ÖSTERREICHISCHES INSTITUT
FÜR WIRTSCHAFTSFORSCHUNG

WORKING PAPERS

Assessing Energy Scenarios for Austria with the ISED-AT Framework

Claudia Kettner, Daniela Kletzan-Slamanig, Angela Köppl

496/2015

ÖSTERREICHISCHES INSTITUT FÜR WIRTSCHAFTSFORSCHUNG
AUSTRIAN INSTITUTE OF ECONOMIC RESEARCH

Assessing Energy Scenarios for Austria with the ISED-AT Framework

Claudia Kettner, Daniela Kletzan-Slamanig, Angela Köppl

WIFO Working Papers, No. 496

March 2015

Abstract

The mitigation of (anthropogenic) climate change requires an extensive decarbonisation of production and consumption activities and thus a major transformation of societal processes and energy systems. In order to monitor and evaluate the transformation path en route to the long-term climate and energy policy targets adequate information and measurement tools are required. In this paper we use the system of Indicators for Sustainable Energy Development for Austria (ISED-AT) and the complementing composite indices in a forward-looking approach, applying them to analyse changes in the energy system in three scenarios for the period until 2030. The analysis of household final energy demand and electricity and heat supply in Austria in the three scenarios reveals substantial progress in terms of ecological aspects, such as the share of renewable energy sources and CO2 emissions. With respect to energy efficiency, until 2030 an accelerated improvement that goes far beyond the rates observed in the past is assumed for the household sector. Making full use of the available potentials for energy efficiency improvements will be decisive for a fundamental transformation of the energy systems.

E-mail address: Claudia.Kettner@wifo.ac.at, Daniela.Kletzan-Slamanig@wifo.ac.at, Angela.Koeppl@wifo.ac.at

2015/076/W/0

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

Assessing Energy Scenarios for Austria with the ISED-AT Framework

Claudia Kettner, Daniela Kletzan-Slamanig, Angela Köppl

Abstract

The mitigation of (anthropogenic) climate change requires an extensive decarbonisation of production and consumption activities and thus a major transformation of societal processes and energy systems. In order to monitor and evaluate the transformation path en route to the long-term climate and energy policy targets adequate information and measurement tools are required. In this paper we use the system of Indicators for Sustainable Energy Development for Austria (ISED-AT) and the complementing composite indices in a forward-looking approach, applying them to analyse changes in the energy system in three scenarios for the period until 2030. The analysis of household final energy demand and electricity and heat supply in Austria in the three scenarios shows that substantial progress in terms of ecological aspects, such as the share of renewable energy sources and CO_2 emissions, is assumed. With respect to energy efficiency, until 2030 an accelerated improvement that goes far beyond the rates observed in the past is assumed for the household sector. Making full use of the available potentials for energy efficiency improvements will be decisive for a fundamental transformation of our energy systems.

Keywords: sustainable energy development, composite index, scenario analysis, Austria

JEL-codes: C34, Q49, Q54

1 Introduction

The mitigation of (anthropogenic) climate change requires an extensive decarbonisation of production and consumption activities and thus a major transformation of societal processes and energy systems. In order to monitor and evaluate the transformation path en route to the long-term climate and energy policy targets adequate information and measurement tools are required. Indicator systems are widely recognised as appropriate tools as they allow for capturing the complexity of the issue as well as the interactions between economy, society and the environment.

Increasing energy consumption is still regarded a prerequisite for (economic) development and welfare. However, energy services – i.e. "the physical amenity provided by energy-using equipment" (Thomas et al., 2000) like a well-tempered living space – and not the amount of energy flows ultimately determine wellbeing. As described in Kettner et al. (2015), incorporating energy services as relevant welfare generating element is hence essential in an indicator based analysis of the energy system's sustainability. A focus on energy services – instead of energy flows – extends the scope for identifying 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).

This paper builds on the work as described in Kettner et al. (2015) who developed indicators for sustainable energy development for Austria (ISED-AT) and specifically the composite index for energy sustainability in residential buildings and electricity and heat supply. In this framework, the demand-side indicators for residential energy demand are complemented by consistent indicators for sustainable electricity and heat supply, with the perspective of the whole energy chain.

We use the ISED-AT indicators and the composite indices in a forward-looking approach, applying them in order to analyse changes in the energy system in three scenarios for the period until 2030, with a particular focus on the years 2020 and 2030. We chose the horizon 2020/2030 for various reasons: The climate and energy targets defined for 2020 represent the intermediate, legally defined milestones on the way to long-term decarbonisation and the cornerstones in terms of the climate and energy targets for 2030 on EU level already have been set. Our paper delivers insights about the implications of changes in key energy indicators on the whole energy system from an ecological, economic and social perspective.

We use three scenarios that describe the development of key parameters of the Austrian energy system for the analysis of sustainable energy development until 2030. Our analysis compares the three recently published energy scenarios in terms of their impact on ecological, economic and social aspects. Two of the scenarios were developed for EU energy and climate monitoring (Monitoring Mechanism, MonMech) (Umweltbundesamt et al., 2013); the other scenario develops transformation options for the Austrian energy system that are consistent with the EU long-term energy and climate policy targets (Köppl and Schleicher, 2014). The information from the scenarios in terms of energy use and supply as well as the energy mix are used as framework conditions for the calculation of the ISED-AT indicators and index. Thus, the impacts of various levels of policy interventions on the energy system and its sustainability can be illustrated. Furthermore, differences in single sub-dimensions due to policy variations can be highlighted.

The paper is structured as follows: We start by describing our methodological framework for analysing changes in the Austrian energy system until 2020 / 2030 and present the development of central input parameters for our assessment. In the next section we discuss the development of the indicators in the three scenarios. The last section concludes and discusses the policy implications of our analysis.

