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Residential Buildings and Electricity and Heat Supply

Claudia Kettner, Daniela Kletzan-Slamanig, Angela Köppl

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AUSTRIAN INSTITUTE OF ECONOMIC RESEARCH

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E-mail address: Claudia.Kettner@wifo.ac.at, Daniela.Kletzan-Slamanig@wifo.ac.at, Angela.Koeppl@wifo.ac.at
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Indicators for Sustainable Energy Development for Austria (ISED-AT): Residential buildings and electricity and heat supply

Claudia Kettner, Daniela Kletzan-Slamanig, Angela Köppl

Abstract

A transformation of prevailing energy systems requires adequate measurement systems. In this paper we propose an energy-service based indicator set and a composite index for monitoring sustainable energy development in the residential sector and electricity and heat supply in Austria. The system of Indicators for Sustainable Energy Development for Austria (ISED-AT) and the composite index focus on energy services instead of energy flows and are hence effective tools for monitoring and guiding the transition, as they allow assessing the whole range of technology options for providing a particular energy service. The analysis of household final energy demand and electricity and heat supply in Austria shows substantial progress in terms of ecological aspects, such as the share of renewable energy sources and CO_2 emissions. With respect to energy efficiency, in contrast, only little improvement can be observed. Efficiency of energy service provision is decreasing except for heating and air conditioning. Final energy demand is rising in all areas of household energy demand. The challenge lies in a substantial improvement of energy efficiency that will allow an absolute decoupling of energy service demand from final energy consumption.

Keywords: sustainable energy development, indicator set, composite index, residential buildings, energy supply

JEL-codes: C34, Q49, Q54

1 Introduction

Climate change is a major global challenge. In order to reach the long-run emission reduction targets required for climate change mitigation, a fundamental transformation of our societies and energy systems is indispensable. Such an energy transition requires adequate information and measurement systems in order to monitor the transformation path. Sets of indicators are considered an appropriate tool to steer an energy transition, as they account for the complexity arising from the interaction between economy, society and ecosystems.

Economic development shows a strong correlation with energy consumption although a relative decoupling can be observed in recent years. Still increasing energy consumption is seen as essential for economic development and welfare. It is, however, energy services that are relevant for wellbeing and not the amount of energy flows. Energy services are "the physical amenity provided by energy-using equipment" (Thomas et al., 2000) like cooking or illumination. A focus on welfare-relevant energy services is crucial for the development of sustainable energy structures since it broadens the options for energy and emission-saving activities (see e.g. Cullen and Allwood, 2010; Gouveia et al., 2012; Haas et al., 2008; Kettner et al., 2012a, 2012b, 2012c; Köppl et al., 2014, 2011; Ma et al., 2012; Sovacool, 2011a, 2011b).

In this paper, we integrate the energy service-based perspective of the energy system and measurement approaches for sustainable energy development. We develop and compile indicators for sustainable energy development for Austria (ISED-AT) for energy services that are related to residential buildings, one major area of final energy demand. With the perspective of the whole energy chain, the demand-side indicators are complemented by consistent indicators for sustainable electricity and heat supply. In addition to implementing the energy service-based approach and developing the indicator system for Austria, we construct a composite index for energy sustainability in residential buildings and electricity and heat supply for Austria. The composite index follows the energy service-focused perspective and captures changes along the whole energy chain, starting from the efficiency of the provision of energy services and ending with the environmental impacts of electricity and heat generation. In this paper we focus on residential final energy demand as an exemplary case and implement the index for the period 2003 to 2012. The conceptual framework is open for integrating additional end use sectors like manufacturing or transport in the indicator system or in the composite index.

The paper is structured as follows: We start by providing an overview of the existing research on energy indicators in the context of sustainable development. We then present the structure of the energy service-focused ISED-AT indicator system and the composite index and report on the data. The next section describes the development of the indicators and the composite index for Austria over time. The final section concludes.

2 Methods

In recent years climate change and resource constraints have gained in importance in the political debate. There is a growing understanding that a fundamental transformation of the prevailing patterns of energy and resource use is necessary although a clear pathway for such a transformatory process is still missing. These issues are closely related to the concept of sustainable development that emphasises the relevance of a broad range of economic, social and ecological aspects for well-being[1]. The multidimensionality of the concept of sustainable development translates into a high degree of complexity. This complexity cannot be captured by a single indicator, but requires indicator sets which are considered a supportive tool to structure these complex issues and to illustrate the interactions between economy, society and ecosystems. Indicators should adhere to a number of quality criteria. In the "Handbook on Constructing Composite Indicators" (OECD et al., 2008) general criteria for the selection of indicators and data quality are listed. The criteria are closely linked to user requirements and have several dimensions. The handbook discusses six criteria that have a decisive influence on the quality of (single) indicators and composite indices:

- *Relevance* refers to the careful selection of data to cover the relevant dimensions of an indicator set or composite index.
- *Accuracy* is to be seen in the context of the credibility of the data used and the confidence users can place in the objectivity of the data generation.
- *Timeliness* has to be considered, especially if indicators are published at different points in time.
- *Accessibility and clarity* refers to ease of access to the data by third parties and the availability of adequate meta-information on the data.
- *Comparability and coherence* are closely related and refer to the issue of comparability over time and across countries and the internal consistency of the data.

With respect to sustainable energy development, a number of indicator sets have been developed over the past 15 years that aim at monitoring the transition towards a sustainable energy system. In some cases, mere (theoretical) indicator frameworks have been proposed while in other cases the indicator systems have also been operationalised, i.e. implemented for certain countries. In this paper, we propose a framework for sustainable energy indicators based on the concept of energy services and implement it for Austria with a focus on residential buildings.

[1] Sustainability is mostly assessed based on three dimensions (economic, environmental and social). In the context of sustainable energy development, sometimes a technological and an institutional dimension are added (Mandelli et al., 2014). As the latter is particularly hard to measure, this dimension is often mentioned but not included in sustainable energy indicator frameworks (e.g. IAEA and IEA, 2001).

2.1 Review of indicators for sustainable energy development

Systems of indicators for sustainable development were developed by a number of international institutions including the EU and the UN (European Commission, 2005; UNDESA, 2001). These indicator systems cover all three dimensions of sustainability (economic, social, environment). All indicator sets have in common that they recognise the central role of energy. Apart from the general indicator frameworks for monitoring sustainable development, other indicator sets focus on energy as a key element of sustainable development. The most prominent examples for the latter are the Sustainable Energy Development (SED) Indicators proposed by the International Energy Agency and the International Atomic Energy Agency (IAEA and IEA, 2001) and the Energy Indicators for Sustainable Development (IAEA et al., 2005). These two approaches represent theoretical indicator frameworks for sustainable energy development but have not been operationalised. The conceptual framework is based on a systemic view of the energy system.

In 1999, the International Atomic Energy Agency (IAEA) initiated a project on "Indicators for Sustainable Energy Development" that should complement the general sustainable development indicators and should assist IAEA Member States in the development of (sustainable) energy strategies (IAEA and IEA, 2001). In the process of indicator development, experts from a number of international organisations (IEA, OECD, EC, UN) and IAEA Member States were involved. A first set of sustainable energy indicators resulting from this process was suggested by IAEA and IEA (2001). They proposed 41 indicators for sustainable energy development covering the whole energy system as well as the driving forces of energy use and supply such as economic and social development. The indicators cover primary energy supply, the efficiency of transformation technologies as well as final energy demand. The indicator set also includes sectoral energy intensities, the mix of primary energy supply and final energy consumption and the demand for energy services. Economic factors (e.g. GDP, prices) and social factors (e.g. population growth) influence the volume of energy demand and supply as well as the resulting emissions.

Building on IEA and IAEA (2001), IAEA et al. (2005) proposed a revised system of energy indicators that covers 30 indicators instead of the previously proposed 41. Just as in the 2001 indicator set, the three dimensions of sustainability are represented unequally with 16 indicators referring to the economic dimension and only ten and four referring to the environmental and social dimension respectively. The indicators focus on energy intensity (of GDP as well as per capita and in specific use categories), energy security, biomass utilisation as well as air, water and waste emissions.

