities should be taken into account and does not claim a final or ready-to-use stage.