2 Methods

Climate change and resource constraints require a fundamental transformation of the prevailing patterns of energy use and supply. Such a transformation calls for adequate measurement systems that are able to capture economic, ecological and social aspects. This multi-dimensionality cannot be accounted for by a single indicator, but requires indicator sets that can structure complex issues and illustrate the interactions between economy, society and ecosystems. Composite indices can complement indicator sets as they facilitate the monitoring of climate and energy policy over time since interpreting and comparing many different indicators proves difficult when an overall conclusion about energy sustainability and emission reductions is aspired.

Sets of sustainable energy development indicators can be used for assessing the historical performance as well as potential future developments. In both cases, the indicators can deliver valuable insights as they broaden the perspective of the energy system and include economic, ecological and social aspects.

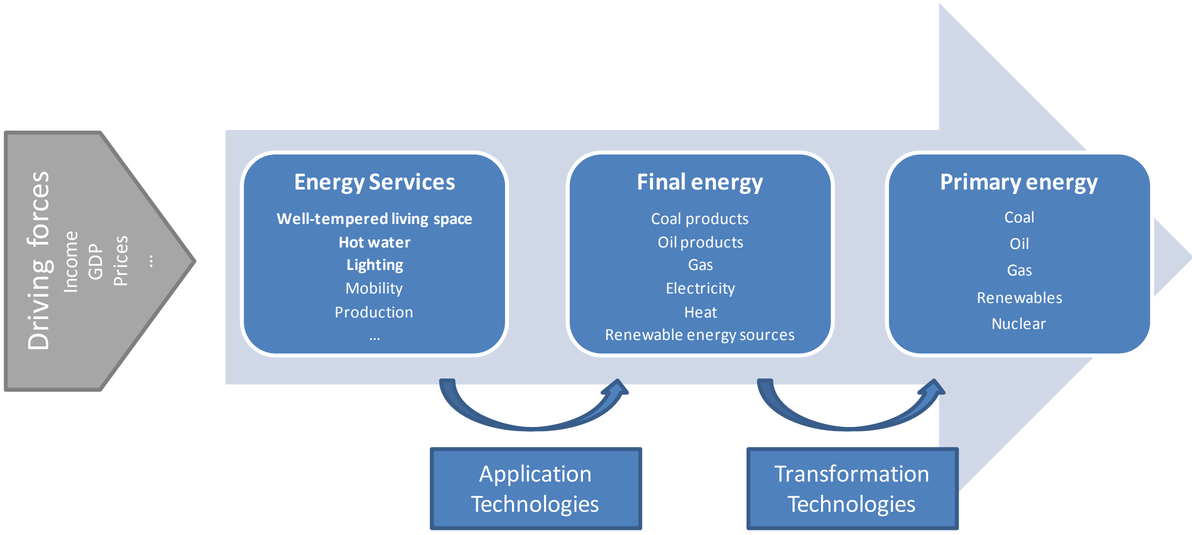
In the next sections we describe the indicator framework we use for the analysis of the sustainable energy development in Austria as well as the key assumptions underlying the scenarios as well as the data sources used.

2.1 The ISED-AT framework

Our analysis is based on the framework of indicators for sustainable energy development for Austria (ISED-AT) and the composite index for sustainable energy development proposed by Kettner et al. (2015). Using the comprehensive indicator concept by IEA and IAEA (2001) and IAEA et al. (2005) as a starting point, Kettner et al. (2015) develop an indicator system and composite index that emphasise the role of energy services instead of energy flows for wellbeing and compile these measures for Austria with a focus on residential buildings and electricity and heat supply. For the residential sector, operational indicators are defined starting from the most relevant energy services.

Energy services (e.g. well-tempered living space, lighting) can be provided by different combinations of capital stocks (buildings, heating systems, etc.) and energy flows. Due to the wide range of available combinations of capital stocks and energy flows, the provision of a given quantity of energy services can entail very different volumes of energy flows and greenhouse gas (GHG) emissions. Figure 1 illustrates this relationship between energy services, energy flows and the technologies embodied in the capital stocks, as well as the socio-economic drivers of energy consumption.

Figure 1. Structure of the energy system



Source: Kettner et al. (2015). Building-relevant energy services are in bold letters.

In the ISED-AT framework, the indicators for residential buildings 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. In addition, social aspects of residential energy use are included[1]. As data on energy services is not readily available in official statistics (see e.g. Köppl et al., 2014; Ma et al., 2012), Kettner et al. (2015) define and compile proxy indicators for six major categories of residential energy services: 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; proxy: number of households). The volume and quality of relevant capital stocks in the housing sector is described with the indicators energy efficiency of the service provision (by service type), by the floor area by type of building and construction period and the number of appliances (by type). Further ISED-AT indicators include final energy consumption in the household sector as result of energy service demand and the energy efficiency of the capital, differentiated by use category (heating and cooling, cooking etc.) and energy source, as well as GHGs and air pollutants (CO_2, NO_x and SO_2) emitted during household final energy consumption.

1 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.

The ISED-AT indicators for electricity and heat supply in Kettner et al. (2015) cover four topics: Electricity and heat consumption as the most important determinants of energy 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. Moreover, cost aspects, i.e. the cost of fossil fuels for electricity and heat generation, are considered.

In addition to the indicator set, Kettner et al. (2015) propose two composite indices that reflect the sustainability of energy use over time in a aggregated way. The indices are based on a selection of indicators that follow an energy service-centred perspective and provide information on the different levels of the energy system and on the three dimensions of sustainable energy development. While aggregate developments are difficult to grasp with indicator systems, as interpreting and comparing many different indicators proves difficult, composite indices provide a condensed view. Compared to systems of indicators, composite indices reduce the complexity and provide a useful instrument for policy monitoring and decision making and can be used as a communication tool. In case of a composite index, one has, however, to keep in mind that by aggregating single indicators into composite indices, information about specific details (e.g. sectoral developments) might get lost. Therefore we also report the single indicators delivering important information about different aspects of sustainable energy development.