The two indicator frameworks have been applied by a number of countries, e.g. Lithuania (Streimikiene, 2005), Cuba (Pérez et al., 2005), Mexico (Medina-Ross et al., 2005) and Africa (Mandelli et al., 2014). The compilation of data for all proposed indicators, however, is fraught with various constraints such as limited data availability. Furthermore, the individual countries face different challenges with respect to sustainable energy development. For most countries therefore only a subset of indicators was used or selected indicators have been modified. Davidsdottir et al. (2007) compiled a set of SED indicators for Iceland, UK, USA, Sweden, Brazil and Mexico. In addition to the single indicators, Davidsdottir et al. (2007) and Ibarrarán Viniegra et al. (2009) aggregate the SED to a composite index, the so-called Sustainable Energy Index, which consists of one sub-index for each dimension of sustainable development, and illustrates the overall direction of the development of the energy system. Mainali et al. (2014) propose a composite Energy Sustainability Index (ESI) for rural energy sustainability in developing countries. For this index, 13 indicators in four dimensions of sustainable energy development (social, economical, technical, environmental) are selected based on a literature survey and aggregated using principal component analysis[2]. Ten indicators are also included in the indicator system by IAEA et al. (2005); the additional indicators mainly address energy access in developing countries.

Other indicator frameworks address energy security instead of sustainable energy consumption. If energy security is defined broadly[3], 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. In an expert survey, Sovacool et al. (2011) find that for the respondents "energy security is almost synonymous with energy sustainability". Except for Martchamadol and Kumar (2014, 2013), these indicator sets do in general not rely on a systematic framework but are rather ad-hoc. Portugal-Pereira and Esteban (2014), for instance, develop a multi-dimensional indicator set for the assessment of energy security in Japan. They use a broad definition based on five dimensions they consider relevant for the country: availability, reliability, technological development (efficiency of electricity generation) as well as global environmental sustainability (GHG emissions) and local environmental protection (local air pollutants). They perform a forward-looking, scenario-based analysis (up to 2030) comparing different scenarios to a baseline development that reflects the "pre-Fukushima" situation in Japan. Sovacool and Mukherjee (2011) present an extensive list of energy security indicators based on a similar concept as used in Portugal-Pereira and Esteban (2014). Different aspects of energy security are categorised along five dimensions (availability, affordability, technology development and efficiency, environmental and social sustainability, as well as regulation and governance) that were identified using semi-structured interviews, a survey, as well as an international expert workshop. They develop a general indicator framework for assessing national energy security policies and performance. The selection of indicators for the different dimensions is based on the literature as well as on the results of from interviews, surveys, and workshops. Based on the framework by Sovacool and Mukherjee (2011), Sovacool et al. (2011) analyse energy security in 18 countries in the period 1990 to 2010. They aggregate 20 indicators related to the five dimensions of energy security described above into a composite index and compare the countries' performance with respect to energy security over time. Starting from an extensive literature review, Martchamadol and Kumar (2012) use five

2 Principal component analysis (PCA) is a statistical procedure that is used to structure and simplify large data sets via approximating a variety of variables by a smaller number linear combinations of the initial variables ("principal components").

3 In a broad sense energy security can be "defined as how to equitably provide available, affordable, reliable, efficient, environmentally benign, proactively governed and socially acceptable energy services to end-users" (Sovacool et al., 2011).

dimensions (energy demand, availability of energy supply resources, environmental concerns, energy market, energy price / cost / expenditures) to study energy security in Thailand. Within these five dimensions, they select 19 indicators from the literature and analyse the historical development between 1986 and 2009 as well as possible future development in different scenarios up to 2030. Martchamadol and Kumar (2013) develop a general framework for a composite index of energy security, the Aggregated Energy Security Performance Indicator (ASEPI), based on a broad review of indicators for the institutional, economic, environmental and social aspects. The starting point for this framework is the indicator system proposed by IAEA et al. (2005) as described above. For the ASEPI Martchamadol and Kumar (2013) select 25 SED indicators and propose them for the composite index. The different dimensions for sustainability are again not proportionally reflected in the index, i.e. 20 are assigned to the economic dimension[4], two to the environmental dimension and three to the social dimension. For the aggregation of the indicators Martchamadol and Kumar (2013) propose a procedure based on principal component theory. In a follow-up paper (Martchamadol and Kumar, 2014), they implement the ASEPI for Thailand, analysing past as well as possible future developments.

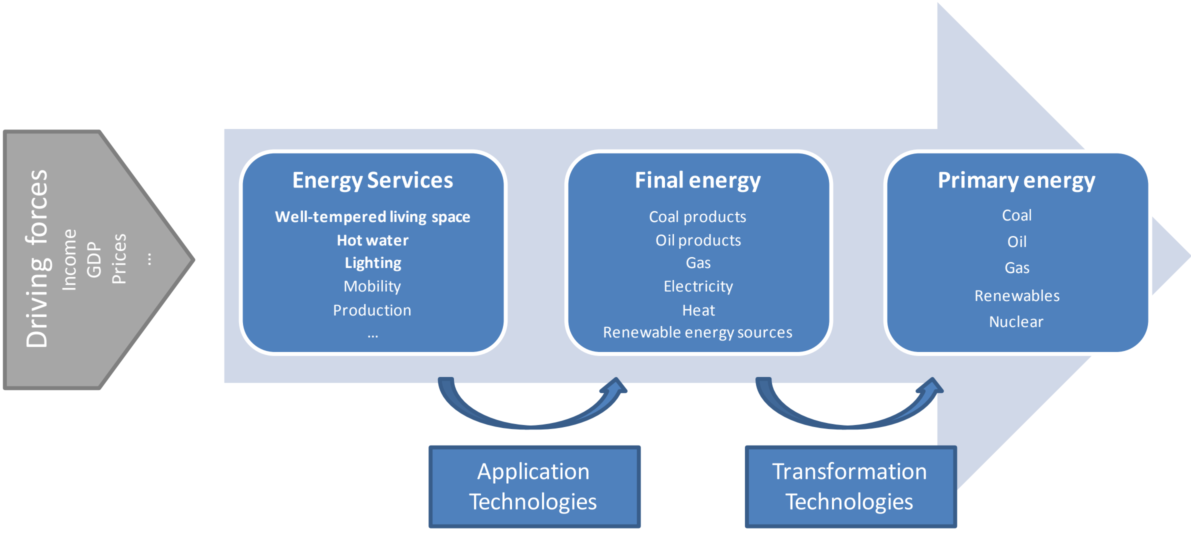
2.2 An energy service-focused perspective for sustainable energy development indicators

The approaches described above indicate the different foci of (sustainable) energy indictor sets depending on the specific research questions and the underlying conceptual frameworks. In the following we describe the conceptual framework for our set of sustainable energy indicators. We put energy services as welfare relevant outcome of the energy system in the centre of our research approach. Energy services are a key factor for the development of sustainable energy structures (see e.g. Cullen and Allwood, 2010; Gouveia et al., 2012; Haas et al., 2008; Kettner et al., 2012a, 2012b, 2012c; Köppl et al., 2014, 2011; Luo and Zhang, 2012; Ma et al., 2012; Nussbaumer et al., 2012; Sovacool, 2011a, 2011b). It is not the quantity of energy demanded by households and companies that is relevant for welfare and development, but the amount and quality of the energy services consumed.

Energy services, like well-tempered living space, are provided by capital stocks (such as buildings, heating systems, etc.) and energy flows. A certain level of energy services can be provided by different combinations of technologies (incorporated in the capital stocks) and energy flows. The range of available transformation and application technologies and energy sources thus opens up a spectrum of options, which result in different volumes of energy flows and GHG emissions for any given quantity of services demanded. The relationship between energy services, energy flows, technologies, socio-economic driving forces of energy consumption and supply and related GHG emissions for the whole energy system is illustrated in Figure 1.

[4] Martchamadol and Kumar (2013), for instance, also assign indicators capturing the share of renewable energy sources to this dimension.

Figure 1. Structure of the energy system



Source: Own illustration based on Köppl et al. (2011). Building-relevant energy services are in bold letters.

As pointed out e.g. in Köppl et al. (2011) and Ma et al. (2012), data on energy services is not readily available. Therefore, the analysis of energy systems focuses generally on energy flows instead of energy services. Such a perspective suggests that "fuels and technologies are the only important elements of energy systems", a narrow perspective which might foster lock-ins in inefficient structures as alternative options for providing a particular energy service are not considered (Gouveia et al., 2012). The concept of energy services recently gained in importance in studies of (sustainable) energy development both in less developed countries and in Western urban areas (Chaturvedi et al., 2014; Gouveia et al., 2012; Ma et al., 2012; Nussbaumer et al., 2012; Oparaocha and Dutta, 2011; Serwaa Mensah et al., 2014; Sovacool, 2011a, 2011b). By allowing a broader perspective for energy- and emission-saving activities, a stronger focus on energy services can play a crucial role for the development of sustainable energy structures (see e.g. Cullen and Allwood, 2010; Gouveia et al., 2012; Haas et al., 2008; Kettner et al., 2012a, 2012b, 2012c; Köppl et al., 2014, 2011; Ma et al., 2012). Although the idea of energy services has become more common in the analysis of energy systems, the operationalisation faces limits especially related to data availability. Energy services typically are not measured and thus not available in official statistics. So it is necessary to define proxies that are close to the energy services (see e.g. Köppl et al., 2014).

