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AUSTRIAN INSTITUTE OF ECONOMIC RESEARCH

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### Abstract

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CIEP

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# Monitoring Sustainable Energy Development: A cross-country comparison of selected EU Members

## CIEP Working Paper 2


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Keywords: sustainable development, composite indices, energy policy, climate policy, cross-country comparison, EU Member States

JEL codes: Q01, Q48, Q54




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# 1 Introduction

In 2015 two major international frameworks were agreed on that provide landmarks for the development paths that countries should follow in the period 2030/2050: the UN Sustainable Development Goals (SDGs) and the Paris Climate Agreement. Both sets of (long-term) targets require a fundamental restructuring of economies and societies to be achieved. The complexity and ambition of the targets pose a challenge to research/policy analysis as well as to implementation/policy making. In addition to monitoring the progress towards achieving the individual goals a multitude of synergies and trade-offs has to be considered. In many cases there will be synergies and co-benefits for other targets if one is achieved (Allen et al. 2018; TWI2050 - The World in 2050 2018). But especially when there is no integrated view on the whole set of targets unintended adverse side-effects (e.g. lock-ins) might occur. Extended information and measurement systems are called for to structure the high degree of complexity implicated by the multidimensionality of sustainable development and to highlight the interdependencies between various issues.

In this paper we use the climate and energy policy indicators developed in the CIEP project (C. Kettner et al. 2018) as starting point to analyse the two areas of energy and climate for Austria and other selected European countries. The assessment is carried out in great detail, i.e. based on a multitude of indicators, and with a focus on the interdependencies between targets or dimensions of sustainable development. In the centre of our approach are energy services that instead of energy flows represent the relevant determinants for well-being. Based on a comprehensive view of the energy system (starting from energy services via final energy demand to energy supply) we calculate composite indices taking onto account five distinct sectors: households, manufacturing, services, transport, and electricity and heat supply. This approach allows us to carry out cross-country comparisons of overall sustainability in terms of the economic, ecologic and social dimensions of sustainability on the one hand and with a sectoral perspective on the other hand. The nine selected countries can be compared with regard to their current status of sustainable energy development. In addition, their development over time can be assessed and furthermore the synergies and trade-offs between sub-indices or individual indicators can be identified.

The paper is structured as follows: In section 2 the methodological approach for calculating the composite indices is laid out. Then the selection of countries is described, and the results of the cross-country comparison based on the composite indices are presented, including a sensitivity analysis. Section 5 discusses the findings and identifies lessons to be learned. The final section concludes.

## 2 Methodology and Data

In addition to the indicator set described in detail in Kettner et al. (2018) we calculate two sets of composite indices that illustrate the sustainability of energy use in the selected sectors over time in a condensed way and allow for cross-country comparisons of development. The main advantage of this approach is that aggregate indices facilitate the monitoring of energy/climate policy over time. The comparison or evaluation of a multitude of different indicators (as are included in our database) would be an overly complex task. An overall conclusion about energy sustainability and emission reductions is more easily reached by focussing on one global figure describing the relevant development (comparable to the role of GDP in national accounts for assessing economic development). The purpose of a composite index is to reduce complexity and to provide a useful instrument for policy monitoring and decision making. In addition, the index can serve as a communication tool. In addition, the set of individual indicators provide useful background information.

Through the aggregation of single indicators to composite indices, information about specific details (e.g. sectoral developments), however, can be lost (e.g. OECD 2002, 2008). A composite index is hence to be seen as a complement for the set of detailed indicators containing important information about energy sustainability in different areas. While focussing on energy and climate related indicators (reflecting the context of SDGs 7 and 13) special attention was dedicated on including the social dimension of sustainable energy development in a more comprehensive way.

There are several challenges that arise when accounting for social aspects, including the so-called "measurement problems" in the social sciences, i.e. the difficulty to reproduce theoretical constructs exactly and uniformly, such as "peace" and "gender equality", as these constructs depend on the subjective perception of the individual, as various characteristics are regarded as essential and as they often depend on contexts (Wroblewski, Kelle, and Reith 2017). Following the theoretical considerations about what information would be useful to include in the indicator framework, further adjustments were made during the implementation process due to lack of relevant data in terms of absence of 1) time series to map a time course (e.g. temporary contracts); 2) allocation to particular economic sectors (e.g. involuntary temporary employment, atypical working hours, continuing vocational training) and 3) internationally comparable data for other European countries (e.g. collective pay agreement, mobility data – share of distances covered by foot, bicycle, public transport, car sharing)[1]. Further adaptation of the indicator framework were made due to the fact that available indicators – collected for instance by the United Nations Statistics Division and Eurostat – are qualitative, depicting attitudes (e.g. job satisfaction, work under pressure, job autonomy (possibility to influence content and order of tasks) or survey qualitative characteristics about activities which are highly contingent which makes them impossible to interpret properly outside of the specific context (such as time

[1] Despite the fact that gender matters with regard to climate change and related policies and jobs little attention is dedicated to these issues. Empirical research and data on gender inequalities are rare. (Cohen 2017).

budgets[2], i.e. time use[3] and satisfaction) rather than providing quantitative figures as is generally the case with the economic or ecologic indicators.

At this juncture, it should be pointed out that such numerical reduction to a few key indicators, in addition to providing for the necessary focus, also inevitably generates gaps.

Based on the indicator framework developed for CIEP (Kettner et al. 2018) we calculate composite indices for sustainable energy development. The methodology for the calculation of this sustainable energy index follows Davidsdottir et al. (2007); Ibarrarán Viniegra, Davidsdottir, and Gracida Zurita (2009) and Kettner, Kletzan-Slamanig, and Köppl (2015). Our index is based on five sub-indices, one for each area (transport, residential buildings, manufacturing, services, electricity and heat supply). The sub-indices are calculated with the following equation:

$$I_{k,i,t} = \sum_{j=1}^{n} w_j * \left(\frac{E_{k,i,j,t}}{E_{i,j,t=0}} - 1\right)$$

where $I_{k,i,t}$ gives the sub-index of area i in country k in year t, j is the energy indicator, n is the number of indicators, $w_j$ is the weight for each indicator, and $E_{k,i,j,t}$ is the value of the energy indicator in year t. This means that each sub-index is the weighted sum of the change in the indicators compared to an assumed base year. The aggregate index is calculated as the weighted sum of the sub-indices. The indicators used to compute the index were normalised with the figures for Austria in 2010 to equal 100 in order to allow for a cross-country comparison.

Especially with respect to the social dimension, relevant data are rarely available for multiple countries or as time series. Therefore, we chose to provide an alternative composite index that requires fewer input data, i.e. it neglects the temporal dimension but performs a cross-country comparison based on the latest available data. While we could have also opted for a distance to reference country approach for calculating the extended composite index, we use the Min-Max methodology described by the following equation

$$I_{k,i} = \sum_{j=1}^{n} w_j * \left(\frac{E_{k,i,j} - E_{min,i,j}}{E_{max,i,j} - E_{min,i,j}}\right)$$

with the aggregate index being again calculated as the weighted sum of the sub-indices. This approach is frequently used for calculating composite indices in the context of the measurement

[2] For example, the United Nations Statistics Division (UNSD) provides time-use data and points out the importance of collecting this information: "They [time-use statistics] offer a unique tool for exploring a wide range of policy concerns including assessing quality of life or general well-being, analysing division of labour between women and men, improving estimates of all forms of work (paid and unpaid) and estimating household production and its contribution to GDP. " ((United Nations Statistics Division, https://unstats.un.org/unsd/gender/timeuse/)

[3] Statistics Austria`s "Time use survey 2008/09" provides data about time distribution of different groups in society on different activities per day. The micro data was collected from around 8 200 individuals aged 10 and over, who wrote a diary for each day, where they entered all activities lasting longer than 15 minutes. The diaries generate information about the time spent for e. g. occupational activities, education, social contacts, gender specific division of housework, childcare, whereby the different facets are considered, and "real leisure time" in contrast to time for paid and unpaid work on the one hand and "spare time" used for sleeping, eating or personal care on the other (Available on the homepage of Statistics Austria: https://www.statistik.at/web_de/statistiken/menschen_und_gesellschaft/soziales/zeitverwendung/zeitverwendungserhebung/index.html, Time use surveys were previously carried out in Austria in 1981 and 1992).

of wellbeing and sustainable development, for instance for the Human Development Index or the OECD Better Life Index. The values of the extended composite index will hence range between 0 (if a country showed the worst performance with respect to all indicators included) and 1 (if a country showed the best performance with respect to all indicators included).