The (sub-)indices are calculated as the weighted sum of the changes in the selected indicators compared to the base year and aggregated by applying two alternative two-step procedures. One option is to first aggregate the indicators into sectoral sub-indices and then aggregate these sectoral sub-indices by dimension (SEID). Alternatively, the first aggregation step is performed along the dimensions of sustainable energy development and then the sub-indices are aggregated on the sector level (SEIS). The SEID illustrates progress in the different dimensions of sustainable energy development, while the SEIS focuses on the sectoral dimension of sustainable energy development. Both indices are calculated using equal weights for the sectors and dimensions[2] and a linear aggregation procedure (see Appendix 1).

2.2 The indicators used for the outlook until 2030

Kettner et al. (2015) demonstrate the use of the energy service-based indicator framework and the derived composite indices for residential buildings and electricity and heat supply for the period 2003 to 2012. For our forward-looking analysis of changes in the Austrian residential sector and electricity and heat supply up to 2030 we chose 23 indicators as summarised in Table 1. On the one hand, the indicators can be grouped according to the dimension of sustainable development they describe; on the other hand the indicators can be grouped according to their sectoral focus. The indicators chosen are characterised by good data availability and quality and provide information on all levels of the energy system – from

[2] For power and heat supply and the household sector, indicators addressing the efficiency of energy supply and of final energy consumption respectively are weighted according to their relevance in terms of energy flows.

energy services to the provision of energy – and on all dimensions of sustainable energy development.

Out of the 23 indicators, four indicators describe the volume of energy services in the demand side sectors reflecting four central categories of energy services that are taken into account: well-tempered living space (approximated by the floor area of dwellings in m^2), warm water and cooking (approximated by population), communication and entertainment (also approximated by population), and other energy services (i.e. energy services provided by household appliances like freezers or washing machines; for these energy services we use the number of households as proxy). Eight indicators focus on the environmental dimension of sustainable energy; they capture the share or renewable energy sources and CO_2 efficiency in the four demand sectors and in electricity and heat supply respectively. Seven indicators refer to the economic dimension. These indicators include the efficiency of energy service provision in the residential sector as well as the efficiency of electricity and heat supply. Furthermore, energy expenditures per household are considered. Four indicators refer to the social dimension of sustainable energy development; they measure the share of households that can afford a certain equipment.

In terms of sectoral disaggregation, 17 indicators focus on the residential sector and six on electricity and heat supply.

15 out of the 23 indicators are aggregated into composite indices (see Table 1). As they cannot be interpreted in an unambiguous way changes in the energy service proxies are not included in the composite indices – 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. All variables that are included in the composite indices are standardised with the basis 2010 = 100. The indicator 'energy costs per household' describes a negative development and is hence recalibrated so that an increase in the indicators represents an improvement just as an increase of the other indicators.

Table 1. Indicators of the composite index for sustainable energy development in residential buildings and electricity and heat supply in Austria

Sector / Dimension	Households	Electricity and heat supply
Ecological Dimension	**RES-share in final energy consumption** **CO_2 efficiency of final energy consumption** Final energy consumption Energy-related CO_2 emissions	**RES-share in transformation input** **CO_2 efficiency of transformation input** Transformation input Energy-related CO_2 emissions
Economic Dimension	**Efficiency of heating and air conditioning** **Efficiency of warm water and cooking** **Efficiency of lighting and computing** **Efficiency of household appliances** **Energy costs per household**	**Transformation efficiency** **Distribution efficiency**
Social Dimension	**Share of HH who can afford TV** **Share of HH who can afford PC** **Share of HH who can afford washing machine** **Share of HH who can afford dish washer**	
Energy Service	Well-tempered living space Warm water and Cooking Illumination, Communication and Entertainment Other	

Indicators that are included in the composite indices are written in bold letters.

2.3 Scenarios

With the composite indices and the ISED-AT indicator framework, we analyse the development of the Austrian energy system until 2030. We chose the horizon 2020/2030 for various reasons. 2020 represents the year for which the EU has defined its targets in the Climate and Energy Package (European Commission, 2008) that were subsequently integrated into Europe 2020 as headline targets: Reducing greenhouse gas (GHG) emissions by 20% compared to 1990; a 20% share of renewable energy sources in gross final energy consumption; and improving energy efficiency by 20% compared to a business as usual scenario. The European targets were translated into national targets for the Member States. These targets represent the intermediate, legally defined milestones on the way to long-term decarbonisation. According to the effort sharing decision, the European target for Austria implies an emission reduction of 16% for non-ETS sources until 2020 as well as a 21% cut in GHG emissions from sectors covered by the EU ETS (relative to 2005). Regarding renewable energy sources, Austria's 2020 target is a share of 34% in gross final energy consumption. As for the energy efficiency target, the Austrian Energy Efficiency Act (BGBl. I Nr. 72/2014, 2014) determines that Austria's final energy consumption in 2020 shall be reduced to a maximum of 1.050 PJ[3]. For 2030, the EU aims at a further decarbonisation of the energy system (European Commission, 2014; European Council, 2014): Greenhouse gas emissions shall be reduced by 40% compared to 1990, the share of renewable energy sources should be increased to 27% and energy efficiency should be increased by 27-30%. Although no specific targets for the EU Member States have been defined (yet), the 2030 EU targets imply that significant progress in terms of the transformation of the energy system will be required in all Member States.