2.3 Indicators for Sustainable Energy Development for Austria (ISED-AT)

We develop an indicator system on the basis of specific energy services for residential buildings and electricity and heat supply, compiling these indicators for Austria. We take the comprehensive indicator concept proposed by IEA and IAEA (2001) and IAEA et al. (2005) as starting point, but advance it in several respects:

- We define operational indicators that emphasise the role of energy services instead of energy flows for welfare, with a focus on the energy services in residential buildings (e.g. well-tempered living space).

- For the development of the indicator system, we follow an integrated perspective of the energy system that covers the whole energy chain from energy services to primary energy supply, with energy services as starting point. In this framework, we define consistent indicators for sustainable electricity and heat supply.
- We aggregate a selection of indicators to composite indices and use them to discuss the historic development of energy sustainability in Austria in the period 2003 to 2012 in order to describe energy development in residential buildings and electricity and heat supply in a condensed form.

Figure 2 and Figure 3 illustrate the structure of the ISED-AT indicator system, derived from a integrated view of the energy system as described above. The first figure illustrates the indicators we propose for residential buildings. The indicators are arranged in four modules, each reflecting a different level of the energy system: energy services, capital stocks reflecting the different application and transformation technologies, energy flows, and GHG emissions. With respect to energy services in the residential sector, we define and compile proxy indicators for six major categories:

- well-tempered living space (proxy: floor area in m^2);
- illumination (proxy: floor area in m^2);
- warm water (proxy: population);
- cooking (proxy: number of households);
- communication / entertainment (proxy: population); and
- other (i.e. energy services provided by household appliances like freezers or washing machines[5]; proxy: number of households).

We further include indicators that capture context indicators like household size, household income (by quintile), energy prices or heating degree days (HDDs).

To describe the development of the volume and quality of important capital stocks in the housing sector, we use the following indicators:

- energy efficiency of the service provision (by service type);
- floor area by type of building and construction period (as the energy efficiency of the building stock largely depends on these factors); and
- the number of appliances (by type).

Again, context factors affect changes in capital stocks. Some of these context indicators are identical to those for energy service demand as described above (e.g. energy expenditures).

The third module of indicators captures final energy consumption in the household sector as result of energy service demand and the energy efficiency of the capital stock. With respect to these energy flows, we differentiate by use category (heating and cooling, cooking etc.) and by energy source.

[5] The indicators chosen here are good, but not perfect proxies for energy services and energy use. With respect to washing machines, e.g. the stock will depend on the number of households, while the frequency of use will rather reflect the number of persons.

Finally, GHGs and air pollutants (CO_2, NO_x and SO_2) directly emitted during household final energy consumption and reflecting the emission intensities of the different fuel types are displayed.

Figure 2. ISED-AT: Energy indicators for housing

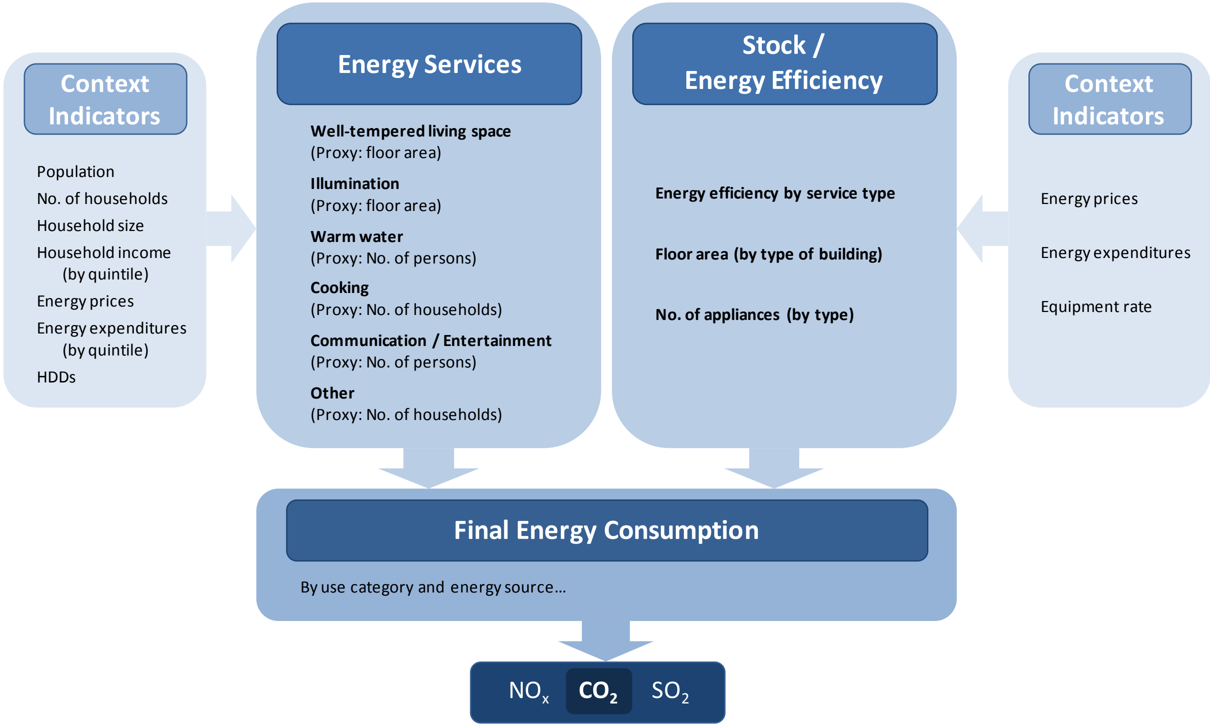
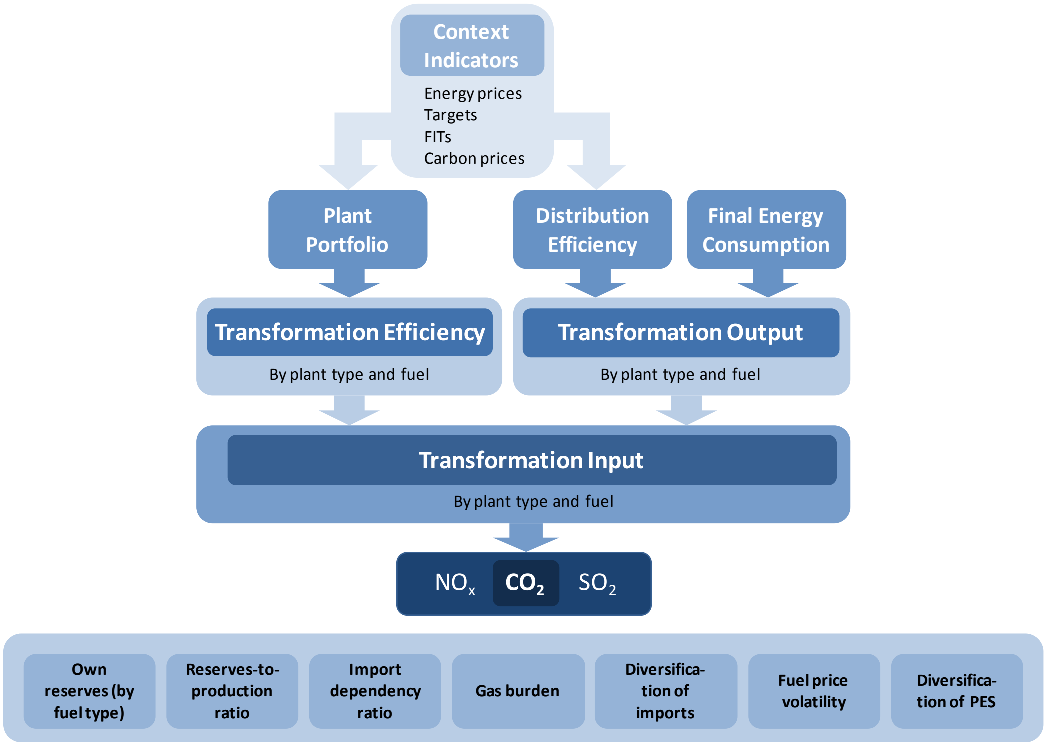


Figure 3 presents the ISED-AT indicators describing electricity and heat supply. The indicators for this sector are arranged in the following modules: Electricity and heat consumption as the most important determinant of electricity and heat supply, stock indicators that capture the efficiency of the distribution and transformation processes, energy flows (i.e. electricity and heat generated and the corresponding transformation input) and GHG emissions from electricity and heat supply.

