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Monitoring Sustainable Development

Climate and Energy Policy Indicators

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573/2018

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AUSTRIAN INSTITUTE OF ECONOMIC RESEARCH

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WIFO Working Papers, No. 573

December 2018

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2018/363/W/6716

Medieninhaber (Verleger), Hersteller: Österreichisches Institut für Wirtschaftsforschung • 1030 Wien, Arsenal, Objekt 20 • Tel. (43 1) 798 26 01-0 • Fax (43 1) 798 93 86 • http://www.wifo.ac.at/ • Verlags- und Herstellungsort: Wien

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Monitoring Sustainable Development: Climate and Energy Policy Indicators

ClEP Working Paper 1

December 2018

Claudia Kettner, Angela Köppl, Daniela Kletzan-Slamanig, Beate Littig, Irina Zielinska

Abstract. Both the UN SDGs and the Paris Agreement imply ambitious long-term targets which only can be met with a fundamental restructuring of economic and social systems. We propose a set of energy and climate policy indicators that allows informed policy making and goes beyond the approaches that mainly focus on progress based on the UN indicator set. The sustainable energy indicators cover the whole energy system as well as the three dimensions of sustainability. The approach combines an energy service centred perspective with research on energy and climate indicators and embeds the indicator framework in broader socio-ecologic context. For the four demand-side sectors a set of 118 high-level energy indicators has been assembled that can be further disaggregated to about 387 indicators. For electricity and heat supply a set of 25 energy indicators has been compiled that can be further disaggregated to about 130 indicators differentiating by energy source and plant type. Interactions (i.e. synergies and conflicts) between the different target dimensions and the corresponding indicators need to be carefully considered. Given the complexity of the issue and the lack of adequate indicators / gaps in data availability it is difficult to interpret certain observable trends. This needs to be kept in mind when using the indicator system for policy analysis.

Keywords: sustainable development, indicator systems, energy policy, climate policy

JEL codes: Q01, Q48, Q54

1 Introduction

2015 is marked by two important outcomes of international negotiations with implications for future development: the agreement on the UN Sustainable Development Goals (SDGs) and the Paris climate agreement. Both imply ambitious (long-term) targets which only can be met with a fundamental restructuring of economic and social systems. The greenhouse gas (GHG) emission reductions – required to limit climate change to well below 2 °C or even 1.5 °C – above pre-industrial levels as stated in the Paris Climate Agreement – call for a fundamental decarbonisation of our societies. A substantial contribution to reducing emissions needs to come from the energy system since energy-related emissions account for the largest share in total GHG emissions, i.e. for 67% of Austrian and for 78% of EU GHG emissions respectively. This challenge of deep emission cuts is underpinned by the results of the IPCC Special Report (2018) which on the one hand emphasises the differences between a 1.5°C and a 2°C increase in temperature and on the other hand illustrates pathways how the target of 1.5°C could be achieved. The report also includes an illustration on the synergies and trade-offs between deep emission cuts and the SDGs.

Research took up the task to facilitate monitoring and implementing the 17 SDGs in a number of projects since 2015 with a focus on the interactions, synergies and trade-offs between the individual targets as well as on research in feasible development pathways (Nilsson, Griggs, and Visbeck 2016; Fuso Nerini et al. 2018; TWI2050 - The World in 2050, 2018; McCollum et al. 2018).

For both, the Paris Agreement and the SDGs, research is challenged as the scope of the changes needed calls for new measurement and monitoring approaches. This comprises work on governance structures, pathway analyses as well as suitable indicator sets that capture the socio-economic and environmental layer and allow depicting synergies and trade-offs among these three layers as well as between targets (TWI2050 - The World in 2050 2018; Bierman, Kanie, and Kim 2017). In this sense, indicator sets that go beyond the set of targets and indicators proposed by the UN are called for. The CIEP indicator system as proposed here aims at providing such an effective framework for the EU Member States that allows informed policy making and goes beyond the approaches that mainly focus on progress based on the UN indicator set (Mulholland, Dimitrova, and Hametner 2018).

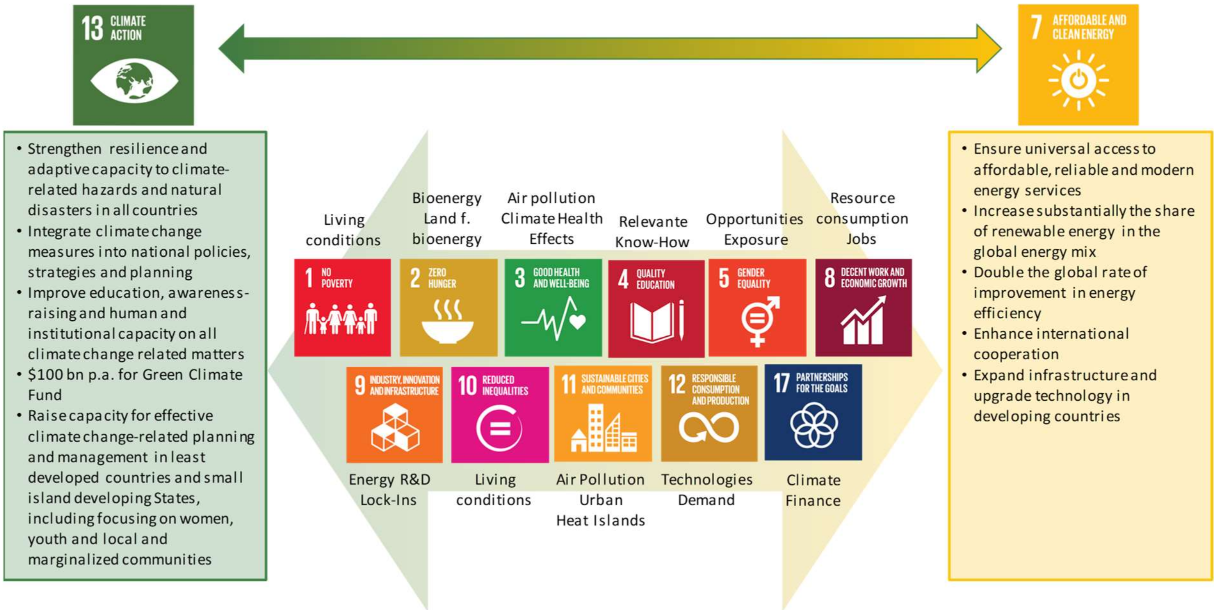
The sustainable energy indicators proposed in CIEP cover the whole energy system as well as the three dimensions of sustainability. The approach combines an energy service centred perspective with research on energy and climate indicators and embeds the indicator framework in broader socio-ecologic context. The paper is structured as follows: Section 2 provides the broader context, embedding the climate and energy policy indicators into a broader socio-ecological framework which is defined by the UN Sustainable Development Goals. In section 3 the conceptual approach of the CIEP indicator framework is presented and challenges for the collection of relevant data are discussed in section 4.