For the outlook until 2030 we use three recent energy and climate policy scenarios for Austria. Two scenarios that are used in our analysis – the MonMech "WAM" and "WEM" scenario – were developed by Umweltbundesamt et al. (2013) as a part of the reporting obligations under the EU's Monitoring Mechanism (European Parliament and Council, 2013) and serve as a basis for the discussion for national climate policy. The other scenario develops transformation options for the Austrian energy system that are consistent with the EU long-term energy and climate policy targets (Köppl and Schleicher, 2014).

The MonMech scenarios cover the period from 2010 to 2030. With respect to the context parameters such as economic and price development, both scenarios share the same assumptions (Table 2): Population and dwelling area are assumed to increase by 7% and 13% respectively until 2030. Furthermore, the scenarios are based on the assumption of rising energy and carbon prices. The scenarios implyaverage annual growth rates of 1.5% (Kratena et al., 2013).

Table 2. Development of context indicators in the MonMech scenarios

Parameter	2010	2020	2030
GDP (bn. 2010 €)	286	340	410
Population (1,000)	8,382	8,733	9,034
Heating Degree Days	3,241	3,100	3,006
Dwellings (1,000)	3,683	3,957	4,166
International coal price (2010 US$ / t)	99.2	109	116
International oil price (2010 US$ / bbl)	78.1	118	135
International gas price (2010 US$ / GJ)	7.1	10.4	11.9
Carbon price (€ / t CO_2)	13	20	30

Source: Data from Umweltbundesamt et al. (2013).

The baseline scenario "WEM" (with existing measures) incorporates all measures and policies on energy use and climate protection bindingly enacted before March 8, 2012. The scenario "WAM" (with additional measures) includes assumptions on additional measures, which are being discussed on the political level and whose implementation is regarded as likely and will

[3] Initially, Austria aimed at a stabilisation of final energy consumption at 2005 levels, i.e. 1,100 PJ. In 2014, a target of 1,050 PJ was adopted in the Austrian Energy Efficiency Act.

reach their full effectiveness only until 2030. The measures assumed in the WEM and WAM scenario are listed in Appendix 2 differentiated by the sector to which they apply.

In the WEM scenario, final energy consumption increases by approximately 40 PJ (from 1,119 PJ to 1,157 PJ) between 2010 and 2020 despite the measures in place; in 2030 final energy consumption reaches 1,235 PJ. Gross final energy consumption rises from 1,458 PJ in 2010 to 1,504 PJ in 2020 and 1,617 PJ in 2030. The share of renewables in final energy consumption in the WEM scenario peaks at 33.4% in 2020 and subsequently decreases to 32.6% in 2030. Greenhouse gas emissions in the Non-ETS sectors are reduced by 10% in 2020 compared to 2005.

In the WAM scenario, the additional measures ensure that final energy consumption in 2020 is slightly below 1,100 PJ – the initial Austrian energy efficiency target – and subsequently slightly increases to 1,150 PJ in 2030; the target of a reduction of final energy consumption to 1,050 PJ as defined in the Austrian Climate and Energy Protection Act is not met. Gross final consumption amounts to 1,444 PJ in 2020 and 1,526 PJ in 2030. The share of renewable energy sources increases to 34.7% in 2020 and 36.0% in 2030 respectively. Greenhouse gas emissions from Non-ETS sources are 16% below 2005 levels.

Table 3. Development of key parameters in the WEM and WAM scenario

Parameter	2010	WEM		WAM	
		2020	2030	2020	2030
Final energy consumption (PJ)	1,119	1,157	1,235	1,099	1,150
Household final energy consumption (PJ)	287	241	217	244	224
Primary energy supply (PJ)	1,458	1,504	1,617	1,444	1,526
RES-share in gross final energy consumption (%)	30.8	33.4	32.6	34.7	36.0
GHG emission reduction in Non-ETS sectors (%)		10.0		16.1	

Source: Data from Umweltbundesamt et al. (2013).

Köppl and Schleicher (2014), in contrast, use a backcasting approach for analysing changes in the Austrian energy system up to 2030. The choice of a backcasting approach was motivated by the (inherent) uncertainties regarding future economic development and its relationship with energy use. As in the ISED-AT framework, the analysis focuses on welfare-generating energy services instead of energy flows and illustrates the role of different technology options for the provision of energy services (see Figure 1. Structure of the energy systemFigure 1 above). The "A scenario" (EA) is consistent with the long-term EU energy and climate policy targets and ensures that Austria meets its targets for 2020.

Based on the structure of the Useful Energy Balances for Austria (Statistics Austria, 2013a), Köppl and Schleicher (2014) present long-term innovation potentials for the demand side sectors. These potentials take into account the long-term changes in useful energy demand due to changes in the volume of energy services and application technologies, an alignment of the quality of the final energy demand to the structure of the useful energy[4] as well as a shift of the primary energy towards renewable energies. The estimated energy flows in 2020 and 2030 are derived based on detailed assumptions of the diffusion rates of structural parameters (i.e. energy service demand, energy efficiency and share of low-carbon technologies in the energy mix) towards their long-term potentials.

In the EA scenario by Köppl and Schleicher (2014), final energy consumption is reduced to 1,050 PJ and to 905 PJ in 2030. Gross final energy consumption decreases from 1,458 PJ in 2010 to 1,361 PJ in 2020 and 1,168 PJ in 2030. The share of renewables in gross final energy consumption amounts to 35.5% in 2020 and further rises up to 44.2% in 2030.

Table 4. Development of key parameters in the EA scenario

Parameter	2010	EA 2020	EA 2030
Final energy consumption (PJ)	1,119	1,050	905
Household final energy consumption (PJ)	287	260	232
Primary Energy Supply (PJ)	1,458	1,361	1,168
RES-share in gross final energy consumption (%)	30.8	35.5	44.2

Source: Data from Köppl and Schleicher (2014).

