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ÖSTERREICHISCHES INSTITUT FÜR WIRTSCHAFTSFORSCHUNG

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Research assistance: Katharina Köberl

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Abstract

The present study develops three energy scenarios for the Austrian economy up to 2030. These scenarios incorporate existing measures and policies on energy use and climate protection enacted before March 2012 (WEM – "with existing measures"). In addition to the main WEM scenario, two sensitivity scenarios (WEM Sens 1 and WEM Sens 2) are computed based on alternative assumptions of world economic and fossil fuel price developments. The methodological approach to modelling energy scenarios takes a top-down macroeconomic perspective based on the dynamic econometric Input-Output model DEIO in order to generate national economic and energy data, i.e., GDP and the final energy demand of households and industries. The top-down economic model is interlinked with bottom-up models that derive sectoral energy demands and supply scenarios as well as energy efficiency data for energy-relevant capital stocks from a micro-data perspective. Both results – an annual average GDP growth of 1.5 percent with an average annual growth in energy demand of 0.8 percent (WEM), or a much lower average annual GDP growth of 0.8 percent with an average growth in energy demand of 0.6 percent (WEM Sens 2) – produce a final energy demand of close to 1,100 PJ in 2020 (as stipulated by the Austrian Energy Strategy). The WEM scenario thus attests to a higher energy efficiency which is the result of higher international energy prices. By contrast, the high-growth scenario (WEM Sens 1) with an average annual GDP growth of 2.5 percent and an average annual rise in energy demand of 1.5 percent overshoots the 1,100 PJ target in 2020 by about 100 PJ which grows further to 1,429 PJ in 2030. Thus higher growth would require additional intervention in terms of enacting further climate and energy policy measures to keep final energy demand strictly below 1,100 PJ by 2020.

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1. Introduction

The present study develops energy scenarios for the Austrian economy up to 2030. These scenarios can be used, on the one hand, as input data for calculating potential future greenhouse gas (GHG) emissions, and, on the other hand, can serve as a source of information to fulfill the reporting requirements under the Monitoring Mechanism 2013, the United Nations Framework Convention on Climate Change (UNFCCC), and under Austrian climate protection law. The energy scenarios thus serve as a source of information with respect to the European 20-20-20 targets and the respective national targets. These targets are:

a) Reducing GHG emissions by 20%

b) Generating 20% of energy use from renewable energy resources

c) Improving energy efficiency by 20%.

These targets are the result of an integrated European approach to a climate and energy policy that aims to combat climate change, increase the EU's energy security and strengthen its competitiveness. They are also headline targets in the Europe 2020 strategy for smart, sustainable and inclusive growth (*European Commission,* 2010).

Targets a) and b) were set by EU leaders in March 2007, when they committed Europe to becoming a low carbon and highly energy-efficient economy, and were enacted through the climate and energy package in 2009. The climate and energy package does not address the energy efficiency target directly. This is rather contained in the 2011 Energy Efficiency Plan and the Energy Efficiency Directive 2012/27/EU adopted on 25 October 2012.

Target b) includes the sub goal of 10% renewable energy use, including green electricity in the transport sector. Recently, this target has been refined in a proposed directive to amend Directive 98/70/EU (directive on quality of petrol and diesel fuels) and Directive 2009/28/EU (renewable energy directive) in order to limit global land conversion for biofuel production, to restrict indirect land-use changes, and thus to raise the climate benefit of biofuel use in the EU (*European Commission*, 2012a).

Within the EU climate and energy package, the Effort Sharing Decision establishes binding annual GHG emissions targets for member states for the period 2013-2020 from sectors not included in the EU Emissions Trading System (EU ETS) such as transport (except aviation), buildings, agriculture and waste. In these sectors emissions should be reduced by 10% as compared with their 2005 levels. Emission targets within the Effort Sharing Decision have been allocated at the national level of member states according to their national per capita GDP levels. For Austria, GHG emissions should be reduced by 16% as compared with the 2005 emission level. By 2020, the national targets will collectively deliver a reduction of around 10% in total EU emissions from the sectors covered under the Effort Sharing Decision. Together with a 21% cut in European GHG emissions covered by the EU ETS, the key instrument for cutting industrial GHG emissions, this will accomplish the overall emission reduction goal of the climate and energy package of a 20% cut in GHG emissions from 1990 levels by 2020. Based on the actual data, the Environment Agency Austria (*Anderl et al.,* 2012) calculated the target for Austria's GHG emissions in 2020 to be 47.7 $MtCO_{2e}$ for the non-ETS sectors.