Section 5 discusses interactions between the different target dimensions and indicators. The final section concludes.

2 Climate and Energy Policy Indicators in the Context of the UN SDGs

The intense discussions regarding the manifold interactions between the 17 headline goals as well as on interactions between different targets (Nilsson et al. 2016b, 2016a; McCollum et al. 2017; TWI2050 - The World in 2050 2018) is taken up in Figure 1. The SDGs implicitly depend on each other, but the nature of the interlinkages between the different goals and indicators are still a broad research area. This is of high relevance, since ignoring overlaps, synergies or trade-offs between targets bears a risk of perverse outcomes. This does not only hold true for the broad scope of the SGDs, but also for the set of the CIEP energy and climate policy indicators as described below. Figure 1 illustrates which thematic areas of SDG 7 and 13 we identified as being strongly or directly linked to eleven other goals and which interactions between these objectives must be taken into account in order to achieve the targets and design adequate monitoring approaches. For instance, policies aiming at reducing energy expenditures of poor households (and therefore contributing to improvements in the social dimension / SDG 10) might increase energy demand and in turn emissions (with negative effects on the environmental dimension / SDG 13) if not properly designed.

Figure 1. Interaction of the SDGs "Climate Action" and "Affordable and Clean Energy" with other SDGs



Starting from this broader view on the SDGs we then focus on SDG7 and SDG13. For this subset of SDG targets we develop the CIEP indicator set, which comprises operational indicators that emphasise the role of energy services instead of energy flows for generating welfare. The focus is laid on the energy services in four demand-side sectors (residential buildings, transport, manufacturing and services). In addition, consistent indicators for sustainable electricity and heat supply are included in the indicator set.

We embed the CIEP indicators into a broader socio-ecological framework which is defined by the UN Sustainable Development Goals. The SDGs contain objectives for a total of seventeen areas, two of which are addressed by the CIEP research: "Affordable and clean energy" and "Climate Action".

Figure 2(a) presents a conceptual illustration for a better understanding of the interlinkages between the SDGs. The 17 SDGs in turn are embedded into a broader socio-ecological context. The figure illustrates the three layers to which the SDGs can be assigned or for which they are of particular relevance – wellbeing, governance and planetary boundaries (TWI2050 - The World in 2050 2018; Kettner, Köppl, and Stagl 2014). This combination of the concept of wellbeing and the concept of planetary boundaries creates a space in which sustainable development can be achieved, i.e. social goals are met while at the same time sustaining the integrity of ecosystems is preserved so that they can provide the services on which our societies depend. In this representation we define ten SDGs to pertain to the layer of wellbeing. These are embedded in governance structures (including three SDGs) that constitute the supporting structures for wellbeing. The outermost layer are the planetary boundaries that represent the bio-physical base as well as the natural limits for all societal processes and activities. Climate change and its impacts, for instance, are relevant for the successful implementation of all SDGs.

Figure 2(b) subsequently illustrates how the energy system approach that represents the basis for our indicator set relates to this socio-ecological framework and the SDGs. While the issues of energy and climate change pertain to the layer of "planetary boundaries" the energy services, that are the starting point for our indicator framework, are an integral part of the layer representing "wellbeing". The provision of energy services as outcome of stock flow interactions is crucial for economic and social development. If fossil energy is used to provide energy services, however, this also contributes to total anthropogenic greenhouse gas emissions that are a key driver for global warming and climate change as well as other environmental problems.

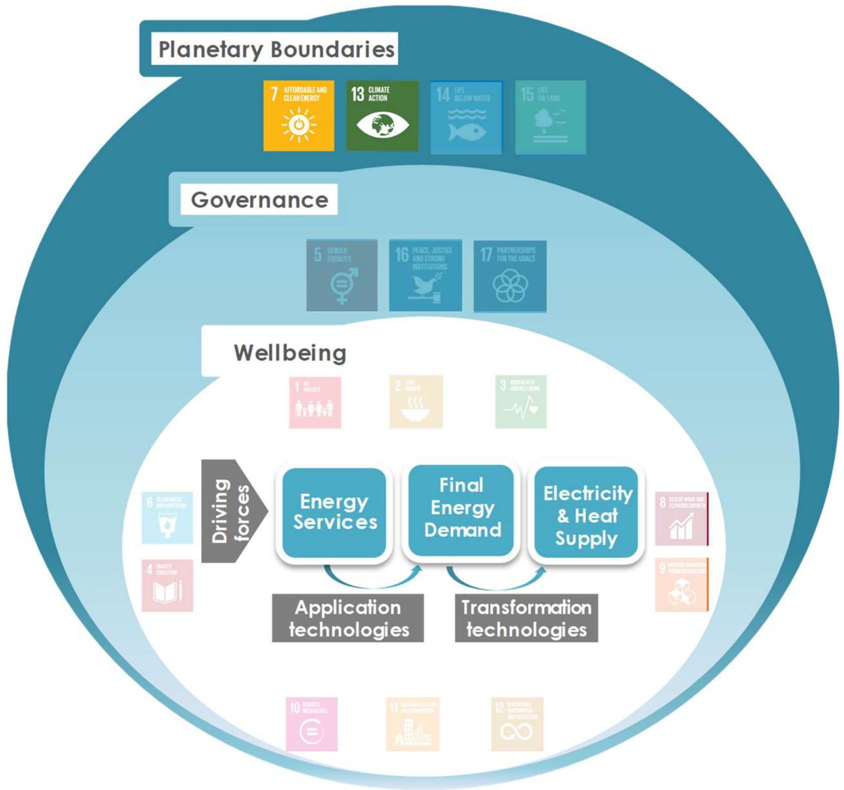
The volume of energy services is influenced by economic activity, income and individual preferences, and mirrors economic welfare. The energy demand for providing energy services depends on the application and transformation technologies used in households and companies. In buildings, for example, the energy required to deliver a "well-tempered living space" depends on the thermal quality of the building as well as the heating system. The overall objective is a reduction of energy flows and emissions.