For the composite indices, we initially selected 30 indicators that are shown in black in Table 1. 14 indicators can be assigned to the ecologic dimension, 13 to the economic dimension and 3 to the social dimension. In terms of sectoral disaggregation, 10 indicators apply to the household sector, 7 to the transport sector, 4 each to the industry and service sector and 1 to electricity and heat supply.

As explained above, because of data limitations particularly for the social dimension an additional extended version of the index was calculated including also indicators that are only available for individual years (in total 42 indicators). These indicators are displayed in grey in Table 1. For the extended index, 13 indicators can be assigned to the residential sector, 12 to transport and 9 to electricity and heat supply; for industry and services again the same 4 indicators were used. When grouped by dimension of sustainable development, 15 indicators refer to the ecological dimension, 14 to the economic dimension and 13 to the social dimension.

The indicators for the composite index were selected in order to provide information on the different levels of the energy system as illustrated above and on all dimensions of sustainable energy development. While we stress the importance of energy services as energy and climate policy indicators (see Kettner et al. 2018), we do not include the proxies for measuring the energy service demand in the composite index (e.g. passenger and tonne kilometres for mobility as a proxy for the energy service "access to people, goods and services at different distances"). The rationale for that is that the proxies cannot be interpreted in an unambiguous way (i.e. an improvement in energy efficiency, for instance, will always be beneficial for sustainability while this is not straightforward for an increase in the stock of appliances). Furthermore, the indicators should be characterised by good data availability and quality.

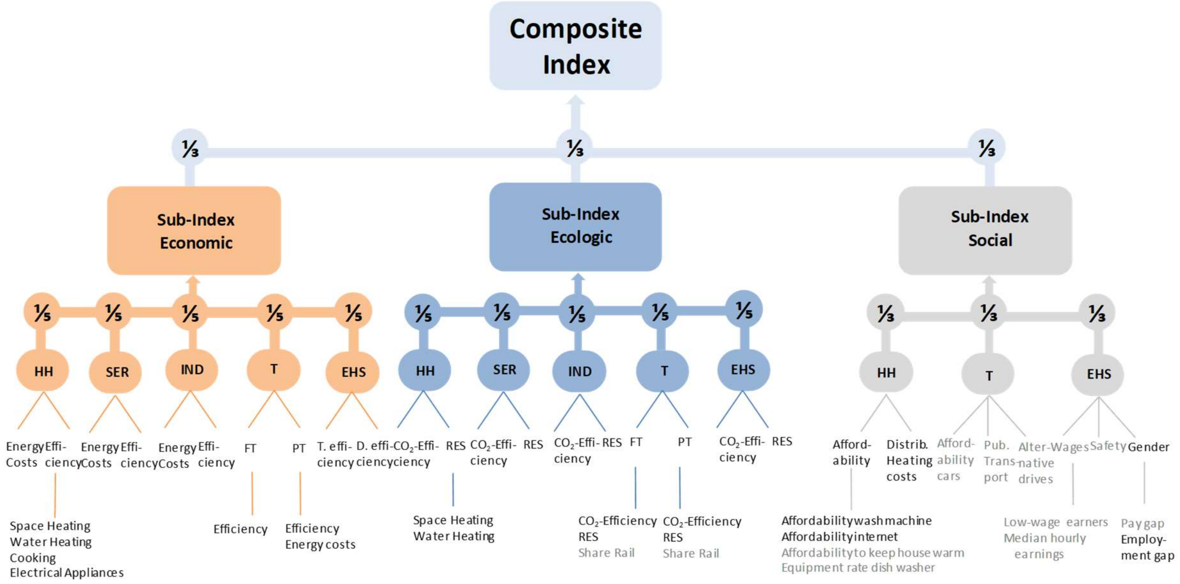
*Table 1. List of indicators included in the composite indices*

| | Residential | Transport | | Industry | Services | Electricity and Heat Supply |
|---|---|---|---|---|---|---|
| | | Passenger T. | Freight T. | | | |
| **Economic** | Energy efficiency by use category<br>Energy cost share | Energy efficiency<br>Energy cost share | Energy efficiency | Energy efficiency<br>Energy cost share | Energy efficiency<br>Energy cost share | Transformation efficiency<br>Distribution efficiency |
| **Environ-mental** | Share of RES<br>$CO_2$ Efficiency | Share of RES<br>$CO_2$ Efficiency<br>Share Rail in MS | Share of RES<br>$CO_2$ Efficiency<br>Share Rail in MS | Share of RES<br>$CO_2$ Efficiency | Share of RES<br>$CO_2$ Efficiency | Share of RES<br>$CO_2$ Efficiency |
| **Social** | Affordability of washing machine<br>Affordability to keep the house warm<br>Affordability of internet connection<br>Equipment rate of dishwashers<br>Share of heating costs in HH income | Share of alternative drives in new registrations<br>Accessibility of public transport<br>Affordability of cars | | | | Low wage earners<br>Median hourly earnings<br>Fatal incidents<br>Gender pay gap<br>Gender employment gap |

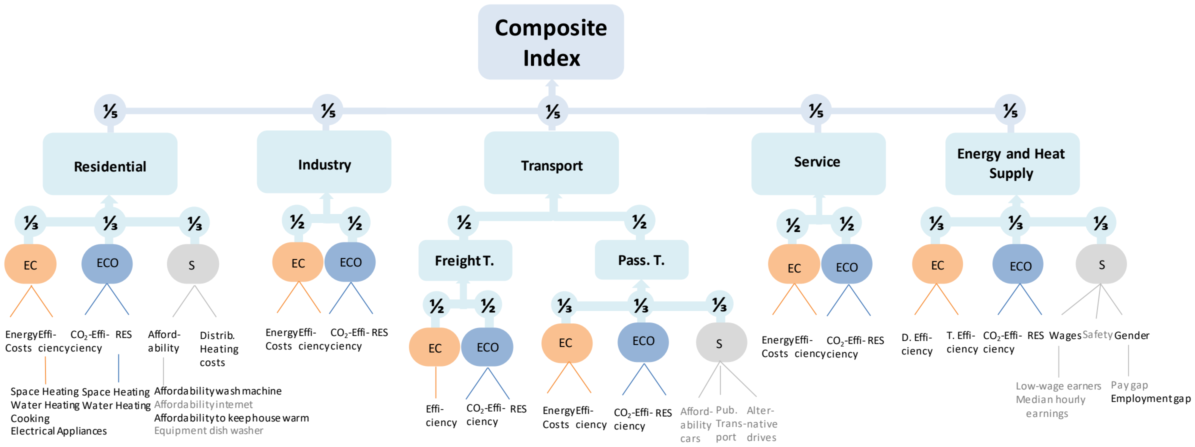
Figures 1a and 1b illustrate the way in which the indicators were aggregated in order to calculate the sectoral and dimensional sub-indices and finally the composite index. The different composition of the sub-indices thus determines the weight of the individual indicators in the calculation of the composite index and thus explains the disparity in the total values. The lack of appropriate social indicators for the sectors manufacturing and services implies that in the aggregation by sector the social dimension is somewhat underrepresented. A better data availability of (quantitative) social indicators would improve the analysis.

*Figure 1. Aggregation structure of the composite indices*

*(a) Aggregation by sector and dimension*




*(b) Aggregation by dimension and sector*




For the calculation of the aggregate index, two different weighting procedures are applied: First, we assign equal weights to all sectors included in the index (standard approach); in addition, we weight the sectors according to their shares in total energy related $CO_2$ emissions ($CO_2$ weighted approach). The latter is used as a sensitivity analysis (see section 4.2.1).

In the following sections we describe the development of the CIEP composite index for sustainable energy development in selected European countries. Furthermore, we present the results of sensitivity analyses for the composite index.

Diverse databases were used to collect the indicators. Proxy data for energy services, i.e. the floor area of dwellings, passenger and freight transport performance as well as gross value added of the manufacturing and service sectors, and the related efficiency data are derived from the Odyssee database. The number of households, information on the different capital stocks and equipment rates as well as the sectoral shares of renewable energy sources are also taken from this database. Data on newly registered vehicles are obtained from the European Environment Agency's databases. Data on energy flows, i.e. final energy demand, transformation input and transformation output by energy source, are taken from the IEA's Energy Balances. Sectoral GHG emissions are taken from the UNFCCC's National Inventories. Household income and expenditure originate from Eurostat, energy prices and sectoral public energy expenditure from the IEA. Data on the social dimension are all taken from Eurostat, i.e. from the Structure of Earnings Survey, the Labour Force Survey and the European Statistics on accidents at work.