The Austrian target regarding the share of renewable energy sources in gross final energy consumption in 2020 is 34% (*European Commission*, 2009). In order to support the renewable energy objective, each member state is requested to submit a national renewable energy action plan (NREAP) detailing how they will reach their individual targets (*Karner et al.,* 2010). Since Austria's share of renewable energy sources was at 31% in 2011 (*Statistik Austria,* 2012a) the target must be viewed as somewhat lacking in ambition.

The aim of the new Energy Efficiency Directive (*European Commission*, 2012b; target c) is to cut energy consumption by 20% by the year 2020. This corresponds to 368 Mtoe (million tonnes of oil equivalent) less energy use in 2020 to be achieved by the EU as a whole with regard to the baseline development. Energy efficiency is one of the main aspects of the Europe 2020 flagship initiative for a resource-efficient Europe (*European Commission*, 2010). According to the European Commission, energy efficiency is the most cost-effective way to increase the security of supply and, at the same time, to reduce the GHG emissions responsible for climate change (cf. target a). The desired decrease in energy consumption should also help to achieve the target for the share of energy from renewable sources set by the Renewable Energy Directive (*European Commission*, 2009; cf. target b). Finally, producing more using less energy input should improve the competitiveness of industries and thus allow energy efficient technologies to sustain their lead in the global markets. For these reasons, the European Energy Strategy 2020 identified energy efficiency as one of the key priorities of EU energy policy for the coming years. Member states have committed to achieving the 2020 targets for energy efficiency in terms of primary energy savings.According to its Energy Strategy, Austria has committed to an indicative energy use reduction target of 7.16 Mtoe of primary energy consumption or 300 PJ by 2020 with regard to its baseline development (or 200 PJ with respect to final energy consumption). This corresponds to freezing its primary energy consumption at the 2005 level (*BMLFUW/BMWFJ*, 2010). The reduced primary energy demand of 300 PJ is equal to about 21% of the current primary energy supply in Austria (2011). However, the method for assessing national progress in energy efficiency is currently under discussion in negotiations between the EU institutions of the Energy Efficiency Directive. Austria needs to submit a national target of energy efficiency improvement to the European Commission by April 2013. Thus, the above mentioned efficiency reduction target of 300 PJ given by Austria's Energy Strategy might be adapted and the target presented here must therefore be understood as preliminary.

Given this political framework, the Environment Agency Austria (Umweltbundesamt) acted as the coordinator of a project team of four Austrian research institutes, each one tasked with addressing different energy domains from the energy scenarios 2030 which need to be modeled.

As in the previous study (*Kratena – Meyer,* 2011) the methodological approach to modeling energy scenarios applied by the Austrian Institute of Economic Research (WIFO) takes a top-down macroeconomic perspective based on the dynamic econometric Input-Output model DEIO in order to generate national economic and energy data, i.e. GDP and the final energy demand of households and industries (cf. section 2). This top-down economic model is interlinked with the bottom-up models of the project partners who derive sectoral energy demands and supply scenarios from a micro-data perspective. The Energy Economics Group (EEG) of the Technical University Vienna (TU Wien) addresses the subject of heating (space and water heating), cooling and heat demand (*Müller – Kranzl, 2013*). The Institute of Internal Combustion Engines and Thermodynamics at the Technical University Graz (TU Graz) establishes transport scenarios concerning the different modes of transport including electricity and biofuel demand (*Hausberger – Schwingshackl, 2013*). The Austrian Energy Agency (AEA) analyses electricity demand and electricity and district heat generation (*Baumann – Lang, 2013*). Energy efficiency data for energy-relevant capital stocks such as fuel efficiency of car fleets, efficiency of electrical household devices or heating systems are also quantified within the bottom-up models of the project partners. These data thus constitute another link with the top-down macroeconomic model. Energy efficiency of industries is calculated on the basis of historical trends and taken from econometric estimations of factor demand in European industries (*Kratena – Wüger, 2012*). The data are thus used as exogenous variables with regard to the DEIO model while macroeconomic data derived from the top-down economic perspective such as the GDP is employed as input data in the bottom-up models. The different energy use models and methodological approaches of the project consortium are built upon a consistent and common set of economic, technological, demographic and climate data that is delineated in section 3. These data are employed and/or generated within both the bottom-up and top-down models and this common thread of data constitutes a solid link between the top-down and bottom-up spheres.