The starting point are indicators that capture relevant context factors like energy prices or political targets for the energy mix, for energy efficiency or for GHG emissions that affect the plant portfolio and the efficiency of electricity and heat distribution. Final electricity and heat consumption is another relevant indicator that, together with distribution efficiency, determines the sector's transformation output, i.e. the amount of electricity and heat generated. The plant portfolio defines the quality of the capital stock and determines which transformation input is required to deliver a certain amount of electricity and heat. On the next level, again GHGs and air pollutants (CO_2, NO_x, SO_2) are displayed that depend on the level of transformation input on the one hand and on the energy mix for electricity and heat generation on the other.

This structural system of energy indicators that follows the energy chain as presented above is complemented by a selection of indicators capturing energy security aspects. These include the own energy reserves (by fuel type), the reserves-to-production ratio, the import dependency ratio, the gas burden, the diversification of imports and primary energy supply and fuel price volatility.

Figure 3. ISED-AT: Energy indicators for electricity and heat supply



2.4 A sustainable energy development index for Austria

In addition to the indicator set, we construct composite indices that reflect the sustainability of energy use in the residential sector and in electricity and heat supply over time in a condensed way. The main advantage of calculating a complementary composite index is that aggregate indices facilitate the monitoring of energy policy over time as interpreting and comparing many different indicators proves difficult when an overall conclusion about energy sustainability and emission reductions is aspired. The purpose of a composite index is to reduce the complexity and to provide a useful instrument for policy monitoring and decision making. In addition, an index can serve as a communication tool. Through aggregating 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 single indicators containing important information about energy sustainability in different areas.

The procedure for the calculation of the sustainable energy index follows Davidsdottir et al. (2007) and Ibarrarán Viniegra et al. (2009). The composite indices in these studies are based on three sub-indices, one for each dimension of sustainability (economic, environmental and social dimension). The sub-indices are calculated according to the equation (1):

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

where $I_{i,t}$ gives the sub-index of dimension *i* in year *t*, *j* is the energy indicator, *n* is the number of indicators, w_j is the weight for each indicator, and $E_{i,j,t}$ 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. Ibarrarán Viniegra et al. (2009)and Davidsdottir et al. (2007) assume equal weights both for the calculation of the sub-indices and for the calculation of the aggregate index.

Davidsdottir et al. (2007) include ten energy indicators in the composite index and compile it for six countries (Brazil, Iceland, Mexico, Sweden, the United Kingdom and the United States) over a period of 15 to 20 years. Their index covers four indicators reflecting the economic dimension of sustainable energy development (energy intensity, share of renewables in primary energy supply, net energy import dependency and energy diversification), two indicators reflecting the social dimension (share of population with no adequate access to energy, fraction of disposable income spent on energy), and four indicators for the environmental dimension (CO_2 emissions, NO_x emissions, SO_2 emissions, and accumulation of spent nuclear fuel). Ibarrarán Viniegra et al. (2009) construct a composite index for sustainable energy development for Mexico in the period 1980 to 2006. The index is based on eight indicators that form a subset of the indicators used in Davidsdottir et al. (2007): three economic indicators (total energy intensity, import dependency, share of renewable energy sources), two social indicators (share of energy expenditures in household income, share of the population with access to energy) and three environmental indicators (CO_2 emissions, NO_x emissions, SO_2 emissions).

Building on Davidsdottir et al. (2007), we develop a composite index of sustainable energy development for Austria. The index has the following innovative features: It is based on indicators that follow an energy service-centred perspective and are derived from a structural model of the energy system. In addition to a disaggregation according to the different dimensions of sustainability, our composite index provides a sectoral disaggregation of energy development. This detailing allows for valuable insights in the analysis of sectoral energy policy; at the same time the aggregation into a composite index ensures that information can be communicated easily.

For our composite index, we select 19 indicators as illustrated in Table 1. Four indicators refer to the ecological dimension (share or renewables and CO_2 efficiency in the residential sector and in electricity and heat supply respectively), eight indicators refer to the economic dimension (four of which address the efficiency of energy service provision in the residential sector, two the efficiency of electricity and heat supply and two apply to energy expenditures) and the remaining seven indicators refer to the social dimension (i.e. they measure the share of households that can afford a certain equipment). In addition to the disaggregation by dimension of sustainable energy development, the indicators can also be disaggregated by sector: 14 indicators can be assigned to the residential and five indicators to the energy sector. The selection criteria for the indicators for the composite index were that they provide information on the different levels of the energy system as illustrated above and on all dimensions of sustainable energy development. Changes in the energy service proxies are not included in the index, as they 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. Indicators of the composite index for sustainable energy development in Austria

Indicator	Dimension of sustainability	Sector
Share of RES in final energy consumption	Ecological	Residential
CO_2 efficiency of final energy consumption	Ecological	Residential
Share of RES in electricity and heat supply	Ecological	Electricity and heat supply
CO_2 efficiency of electricity and heat supply	Ecological	Electricity and heat supply
Efficiency of heating and air conditioning	Economic	Residential
Efficiency of warm water and cooking	Economic	Residential
Efficiency of lighting and computing	Economic	Residential
Efficiency of household appliances	Economic	Residential
Household energy expenditure	Economic	Residential
Transformation efficiency	Economic	Electricity and heat supply
Distribution efficiency	Economic	Electricity and heat supply
Gas burden	Economic	Electricity and heat supply
Share of households that can afford mobile	Social	Residential
Share of households that can afford internet	Social	Residential
Share of households that can afford TV	Social	Residential
Share of households that can afford PC	Social	Residential
Share of households that can afford DVD player	Social	Residential
Share of households that can afford washing machine	Social	Residential
Share of households that can afford dishwasher	Social	Residential

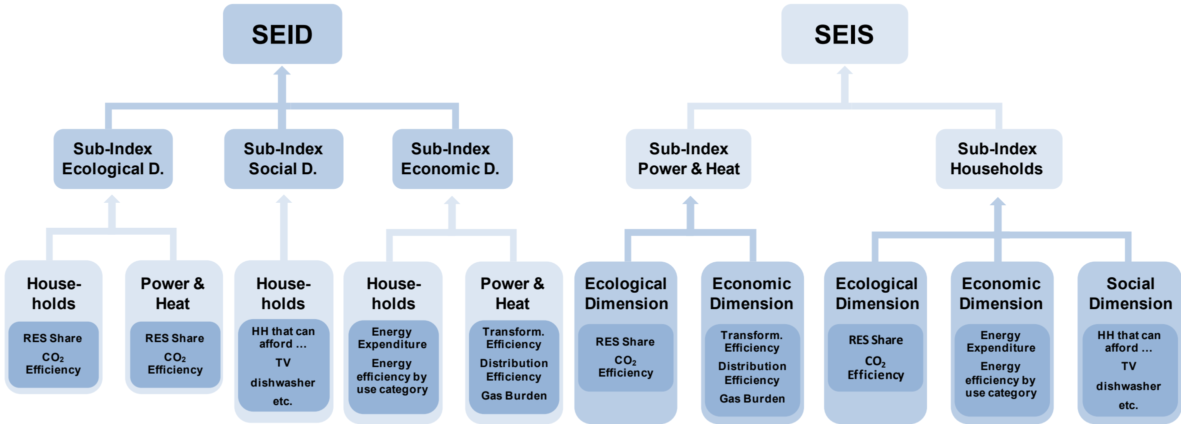
For the calculation of our sustainable energy index, we extend the method developed by Davidsdottir et al. (2007): The (sub-)indices are calculated as the weighted sum of the changes in the indicators compared to the base year and we also use a linear aggregation procedure and equal weights for computing the (sub-)indices[6]. In contrast to Davidsdottir et al. (2007), the sub-indices are then aggregated in two alternative two-step procedures (see Figure 4).

[6] Two indicators which contribute negatively to sustainable energy development – household energy consumption and gas burden – have to be included in the calculation with a negative sign.