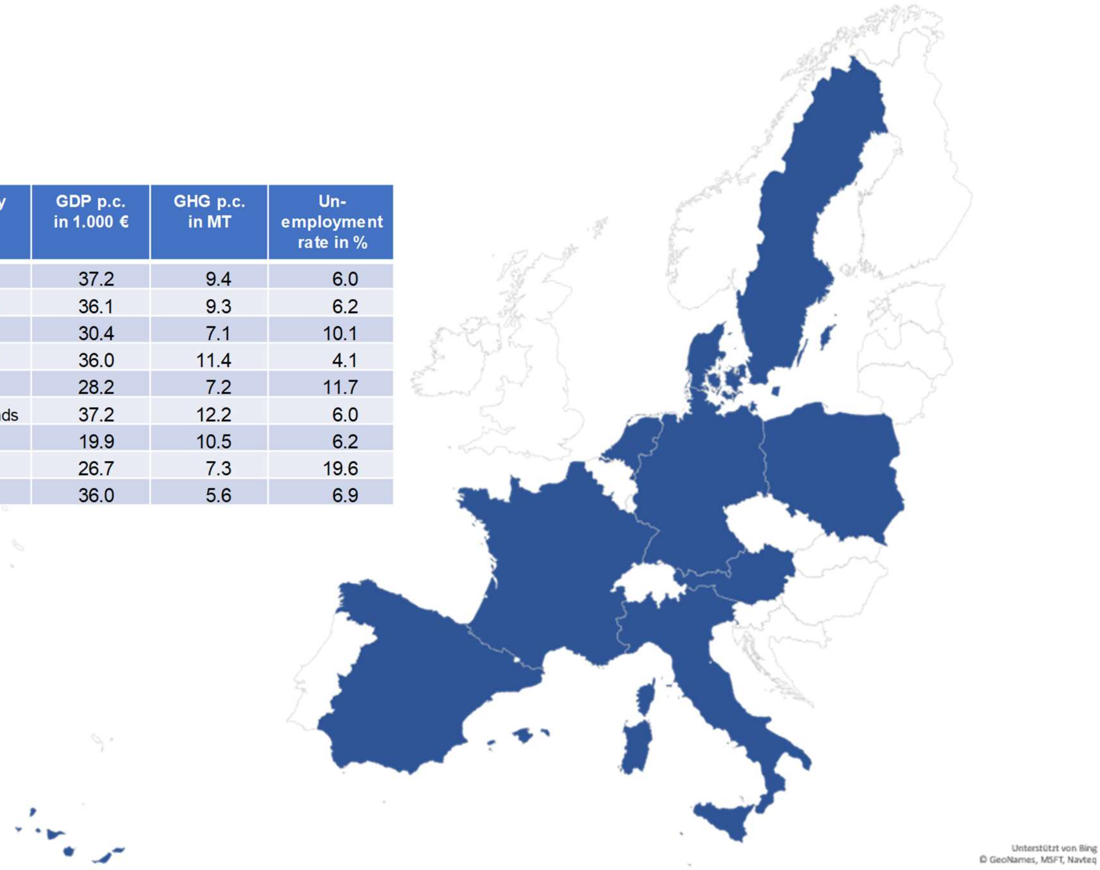
# 3 Results

## 3.1 Selection of countries

In total nine countries were selected for the detailed assessment of their sustainable energy development based on the indices described above. Apart from Austria these include Denmark, France, Germany, Italy, the Netherlands, Poland, Spain and Sweden. In the selection of countries we aimed at achieving a good mix, i.e. small and large countries, northern and southern countries as well as old and new EU member states. Although the group of countries chosen represents a broad spectrum, eventually the selection was also determined by data availability. In order to be able to calculate the indices from the CIEP database and carry out cross-country comparisons we had to make sure that for the selected group of countries the major part of the indicators required was available.

Figure 2 illustrates the country selection including some economic, ecologic and social context indicators.

*Figure 2. Context indicators for the selected countries*




| Country | GDP p.c. in 1.000 € | GHG p.c. in MT | Un-employment rate in % |
|---|---|---|---|
| Austria | 37.2 | 9.4 | 6.0 |
| Denmark | 36.1 | 9.3 | 6.2 |
| France | 30.4 | 7.1 | 10.1 |
| Germany | 36.0 | 11.4 | 4.1 |
| Italy | 28.2 | 7.2 | 11.7 |
| Netherlands | 37.2 | 12.2 | 6.0 |
| Poland | 19.9 | 10.5 | 6.2 |
| Spain | 26.7 | 7.3 | 19.6 |
| Sweden | 36.0 | 5.6 | 6.9 |

For each country various analyses were carried out: for the period 2005 to 2015 the sectoral and dimensional sub-indices as well as the composite indices were calculated in order to describe the development towards sustainable energy development. In addition, sensitivity analyses were carried out; firstly by using alternative weighting approaches for the aggregation of the indices, secondly, by calculating extended indices for the latest available year (2015) mainly broadening the view on the social dimension of sustainable energy development.

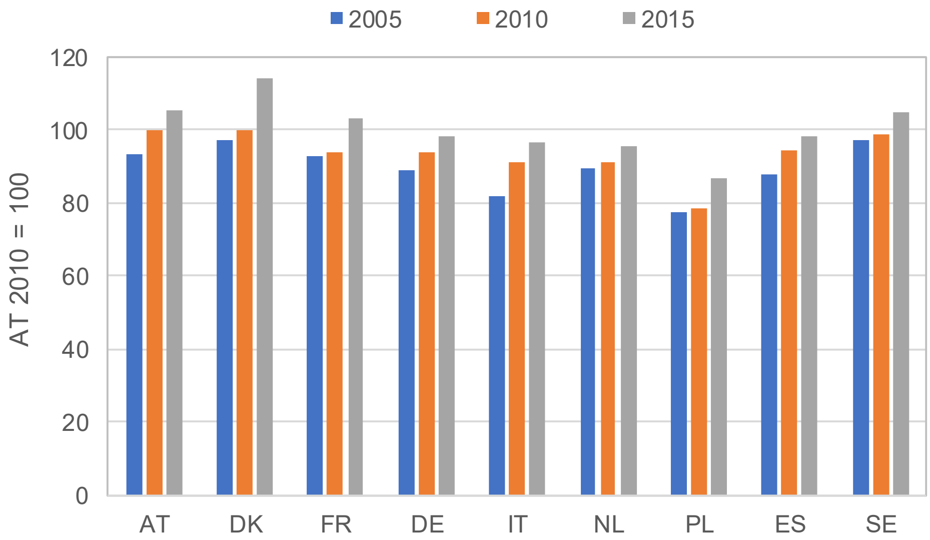
## 3.2 Sectoral/dimensional/composite indices over time – results

For the cross-country comparison of the composite indices the approach was chosen to normalise the index with the figures for Austria in 2010 to equal 100. Using this distance to reference country approach the development in the selected countries is measured against this benchmark, i.e. the focus is on how one country performs compared to others.

Figure 3 summarises the development of the index aggregated by dimension using equal weights for all indicators. Between 2005 and 2015 the composite index increases for all countries albeit on different levels. While in the initial year 2005 two countries (Denmark, Sweden) ranked higher than Austria, due to different rates of change in 2015 only Denmark shows a higher value than

Austria (with Sweden close behind). Although starting from a high level, Denmark managed to improve its position significantly over time (+17%). Also, in both years France holds the 4th rank. Another group of countries (Germany, Netherland, Italy, Spain) achieve figures that are 8 to 10 points below Austria in both years. Of these countries Italy shows the largest improvements over time, closing the gap on countries like Germany or the Netherlands. Clearly lagging behind is Poland, although this country – together with Spain – shows one of the highest increases in the index over time (12%). However, by and large the increase is not sufficient for Poland to catch up with the other EU countries. Another aspect worth noting is the temporal distribution of improvements. In some countries (most notably Denmark, France, Poland, Sweden) the advances in sustainability mainly occurred after 2010, while in others (Germany, Austria, Italy) the upward trend was stronger before 2010.