The present study describes the modeling results of three baseline scenarios for Austria until the year 2030. These scenarios incorporate existing measures and policies on energy use and climate protection enacted before March, 8 2012.[1] They are thus labeled WEM – 'with existing measures'. In addition to the main WEM scenario, two sensitivity scenarios 'WEM Sens 1' and 'WEM Sens 2' are computed based on alternative assumptions of world economic and fossil fuel price developments. Table 1 summarizes key input and output data for the three scenarios.

[1] These include for example: The Green Electricity Act 2011, The Heat-Power Cogeneration Act (BGBl. INr. 111/2008), enhanced use of photovoltaic technology (Klima- und Energiefonds), optimizing hydro power plants, the program for thermal building insulation and boiler exchange, the promotion of district and local heating, renewable energy use, making the car registration tax more green, Klima:aktiv mobil program, increase of mineral oil tax in 2011, the promotion of public transport and mobility management, and efficiency improvements in industries as well as further initiatives.

Due to the international division of labor and the increasingly international intertwining of markets, world economic development constitutes one central external determinant of Austria's economic development and energy demand. International trade relations (structure and scale of imports and exports) constitute the link between the assumed global and the derived national economic development in the three scenarios. World energy prices thereby play a crucial role as a variable of economic growth and energy demand.

Table 1: Key data on growth and energy prices in the three scenarios

Input/Output Variables			WEM	WEM Sens 1	WEM Sens 2
GDP Growth, real	ø % p.a.	2012-2030	1.5	2.5	0.8
CO2-Certificate Price	€/t CO_2	2020	20	30	15
		2030	30	40	20
Crude Oil (Brent) Price	US$/bbl	2020	118	135	108
		2030	134	180	117
Natural Gas Price	US$/Mbtu	2020	11	13	10.5
		2030	12.6	18	10.8

S: Own assumptions.

The WEM scenario is characterized by a medium world economic development resulting in a 1.5% average annual growth of Austria's GDP between 2012 and 2030. The WEM Sens 1 scenario represents a world with higher economic dynamics and thus higher crude oil and natural gas prices than the benchmark (WEM). Besides a lower growth dynamic the main characteristics of the WEM Sens 2 scenario are a decoupling of natural gas prices from crude oil prices. This price spread between oil and natural gas draws upon the suggestion of a "golden age of gas" that the International Energy Agency (IEA) discussed e.g. in its special report "Golden Rules for a Golden Age of Gas" (IEA, 2012a). Natural gas is thus relatively more attractive than oil in WEM Sens 2. However, as the growth dynamic remains low up to 2030 (0.8% GDP growth on an average annual base), the impact of the spread in oil and natural gas prices on energy demand and interfuel substitution in production and service remains small. Details of the three scenarios such as the household and industry energy price trajectories derived from crude oil price developments are outlined in the respective scenario sections (cf. section 4).

In addition, WIFO calculated the impact of energy efficiency improvements based on the Energy Efficiency Directive and the Austrian Energy Efficiency Act on production output of the industrial sectors thereby contributing to the WAM scenario – 'with additional measures'. The WAM climate and energy policy scenario was modeled by the project partners who employed this industrial output data under efficiency measures in their bottom-up models (cf. section 3).