The measures analysed in the WEM scenario are not sufficient for achieving the 2020 targets. In the case of the WAM scenario, in contrast, Austria’s Non-ETS greenhouse gas reduction target is met and the renewables target is even overachieved. With respect to the energy efficiency target, the initial target of 1,100 PJ in 2020 is reached, while the target of 1,050 PJ according to the Austrian Energy Efficiency Act is exceeded. In the EA scenario, the renewables target is overachieved and the 1,050 PJ energy efficiency target is met. But what do these key figures mean in terms of a transformation of the energy system? I.e., for which sectors the highest energy efficiency improvements are expected, where are the most pronounced changes in the energy mix assumed, and what are the cost implications? We assess these issues using the composite indices of sustainable energy development that we presented above. These indices on the one hand provide a condensed view of energy development in the three scenarios and on the other hand allow for a sufficiently detailed analysis both on the sectoral level and with respect to the different aspects of sustainable energy development.

2.4 Data sources

With regard to the historical data up to 2010, we mainly use data from Statistics Austria (2014a, 2014b, 2014c, 2013a, 2013b, 2013c, 2004, 1993). 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.

[4] E.g. a reduction of gas and electricity for low-temperature heat.

For the development of the parameters up to 2030 in the MonMech scenarios, we use data from Umweltbundesamt et al. (2013) on energy flows, GDP, population and living space[5]. With respect to the EA scenario, information on the development of energy flows is taken from Köppl and Schleicher (2014)[6]. These data are complemented with data from the household and population projections by Statistics Austria (2014a, 2014b) and own estimations of the development of living space based on the household forecasts. On the development of the social indicators no information is available in the three scenarios. For the social indicators we therefore assume that in 2030 100% of the Austrian population can afford the use of certain electronic devices, which implies only little improvement compared to 2010.

3 Results and Discussion

In this section we use the composite index for sustainable energy development in Austria to analyse developments in the three scenarios, the MonMech scenarios "WEM" (with existing measures) and "WAM" (with additional measures) and the EA scenario, until 2030. The composite indices follow the energy service-focused perspective as described above and capture changes along the whole energy chain, starting from the efficiency of the provision of energy services in the demand-side sectors and ending with the environmental impacts of electricity and heat generation.

Figure 2 presents the development of the SEIS, where the indicators are first aggregated by dimension and then by sector. In Figure 2(a) the development of the SEIS in the scenarios between 2003 and 2030 is illustrated; Figure 2(b) disaggregates the results by sector.

Between 2010 and 2020 the SEIS increases by 16% in the WEM scenario, by 17% in the WAM scenario and by 8% in the EA scenario; the assumed improvement in terms of sustainable energy demand is hence higher than it was observed in the period 2003 to 2010 For the period 2020 to 2030, improvements accelerate in the EA scenario while they decelerate in the MonMech scenarios. Overall, in 2030 the index values of the SEIS are 18% higher than in 2003 in the WEM scenario, and 24% higher in the WAM and in the EA scenario.

The contribution of the subsectors to this development is illustrated in Figure 2(b). In all scenarios, the lion's share of the improvement of the composite index can be attributed to developments in power and heat supply, and mainly reflect an improvement of CO_2 efficiency as well as in the share of renewable energy sources in these sectors[7]. Especially in the EA scenario until 2030, the CO_2 efficiency of electricity and heat supply makes a significant contribution as it increases by more than 90% (reflecting i.a. a strongly decreasing share of coal in transformation input); the share of renewables between 2010 and 2030

[5] The variables of the MonMech scenarios are reported for four years (2015, 2020, 2025 and 2030); in order to derive annual values we interpolate between these years.

[6] In Köppl and Schleicher (2014), the variables are reported for 2020 and 2030; in order to derive annual values we interpolate between these years.

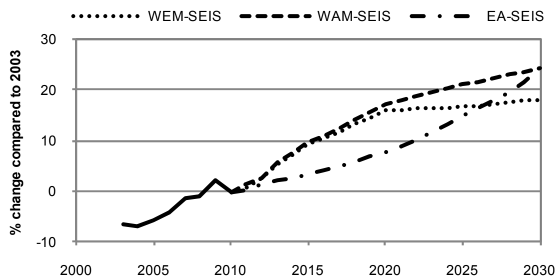
[7] A link between the share of renewable energy sources and CO_2 efficiency exists, as a stronger role of renewable energy sources reduces the average carbon content. The fossil energy mix is, however, a second decisive factor that influences CO_2 productivity.

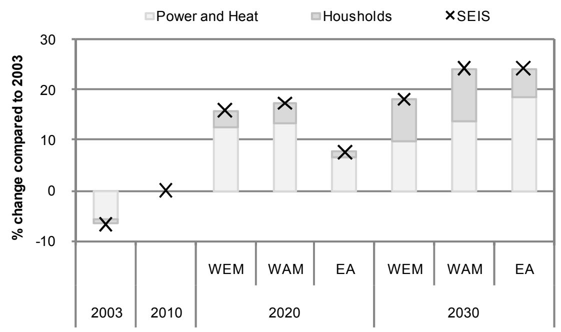
increases continuously and eventually is 40% above the level of 2010. In comparison, CO_2 efficiency of electricity and heat supply in the WEM and WAM scenario until 2030 increases by 40% and 60% respectively; the renewables share in electricity and heat generation in these scenarios rises by 30% in the WEM and WAM scenario until 2020; then it stays constant in the WAM scenario until 2030, while it declines again in the WEM scenario (see Table A - 1 in the Appendix).

Until 2020, the index shows a moderate improvement for the household sector in all scenarios, reflecting mainly improvements in energy efficiency as well as in the share of renewable energy sources. Improvements in the sector accelerate until 2030, especially in the WEM and the WAM scenario. In all scenarios, an increasing share of renewable energy sources contributes to the development of the index; in the WAM and WEM scenario energy efficiency improvements, however, also deliver a significant contribution.