Thus, the detailed indicator set on the one hand describes or quantifies the areas of energy and climate but on the other hand emphasises the relevance of these areas for people's well-being. And while the interlinkages between energy and climate are at the centre of our analysis, interlinkages with other SDGs also exist and are of relevance (Figure 1) but a comprehensive analysis of these spill-overs is beyond the scope of this project.

Figure 2. Socio-ecological context

(a) Embedding the SDGs into the broader socio-ecological context

(b) Embedding the CIEP indicator approach into the broader socio-ecological context



3 The CIEP Indicator Framework

3.1 Literature Overview

The multidimensionality of the concept of sustainable development entails a high degree of complexity. Sets of indicators are considered as an appropriate tool to reduce this complexity and to illustrate the interactions between society and ecosystems. Systems of indicators for sustainable development were developed by a number of international institutions, including the EU and the UN (European Commission 2005; UN Social and Economic Council 2016; UN 2016; UNCSD 2001; General Assembly of the UN 2015).

The adoption of the SDGs and the publication of the corresponding indicator framework have stimulated the newest wave of developing comprehensive indicator frameworks, e.g. by Eurostat. The 17 SDGs of the 2030 Agenda for Sustainable Development are the continuation of the Millennium Development Goals (UNCSD 2001) and were adopted by 156 states in September 2015 at the UN Summit in New York after an extensive planning and consultation process. In the SDGs the overarching aim of ending all forms of poverty, protecting the planet and ensuring prosperity for everyone has been broken down to 17 goals and 169 more detailed targets. In contrast to the Millennium Development Goals, the SDGs do not only refer to developing countries but to all signatories.

For the monitoring of the SDGs and the respective sub-targets an indicator system comprising 244 indicators or respectively 233 indicators was developed, some of which are used to monitor more than one target (UN 2016). In general, the goals/targets and the respective indicators are based on the three dimensions of sustainable development (social, ecological, economic) and can be divided into five categories (the five "Ps" – people, planet, prosperity, peace, partnership).

In the EU, the UN SDG framework has been implemented by Eurostat as well as on Member State level[1]. For Austria, the national statistical office (Statistics Austria 2018) implemented an indicator framework closely related to the UN indicators. For almost half of the indicators proposed by the UN, national data are currently available from Statistics Austria or from external data providers. However, 45 indicators (19% of the UN indicators) that are not relevant for Austria (e.g. indicators related to marine life or targeted at developing countries) have been deleted. For another 19% of the proposed UN indicators no data for Austria are available. However, new indicators have been added that are of

[1] A different approach is followed by the Sustainable Development Solutions Network (SDSN) and the Bertelsmann Stiftung who provide a composite SDG Index and dashboards describing countries' progress towards achieving the SDGs (e.g. Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN) 2016). The 2018 SDG Index includes 88 global indicators and 111 indicators for the Dashboard for OECD countries for 156 countries. 39 of these indicators exactly match UN indicators, 28 are closely aligned and 44 are not included in the UN framework.

particular relevance from an Austrian perspective (headline indicators from the national wellbeing measurement initiative "Wie geht's Österreich").

The EU's statistical office, Eurostat, in contrast has only followed the 17 SDGs in general and developed its own indicator set that puts emphasis on inter-linkages between targets by defining so-called multi-purpose indicators. In total the SDG monitoring framework developed by Eurostat consists of 100 indicators, with a maximum of 6 indicators being assigned to each SDG (excluding the multi-purpose indicators).

Table 1 lists the indicators used for monitoring SDG 7 "Affordable and clean energy" and SDG13 "Climate Action" developed by the UN, Statistics Austria and Eurostat, along with the sub-targets of the SDGs. The indicators by the UN and Statistics Austria largely correspond to the ten sub-targets of the two SDGs. With respect to SDG 7, these include providing access to affordable, reliable and modern energy services for all, substantially increasing the share of renewable energy and accelerating the global rate of improvement in energy efficiency, along with assistance for lower-income countries. While Statistics Austria has not adopted the indicators "7.1.1 Proportion of population with access to electricity" and "7.1.2 Proportion of population with primary reliance on clean fuels and technology" since these targets have already been achieved in Austria, final energy consumption has been included as an additional indicator for Austria. The six indicators used by Eurostat include information on energy poverty, final energy consumption, energy dependence, energy productivity as well as the greenhouse gas emissions intensity of energy consumption as a multi-purpose indicator.

For SDG13, the UN indicators focus mostly on a policy/finance dimension and cover both climate change mitigation and adaption. Most of these indicators have a global dimension, such as the "13.3.2 Number of countries that have communicated the strengthening of institutional, systemic and individual capacity-building to implement adaptation, mitigation and technology transfer, and development actions" or "13.a.1 Mobilized amount of United States dollars per year between 2020 and 2025 accountable towards the $100 billion commitment". Statistics Austria has omitted most of these global targets (and respectively adapted some of them to the national context). In addition, it included GHG emissions as indicator. The indicators chosen by Eurostat, in contrast, focus primarily on greenhouse gas emissions as well as the impacts of climate change. Moreover, the nexus between greenhouse gas emissions and energy use is stressed by including final energy consumption and the share of renewables as multi-purpose indicators.