*Figure 3. Development of composite index aggregated by dimension, 2005, 2010 and 2015*



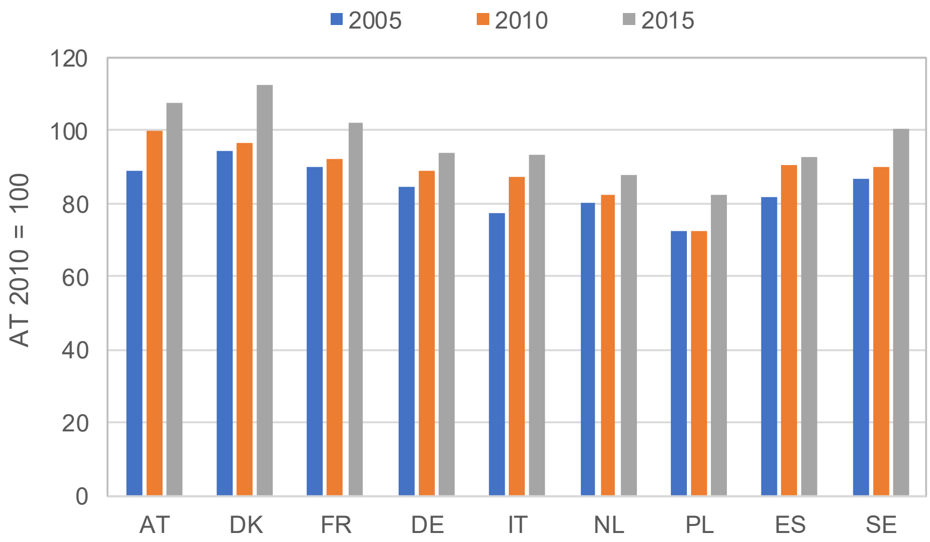

When taking a closer look at the developments in the three dimensions per country (see Figure 8 in the Annex) it stands out that the strongest dynamic arises in the ecological dimension, i.e. caused by rising shares of renewables and improved $CO_2$ efficiency. Especially Austria, Italy, Denmark, France and Spain show high improvements, although the patterns of change are divergent. While for instance Austria improved quite rapidly until 2010, after that the development stagnated. In contrast, the improvements in Denmark were more continuous, whereas Italy and Spain achieved some catching up in the ecological dimension but have still not achieved a high level of environmental sustainability in their energy systems. Sweden showed little but continuous improvements but had the highest ecological sustainability level from the outset. On the other end of the scale we find countries like Poland or also the Netherlands and Spain with low to medium improvements and still low levels of ecological sustainability.

Compared to the ecological dimension little dynamic can be seen in the economic and social dimensions. In the former this hints at a lack of significant improvements in energy efficiency, with the exception of Sweden, that definitely stands out in this regard with an increase that is twice as high as the one achieved by Denmark, which is also above average. However, this can be interpreted as a catching up process as Sweden starts out with a comparably low level of economic sustainability. With respect to the social dimension, improvements are generally modest. Contrary developments occurred in Austria and Sweden, which show a decrease in social sustainability. This is mainly due to the prevailing gender employment gap in the energy supply sector.

For the sectoral aggregation the overall development (using equal weights) is depicted in Figure 4. The general pattern and positive development conform to the dimensional aggregation. Also, the group of the four best performing countries remains the same as for the aggregation by dimension (Austria, Denmark, France and Sweden). In this case, however, Sweden does not perform as well (rank 4), it shows more of a catching up development. The medium performers consist of three countries in this analysis (Germany, Italy and Spain). The Netherlands in turn are in this case closer to Poland, which brings up the rear.

Compared to the dimensional perspectives the improvements are moderate when taking into account the five sectors. Very little improvements (in terms of efficiencies and share of renewables) can be detected in the residential sector. Interestingly, in this area Sweden shows nearly as low a level of sustainability as Poland. This might however be due to the rather large share of electricity in heating. In transport the dynamics are a little bit stronger – especially France improves considerably. In contrast, in Sweden and Germany the sub-index remains largely unchanged. The other countries achieved low to medium continuous improvements (starting from diverging levels of sustainability). The exceptions are Austria (with improvements only until 2010) and Denmark (improvements after 2010). In general, industry shows the strongest positive dynamic of all the sectors. However, the patterns of development differ between the countries. While Austria, the Netherlands and Germany are basically stagnating in terms of industrial sustainability, other countries improve considerably. Especially Denmark manages to improve from an already high level of sustainability. This holds true also for Sweden, although on a somewhat lower level. Countries like Spain and Italy make good progress in catching up. The service sector in contrast remains practically unchanged with little to no improvements. The only exceptions are Austria with considerable efficiency improvements and Sweden with continuous but slightly lesser progress. The sub-index for energy supply is largely stagnating. Only Denmark and Italy achieved increases in sustainability. Poland and Spain manage some catching up but remain under average. This leads to the conclusions that the efforts to increase the share of renewables in electricity generation have not yet paid off in this respect. However, for countries with high renewables shares from the outset (e.g. Austria or Sweden) significant improvements are difficult to achieve. In other countries, especially those with a high share of nuclear energy there is also strong inertia in the energy market.

*Figure 4. Development of the composite index aggregated by sector, 2005, 2010 and 2015*




## 3.3 Sensitivity analyses

In order to check the stability of index and the results we carried out several sensitivity analyses. The first approach was to use alternative weighting factors in the aggregation of the indices, i.e. we used the sectors' relative shares in $CO_2$ emissions as weights. These results are presented in section 4.2.1.

In addition, an extended database was used to calculate the indices for 2015. Some indicators – especially regarding the social dimension – are not available for the whole period. But we regarded this information as important for emphasising the social aspects in relation to energy development as this is usually largely blended out in energy analyses. This sensitivity analysis thus focussed on checking these indicators' influence on the aggregate outcome.

Finally, we corrected for fluctuations in energy generation from intermittent renewable sources (smoothed as proposed by the EU's Renewable Energy Directive) as weights. The results from this analysis are not shown separately here as they are identical to the baseline case.

### *3.3.1 Alternative weighting factors*

Comparing the results with equal weights to those achieved with the alternative weighting approach (weighting by $CO_2$ emissions) the overall picture remains largely the same regarding the general positive trend as well as the leading and lagging countries. Also, the rates of change differ only marginally. The single noticeable difference is that the decrease in social sustainability in Sweden is even more pronounced.

*Figure 5. Development of composite index aggregated by dimension ($CO_2$ weighted), 2005 and 2015*

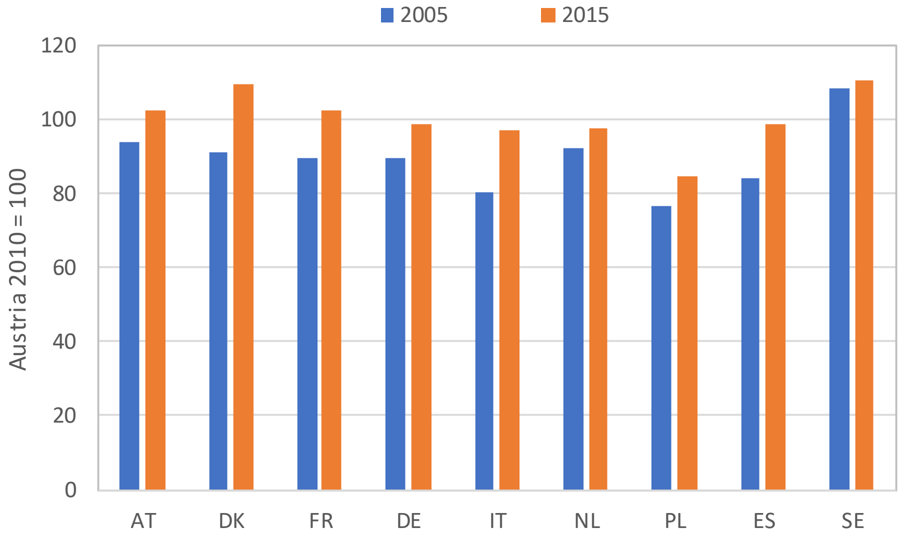
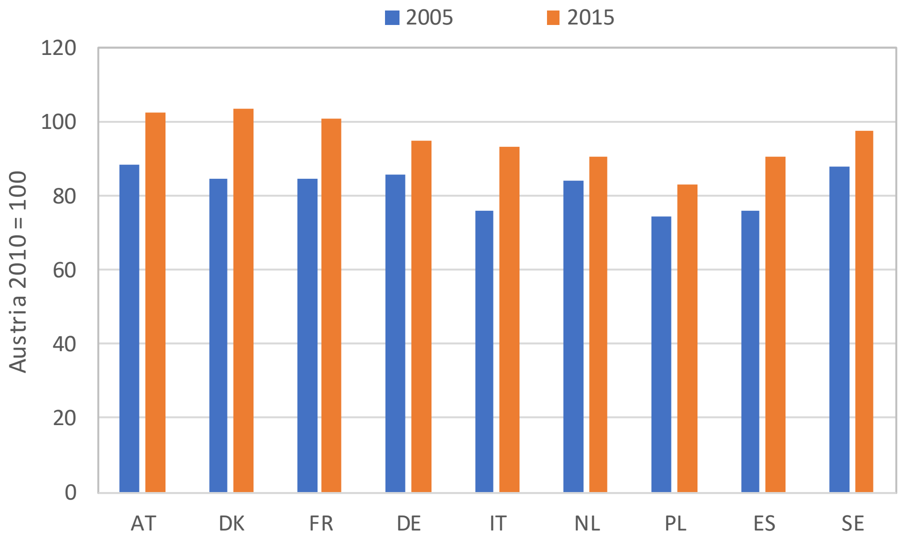