Figure 2. Development of the Austrian Sustainable Energy Index by sector (SEIS) in energy scenarios up to 2030

(a) Aggregate results *(b) Results by sector*





The development of the SEID, for which the indicators are first aggregated by sector and then by dimension, is presented in Figure 3. The development of the composite index in the three scenarios between 2003 and 2030 is illustrated in Figure 3(a); Figure 3(b) shows the results disaggregated by dimension.

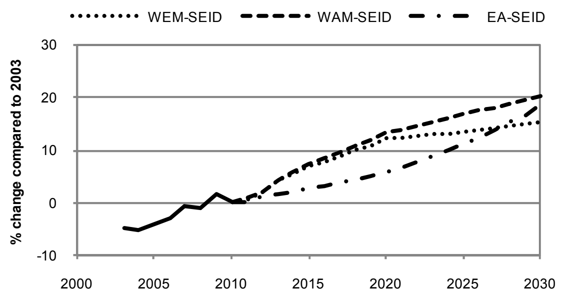
Overall, the SEID shows a somewhat lower improvement than the SEIS. Until 2020, the index improves by 12% in the WEM scenario and by 13% in the WAM scenario respectively compared to 2010. In the EA scenario, the index improves by 6% which is in line with improvements in the period 2003 to 2010. For 2030 the respective values are +15% in the WEM, +20% in the WAM scenario and 19% in the EA scenario. Between 2020 and 2030, improvements accelerate again in the EA scenario while they decelerate in the MonMech scenarios.

The largest improvements stem from advancements in the ecological dimension of sustainable energy development, i.e. CO_2 efficiency and the share of renewable energy sources, especially in power and heat supply. Changes in the economic dimension of sustainable energy development make a comparably little contribution to the SEID. Only in the WEM and WAM scenario in the horizon until 2030, efficiency improvements in the household sector deliver a non-negligible contribution and are significantly higher than in the past where they were not sufficient to compensate for rising energy service demand.

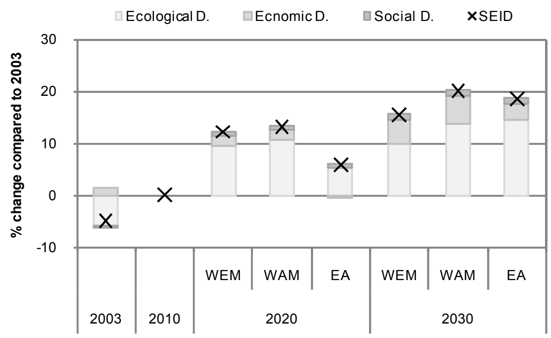
As noted above, with respect to the social dimension of sustainable energy development the same rate of improvement is assumed for all scenarios[8]. Here, little improvement is observed until 2030; this is due to the fact that the indicators we use for this dimension, i.e. the affordability of a range of electronic devices, have already achieved high values, which means that now there is not much potential left for improvements.

Figure 3. Development of the Austrian Sustainable Energy Index by dimension (SEID) in energy scenarios up to 2030

(a) Aggregate results



(b) Results by dimension



It is worth noting that the WAM and the WEM scenario that do not meet (all) the Austrian energy and climate policy targets defined for 2020 show a higher improvement for the SEID and the SEIS compared to the EA scenario, particularly until 2020. This is due to the fact that in our analysis only two sectors are included, one of which is the household sector who shows the largest improvements in the MonMech scenarios. With respect to the other sectors that are not included in our assessment until 2030 – i.e. transport, industry, agriculture and services – higher improvements are expected in the EA scenario that lead to a better performance on the whole in terms of overall sustainable energy development.

4 Conclusions and Policy Implications

Climate change and resource constraints have gained in importance in the political discussion over the past two decades. The targets defined in the Energy and Climate Package for 2020 constitute a first milestone in European climate policy: EU greenhouse gas emissions shall be reduced by 20% compared to 1990; the share of renewable energy sources in gross final energy consumption shall be increased to 20%; and energy efficiency shall be improved by 20% compared to a business as usual scenario. For Austria, these targets translate into an emission reduction of 16% for non-ETS sources until 2020 and of 21% in EU ETS

[8] Data availability and quality with respect to the social indicators is far from being sufficient. In addition, no long-term targets for the social dimension of energy development exist in Austria or in the EU and no assumptions on this issue were made in the three scenarios.

sectors (relative to 2005), a share of renewables in gross final energy consumption of 34%, and a limit of final energy consumption of 1,050 PJ. For the period until 2050, the EU aims at a significant decarbonisation of existing energy systems, which entails a radical transformation of the existing patterns of energy use and supply (European Commission, 2011).

Indicator systems and composite indices are supportive tools for structuring information on an energy transition and taking into account the interactions between economy, society and ecosystems. In this paper, we apply the framework of indicators for sustainable energy development for Austria (ISED-AT) developed by Kettner et al. (2015) to analyse sustainable energy development in energy and climate policy scenarios for Austria up to 2030.

For the assessment of future energy development, we use three scenarios. One scenario, WEM, describes the development of energy flows until 2030 based on existing policy measures; the other scenario, WAM, assumes that additional measures to promote energy efficiency and a decarbonisation of the energy mix are implemented. The measures as simulated in the WEM and WAM scenario are not sufficient for complying with the 2020 climate and energy policy objectives for Austria. The EA scenario assumes that both the energy efficiency target and the target for renewable energy sources are achieved in 2020.

Our analysis with the composite index and the indicator system detects large differences at the sectoral level as well as regarding the different dimensions of sustainable energy development. In general stronger improvements are achieved in the ecological dimension than with respect to the economic aspects. The progress in the two sectors differs significantly: The share of renewable energy sources in the provision of electricity and heat increases by 20% (in the WEM scenario) to 91% (in the EA scenario) until 2030; in the household sector an increase of 13% (in the EA scenario) to 16% (in the WEM and WAM scenario) is observed. Also with respect to changes in energy efficiency, there are large differences across sectors; here substantial improvements are assumed in the household sector in the WEM and WAM scenario, while only a slight improvement shows for electricity and heat supply. In the EA scenario, energy efficiency improvements are of little importance.