2. Methodological Approach

The model approach used for the projection of the energy scenarios can best be described as a dynamic (macro-)econometric input-output (DEIO) model, as elaborated in *Kratena – Streicher* (2009). The first step in developing this model for Austria is described in *Kratena – Wüger* (2010) and has been used for the energy scenarios 2030, and published by WIFO in 2011 (*Kratena – Meyer, 2011*). Further developments to this model type led to a first operational version being evolved for the EU 27, named FIDELIO (Full Interregional Dynamic Econometric Long-term Input-Output model) and described in *Kratena et al.* (2012). The modeling work in this direction has been very much inspired by the work of Jorgenson and his collaborators (*Goettle et al.,* 2007), who have recently published a description of a new dynamic CGE (Computable General Equilibrium) model for the U.S., named IGEM (Intertemporal General Equilibrium model), that has widely been used for U.S. climate policy analysis. The main differences between the dynamic (macro-) econometric approach in the model used here as well as in FIDELIO as compared with the dynamic CGE models are the macroeconomic mechanisms and closure rules. In CGE models savings (including external savings, i.e. the current account balance) usually determine investment and fiscal policy shocks have almost no macroeconomic multiplier effect. In the DEIO model, agents strive for the optimum in a dynamic context, but many rigidities and restrictions that appear in modern economies, are at work. This is true for private consumption, which not only depends upon the expectations of permanent income, but also on current income due to buffer stock saving behavior and liquidity constraints. Another restriction is at work in the labour market, where prices (wage rates) are set in union wage bargaining systems and are not fully flexible. Therefore, though agents' behavior leads the economy towards a long-run equilibrium, fiscal policy can have considerable short-term multiplier effects.

A full DEIO model like FIDELIO (*Kratena et al., 2012*) takes account of all these features and integrates them into the model blocks: consumption, production, trade as well as labour market. This is not the case in the version of the Austrian DEIO model used for this study. As environmental and economic impacts of climate policies have not been included in WIFO's present scenario analysis, the consumption and production block have been simplified considerably.

Emphasis is given in the model approach to all relevant aspects of energy demand and emissions generation. This includes the role of energy efficiency in consumer durables and their demand. An important aspect in this context is the explicit treatment of different types of 'rebound effects' (*Greening et al.,* 2000; *Henly et al.,* 1998). The modeling of energy ('service') demand of households has been developed starting from former model versions (*Kratena – Wüger*, 2010 or *Kratena – Meyer*, 2011). Technological progress, i.e. energy efficiency, has also been considered as an important long-term source of the energy demand of industries, based on work carried out in another European project (*Kratena – Wüger,* 2012).

Finally, an important extension of the model refers to modeling interfuel substitution in production. The interfuel substitution process is driven by relative energy prices as well as technological change.

2.1 Production

The model is constructed based on the structure of Supply and Use Tables (SUT) which contain the full resolution of 59 industries in the NACE2003 classification and the corresponding 59 commodities from the CPA classification (cf. Appendix 1). The production activities are determined by the SUT-structure itself and by the structure and magnitude of total final demand. By using SUT – instead of an input-output structure – it was possible to integrate a wider range of data and furthermore an iterative solution algorithm had been implemented instead of a Leontief inverse. The following matrix equations of production (Q) and final demand (FD) display the core of the model.

(1) $$Q = D * QG$$

(2) $$QG_e = SED * SEQ * Q + FD_e$$

(3) $$QG_{ne} = SXD * SXDQ * Q + FD_{ne}$$

(4) $$FD = FD_e + FD_{ne}$$

(5) $$QG = QG_e + QG_{ne}$$

(6) $$M = SXM * SXMQ * Q + FM$$

Equations (1) to (5) display the iterative loop of the model, the result obtained in (5) is inserted into (1). The output activity of each industry (Q) is calculated by the transformation of the demanded domestic commodity output (QG) via a market shares matrix (D). This market share matrix represents the production structure of commodities by industries and is derived from the structure of the supply table. Equation (6) describes how imports of goods (M) are connected to the domestic production via a set of exogenous coefficients as well as to final demand (FM).