*Figure 6. Development of the composite index aggregated by sector ($CO_2$ weighted), 2005 and 2015*




The results of the former approach (equal weights) show an overall upward trend for the countries covered by the index over the whole period 2005 to 2015. This points at a continuous improvement towards a more sustainable energy system. In some cases "real" progress can be observed – e.g. when a country achieves significant improvements despite starting from an already comparatively high level of sustainability. In other cases the improvements are more in line with a catching up process towards other, more sustainable countries.

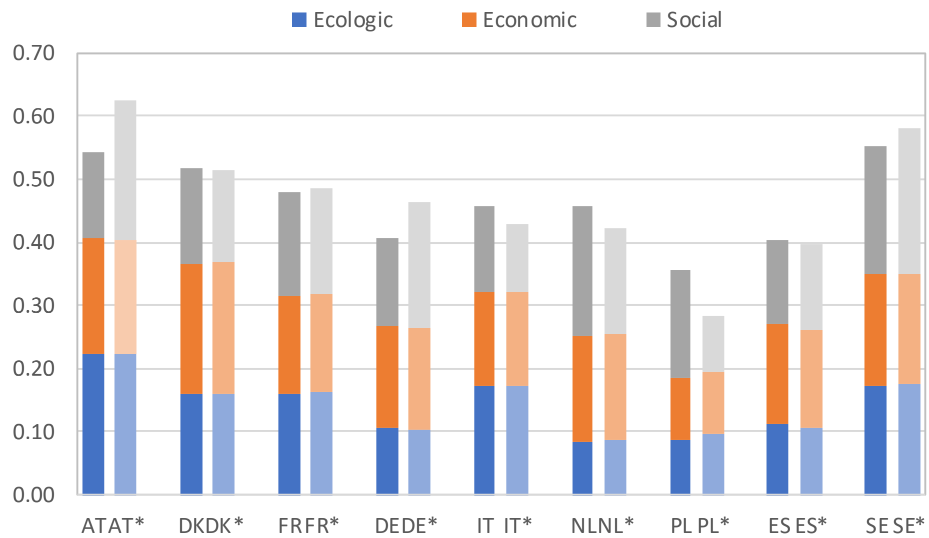
Weighting the sectors by their shares in $CO_2$ emissions does not considerably change the aggregate results. The ranking of countries according to the level of sustainability achieved in 2015 remains largely constant. In addition, also the sectoral sub-indices do not change significantly. In some cases the more pronounced effects observed in the analysis using equal weights – especially the strong positive development in the service sectors of Austria and Sweden are alleviated and now conform to the only marginal improvements stated for the other countries. In turn, the weight of the transport sector for sustainable energy development increases further as the improvements over time result twice as high in Austria, France and Spain. Also, the sector energy supply increases its sustainability at a significantly higher rate in Denmark and Germany. These results show the general importance of these two sectors which are on average responsible for two thirds of the $CO_2$ emissions.

### *3.3.2 Extending the database for 2015*

For an extended set of indicators (as summarised in Table 1), including data that are not available for the whole period but that are regarded as important for assessing sustainable energy development an adjusted index was calculated for 2015 only. The additional indicators comprise central information for the environmental and social dimensions like the share of rail in the modal split, access to public transport, gender issues and working conditions in the energy supply sector. Again, the sub-indices for dimensions of sustainability and sectors were calculated and subsequently aggregated further to compile the composite indices.

Figure 7 compares the total indices using the extended approach versus the 2015 results from the time series indicators.

*Figure 7. Comparison of the standard and the extended composite index*




* denotes the extended composite index with reduced indicator set.

The main differences can be summarised as follows: in general, the greater number of indicators – especially related to the social dimension – reduces the spread in the index values between countries. In also leads to a decrease in the index values in Austria, Germany and Sweden. This results in a shift in the ranking of countries – Sweden and Austria change places (Austria falls from first to second rank), Germany loses two positions. In other countries (Italy, Netherland and Poland) the additional indicators lead to increases in the index. This hints at a relatively better performance in terms of the social dimension in these countries.

The first conclusions that can be drawn is, that if only one single year is analysed there are no significant changes in the overall ranking of countries or the composition of country groups (top performers Austria, Denmark, France and Sweden; medium performers Germany, Italy, Netherlands and Spain; tail light Poland) as compared to the results for 2015 from the time series analysis.

However, the altered composition of the indicator set and the more comprehensive database deliver some changes at the sub-index level.

# 4 Discussion and lessons to be learned

The time series analyses of the energy sustainability indices revealed on average rather modest improvements over the period of 2005 to 2015. Apart from developments that can be classified as catching-up processes (e.g. in Italy or Spain) it shows that countries that already started from a high level of sustainability in the energy system still managed to significantly improve further. This comprises Denmark, France and to a lesser extent Sweden. In this section we take a closer look at energy and climate policies in these countries that might explain the positive trends. In addition, we will also briefly discuss the policy landscape in Poland – being the permanent laggard with respect to energy sustainability – in order to explain the lack in improvements over the major part of the period under consideration especially with regard to emission and energy efficiencies as well as the share of renewables. More or less all increases in efficiencies or the shares of renewables happened after 2012. The exceptions are the developments in the social dimension that for the residential sector are clearly positive over time.

## 4.1 Denmark

Denmark has a long tradition of environmental and climate policies, complementing international agreements with ambitious national targets and corresponding policy instruments. One major example being the early introduction of a $CO_2$ tax (1992), which i.a. included differentiated tax rates for industry depending on the energy intensity of the processes applied and which led to energy monitoring, management and energy saving investments using a kind of "forced volunteerism" (Surmeli-Anac, Kotin-Förster, and Schäfer 2018).Not least the $CO_2$ tax scheme coupled with the energy efficiency agreements resulted in a significant reduction of final energy demand in industry (-16% between 1990 and 2017; between 2005 and 2015 the decrease was even stronger with -25%). The carbon taxation scheme was complemented by other measures like the Energy Efficiency Obligation (EEO) Scheme for energy suppliers that in the beginning focussed on awareness raising about energy savings and later (from 2006 onwards) encompassed the implementation of measures for end users (especially in the areas buildings, appliances and industry)[4]. The scheme is based on a voluntary agreement and currently three gas companies, six oil companies, 74 electricity companies and 417 district heating companies are participating (Surmeli-Anac, Kotin-Förster, and Schäfer 2018). In most years overachievements of the aspired energy savings have been reached. Only in 2013 to 2015 this was not the case as the targets set in the EEO have been raised significantly and the low-cost energy saving measures had already been implemented or were not eligible any more due to stricter additionality criteria. Thus, in 2016 the energy saving targets have been revised downward again (to 10.1 PJ/year, corresponding to about 2,5% of final energy demand). Despite its success the scheme will be discontinued after 2020 and be substituted by other approaches for energy saving.