Table 1. Indicators used by statistical offices for Monitoring SDGs 7 and 13

Goal/Target	Indicators		
	UN	Statistics Austria	Eurostat
SDG 7. Ensure access to affordable, reliable, sustainable and modern energy for all			
7.1 By 2030, ensure universal access to affordable, reliable and modern energy services	7.1.1 Proportion of population with access to electricity	-[a]	07.10 Percentage of people affected by fuel poverty (inability to keep home adequately warm) 07.20 Share of renewable energy in gross final energy consumption 07.30 Primary energy consumption; final energy consumption by sector 07.32 Final energy consumption in households per capita 07.33 Energy dependence 07.35 Energy productivity 13.14 Greenhouse gas emissions intensity of energy consumption[c]
	7.1.2 Proportion of population with primary reliance on clean fuels and technology	-[a]	
7.2 By 2030, increase substantially the share of renewable energy in the global energy mix	7.2.1 Renewable energy share in the total final energy consumption	Renewable energy share in gross final energy consumption	
7.3 By 2030, double the global rate of improvement in energy efficiency	7.3.1 Energy intensity measured in terms of primary energy and GDP	Energy intensity: Final energy consumption per GDP	
	-	Final energy consumption	
7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology	7.a.1 International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems	International financial flows to developing countries in support of clean energy research and development and renewable energy production	
7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support	7.b.1 Investments in energy efficiency as a proportion of GDP and the amount of foreign direct investment in financial transfer for infrastructure and technology to sustainable development services	-	

[a] Not relevant for Austria / already achieved, [b] Indicator at UN level, [c] Multipurpose indicator

Table 1 continued

Goal/Target	Indicators UN	Statistics Austria	Eurostat
Goal 13. Take urgent action to combat climate change and its impacts			
13.1 Strengthen resilience and adaptive capacity to climate- related hazards and natural disasters in all countries	13.1.1 Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population	Number of deaths attributed to disasters per 100,000 population	13.11 Greenhouse gas emissions (indexed totals and per capita) 13.14 Greenhouse gas emissions intensity of energy consumption 13.21 Global (and European) near surface average temperature 13.45 Economic losses caused by climate extremes (consider climatological, hydrological, meteorological) 13.51 Contribution to the 100bn international commitment on climate related expending (public finance) 13.63 Share of EU population covered by the new Covenant of Mayors for Climate and Energy (integrating mitigation, adaptation, and access to clean and affordable energy) 07.20 Share of renewable energy in gross final energy consumption[c] 07.30 Primary energy consumption; final energy consumption by sector[c] 12.51 Average CO_2 emissions per km from new passenger cars[c] 14.31 Ocean acidification[c]
	13.1.2 Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030	National Crisis and Disaster Management	
	13.1.3 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies		
13.2 Integrate climate change measures into national policies, strategies and planning	13.2.1 Number of countries that have communicated the establishment or operationalization of an integrated policy/strategy/plan which increases their ability to adapt to the adverse impacts of climate change, and foster climate resilience and low greenhouse gas emissions development in a manner that does not threaten food production	Austrian National Adaptation Strategy	
	-	Greenhouse gas emissions	
13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	13.3.1 Number of countries that have integrated mitigation, adaptation, impact reduction and early warning into primary, secondary and tertiary curricula	-[b]	
	13.3.2 Number of countries that have communicated the strengthening of institutional, systemic and individual capacity-building to implement adaptation, mitigation and technology transfer, and development actions	-[b]	
13.a Implement the commitment undertaken by developed country parties to the UNFCCC to a goal of mobilizing jointly $100 billion annually by 2020 from all sources	13.a.1 Mobilized amount of United States dollars per year between 2020 and 2025 accountable towards the $100 billion commitment	-[a]	
13.b Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities	13.b.1 Number of least developed countries and small island developing States that are receiving specialized support, and amount of support, including finance, technology and capacity-building, for mechanisms for raising capacities for effective climate change-related planning and management, including focusing on women, youth and local and marginalized communities	-[b]	

[a] Not relevant for Austria / already achieved, [b] Indicator at UN level, [c] Multipurpose indicator

The indicator systems described above cover all the three pillars of sustainability (see e.g. Schepelmann, Goossens, and Makipaa 2008), also recognising the central role of energy and climate change. Since the scope of these indicator systems is very broad, they are not suitable for a detailed monitoring or steering of policy towards achieving of the SDGs. A number of indicator sets are available that focus mainly on energy as a key element in sustainable development and will be described in more detail in the following paragraphs, most notably the IEA/IAEA Sustainable Energy Development (IEA and IAEA 2001) Indicators or the IAEA Indicators for Energy Indicators for Sustainable Development (IAEA and IEA 2005)[2].

The SED indicators measure the progress towards "the provision of adequate energy services at affordable cost in a secure and environmentally benign manner, in conformity with social and economic development needs" (IEA and IAEA 2001). IEA and IAEA propose 41 indicators for sustainable energy development that cover the whole energy system and its driving forces such as economic and social development. This means the indicators cover primary energy supply, transformation technologies and final energy demand as well as energy intensities, the fuel mix and the demand for energy services. Economic factors (e.g. GDP, prices) and social factors (e.g. population growth) affect the energy system and emissions resulting from energy consumption and energy supply.

By now, the IEA/IAEA SED indicators have been applied to a number of countries (e.g. Lithuania (Streimikiene 2005), Cuba (Pérez, López, and Berdellans 2005) and Mexico (Medina□Ross, Mata□Sandoval, and López□Pérez 2005). Depending on the challenges of sustainable energy policy and data availability in most cases only a subset of indicators was used. Davidsdottir et al. 2007 applied a set of SED indicators to Iceland, UK, USA, Sweden, Brazil and Mexico. In addition, Davidsdottir et al. (2007) and Ibarrarán Viniegra, Davidsdottir and Gracida Zurita 2009) show that the SED indicators become highly operational when they are aggregated to a composite index, the so-called Sustainable Energy Index, which consists of one sub-index for each dimension of sustainable development. Kettner, Kletzan-Slamanig, and Köppl (2015b, 2015a) developed a set of sustainable energy indicators for residential buildings and electricity and heat supply in Austria as well as composite indices for monitoring overall energy development in the two sectors.