The value shares of aggregate inputs (domestic non-energy, energy, imported non-energy) *SXDQ*, *SEQ*, and *SXMQ* are treated as exogenous to the input-output core model described by the equation system (1) to (6). These shares are part of a full model like FIDELIO – together with the shares for the other inputs capital (*K*) and labour (*L*) – and are modelled in a production block with cost and factor demand functions. In this context we only use the link between economic production and energy demand, as described in more detail in the following section. Furthermore, the interfuel substitution feature will be outlined in the last section of this chapter. SXD, SED and SMD are matrices of input shares of individual commodities in the aggregate inputs *SXDQ*, *SEQ*, and *SXMQ*.

QG_e represent the goods of the 5 energy sectors (Coal and lignite; peat: CPA 10, Crude petroleum and natural gas: CPA 11, Coke, refined petroleum products and nuclear fuels: CPA 23, Electrical energy, gas, steam and hot water: CPA 40) whereas QG_{ne} contain data on the goods of the non-energy sectors, i.e. all the other two-digit CPA categories. Both are linked to the respective final demand (of domestic goods) (FD) as well as to production activities via coefficient matrices that represent the interconnected production relationship between the respective industries. These coefficient matrices are exogenous with the exception of SEQ. The coefficients of this matrix represent the energy intensities of the industries which change, if energy efficiency improves (as a result of policy measures or via technological progress over time) or energy prices change. This is outlined in more detail in the following section.

In (5) the loop ends and the demanded commodities determine the production activities. If a consistent set is disturbed (e.g. by an increase in exports) the model algorithm iterates towards the necessary production. So, in essence, the production (i.e. economic growth) is determined by the development and structure of the final demand of domestic goods.

2.1.1 Energy demand of domestic production activities

As mentioned in the introduction of this chapter the model contains a set of parameters that represent the link between physical energy demand and economic production activities. This is SEQ (nominal share of energy goods in the industry's production). SEQ defines the nominal demand as a share of the nominal industry activity Q, i.e. the cost share of the energy input. The value of SEQ changes yearly and depends on energy prices (PE) via price elasticity and the trend of efficiency improvement due to technological improvement represented by ρ and both estimated in a Translog model (cf. *Kratena – Wüger*, 2012). The price elasticity in the Translog model is a function of the parameter γ and the value share, so that γ has been calibrated for the elasticity in *Kratena – Wüger* (2012) and the value shares in the SUT 2005 for Austria. That gives the following function for SEQ:

(7) $$SEQ_t = SEQ_{t-1} + \rho + \gamma * \ln(PE_t)$$

The link between the economic production and energy demand starts in (8) which is a part of (2) and represents the nominal input of energy goods in the domestic production (E)[2].

(8) $$E = SEQ * Q$$

"E" represents the nominal energy input of each of the 59 economic sectors. As available energy prices and energy consumption balances are structured in the form of 18 final-energy-demand sectors (listed in the Appendix), E had to be aggregated by using a Bridge-matrix (BJK) to aggregate from 59 to 18 sectors:

[2] In other words: "E" represents the sum of the nominal energy goods input (i.e. sum of CPA 10, 11, 23, 40) in each industry's production.

(9) $E\_k = E * BJK$

The next step to link physical energy to nominal values is to convert the nominal values into real (with 2005 as price base) values (10). To achieve this, a set of 18 sectoral energy price indexes (PE_k) with 2005 as the base year, were applied. The determination of PE_k is shown in equation (12).

(10) $rE\_k = \frac{E\_k}{PE\_k}$

Finally, a set of coefficients "Z" was identified and extrapolated, which links the real value of energy goods demand in economic terms (i.e. deflated nominal values) to physical energy unit demand. These coefficients are based on Austria's historic energy balance and economic activities and represent the energy inputs in energy per unit of real input:

(11) $EngyDem\_k = rE\_k * Z$

This results as energy demand due to the production activities in the various classifications in the energy balance (18 sectors of final energy demand).

Note that this part of the model only relates to energy demand in production. The energy demands of sector 17 "private households" will be explained in detail in the consumption model block. Accordingly, sector 13 "Land based transport" comprises of freight transportation only. Private transport will also be calculated separately as outlined in detail in chapter 2.2.2.

The previous part displayed the determination of the general energy demand of each of the 18 energy balance-sectors, where energy demand reacts to energy prices via SEQ.