Figure 4. Structure of the composite index for sustainable energy development in Austria

(a) Sustainable Energy Index aggregated by sector and dimension (SEID)

(b) Sustainable Energy Index aggregated by dimension and sector (SEIS)



The indicators can either be first aggregated by sector and in a subsequent step these sub-indices are aggregated by dimension (model A, SEID, equations 2a-2b) or vice versa (model B, SEIS, equations 3a-3b). $E_{s,j,t}$ and $E_{d,j,t}$ give the value of energy indicator *j* in year *t* and sector *s* and dimension *d* respectively. $SI_{s,t}$ is the sub-index for sector *s* in year *t* and $SI_{d,t}$ is the sub-index for dimension *d* in year *t*; *w* denotes the respective weights. The SEID illustrates progress in the different dimensions of sustainable energy development, while the SEIS puts the sectoral dimension of energy development in the centre.

(A) Aggregation by sector and dimension (SEID)

$$SI_{s,t} = \sum_{j,t} w_j * \left(\frac{E_{s,j,t}}{E_{s,j,t=0}} - 1\right) \quad (2a)$$

$$SI_{d,t} = \sum_{s,t} w_s * \left(\frac{SI_{s,t}}{SI_{s,t=0}} - 1\right) \quad (2b)$$

$$I_t = \sum_{d,t} w_d * \left(\frac{SI_{d,t}}{SI_{d,t=0}} - 1\right) \quad (2c)$$

(B) Aggregation by dimension and sector (SEIS)

$$SI_{d,t} = \sum_{j,t} w_j * \left(\frac{E_{d,j,t}}{E_{d,j,t=0}} - 1\right) \quad (3a)$$

$$SI_{s,t} = \sum_{d,t} w_d * \left(\frac{SI_{d,t}}{SI_{d,t=0}} - 1\right) \quad (3b)$$

$$I_t = \sum_{s,t} w_s * \left(\frac{SI_{s,t}}{SI_{s,t=0}} - 1\right) \quad (3c)$$

2.5 Data sources

We use mainly data from Statistics Austria that we complement with information from other publicly available databases. Energy-related CO_2 emissions are calculated using emission factors from the UNFCCC Inventory Submissions (UNFCCC, 2014) and can hence be provided for different energy use categories; data on air pollutants are taken directly from the Inventory Submissions. For energy R&D expenditures we use the IEA databases (IEA, 2014).

Data on the stock of household appliances are retrieved from the Odyssee Database (Odyssee, 2014); data on oil and gas reserves are from Geologische Bundesanstalt (2014). The data sources we use to compile the energy indicators are listed in detail in Table A - 1 in the Appendix, supplemented by information on data availability.

3 Results and Discussion

In this section we describe the development of the ISED-AT indicators and of the composite index for sustainable energy development in Austrian residential buildings and electricity and heat supply. Furthermore, we present the results of a sensitivity analysis for the composite index addressing the use of alternative weighting factors and aggregation methods as well as procedures for correcting for annual fluctuations in selected indicators.

3.1 Development of the ISED-AT indicators over time

Table 2 summarises the proposed energy indicators for the years 1990 and 2012 as well as their percentage change over this 22-year period. Starting from proxies for energy service demand, the indicators provide information on the development of final energy demand in the residential sector that is traced back over the whole energy chain to transformation input for electricity and heat supply.

From Table 2, one can see that energy service demand has considerably increased over time. With respect to the other areas, the indicators provide mixed evidence. The economic indicators show e.g. a decrease in the efficiency of energy service provision except for heating and air conditioning. This reflects the fact that the quality of the energy services warm water and cooking, lighting and computing and other energy services has improved, which is expressed by a pronounced increase of the number of appliances and electronic equipment per household over time and a corresponding increase of energy demand. While transformation efficiency of fossil power plants has improved, the efficiency of renewable plants deteriorated. This mirrors an increased use of biomass, which according to accounting conventions in energy balances, has a lower transformation efficiency than hydropower[7].

With respect to the ecological indicators, one can see that the share of renewable energy sources improved both in final energy consumption of the residential sector as well as in electricity and heat supply. The emission productivity, i.e. energy flows per unit of GHG and air pollutant emissions, also improved considerably between 1990 and 2012 which translated in an absolute decline of emissions. Total energy flows, in contrast, increased due to the increasing energy service volume and rising electricity and heat output. For the Kyoto commitment period 2008 to 2012, for Austria a GHG emission reduction target of 13% compared to 1990 applied. In the residential sector and in electricity and heat generation, emissions could be reduced even more. Total Austrian GHG emissions in contrast increased by 6% compared to 1990 in the Kyoto period, especially due to rising emissions from the transport and manufacturing sectors (UNFCCC, 2014); to comply with the Kyoto target, the

[7] For hydropower (as well as for wind power and PV) and transformation efficiency of 100% is assumed in energy balances.

reduction gap had to be filled with international emissions credits. In order to achieve the GHG reduction targets for 2020[8], the decarbonisation of the residential sector needs to be advanced and efforts in other sectors have to be intensified even further. With respect to the share of renewable energy sources in gross final energy consumption, Austria is well on track for reaching its target value of 34% in 2020 as defined by the EU's renewable energy directive (European Parliament and Council, 2009). Regarding energy efficiency, Austria aims at stabilising final energy consumption at 1,050 PJ until 2020. Particularly due to increasing energy service demand, little progress has been achieved in the reduction of final energy consumption in Austria. This holds also true for the residential sector. Until 2020, the challenges for Austrian energy and climate policy will hence lie particularly in increasing energy efficiency and reducing GHG emissions calling for an early and ambitious transformation of the energy system in order to achieve reductions in emissions and energy flows despite economic growth.

The social indicators also show a positive trend. With respect to the affordability of certain electricity consuming devices, good indicator scores were already achieved in 1990 and the indicators further improved until 2012. The share of energy costs in household income decreased for the first and fifth income quintile, but it slightly increased for the other income groups.

[8] EU-wide 20% compared to 2005 for sectors covered by the EU Emission Trading Scheme (EU ETS) and 16% for the Austrian Non-ETS sectors (Decision 406/2009/EC).

Table 2. Sustainable Energy Indicators for Austria 1990 and 2012

Dimension [of sustainability]	Sector	Indicator	Unit	1990	2012	(%-)change
Drivers / Context	Residential	Number of households	Mio.	2.9	3.7	26
		Household size		2.6	2.3	-13
		Average household income[1)]	1,000 €	12.5	13.9	11
		Average household income of first quintile[1)]	1,000 €	20.4	22.6	11
		Household energy prices	Index (1990=100)	100.0	200.6	101
		Floor area p.c.	m^2	36.1	48.1	33
		Refrigerators per household		1.0	1.0	2
		Freezers per household		0.6	0.9	33
		Washing machines per household		0.8	0.9	14
		Dishwashers per household		0.3	0.7	143
	Electricity and heat supply	Fuel prices	Index (1990=100)	100.0	331.3	231
		Energy R&D expenditures	‰ of GDP	0.1	0.4	670
		Installed renewable capacity	GW	10.9	14.6	33
		Installed fossil capacity	GW	5.7	8.2	42
Services	Residential	Well-tempered living space (Proxy: floor area)	Mio. m^2	276.8	405.0	46
		Illumination (Proxy: floor area)	Mio. m^2	276.8	405.0	46
		Warm water (Proxy: number of persons)	Mio.	7.7	8.4	10
		Cooking (Proxy: number of households)	Mio.	2.9	3.7	26
		Communication / Entertainment (Proxy: number of persons)	Mio.	7.7	8.4	10
		Other (Proxy: number of households)	Mio.	2.9	3.7	26
Economic	Residential	Efficiency of heating and air conditioning		1.4	2.1	49
		Efficiency of warm water and cooking		0.2	0.2	-3
		Efficiency of lighting and computing		1.2	0.7	-41
		Efficiency of household appliances		0.8	0.6	-26
		Share of energy expenditure in household expenditure	%	4.4	4.1	-8
	Electricity and heat supply	Transformation efficiency of fossil plants	%	48.3	62.1	29
		Transformation efficiency of renewable plants	%	98.0	85.7	-13
		Distribution efficiency	%	0.90	0.92	2
		Own gas reserves	Mrd.m^3n	17.6	20.6	17
		Own oil reserves	Mio. t	14.8	11.9	-20
		Reserves-to-production ratio (gas)	%	7.3	8.4	15
		Reserves-to-production ratio (oil)	%	9.5	7.1	-26
		Import dependency ratio	% of PES	73.7	92.7	26
		Gas burden	% of GDP	0.29	0.41	42
		Diversification of gas imports[1)]	Stirling index	0.26	1.04	
		Diversification of PES	Stirling index	1.54	1.67	