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[2] Other indicator frameworks address energy security instead of sustainable energy consumption. If energy security is defined broadly, there is a strong overlap with sustainable energy development. The broad notion of energy security comprises economic, social and ecological aspects, albeit often with a stronger focus on economic aspects. Relevant work in this broad context of energy security indicators include (Martchamadol and Kumar 2012, 2013, 2014; Portugal-Pereira and Esteban 2014; Sovacool and Mukherjee 2011) and (Sovacool 2011b, 2011a).
With respect to climate change, a number of indicator systems are also available. These indicators or indices do, however, follow a less comprehensive p approach addressing mainly environmental aspects. Examples for these indicator frameworks include the National Climate Indicators System Report (National Climate Assessment and Development Advisory Committee 2014), The Climate Change Performance Index (Germanwatch 2015), and Climate Change Cooperation Index (Bernauer and Böhmelt 2013).

3.2 The CIEP Approach

The IEA and IAEA (2001) system of Sustainable Energy Development (SED) indicators provide a broad range of indicators for all levels of the energy system. These indicator sets are the starting point for choosing relevant indicators in the demand-side sectors (residential buildings, mobility, manufacturing and services) and electricity and heat supply in CIEP that could be applied to monitor progress in energy and climate policy at EU or Member State level. With respect to final energy demand the focus is on indicators that relate to energy services since these determine welfare and economic development. The conceptual development of indicators was closely connected to a first screening of relevant databases (e.g. Odyssee database, IEA database or Eurostat) with respect to the availability of suitable data. Limited data availability (i.e. many indicators are not available for all countries and years) required iterations to compile the final set of indicators.

For identifying indicators for sustainable energy demand all levels of the energy system have to be considered, from energy services to final energy demand and primary energy supply. Since data on energy services are not readily available, proxy indicators must be used in order to capture energy service demand. These proxies include transport performance, i.e. passenger and tonne kilometres for mobility as a proxy for the energy service "access to people, goods and services at different distances", the floor area of residential buildings as proxy for "well-tempered living space" or "lighting", population for "information, communication and other services related to consumer electronics" or "cooking" and gross value added as proxy for energy services in the sectors manufacturing and services.

Figure 3 illustrates the structure of the CIEP indicator framework for energy and climate policy. For each of the five sectors, the indicators are arranged in five modules, comprising context indicators, energy service indicators as well as energy system indicators covering the three dimensions of sustainable development. Context indicators include for instance average household size, energy prices or heating degree days (HDDs). For the demand side-sectors, indicators for the economic dimension include the efficiency of energy service provision (i.e. the energy service proxy divided by final energy consumption), energy costs as well as patents related to energy efficiency. Economic indicators for electricity and heat supply capture transformation and distribution efficiency as well as energy technology patents and public energy R&D expenditures. The environmental dimension covers the share of renewable energy sources as well as CO_2, NO_x and SO_2 emissions and intensities for all sectors. With respect to the social dimension, indicators have been developed for the sectors residential buildings, transport and electricity and heat supply. These indicators cover i.a. the affordability of energy-related appliances and comfortable room temperature, household equipment rates with certain appliances, differences in the shares of energy costs in household expenditure by income quintiles or the share of electric and alternative vehicles in new registrations for the demand side sectors.

In contrast to the demand-side sectors, electricity and heat supply is only indirectly related to energy services. Final energy demand from residential buildings, mobility, manufacturing and services determines the energy input required to supply power and heat. Thus, emissions are a result of the transformation technologies used (plant types), the fuel mix and the level of final demand that has to be satisfied. The structure of energy indicators for this sector hence deviates from the demand-side sectors. The social indicators for energy supply include the gender pay and employment gap, wage issues and work health aspects.

Figure 3. Structure of the CIEP indicator framework

Sector / Dimension	Residential Buildings	Mobility		Industry	Services	Electricity & Heat
		Passengers	Goods			
Drivers / Context						
Energy Services						
Energy System Indicators						
Economic						
Ecological						
Social						

For the four demand-side sectors a set of 118 high-level energy indicators has been assembled. These indicators can be further disaggregated to about 387 indicators (e.g. energy efficiency of electricity and heat supply can be disaggregated by plant type, household energy efficiency can be differentiated by use category). Ultimately, for electricity and heat supply a set of 25 energy indicators has been compiled providing an aggregate view on the sector. These indicators can be further disaggregated to about 130 indicators differentiating by energy source and plant type. The list of indicators can be found in Annex 1 to this working paper. In addition to the indicator set, composite indices have been developed to allow tracking countries' overall energy development over time (Kettner et al. 2018).

4 Available data sources and data gaps

Diverse databases were used to collect the demand-side indicators (see Table A - 2 and Table A - 3). 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. Plant capacity, energy prices and public energy R&D expenditures are also derived from IEA databases. 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. Complimentary information on sectoral patenting activities is taken from the OECD's EPO database.

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.

4.1 Data gaps for demand-side indicators

Data availability was generally good with respect to indicators describing the economic and ecological dimensions. For the transport sector it must be noted, however, that the statistical data available are limited to motorised transport. Additional data on non-motorised transport (e.g. with respect to distances travelled or infrastructure) would be needed to gain more meaningful insights on structural changes in mobility. Concerning the industry and service sectors a differentiation of useful energy categories such as those included in the Austrian energy balances would allow a more in-depth analysis[3]. In addition, life cycle emissions of the different technologies would deliver valuable insights.