The measures that are already in place or currently are being planned, represent only a small building block for the transformation of the energy system. For a fundamental transformation of the energy system an absolute decoupling of energy service demand and energy consumption is essential. This means that comprehensive measures must be taken in all sectors. For the household sector the greatest potential lies in the reduction in energy consumption for space heating and cooling as also assumed in the MonMech scenarios until 2030. This will pose a major challenge for energy policy, as energy efficiency improvements in the past have been comparably low. In this area, the building standards need to be raised and the refurbishment of the building stock needs to be increased. A change of spatial planning in terms of compact residential structures, can also contribute to a reduction of energy demand for space heating and cooling. With respect to electrical equipment, standards can contribute to the reduction of energy consumption. With respect to electricity and heat supply, the use of renewable energy sources needs to be further expanded. Since the "new" renewable electricity generation technologies such as wind power or PV provide variable output, the expansion of renewables needs to be complemented by a transformation of power grids; The long-term transformation of energy systems not only requires fundamental changes in patterns of energy use and primary energy supply but also in all relevant technologies along the energy chain.

Acknowledgements

This research was funded by the Jubiläumsfonds of the Oesterreichische Nationalbank (OeNB), project number 15488. We would like to thank Katharina Köberl and Susanne Markytan for excellent research assistance and Ina Meyer for invaluable research guidance.

5 References

BGBl. I Nr. 72/2014, 2014. Austrian Energy Efficiency Act ('Österreichisches Bundes-Energieeffizienzgesetz').

Cullen, J.M., Allwood, J.M., 2010. The efficient use of energy: Tracing the global flow of energy from fuel to service. Energy Policy 38, 75–81. doi:10.1016/j.enpol.2009.08.054

European Commission, 2014. A policy framework for climate and energy in the period from 2020 to 2030. COM/2014/015.

European Commission, 2011. Roadmap for moving to a low-carbon economy in 2050. COM (2011) 112.

European Commission, 2008. 20 20 by 2020 - Europe's climate change opportunity. COM/2008/30.

European Council, 2014. European Council 23/24 October 2014 – Conclusions.

European Parliament and Council, 2013. Regulation 525/2013/EU of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change.

Gouveia, J.P., Fortes, P., Seixas, J., 2012. Projections of energy services demand for residential buildings: Insights from a bottom-up methodology. Energy, Asia-Pacific Forum on Renewable Energy 2011 47, 430–442. doi:10.1016/j.energy.2012.09.042

Haas, R., Nakicenovic, N., Ajanovic, A., Faber, T., Kranzl, L., Müller, A., Resch, G., 2008. Towards sustainability of energy systems: A primer on how to apply the concept of energy services to identify necessary trends and policies. Energy Policy, Transition towards Sustainable Energy Systems 36, 4012–4021. doi:10.1016/j.enpol.2008.06.028

IAEA, IEA, 2001. Indicators for Sustainable Energy Development. International Atomic Energy Agency, Vienna.

IAEA, UNDESA, IEA, Eurostat, EEA, 2005. Energy indicators for sustainable development: guidelines and methodologies. International Atomic Energy Agency, Vienna.

Kettner, C., Fritz, O., Köppl, A., Haddad, E.A., Porsse, A., 2012a. Volkswirtschaftliche Effekte von Maßnahmen zur Steigerung der Energieeffizienz und des Anteils erneuerbarer Energien in den österreichischen Klima- und Energiemodellregionen (report).

Kettner, C., Kletzan-Slamanig, D., Köppl, A., 2015. Indicators for Sustainable Energy Development for Austria (ISED-AT): Residential buildings and electricity and heat supply. WIFO Working Paper 2015 (495).

Kettner, C., Kletzan-Slamanig, D., Köppl, A., Köberl, K., 2012b. Indicators for Sustainable Energy Development. The PASHMINA Approach (report).

Kettner, C., Köppl, A., Köberl, K., 2012c. The PASHMINA Indicators for Sustainable Energy Development – How Does the EU Perform? (report).

Köppl, A., Kettner, C., Kletzan-Slamanig, D., Schleicher, S., Damm, A., Steininger, K., Wolkinger, B., Schnitzer, H., Titz, M., Artner, H., Karner, A., 2014. Energy Transition in Austria: Designing Mitigation Wedges. Energy & Environment 25, 281–304. doi:10.1260/0958-305X.25.2.281

Köppl, A., Kettner, C., Kletzan-Slamanig, D., Schleicher, S., Schnitzer, H., Titz, M., Damm, A., Steininger, K.W., Wolkinger, B., Lang, R., Wallner, G., Artner, H., Karner, A., 2011.

EnergyTransition 2012\2020\2050. Strategies for the Transition to Low Energy and Low Emission Structures (report).

Köppl, A., Schleicher, S., 2014. Energieperspektiven für Österreich. Teilbericht 2: Zielorientierte Strukturen und Strategien bis 2030 (report).

Kratena, K., Meyer, I., Sommer, M.W., 2013. Energy Scenarios 2030. Model Projections of Energy Demand as a Basis to Quantify Austria's Greenhouse Gas Emissions. WIFO, Vienna.