Table 2. Sustainable Energy Indicators for Austria 1990 and 2012 (continued)

		Share of RES in FEC	%	24.4	29.6	21
		CO_2 efficiency of residential final energy consumption	TJ/kt	24.4	40.0	64
		NO_x efficiency of residential final energy consumption	PJ/kt	17.5	24.2	38
		SO_2 efficiency of residential final energy consumption	PJ/kt	9.4	169.0	1,699
		CO_2 emissions from residential final energy consumption	Mt	10,0	6,9	-31
	Residential	NO_x emissions from residential final energy consumption	kt	13,9	11,4	-18
		SO_2 emissions from residential final energy consumption	kt	25,9	1,6	-94
		Final energy consumption for heating and air conditioning	PJ	192.7	201.9	5
		Final energy consumption for industrial furnaces	PJ	34.5	39.3	14
		Final energy consumption for lighting and computing	PJ	6.2	11.5	86
Ecological		Final energy consumption for stationary engines	PJ	10.0	22.4	123
		Share of RES in electricity and heat supply	%	40.6	59.7	47
		CO_2 efficiency of electricity and heat supply	TJ/kt	27.6	48.3	75
		NO_x efficiency of electricity and heat supply	PJ/kt	25.0	35.8	43
		SO_2 efficiency of electricity and heat supply	PJ/kt	25.5	177.8	596
		CO_2 emissions from electricity and heat supply	Mt	10.9	9.0	-17
	Electricity and heat supply	NO_x emissions from electricity and heat supply	kt	12.0	12.1	0
		SO_2 emissions from electricity and heat supply	kt	11.8	2.4	-79
		Transformation output from fossil fuels	PJ	86.3	108.5	26
		Transformation output from renewable energy sources	PJ	119.6	221.8	85
		Fossil transformation input	PJ	178.9	174.6	-2
		Renewable transformation input	PJ	122.1	258.9	112
		Share of households that can afford mobile[2)]	%	95.7	99.4	4
		Share of households that can afford phone[2)]	%	96.0	95.7	0
		Share of households that can afford internet[2)]	%	88.9	96.0	8
		Share of households that can afford TV[2)]	%	99.5	99.3	0
		Share of households that can afford PC[2)]	%	91.5	96.6	5
		Share of households that can afford DVD player[2)]	%	88.7	96.7	9
Social	Residential	Share of households that can afford washing machine[2)]	%	99.3	99.4	0
		Share of households that can afford dishwasher[2)]	%	92.9	96.1	3
		Share of heating costs in households income in first quintile[3)]	%	7.8	7.3	-6
		Share of heating costs in households income in second quintile[3)]	%	5.6	5.7	2
		Share of heating costs in households income in third quintile[3)]	%	5.0	5.1	2
		Share of heating costs in households income in fourth quintile[3)]	%	4.1	4.2	3
		Share of heating costs in households income in fifth quintile[3)]	%	3.1	3.0	-3

[1)] First year: 1995

[2)] First year: 2003

[3)] First year: 2004, second year: 2009

[4)] * denotes a positive development, - denotes a negative development

3.2 Development of the sustainable energy index for Austria over time

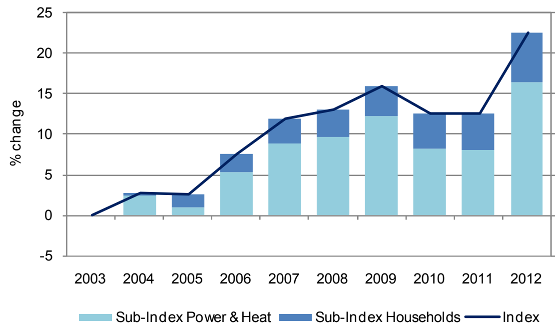
The composite index complements the ISED-AT indicator set as described above. It follows the energy service-focused perspective and captures changes along the whole energy chain, starting from the efficiency of the provision of energy services in the residential sector and ending with the environmental impacts of electricity and heat generation.

The development of the Sustainable Energy Development Index is presented in Figure 5 for the SEIS where the indicators are first aggregated by dimension and then by sector and in Figure 6 for the SEID where the information is first assembled by sector and then by dimension of sustainable development. The figures illustrate both the development of the aggregate index in the period over time and the development of the underlying sub-indices.

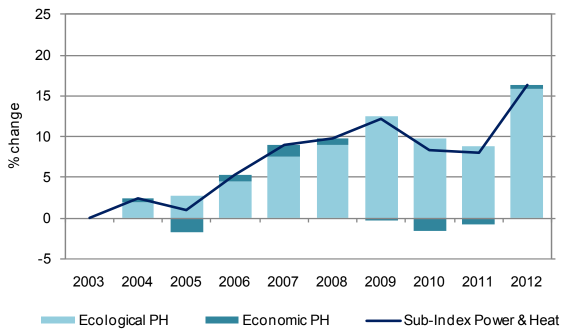
Between 2003 and 2009 the composite index increases by 15% for the sectoral aggregation model SEIS (Figure 5(a)). In 2010 and 2011 the index values declined by 3%. The SEIS finally recovers in the last years of the analysis, 2012, delivering an improvement of the index score of 23%. The lion's share of the improvement of the composite index can be attributed to developments in the power and heat sector. The detailed development of the sectoral sub-indices of the SEIS is illustrated in Figure 5(b) and Figure 5(c). The sub-index that describes the sustainability of the development in electricity and heat supply increased by 16% between 2003 and 2012. The increase was mainly driven by improvements of ecological aspects, i.e. rising CO_2 efficiency and a growing share of renewable energy sources. Economic aspects of power and heat generation, i.e. transformation and distribution efficiency and the gas burden, exhibit comparably little changes and in some years show a lower performance than in the base year 2003 which is mostly driven by changes of the indicator gas burden. The sub-index that describes the sustainability of energy development in the residential sector (Figure 5(c)) shows a continuous improvement between 2003 and 2012. As for electricity and heat supply, the development is mostly driven by a rising share of renewable energy sources used by the sector as well as improved CO_2 efficiency. Economic and social aspects make a small but positive contribution to the development of the index.