As another pillar energy policy focussed on the transformation of an electricity system based on fossil fuels into one with a high share of renewables, which was driven by ambitious investments (mainly in wind energy) but also emphasising the importance of RD&I. Denmark is among the global leaders in using energy-efficient technologies, including combined heat and power (CHP), which provides half the electricity and two-thirds of heat needed.

Denmark's energy intensity and carbon intensity are among the lowest of all IEA member countries (IEA 2017). Between 2005 and 2015 Denmark managed to reduce primary energy consumption by 14% and final energy consumption by 10% (Eurostat). At the same time the share of renewable energy in gross final energy consumption nearly doubled from 16% to 31%. Greenhouse gas emissions declined by 25% (the reduction rises to 35% when looking at the period 1990 to 2017). All sectors reduced their emissions apart from transport.

According to IEA (2017) the Danish energy policy is i.a. characterised by:

- a broad and sustained political support for a low-carbon transition;
- a holistic approach to energy planning, paying great attention to interactions and synergies between different sectors and various policies and regulatory instruments; and
- stakeholder engagement and informed decision making (based on socio-economic analysis and projections), with a long tradition of building consensus between political parties.

These elements and the reliance on broad energy agreements have contributed to achieving a high degree of predictability and continuity in energy policy, which in turn increases investment security for renewable energy or energy efficiency projects. Danish energy policy is defined in Energy Agreements that are revised every five years. The latest has been passed in 2018 and includes the pathway to reach the 2030 climate policy targets. The Energy Agreements include specific sub-targets (e.g. for the development of certain renewables, energy efficiency etc.) together with particular initiatives, the respective time paths and funding volumes per year. This, in turn, facilitates monitoring and the evaluation of outcomes and of the effectiveness of policies implemented (The Danish Government 2013). In addition, based on the Climate Law passed in 2014 a scientific council on climate change was instated, an annual energy policy report is submitted to parliament and new national climate targets are established each year. The overall objective of the law was to establish a stable framework and give directions towards the 2050

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4 Energy Efficiency obligations are described as an obligation by a party (usually final energy suppliers or distribution network operators) to deliver a defined amount of energy savings within a certain period of time.

goal of a low carbon society (Danish Energy Agency). A national greenhouse gas reduction target of 40% by 2020 compared to 1990 levels was also approved in Parliament in 2014.

Denmark has set itself national targets that go beyond the EU targets for 2020. Furthermore, it has an ambitious strategy for long-term (2050) emission reduction, renewables and energy efficiency. A broad majority (political as well as societal) supports the 2050 target of an energy system with 100% renewable energy without any reliance on fossil fuels. This political stability, ambitiousness of targets and early implementation of policy instruments (esp. the $CO_2$ tax and the support for wind energy) have led to significant emission reductions on the one hand and technological leadership on the other hand. For the future decarbonisation path challenges remain to be tackled (Sovacool 2017) particularly achieving further improvements in energy efficiency, decarbonising transport and actually reaching the 100% renewables in the energy system including ways to adjust for the variability of wind energy generation and to add flexibility to the heat and power system.

## 4.2 France

In recent years France has made good progress in terms of improving its energy efficiency, its carbon intensity and decoupling carbon emissions from economic activity. One key aspect in France's energy system is however the large share of nuclear power – on average 76% (2005 – 2015) of gross electricity generation (Eurostat)[5]. The share of renewables (mainly hydropower) in electricity generation has, increased in this period from 10,6% to 16,6%. Electricity generation by coal has been reduced drastically and will be phased out as is also the case for oil-fired power plants (IEA 2017). Since 2005 $CO_2$ emissions have been decreasing – by 20% until 2015. There have been emission reductions in all sectors of the economy. The smallest decrease has taken place in transport, which results in this sector being the largest source of $CO_2$ emissions (29%).

Lately, France has increased its efforts towards achieving decarbonisation with the development of an integrated energy and climate policy framework for 2030 and has implemented new policies like the carbon tax[6], the Bonus-Malus scheme for vehicles or the Energy Transition tax credit. In particular the Bonus-Malus scheme for vehicle registration has proven to be effective in reducing average emissions from passenger cars (Monschauer and Kotin-Förster 2016). The scheme has been modified various times since its introduction in 2008 adapting the rates to technological changes and stepping up the incentive for purchasing low emission vehicles. In the scheme bonus payments are granted for electric vehicles (prior to 2017 also for low emission vehicles), which are financed by the revenues from the fees payable for emission-intensive vehicles. Currently, a fee must be paid for vehicles with $CO_2$ emissions equal to or above 120 g/km. The fee starts at 50€ but rises steeply according to a continuous fee function up to 10,500 € (for vehicles with $CO_2$ emissions equal to or above 185 g/km). An additional bonus of 1,000 € is granted when an old diesel or gasoline powered vehicle is scrapped and a used electric or a more efficient internal combustion engine vehicle is purchased (Monschauer and Kotin-Förster 2016).

[5] As e.g. Karakosta et al. (2013) point out nuclear energy can contribute to reducing greenhouse gas emissions but are disputed for other reasons (mainly safety, weapons proliferation, waste handling and high costs) as not being compatible with sustainable development.

[6] The carbon tax, which mainly covers the transport, industry and buildings sectors increased from 30.5€/$tCO_2e$ in 2017 to 44.6€/$tCO_2e$ in 2018 and is scheduled to reach 86.2€/$tCO_2e$ in 2022 (Worldbank and Ecofys 2018).

For new electric and plug-in hybrid vehicles the bonus is 2,500 €. The scheme has been effective as average vehicle emissions have decreased by 25% since the implementation. However, despite recent strong growth electric vehicles still have a share of only 0.4% in the passenger car stock (2017).

The basis for the French national climate and energy policy is the Act on Energy Transition for Green Growth ('La loi relative à la Transition Énergétique pour la Croissance Verte', LTECV, 2015). The Act requires energy suppliers and consumers to contribute to reducing GHG emissions while safeguarding economic growth. The national targets foresee in particular:

- A 40% reduction in GHG emissions by 2030 and a 75% reduction by 2050 ('factor four') from 1990 levels;
- A cut in final energy consumption of 20% by 2030 and 50% by 2050 compared to 2012 and a 2.5% annual reduction rate for final energy intensity until 2030.

For the implementation of the long-term targets and for providing investment security two strategic plans were developed: the Multiannual Energy Programme 2014–2020 ('Programmation Pluriannuelle de l'Énergie' 2014–2020, PPE) and the national low-carbon strategy ('Stratégie Nationale bas-Carbone', SNBC). The SNBC contains five-year carbon budgets that reflect the targets of the LTECV and specifies policies to achieve them. The energy programming covers energy production, energy efficiency, security of supply, and the supply/demand balance for all energy sources.

Sectoral strategies have been adopted for the Energy Transition: a low carbon mobility strategy (2016) with measures that focus on the further deployment of electric vehicles with 7 million EV charging points planned for 2030. In the buildings sector, the object is to renovate 500,000 dwellings per year. The renovation of low-income households is targeted specifically under the Better Living Programme. Building codes have been strengthened with the new thermal renovation regulations of 2012. One key aspect is the accelerated deployment of renewables in electricity generation, which is projected to rise to a share of 40% by 2030 (Légifrance 2015) while at the same time reducing nuclear capacity. In order to achieve this target it will be necessary to double the growth rates for renewables as compared to the past ten years. Therefore, especially non-economic barriers (like administrative procedures, lacking societal acceptance, grid integration) will have to be overcome.

## 4.3 Sweden

Like Denmark Sweden has a long tradition in ambitious environmental policy making and early implementation of a carbon tax, which has been the key climate policy instrument since 1991. The $CO_2$ tax has the highest rate worldwide (currently 120 €/t $CO_2e$) and applies to transport, buildings (heating), industry and agriculture.

The carbon tax combined with other instruments and measures[7] (especially the massive expansion of district heating and accompanying shift to biomass as energy source, electrification

[7] The taxes have further been supplemented with an electricity certificates system for increasing the share of renewables, technology procurement, public information campaigns, a differentiated annual vehicle tax and investment grants (Swedish Environmental Protection Agency 2018).

in heating) has resulted in a decrease in $CO_2$ emissions by approximately 24% between 1990 and 2015 (-19% between 2005 and 2015 (Swedish Environmental Protection Agency[8])) and also a slight decrease in energy consumption[9]. Sweden has the lowest emission intensity (both as emissions per unit of GDP and per unit of energy use). Analyses (Abrell, Kosch, and Rausch 2018; Baranzini et al. 2017; Martin, de Preux, and Wagner 2014; Murray and Rivers 2015) show that the carbon tax was effective in reducing carbon emissions, especially in those sectors that have to pay the full tax rate. Although the energy intensive industry has previously been granted generous tax exemptions and are now exempt from the carbon tax as they participate in the EU ETS $CO_2$ emissions from manufacturing have been reduced by one third since 1990 and emission intensity has improved significantly.