Ma, L., Allwood, J.M., Cullen, J.M., Li, Z., 2012. The use of energy in China: Tracing the flow of energy from primary source to demand drivers. Energy 40, 174–188. doi:10.1016/j.energy.2012.02.013

Sovacool, B.K., 2011a. Conceptualizing urban household energy use: Climbing the "Energy Services Ladder." Energy Policy 39, 1659–1668. doi:10.1016/j.enpol.2010.12.041

Sovacool, B.K., 2011b. Security of energy services and uses within urban households. Current Opinion in Environmental Sustainability, Energy Systems 3, 218–224. doi:10.1016/j.cosust.2011.06.004

Statistics Austria, 2014a. Community Statistics on Income and Living Conditions 2012.

Statistics Austria, 2014b. Households, families and living arrangements.

Statistics Austria, 2014c. Population stock and Population change.

Statistics Austria, 2014d. Household forecast.

Statistics Austria, 2014e. Projected population structure for Austria 2013-2075, according to the main scenario.

Statistics Austria, 2013a. Useful energy analyses 1993-2012.

Statistics Austria, 2013b. Energy balances 1970-2012.

Statistics Austria, 2013c. Housing Census 2011.

Statistics Austria, 2004. Housing Census 2001.

Statistics Austria, 1993. Housing Census 1991.

Thomas, S., Hennicke, P., Berlo, K., Chesshire, J.H., 2000. Energy service use in Germany, in: From Electricity Supply to Energy Services. Prospects for Active Energy Services in the EU. Report Prepared for the European Commission - Directorate General Energy and Transport – and Union of the Electricity Industry – EURELECTRIC.

Umweltbundesamt, WIFO, TU Graz, EEG, AEA, 2013. Energiewirtschaftliche Inputdaten und Szenarien (Report No. REP-0415). Umweltbundesamt, Vienna.

UNFCCC, 2014. UNFCCC Inventory Submissions.

Appendix

Appendix 1: Calculation of the Composite Indices

The sub-indices are aggregated in two alternative two-step procedures. The indicators can either be first aggregated by sector and in a subsequent step these subsectors are aggregated by dimension (model A, SEID, equations 1a-1b) or vice versa (model B, SEIS, equations 2a-2b). $E_{s,j,t}$ 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) SEID: Aggregation by sector and dimension

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

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

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

(B) SEIS: Aggregation by dimension and sector

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

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

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

Appendix 2: Measures in the policy scenarios up to 2030

Measures in the WEM scenario

Energy supply

- Green Electricity Act 2012 ('Ökostromgesetz') under the Framework of the Water Framework Directive 2000/60/EC
- Optimization potential of existing hydropower plants under the Framework of the Water Framework Directive 2000/60/EC

Buildings

- New buildings: Tightening of housing standards in 2010, promotion of renewable heating systems and binding rules for the quality of insulation in the new building

- Thermal refurbishment: Financial support, new standards
- Exchange of heating systems: Financial support, change of fuel taxes, building standards
- Directive 2006/32/EC on energy end-use efficiency and energy services
- Austrian eco-design regulation

Additional measures in the WAM scenario

Energy supply

- Implementation of the Austrian Energy Efficiency Act
- Continued RES support
- Continued support of existing biomass plants

Buildings

- Increased support for thermal refurbishment
- Implementation of tighter standards for thermal refurbishment
- Mandatory installation of highly-efficient heating systems in public buildings
- Mandatory installation of highly-efficient heating systems and solar energy in new residential buildings
- Mandatory use of solar energy in non-residential buildings

Table A - 1. *Set of ISED-AT indicators*

Sector	Dimension	Indicator	Unit	2003	2010	2020 WEM	2020 WAM	2020 EA	2030 WEM	2030 WAM	2030 EA
Electricity and heat supply											
	Ecological										
		RES-share in transformation input	%	44	53	69	70	62	64	69	74
		CO_2 efficiency of transformation input	TJ / kt CO_2	25	33	51	53	42	45	53	62
		Transformation input	PJ	375	432	422	425	428	428	445	409
		Energy-related CO_2 emissions	Mt	15.0	13.2	8.2	8.0	10.1	9.4	8.4	6.5
	Economic										
		Transformation efficiency	%	74	76	82	81	79	84	84	82
		Distribution efficiency	%	87	88	87	87	88	87	87	88
Households											
	Energy Service										
		Well-tempered living space (Proxy: floor area)	m m^2	351	393	431		444	463		494
		Illumination (Proxy: floor area)	m m^2	351	393	431		444	463		494
		Warm water (Proxy: population)	1,000	8,118	8,361	8,711		8,696	9,011		8,985
		Cooking (Proxy: number of households)	1,000	3,319	3,624	3,865		3,849	4,055		4,032
		Communication / Entertainment (Proxy: population)	1,000	8,118	8,361	8,711		8,696	9,011		8,985
		Other (Proxy: number of households)	1,000	3,319	3,624	3,865		3,849	4,055		4,032
	Ecological										
		RES-share in final energy consumption	%	23	28	30	30	29	32	32	31
		CO_2 efficiency of final energy consumption	TJ / kt CO_2	30	37	45	45	41	54	57	48
		Final energy consumption	PJ	268	287	264	261	260	242	234	233
		Energy-related CO_2 emissions	Mt	8.8	7.8	6.2	6.1	6.4	4.7	4.3	4.8
	Economic										
		Efficiency of heating and air conditioning		1.8	1.8	2.2	2.2	2.3	2.6	2.7	3.0
		Efficiency of warm water and cooking		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
		Efficiency of lighting and computing		0.8	0.7	0.7	0.7	0.8	0.7	0.7	1.0
		Efficiency of household appliances		0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.8
		Energy expenditures per household	€ 2010	1,168	1,644	2,007	1,959	2,162	1,916	1,810	2,196
	Social										
		Share of HH who can afford TV	%	99	99	100		100	100		100
		Share of HH who can afford PC	%	92	95	98		98	100		100
		Share of HH who can afford washing machine	%	99	99	100		100	100		100
		Share of HH who can afford dish washer	%	93	93	98		98	100		100