Figure 5. The Austrian Sustainable Energy Index by sector (SEIS), 2003–2012

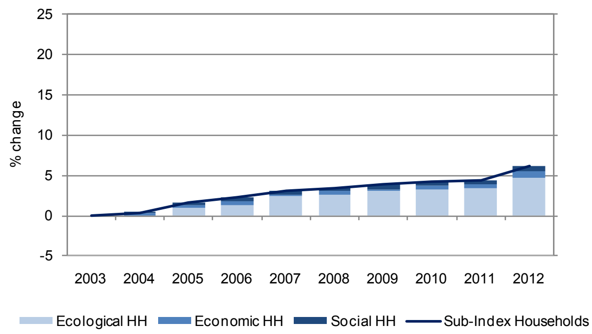
(a) Sustainable Energy Index by Sector



(b) Sub-Index Power and Heat

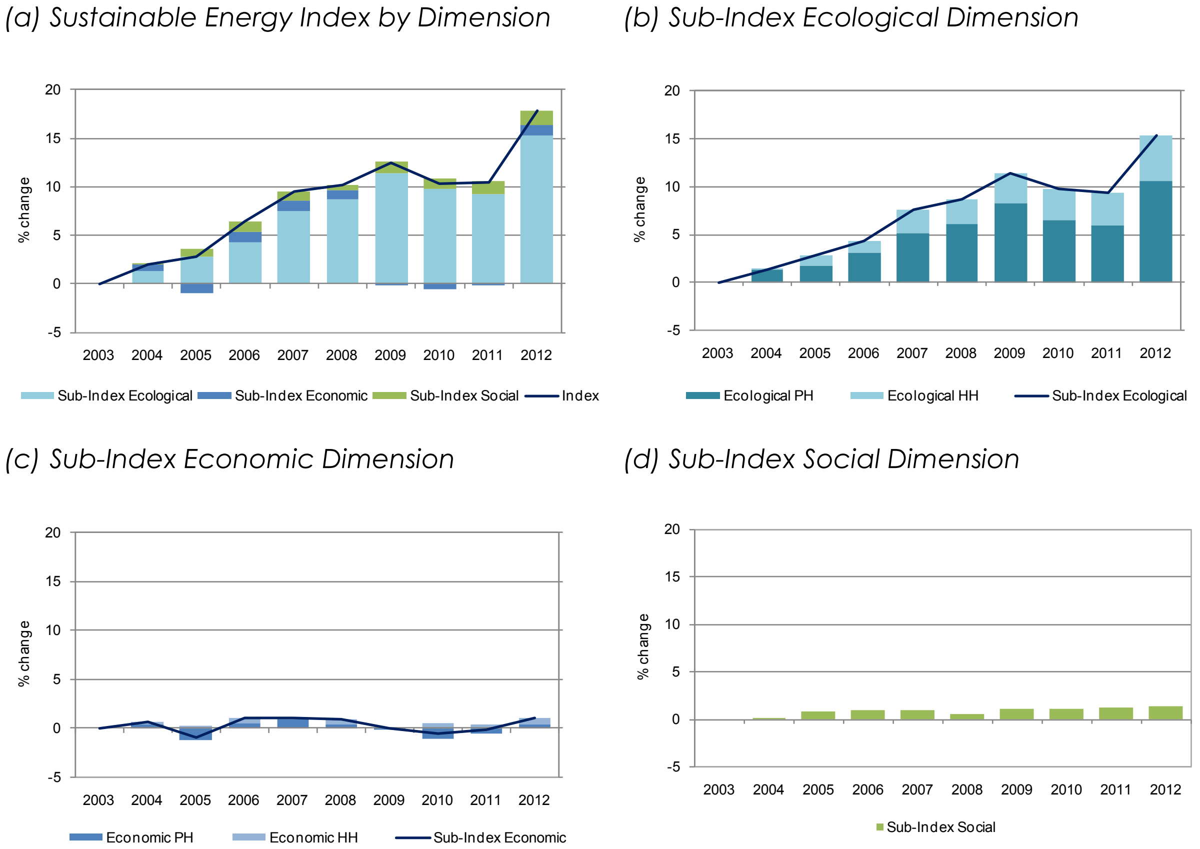


(c) Sub-Index Households



The development of the SEID which is based on three sub-indices for the different dimensions of sustainability (Figure 6(a)) shows a less pronounced increase than that of the SEIS described above, rising by 18% between 2003 and 2012. Again, changes in the ecological dimension account for the lion's share of the improvements of the composite index. Changes in the economic dimension and in the social dimension are, in contrast, of less relevance.

Figure 6. The Austrian Sustainable Energy Index by dimension (SEID), 2003-2012



The development of the composite indices is strongly driven by changes in electricity and heat supply, with the share of renewable energy sources as the predominant sectoral driver. Also with respect to the residential sector, changes in the energy mix, i.e. a shift towards renewable energy sources, are the decisive factor. Irrespective of the aggregation model, the indices show a rather continuous upward trend. When aggregated by dimension (Figure 6), the composite index shows somewhat lower growth rates than the index aggregated by sector (Figure 5). The disparity between the two aggregation models is due to the fact that in the aggregation by dimension, economic and social indicators that developed comparably slowly receive a higher weight (1/3 instead of 1/6 in the sectoral aggregation; compare Figure 4 above).

3.3 Sensitivity analyses

In order to validate the results of the analysis based on the composite index, sensitivity analysis is performed. This refers to the exemplary application of alternative weighting factors and aggregation procedures on the one hand and to utilisation of methods to handle annual fluctuations in the indicators on the other. The results of the sensitivity analysis are discussed for both versions of the composite index, i.e. for the sustainable energy index aggregated by sector (SEIS) as well as for the sustainable energy index aggregated by dimension (SEID).

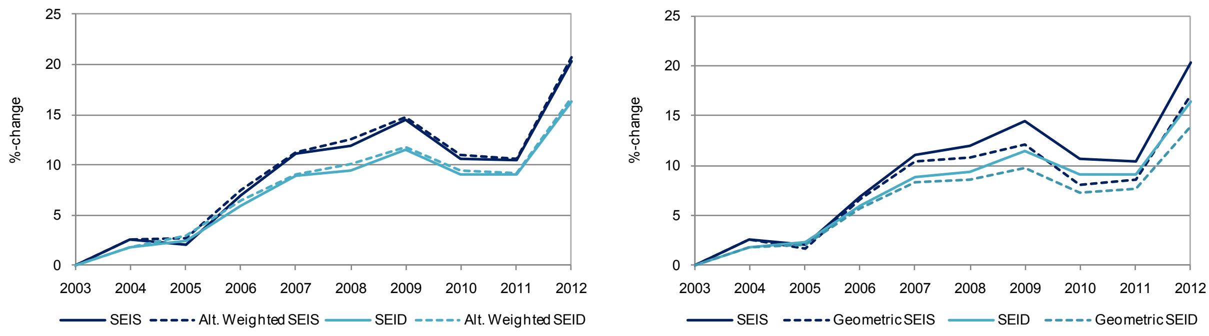
3.3.1 Alternative weighting factors and aggregation methods

One aspect of the sensitivity analysis refers to the application of alternative weighting factors. Initially, the indices were calculated using equal weights at all stages of the aggregation procedure. Alternatively, now for the indicators describing energy flows (efficiency of finale energy consumption by use category, transformation efficiency and distribution efficiency) the shares of the different use categories in final energy consumption and respectively the shares of transformation and distribution losses are used as weighting factors. For the remaining indicators, we continue to use equal weights as from our perspective there is no motivation for a differentiation of weights. The results of the analysis show that the use of this new weighting scheme implies only a small deviation from the initial index versions (see Figure 7(a)), i.e. somewhat lower index scores both for the SEIS and the SEID.

In addition to testing different weighting options, we explore the use of an alternative aggregation procedure. The SEIS and the SEID as described above were calculated with an additive aggregation procedure. One appealing benefit of this approach is that it allows a complete and straightforward graphical representation of the index. At the same time, additive aggregation implies, however, that positive and negative developments underlying the index are completely cancelled out, i.e. if one indicator or dimension deteriorates the index can still show a clear positive trend providing that the remaining indicators or dimensions perform sufficiently well. This is not the case for geometric aggregation procedures[9]. The results of the geometric aggregation are compared to those of the additive aggregation procedure in Figure 7(b). Between 2003 and 2007 there is virtually no difference between the approaches. After 2007, the index values based on the geometric aggregation are somewhat lower than for the initial versions of the SEIS and the SEID.

Figure 7. Implications of alternative weighting factors and aggregation methods

(a) Sustainable Energy Index: Different Weighting Methods | *(b) Sustainable Energy Index: Different Aggregation Methods*



[9] Mathematically, geometric aggregation procedures take the form of $I_t = \prod_{j,t} E_{j,t}^{w_j}$.

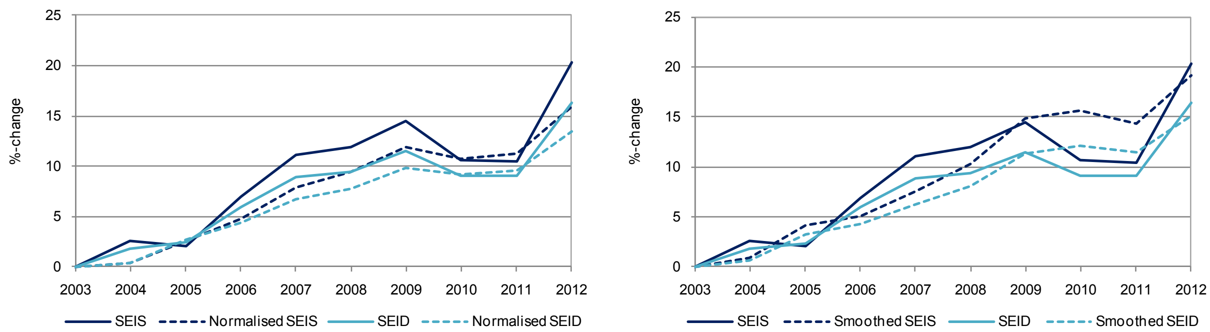
3.3.2 *Correcting for annual fluctuations*

Many energy indicators are prone to annual fluctuations, especially those related to energy supply from variable energy sources – such as wind or hydro power – or space heating demand. For Austria, this issue is of particular relevance due to the historically high share of hydro power for electricity supply. We present two options how to account for this issue. One option is to normalise energy flows from variable energy sources as proposed in the EU's renewable energy directive (European Parliament and Council, 2009), as illustrated in Figure 8 a. Here, transformation output from hydro and wind power plants is normalised by multiplying the installed capacity in each year with the average electricity generation per MW in the period 1990 to 2012. Compared to the initial calculations without standardisation, this approach also results in a clear upward trend, albeit at a somewhat lower level and corrected for the spikes resulting from differences in weather conditions.