The gap between the conceptual perspective of the social dimension and the availability of data is even more pronounced. Considering the scarcity of crosscutting data, we propose two category groups to depict the social dimension of energy services (1) energy poverty and (2) mobility. With respect to energy poverty, the affordability of home appliances and consumer electronics, as well as households' heating costs, are used as indicators (Brunner, Spitzer, and Christanell 2012; Brunner, Christanell, and Mandl 2017), or, more precisely, the potential risk of energy poverty. Mobility is indicated, first, by vehicle availability by type of fuel (gasoline, diesel/electrical energy/alternative energy) and public transport availability expressed as difficulty in having access to public transport – and, second, by mobility affordability in terms of passenger cars. Again, an extended data availability on i.a. non-motorized individual transport (cycling and walking), public transport and mobility infrastructure (accessibility of public transport stations and stops, availability of rent-a-bike stations and car-sharing standpoints) would allow better insights

[3] The Austrian balances of useful energy distinguishes between seven categories of use: space heating and air condition, steam production, industrial furnaces, stationary engines, traction, lighting and computing and electrochemical purposes. Information on final energy consumption by energy use category is available for 20 (sub-sectors) and differentiated by energy source.

in private households' daily conduct of life (Lebensführung) including mobility behaviour with respect to the cross-cutting issues "gender & equity", "quality of life" and "inclusion". In terms of mobility, for example, data about bicycle availability per household, ownership of season ticket for public transport, annual distance covered by foot, by bicycle, distances per main transport mode (modal split) by gender etc. would be useful. but is not available at national level. The STEP25[4] report provides first approaches for Vienna on how such a measurement might look like[5].

4.2 Data gaps for supply-side indicators

As for the demand side sectors, data availability for the supply side was also generally good for the economic and ecological dimension. Nevertheless, data on the costs would provide valuable information with respect to the economic dimension, e.g. the levelised costs of energy generation. Just as for the demand side, information on life cycle emissions and other environmental effects (e.g. land use, water use, etc.) would be desirable in order to get a more comprehensive view of the environmental dimension.

More challenging is again to depict the social dimension for the supply side sector. Based on well-founded concepts of evaluation of the quality of employment such as the "DGB-Index Gute Arbeit"[6], the "decent work" concept of the International Labour Organisation (ILO) (UNDP 2015) and Eurostat's research on European "working conditions"[7] and matched with the data availability, four categories are defined to depict the work conditions on the energy supply side: (1) income and benefits from employment, (2) temporary employment, (3) health and safety at workplace, (4) work-life-balance. Gender-specific differences in employment and wages serve as indicators for equality of opportunity (Cohen 2017; Littig 2017; Littig and Zielinska 2017). Here again the limited availability of data has to be considered. It would be desirable to have extended statistics, some of which already exist, on the national level, which would allow a broader and detailed international comparison of quality of employment in the energy sector with regard to compatibility of family and career (unpaid work by gender, atypical and long working hours, flexibility of the work schedule), satisfaction with commuting time, involuntary' temporary contracts, work-related health problems (physical well-being as well as mental well-being) and job satisfaction.

4 Cf. (Magistratsabteilung 18 – Stadtentwicklung und Stadtplanung 2015)

5 Cf. (Magistratsabteilung 18 – Stadtentwicklung und Stadtplanung 2015)

6 Cf. http://index-gute-arbeit.dgb.de/ downloaded 23.05.2018

7 Cf. Eurofound 2012. European Foundation for the Improvement of Living and Working Conditions: https://www.eurofound.europa.eu/ downloaded 22.05.2018.

5 A glance at interactions between dimensions and indicators

Given the importance of interacting SDGs and sub-targets we attempted to indicate the relationship between the energy service focussed CIEP indicators and the broader context of the SDGs. For example, when integrating the social dimension in the CIEP climate and energy policy indicator set, the focus on the energy supply side is on the quality of employment, and on the energy demand side the focus is on daily conduct of life practices in private households (Littig 2016). Cross-cutting issues that are relevant for all areas and at the same time highlight the relation to some other SDGs are identified: gender equality and gender equity[8] (Röhr 2008) – both for energy supply and energy demand (Räty and Carlsson-Kanyama 2010), increasing the quality of employment (on the energy supply side) and respectively quality of life (on the energy demand side) as well as participation on the energy supply side or inclusion on the energy demand side. This exercise brings sobering findings due to the uncertainty in predicting how particular future trends affect everyday life, consumption and mobility behaviours as well.

Reflecting the outcomes makes the multidimensionality and the ambivalences of the different dimensions visible, in particular as a consequence of the inclusion of the social dimension. For example, an increase in physical assets such as household appliances and vehicles may mean a reduction of social inequality and / or an increase in mobility, but at the same time can have a negative impact on the environment.

Table 2 exemplifies interactions between the different goals using two social indicators. Trade-offs become visible between the different SDGs. Depending on the underlying assumptions, different development paths are conceivable which then however would end in different assessments of their effects.

[8] Cf. about the concept of gender equality (Pimminger and Wroblewski 2017; Pimminger 2017).

Table 2. Interdependence table of social indicators and their impact on the SDGs

		Social							
		Population able to keep home adequately warm				New registrations of passenger cars with electric or alternative drives			
		7 AFFORDABLE AND CLEAN ENERGY	5 GESCHLECHTER-GLEICHHEIT	13 CLIMATE ACTION	GHG emission reduction	7 AFFORDABLE AND CLEAN ENERGY	5 GESCHLECHTER-GLEICHHEIT	13 CLIMATE ACTION	GHG emission reduction
Social	Reduced number of low-wage earners	2	2	-1	-2	1	1	-1	-1
	Reduced gender employment gap	1	1	1/-1	-1	1	2	1/-1	1

The evaluation of interactions follows Nilsson et al. (2018) and ranges from -3 to +3: -3 denotes cancelling targets while +3 denotes indivisible targets.