In general, the Swedish climate policy can be regarded as ambitious and with the national "integrated climate and energy policy" (2009) went beyond the objectives determined by EU policy. However, the previously planned phase-out of nuclear power was annulled and the option to replace the reactors at the existing sites was ensured. Nuclear energy plays a significant role in the Swedish energy system as it contributes between 40 and 50% to electricity generation. The other half is mainly stemming from hydro power with an increasing share of wind power in recent years[10]. Thus, this is one particularity as fossil fuels do not play a role in the Swedish electricity sector.

For the long term, Sweden defined four priority targets in the new climate policy framework (2017) and the Climate Act of 2018:

- Zero net greenhouse gas emissions by 2045 (and negative emissions thereafter),
- by 2030 emissions from domestic transport will be reduced by at least 70% (relative to 2010),
- by 2030 emissions from the sectors covered by the EU Effort Sharing Regulation will be reduced by at least 63% (relative to 1990); rising to 75% by 2040.

In addition, a Climate Council was installed. The emphasis in the country's climate strategy is on the use of economic instruments, supplemented with targeted instruments, for example support for the development and market introduction of technologies or the elimination of barriers to energy efficiency.

Comparable to Denmark Sweden aimed at aligning its RD&D policies with its energy and climate objectives. Research and innovation are strongly focussed on the country's strengths in bio-fuels and smart grids (IEA 2013) as well as being oriented towards market deployment. There is also a strong involvement of the private sector both in terms of financing R&D and in formulating strategic plans. Thus, climate relevant research has received stable public support.

The Swedish Government has adopted the objective to make Sweden one of the world's first fossil-free welfare states. The challenge will mainly lie in achieving the further improvements required starting from the already high level of energy sustainability.

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[8] http://www.naturvardsverket.se/klimatutslapp

[9] Gross inland energy consumption decreased by 4% between 1990 and 2015 (-12% between 2005 and 2015) and final energy consumption was at 1990 levels in 2015 but had decreased slightly (-6%) between 2005 and 2015.

[10] The share of wind power in total electricity generation increased from 1% (2005) to 16% (2015).

## 4.4 Poland

Defining itself as "coal country" Poland in general is not supportive of climate policy targets[11] and seeks to avoid energy system transformations towards more sustainable or decarbonised structures. Although some progress is apparent in our indicator set and is also attested e.g. by the IEA (2016) Poland's performance in terms of energy sustainability and compliance with climate policy targets remains under average (compared to the EU average as well as compared to other Central and Eastern European countries).

The energy system continues to rely heavily on coal, which provides around 50% of primary energy supply and 80% of electricity production in 2015 (Eurostat). The further use of the domestic resources of hard coal and lignite (as the cheapest form of energy generation) are a central element of Poland's energy policy and is also seen as a prerequisite for ensuring security of supply. The combustion of coal is therefore the predominant source of GHG emissions. In addition, the direct and indirect employment related to coal mining is regarded as being of high importance in terms of its social and regional impact. It has to be stated, however, that employment in coal mining has decreased by 78% between 1989 and 2015 with further declines thereafter[12]. Furthermore, despite the public subsidies granted the sector is making huge losses (European Commission 2015).

However, nearly two thirds of Poland's coal fired power plants are more than 30 years old and highly inefficient. Also, the district heating system, which is one of the largest in Europe, is in need of reinvestments. Thus, given these huge reinvestment requirements the energy sector is at a crucial point and the strategic decisions taken with respect to technological choices will determine the country's energy use and emissions for the coming decades. Similarly, the building stock is highly inefficient and in need of comprehensive refurbishment as well as a change in the heating systems (in the part of dwellings not covered by district heating) that are also largely depending on coal.

So far, for preserving the coal-based energy system significant support has been granted. On the one hand, Poland is one of eight EU member states that are allowed to allocate free ETS allowances to existing fossil power plants until 2019. Although the intention was to help finance retrofitting, upgrading of infrastructure or diversifying the energy mix, this measure supports coal-fired power plants. The main support measure benefitting coal fired electricity generation stemmed from the support for biomass, which is largely co-fired in coal power plants and in this case is regarded as a renewable energy source although it is not used independently from its fossil complement (Szulecki 2017)

In contrast, the data show that Poland has made significant progress regarding the use of renewable energy sources – with the share in gross final energy consumption increasing from 6,9% (2005) to 11,7% in 2015[13]. Particularly wind energy has grown significantly in recent years (from 83 MW to 5.100 MW installed capacity between 2005 and 2015), putting Poland in the 7$^{th}$

[11] Poland was the only EU member state who vetoed the Low-Carbon 2050 roadmap and the Energy 2050 Roadmap.

[12] At the end of 2015 around 90,000 people were directly employed in hard coal mining; by the end of 2016 this number decreased to 84,600 (Euracoal 2017; European Parliament 2017) representing 0.5 % of total employment.

[13] In electricity generation the share of renewables rose from 2.7% (2005) to 13.4% (2015) (Eurostat).

place in the EU regarding installed wind power capacity. However, it has to be taken into account that about half of the increase in renewable generation stems from biomass co-firing in coal power plants.

With several changes in the strategies and legislation concerning renewables, the future energy development in Poland is uncertain. Apart from the continuous big role attributed to coal in the medium to long term in the country's energy strategy (60% in 2030; 50% in 2050) complemented by the plans to invest in new coal fired power plants as well as in two nuclear power plants, Poland has significantly changed its renewable electricity support scheme. From 2016 onwards auctions (separate for "technology baskets") will be carried out, replacing the former scheme based on renewables quotas and green certificates (Szulecki 2017). In this context the biggest budget will be dedicated so called "stable sources", i.e. mainly biomass co-firing. Furthermore, a new Wind Farm Act of 2016 considerably restricts further deployment of wind power. The Act prohibits building wind turbines within 1,5 to 2 km from buildings or natural conservation areas thus ruling out 99% of the land. Also, the real estate tax on windmills was raised substantially and stricter control and permitting requirements were passed.

From the current point of view, the transformations in the polish energy system observed over the past years will slow down as the new support scheme further decreases profitability and investment security for renewables. It seems as though renewables development is not supported as a means to reach climate policy goals but only to fulfil requirements imposed on Poland by the EU and that it dismisses decarbonisation and follows its own path – as the energy minister declared in 2016 (Tchórzewski 2016).

# 5 Conclusions and recommendations

The analysis of the composite indices for sustainable energy development for the selected countries deliver several results that are also supported by the assessment of climate and energy policies in some countries. In general the improvements regarding energy efficiency, emissions and deployment of renewables have been moderate in the period under observation. This hints at the time needed for restructuring to take place. Some countries showed above average positive developments. These are mainly countries that have a long tradition in ambitious environmental and climate policy making and are also renowned for their social security systems (e.g. Denmark, Sweden). In contrast, Poland still focusses its energy policy on coal and will continue to do so. Deployment of renewables or emission mitigation is mainly being regarded as a necessary exercise to fulfil requirements posed by the EU. Positive developments, e.g. regarding the increase in renewables, can be regarded as having happened despite rather than because of Polish policy making.

This underlines the importance of credible political commitment to climate targets, the implementation of ambitious instruments and the need for stability in the guiding frameworks in order to effectuate substantial changes. However, the costs of climate policy measures have to be taken into account and especially with regard to effects on low income households targeted compensation mechanisms have to be developed.

In addition, the description of the circumstances and policy frameworks in the selected countries shows, that each one is characterised by a very specific energy system (complemented by specific social structures) that determines the challenges that have to be overcome on the way to decarbonisation. Thus, climate and energy policies have to be customised in order to result in a successful strategy for the respective country. The comparative country and sector analysis of the CLEP composite indices points out problems regarding the progress in transforming the energy system in a sustainable manner.