Another option to correct for annual fluctuations is exponential smoothing of the data. We apply single exponential smoothing[10] to all indicators used in the computation of this index. Figure 8 b shows the smoothed SEIS and SEID using a smoothing factor of 0.7 and compares them with the original versions. The smoothed composite indices exhibit the highest deviations from the initial values while showing a rather constant upward trend that facilitates interpretation. One challenge of this approach lies, however, in the choice of an adequate smoothing factor.

Figure 8. Implications of normalisation and exponential smoothing

(a) Sustainable Energy Index: Normalisation *(b) Sustainable Energy Index: Exponential Smoothing*



[10] Exponential smoothing is a technique in time series analysis that is used to produce smoothed data series for presentation or forecast purposes. Single exponential smoothing takes the form of $s_t = \alpha \cdot x_{t-1} + (1-\alpha) \cdot s_{t-1}$, where s_t denotes the smoothed values of the indicator x in year *t*, x_{t-1} denotes the value of indicator x in the previous year, s_{t-1} denotes the smoothed values of the indicator in the previous year and α is the smoothing factor that can take values between 0 and 1. The smoothed value is hence the result of a weighted average of the previous observation and the previous smoothed value. The higher the value of the smoothing factor, the lower is the memory, i.e. higher factors have a lower smoothing effect and are more responsive to recent changes.

4 Conclusions and Policy Implications

In recent years, climate change and resource constraints have gained in importance in the political agenda. In its "Roadmap for moving to a competitive low carbon economy in 2050" (European Commission, 2011), the EU has defined ambitious long-run GHG emission reduction targets underlining the need of a fundamental transformation of prevailing energy systems for achieving this decarbonisation. For a transformation of our energy systems adequate information and monitoring systems are required. Indicator sets are considered a supportive tool to structure information on transition processes and to illustrate the interactions between economy, society and ecosystems.

The ISED-AT indicator system and the composite index for sustainable energy development that we propose in this paper focus on energy services instead of energy flows. This energy service-centred perspective makes them effective tools for monitoring and guiding an energy transition, as it allows the analysis of the whole range of technology options for providing a particular energy service. While in this paper we focus on the residential sector and electricity and heat supply, the conceptual framework can easily be extended to include other sectors such as transport or manufacturing. Our framework addresses all three dimensions of sustainable energy development. While with respect to the ecological and to the economic dimensions data availability is adequate, for the social dimension little meaningful information is provided in official statistics. In addition, the social indicators chosen here are only available for a short period of time. A further challenge lies in the definition of adequate proxy indicators for energy services. In order to capture energy services like information and communication adequate data on the household appliance stock would be required. In the absence of these data, we use population and the number of households as energy service proxies. This restriction implies the decrease in energy efficiency of cooking, lighting and computing and other specific-electric energy services, as relevant aspects such as energy service quality and the actual level of energy service demand cannot be accounted for.

We collected the ISED-AT indicators for Austria and computed the index to assess energy development in the period 2003 to 2012. The results indicate that Austria has performed particularly well with respect to the expansion of renewable energy sources. This reflects in first place the feed-in tariff system for renewable electricity generation which contributed to the increase of "new" renewable electricity generation, but also investment subsidies for small-scale PV plants, biomass heating systems and solar heating. With respect to energy efficiency, the data highlight that further efforts need to be undertaken, especially in the area of final energy demand. While energy efficiency for space heating and cooling has been increasing, final energy consumption was not substantially reduced over the past years. In other areas of residential final energy consumption, energy demand even rose due to rising energy service demand triggered by population growth and the increasing number of appliances per household. A comprehensive policy mix is hence required in order to incentivise energy efficiency improvements that allow for an absolute decoupling between energy service demand and final energy consumption in the Austrian residential sector. This includes the reorientation of housing subsidies from new buildings towards the thermal insulation of the building stock and energy-efficient urban and regional planning as well as policy instruments targeting household electricity use.

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Appendix

Table A - 1. Data sources

Dimension [of sustainability]	Sector	Indicator	Source
Drivers / Context	Residential	Number of households	Statistics Austria (2014a)
		Household size	Statistics Austria (2014a)
		Household income (by quintile)	Statistics Austria (2009a, 2004a)
		Energy prices	IEA (2014)
		Floor area p.c.	Derived indicator
		Equipment rate (by category)	Odyssee (2014)
	Electricity and heat supply	Prices	IEA (2014)
		Installed capacity (by plant type and energy source)	Eurostat (2014)
		Energy R&D expenditures	IEA (2014)
Services	Residential	Well-tempered living space (Proxy: floor area)	Statistics Austria (2013a, 2004b, 1993)
		Illumination (Proxy: floor area)	Statistics Austria (2013a, 2004b, 1993)
		Warm water (Proxy: number of persons)	Statistics Austria (2014b)
		Cooking (Proxy: number of households)	Statistics Austria (2014a)
		Communication / Entertainment (Proxy: number of persons)	Statistics Austria (2014b)
		Other (Proxy: number of households)	Statistics Austria (2014a)
Economic	Residential	Efficiency of heating and air conditioning	Derived indicator
		Efficiency of warm water and cooking	Derived indicator
		Efficiency of lighting and computing	Derived indicator
		Efficiency of household appliances	Derived indicator
		Share of energy expenditure in household expenditure	Statistics Austria (2009a, 2004a)
	Electricity and heat supply	Transformation efficiency (by plant type and energy source)	Statistics Austria (2013b)
		Distribution efficiency	Statistics Austria (2013b)
		Own gas reserves	Geologische Bundesanstalt (2014)
		Own oil reserves	Geologische Bundesanstalt (2014)
		Reserves-to-production ratio	Derived indicator
		Import dependency ratio	Derived indicator
		Gas burden	Derived indicator
		Diversification of imports	Derived indicator
		Diversification of PES	Derived indicator

Table A-1. Data sources (continued)

Ecological	Residential	% of RES in FEC	Statistics Austria (2013b)
		CO_2 efficiency of FEC	Derived indicator
		NO_x efficiency of FEC	Derived indicator
		SO_2 efficiency of FEC	Derived indicator
		CO_2 emissions from residential final energy consumption	UNFCCC (2014)
		NO_x emissions from residential final energy consumption	UNFCCC (2014)
		SO_2 emissions from residential final energy consumption	UNFCCC (2014)
		Final energy consumption (by use category and energy source)	Statistics Austria (2013c)
	Electricity and heat supply	% of RES in electricity and heat supply	Statistics Austria (2013b)
		CO_2 efficiency of electricity and heat supply	Derived indicator
		NO_x efficiency of electricity and heat supply	Derived indicator
		SO_2 efficiency of electricity and heat supply	Derived indicator
		Transformation output (by plant type and energy source)	Statistics Austria (2013b)
		CO_2 emissions from electricity and heat supply	UNFCCC (2014)
		NO_x emissions from electricity and heat supply	UNFCCC (2014)
		SO_2 emissions from electricity and heat supply	UNFCCC (2014)
		Transformation input (by plant type and energy source)	Statistics Austria (2013b)
Social	Residential	Share of HH that cannot afford mobile	Statistics Austria (2014, 2013d, 2012, 2011, 2010, 2009b, 2008, 2007, 2006, 2005)
		Share of HH that cannot afford phone	Statistics Austria (2014, 2013d, 2012, 2011, 2010, 2009b, 2008, 2007, 2006, 2005)
		Share of HH that cannot afford internet	Statistics Austria (2014, 2013d, 2012, 2011, 2010, 2009b, 2008, 2007, 2006, 2005)
		Share of HH that cannot afford TV	Statistics Austria (2014, 2013d, 2012, 2011, 2010, 2009b, 2008, 2007, 2006, 2005)
		Share of HH that cannot afford PC	Statistics Austria (2014, 2013d, 2012, 2011, 2010, 2009b, 2008, 2007, 2006, 2005)
		Share of HH that cannot afford DVD player	Statistics Austria (2014, 2013d, 2012, 2011, 2010, 2009b, 2008, 2007, 2006, 2005)
		Share of HH that cannot afford washing machine	Statistics Austria (2014, 2013d, 2012, 2011, 2010, 2009b, 2008, 2007, 2006, 2005)
		Share of HH that cannot afford dishwasher	Statistics Austria (2014, 2013d, 2012, 2011, 2010, 2009b, 2008, 2007, 2006, 2005)
		Share of heating costs in HH income by quintile	Statistics Austria (2009a, 2004a)