Thus, it can be seen in the illustration that an increase in the number of low-wage earners suggests considerable material and immaterial deprivations, which may be, for example, an increase in the proportion of the population unable to sufficiently heat their home, or would reflect in a lower number of newly registered electric cars and cars with alternative drive systems. This would negatively impact the achievement of SDG 7 *"Ensure access to affordable, reliable, sustainable and modern energy for all"* and SDG 5 *"Achieve gender equality and empower all women and girls"*. In contrast, there is a positive correlation with the achievement of SDG 13 *"Take urgent action to combat climate change and its impacts"*, it would also cause lower greenhouse gas emissions due to lower consumption, which would have a positive effect on the climate. The opposite would be observed if the gender employment gap decreased. A reduction of the gap between male and female participation in the labour market, thus rising equal participation in society and equality of opportunity is clearly positive in its impact on achieving SDGs 5 and 7 (in terms of more gender equality in the share of population that is able to keep the home adequately warm and/or to afford a new electric car or a vehicle with alternative drive technology (like hydrogen-fuel cell vehicles). At the same time, this raises the question of whether the purchase of a more energy-efficient car will replace a conventional drive or if an additional car (second-, third-car) would be added in the household. The latter may possibly mean an increase in mobility (of women), which would have a negative effect from an environmental perspective. These different lines of argumentation illustrate that depending on the assumptions made, the effect would need to be evaluated differently. More precisely, if an exit from fossil powered motor vehicles is supported by regulation and a new registration of electric / alternative-drive cars results in a reduction in the number of conventional vehicles, this could potentially have a positive effect on greenhouse gas emissions and reflect a development towards SDG 13. Conversely, if the purchase of a new passenger car with alternative drive is promoted while combustion engines are not reduced, new registrations would still lead to conceivable positive effects on participation and inclusion such as increases in mobility and convenience, but bring about also negative effects on climate change.

These lines of argumentation as outlined above point at the comprehensive political and social challenges, both regionally and globally, to find and deploy holistic and coherent measures that address the complex interactions between the SDGs in unison. It should be noted that all SDGs are integrated and complementary and therefore must be considered as equal. Focusing on individual goals and ignoring others creates the risk of overlooking relevant side effects and failing to recognise or exploit potential synergies.[9]

Added to this is the problem of data availability mentioned in the previous chapter. This implies a distortion of the reality depiction due to missing indicators, and thus underexposure of relevant areas.

6 Conclusions

The UN SDGs and the Paris Climate Agreement both imply ambitious (long-term) targets which only can be met with a fundamental restructuring of economic and social systems. In this context monitoring of progress towards achievement of goals is essential and needs thorough measurement systems.

The complexity calls for indicator systems instead of single indicators. While the list of indicators proposed to monitor the 17 SDGs and the corresponding 169 targets is already very comprehensive, for monitoring and steering of policy more detailed indicator sets for individual SDGs are required. Moreover, it was suggested to complement the UN indicator set by operational indicators at the national and regional level to be developed by the countries and reflecting their particular circumstances (UNFCCC 2015). Against this background we propose a set of indicators that allow monitoring of progress towards energy and climate policy targets in the EU context.

We combine the energy service perspective with research on sustainable energy development indicators and apply this approach in the broader context of the SDGs. Furthermore, we put particular emphasis on the consideration of the social dimension and the development of meaningful indicators.

The conceptual development of indicators was closely connected to a first screening of relevant databases (e.g. Odyssee database, IEA database or Eurostat) with respect to the availability of appropriate data. Limited data availability (i.e. many indicators are not available for all countries and years) required iterations to compile the final set of indicators.

Data availability was acceptable for the economic and ecological dimension but is limited for the social dimension. Thus, additional information would be required in order to comprehensively track changes in energy use patterns. Apart from gaps in the available

[9] Cf. TWI2050 - The World in 2050 2018.

data sets – especially, but not only, for the new EU Member States it is not possible to compile a longer time series – there are additional data or indicators that would be of value for our analysis like efficiencies of appliances that go beyond the available data and allow disaggregation the effect of usage time from technical efficiency, non-motorised transport, use categories for final energy demand, investment costs, levelized costs of generation, life cycle emissions and other environmental effects (e.g. land use, water use, etc.). Comprehensive data about energy poverty and mobility behaviour as well as about the quality of employment at sectoral level are also desirable.

The sustainable energy indicators proposed in CIEP cover the three dimensions of sustainability. As for the SDGs, interactions (i.e. synergies and conflicts) between the different target dimensions and the corresponding indicators need to be carefully considered.

Given the complexity of the issue and the gaps in data availability/adequate indicators it is difficult to interpret certain observable trends. For instance, an increase in electric cars can be both beneficial or detrimental from an environmental point of view, depending on whether these cars are substitutes for fossil fuel powered cars or additional vehicles. The opposite applies for the social dimension as a larger number of cars increases the mobility options available for individuals. However, the net effect on mobility is again impossible to assess as no data on non-motorised transport are available. This needs to be kept in mind when using the indicator system for policy analysis.

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Annex

Table A - 1. List of indicators

Dimension [of sustainability]	Sector					
	Residential	**Passenger Transport**	**Freight Transport**	**Manufacturing**	**Services**	**Electricity & Heat Supply**
Drivers / Context	Floor area p.c.	Stock of vehicles by category	Stock of trucks	Share of GVA in GDP	Share of GVA in GDP	Prices
	Housing stock	Share of e-vehicles		Energy prices	Energy prices	Carbon prices
	No. of HH	Modal split	Model split	Share of emission/energy intensive industry		Capacity power plants
	HH size	Energy prices	Energy prices			
	HH income (by qu.)	Road and rail km (Infrastructure indicator)	Road and rail km (Infrastructure indicator)			
	Energy prices	Km of road / km of rail	Km of road / km of rail			
	Heating Degree Days	Specific CO_2 emissions of car stock				
		Specific CO_2 emissions of newly registered cars				
Energy Service Proxies	Well-tempered living space	Mobility	Transport of goods	GVA	GVA	
	Illumination					
	Warm water					
	Cooking					
	Communication / Entertainment					
	Other					
Economic	Efficiency of residential sector	Efficiency of passenger transport	Efficiency of freight transport	Efficiency of manufacturing	Efficiency of service sector	Transformation efficiency
	Share of energy expenditure in household expenditure	Share of transport expenditure in household expenditure	FEC	FEC	FEC	Distribution efficiency
	FEC*	FEC		Public R&D expenditures energy efficiency industry		Transformation input
	Public R&D expenditures energy efficiency buildings	Public R&D expenditures energy efficiency transport		Share of costs	Share of costs	**Public energy R&D expenditures**
	Applied patents energy efficiency buildings	Public R&D expenditures for e-mobility				**Applied energy technology patents**
		Applied patents energy efficiency transport				

Table A - 1 continued.