From the analysis we can derive the following policy recommendations for a climate and energy policy that is in line with the long-term targets:

The country examples highlight the importance of a credible political commitment with respective ambitious policy targets and instruments. This includes that policies have a long-term horizon (beyond the current election cycle) and establish a stable framework ensuring investment certainty and predictability for consumers and firms. In addition, policies have to be evaluated regularly with respect to their effectiveness and be adapted where necessary. For evaluations to be feasible quantifiable goals and programmes have to be designed which in turn implies that the required databases have to be provided. It is necessary to take into account trends such as digitalisation, "crowd-work", "proactive consumers" well in advance, and to consider in how they influence for example the quality of work and work-life balance by developing and using appropriate indicators. In addition to the gender pay gap and gender employment gap, there is a need for further gender sensitive data / indicators that allow an international comparison, e.g. in terms of unpaid care, energy use etc.

Given that data are available comprehensive evaluation frameworks have to be developed – such as proposed in the ClEP project.
The development of the policy framework ought to be founded on evidence based, transparent discussions in order to reach broad societal support. In this context a balance between social and environmental issues has to be reached as these areas are often regarded as being conflicting. But as particularly the examples from the northern countries show it is possible to combine ambitious environmental policies with comprehensive social welfare states.

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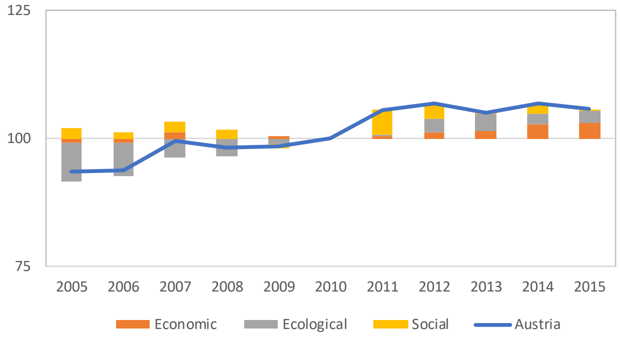
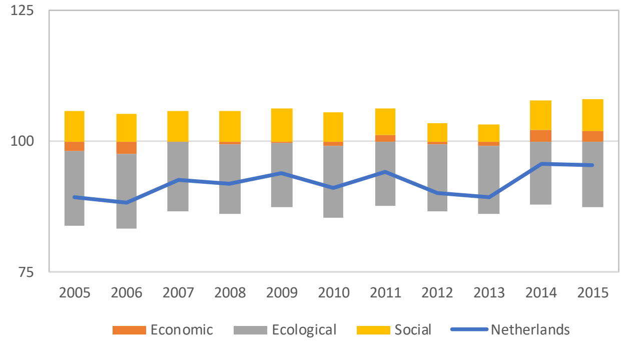
## Annex

Figure 8. Development of composite index aggregated by dimension 2005-2015

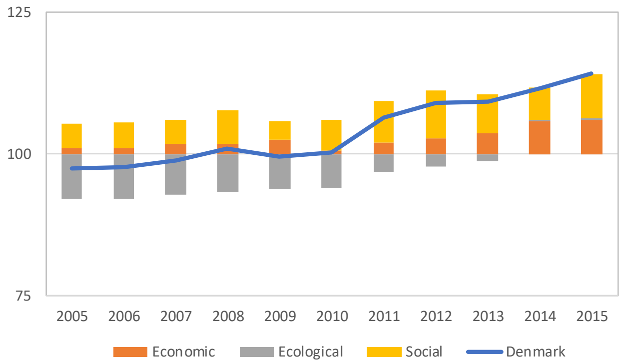
(a) Austria



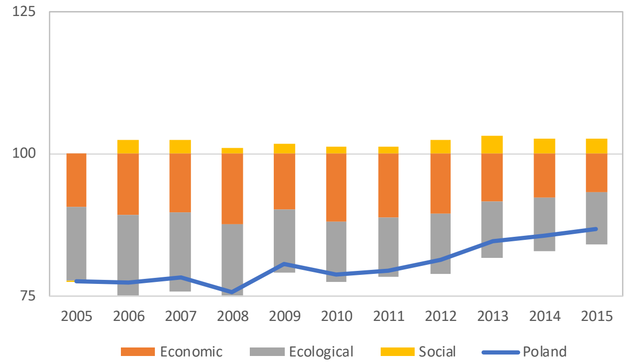

(b) Netherlands



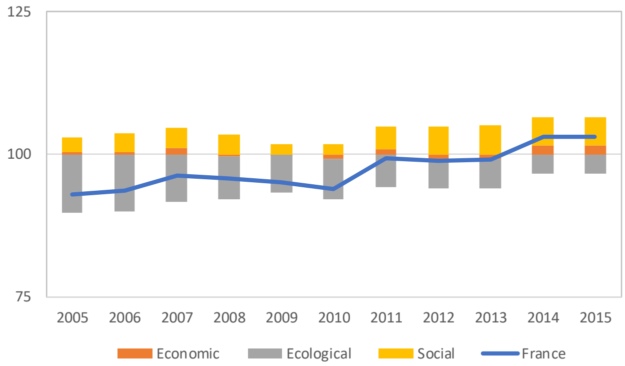

(c) Denmark



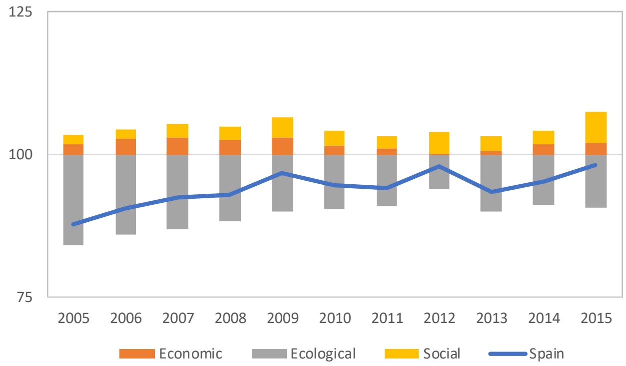

(d) Poland




(e) France

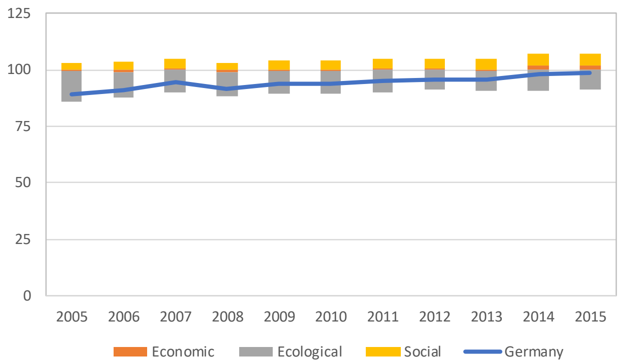



(f) Spain




(g) Germany

(h) Sweden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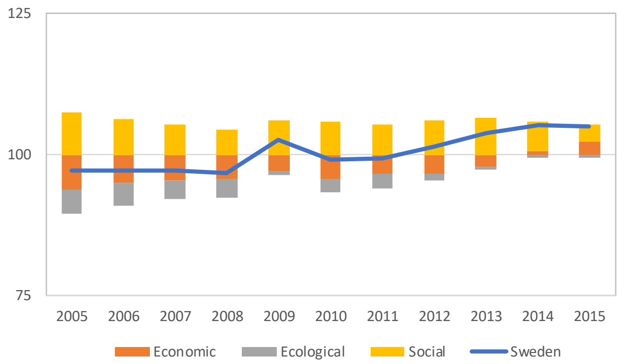
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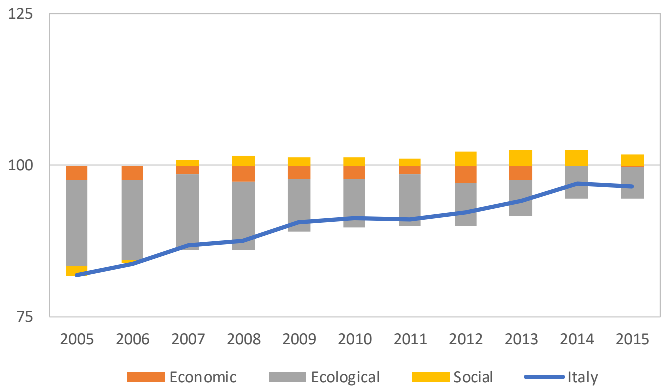
(i) Italy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