Dimension [of sustainability]	**Sector**					
	Residential	**Passenger Transport**	**Freight Transport**	**Manufacturing**	**Services**	**Electricity & Heat Supply**
Ecological	% of RES in FEC	% of RES in FEC	% of RES in FEC	% of RES in FEC	% of RES in FEC	% of RES in E&H supply
	CO_2 **emissions**	CO_2 **emissions**	CO_2 **emissions**	CO_2 **emissions**	CO_2 **emissions**	CO_2 **emissions**
	NO_x **emissions**	NO_x **emissions**	NO_x **emissions**	NO_x **emissions**	NO_x **emissions**	NO_x **emissions**
	SO_2 **emissions**	SO_2 **emissions**	SO_2 **emissions**	SO_2 **emissions**	SO_2 **emissions**	SO_2 **emissions**
	CO_2 **efficiency of FEC**	CO_2 **efficiency of FEC**	CO_2 **efficiency of FEC**	CO_2 **efficiency of FEC**	CO_2 **efficiency of FEC**	CO_2 efficiency of E&H supply
	NO_x **efficiency of FEC**	NO_x **efficiency of FEC**	NO_x **efficiency of FEC**	NO_x **efficiency of FEC**	NO_x **efficiency of FEC**	NO_x efficiency of E&H supply
	SO_2 **efficiency of FEC**	SO_2 **efficiency of FEC**	SO_2 **efficiency of FEC**	SO_2 **efficiency of FEC**	SO_2 **efficiency of FEC**	SO_2 efficiency of E&H supply
Social	Persons who cannot afford a telephone	New registrations of passenger cars				Low-wage earners
	Persons who cannot afford a colour TV	New registrations of electric passenger cars				Median hourly earnings
	Persons who cannot afford a computer	New registrations of passenger cars w alternative drives				Temporary contracts
	Persons who cannot afford a washing machine	Infrastructure public transport				Incidence rate of fatal accidents at work
	Persons who cannot afford internet connection for personal use at home	Persons who cannot afford a car				Flexibility of the work schedule
	Population unable to keep home adequately warm by poverty status					Equal opportunities
	Share of Heating costs in HH income by quintile					Gender pay gap
	Equipment rate - fridge					Gender employment rate gap
	Equipment rate - freezer					
	Equipment rate - washing machine					
	Equipment rate – dishwasher					
	Equipment rate - TV					

Table A - 2. Demand-side indicators: Data sources

Dimension	Sector	Indicator	Source
Context	Residential	Household data	Odyssee database
		HH income (qu.)	EU-SILC
	Transport	Car stock data	Odyssee database
		Modal split	Odyssee database
		Road/rail km	Odyssee database
		Share of e-vehicles	EEA, CO_2 emissions from passenger cars
		Share of alternative drives	EEA, CO_2 emissions from passenger cars
		Specific CO_2 emissions of newly registered cars	EEA, CO_2 emissions from passenger cars
		Specific CO_2 emissions of car stock	Odyssee database
	Industry/Service	GVA	Odyssee database
	All sectors	Energy prices	IEA Energy Price Taxes
Energy Service	Residential	Well-tempered living space proxy: Floor area	Odyssee database
		Illumination Proxy: Floor area	Odyssee database
		Warm water Proxy: Population	Odyssee database
		Cooking Proxy: Households	Odyssee database
		Communication/Entertainment Proxy: Households	Odyssee database
	Passenger Transport	Mobility Proxy: pkm	Odyssee database
	Freight Transport	Transport of goods proxy: tkm	Odyssee database
	Service	Proxy: GVA	Odyssee database
	Industry	Proxy: GVA	Odyssee database
Economic	All sectors	Energy efficiency data	Odyssee database
		R&D data	IEA, Energy R&D Expenditures
		Patent data	OECD, EPO database
	Residential/Transport	Share of energy expenditure	Eurostat, COICOP
	Industry/Service	Share of energy costs	IEA, Odyssee
Ecologic	All sectors	Share of renewables in sectors	Odyssee database
		Emission data	UNFCCC, National Inventory Reports
Social	Residential/Transport	Affordability data	Eurostat, EU-Silc
	Residential	Equipment rates	Odyssee database
		Share of heating costs (qu.)	Eurostat, Household budget survey
	Transport	New registration of cars	EEA, CO_2 emissions from passenger cars
		Accessibility of public transport	Eurostat, EU-Silc

Table A - 3. Supply-side indicators: Data sources

Dimension	Indicator	Source
Context	Energy Prices	IEA Energy Price Taxes
	Carbon prices	EEX
	Capacity power plants	IEA Electricity information
Economic	Transformation efficiency electricity plants	IEA Energy Balances
	Transformation efficiency CHP	IEA Energy Balances
	Transformation efficiency heat plants	IEA Energy Balances
	Distribution efficiency electricity	IEA Energy Balances
	Distribution efficiency heat	IEA Energy Balances
	Transformation input	IEA Energy Balances
	Public energy R&D expenditures	IEA, Energy R&D Expenditures
	Applied energy technology patents	OECD; EPO database
Ecological	% of RES in Electricity and Heat supply	IEA Energy Balances
	CO_2 emissions	UNFCCC, National Inventory Reports
	NO_x emissions	UNFCCC, National Inventory Reports
	SO_2 emissions	UNFCCC, National Inventory Reports
	CO_2 efficiency of Electricity and Heat supply	UNFCCC, National Inventory Reports
	NO_x efficiency of Electricity and Heat supply	UNFCCC, National Inventory Reports
	SO_2 efficiency of Electricity and Heat supply	UNFCCC, National Inventory Reports
Social	Low-wage earners	Eurostat, Structure of Earning Survey
	Median hourly earnings	Eurostat, Structure of Earning Survey
	Collective pay agreement	Eurostat, Structure of Earning Survey
	Temporary contracts	Eurostat, Structure of Earning Survey
	Incidence rate of fatal accidents at work	Eurostat - European Statistics on accidents at work (ESAW)
	Flexibility of the work schedule	Eurostat: Labour Force Survey (LFS)
	Gender pay gap	Eurostat: Labour Force Survey (LFS)
	Gender employment gap	Eurostat - Structure of Earnings Survey (SES)