We further developed an approach to enable interfuel substitution, driven by differences in energy price developments. The datasets used were energy prices (PE_k) and the Austrian energy balance for the years 1995 – 2009. The dataset not only consists of the total energy demand of the 18 sectors, but also the fuel mix of each sector. So far 22 fuel types have been distinguished. The concept here was to aggregate the 22 fuel types into 5 fuel categories and estimate a Translog model. The model consists of a unit cost function and energy demand functions for the 5 fuel categories in each sector. These categories represent products of coal (COA), oil (OIL), natural gas (GAS), renewable sources (REN) and a mix of electricity and district heating (ELD). Equation (12) shows the general form of the Translog (unit) cost function, which determines the aggregated energy price of each sector.

$$(12)\quad \mathbf{log\,PE} = \boldsymbol{\alpha_0} + \alpha_{COA}\log\left(\frac{PE_{COA}}{PE_{ELD}}\right) + \alpha_{OIL}\log\left(\frac{PE_{OIL}}{PE_{ELD}}\right) + \alpha_{GAS}\log\left(\frac{PE_{GAS}}{PE_{ELD}}\right) + \alpha_{REN}\log\left(\frac{PE_{REN}}{PE_{ELD}}\right)$$
$$+\frac{1}{2}\gamma_{COACOA}\left(\log\left(\frac{PE_{COA}}{PE_{ELD}}\right)\right)^2 + \frac{1}{2}\gamma_{OILOIL}\left(\log\left(\frac{PE_{OIL}}{PE_{ELD}}\right)\right)^2 + \frac{1}{2}\gamma_{GASGAS}\left(\log\left(\frac{PE_{GAS}}{PE_{ELD}}\right)\right)^2$$
$$+\frac{1}{2}\gamma_{RENREN}\left(\log\left(\frac{PE_{REN}}{PE_{ELD}}\right)\right)^2$$
$$+\gamma_{COAOIL}\log\left(\frac{PE_{COA}}{PE_{ELD}}\right)\log\left(\frac{PE_{OIL}}{PE_{ELD}}\right) + \gamma_{COAGAS}\log\left(\frac{PE_{COA}}{PE_{ELD}}\right)\log\left(\frac{PE_{GAS}}{PE_{ELD}}\right)$$
$$+\gamma_{COAREN}\log\left(\frac{PE_{COA}}{PE_{ELD}}\right)\log\left(\frac{PE_{REN}}{PE_{ELD}}\right)$$
$$+\gamma_{OILGAS}\log\left(\frac{PE_{OIL}}{PE_{ELD}}\right)\log\left(\frac{PE_{GAS}}{PE_{ELD}}\right)$$
$$+\gamma_{OILREN}\log\left(\frac{PE_{OIL}}{PE_{ELD}}\right)\log\left(\frac{PE_{REN}}{PE_{ELD}}\right)$$
$$+\gamma_{GASREN}\log\left(\frac{PE_{GAS}}{PE_{ELD}}\right)\log\left(\frac{PE_{REN}}{PE_{ELD}}\right)$$
$$+\rho_{tCOA}\,\mathrm{t}\log\left(\frac{PE_{COA}}{PE_{ELD}}\right) + \rho_{tOIL}\,\mathrm{t}\log\left(\frac{PE_{OIL}}{PE_{ELD}}\right) + \rho_{GAS}\,\mathrm{t}\log\left(\frac{PE_{GAS}}{PE_{ELD}}\right) + \rho_{tREN}\,\mathrm{t}\log\left(\frac{PE_{REN}}{PE_{ELD}}\right)$$

The unit cost function has been used, since we assume constant returns to scale for the inputs of different energy carriers into the energy bundle E_k (in nominal terms). The individual fuel prices (PE_{coa}, PE_{oil}, PE_{gas}, PE_{ren}, PE_{eld}) are derived for each sector from IEA energy price data and from fuel sub-shares (22 fuel types mapping to the 5 fuel categories) based on the energy balances.

The **nominal shares** of the fuel categories are then given by the equations seen in (13) to (17).

$$(13)\quad s_{COA} = [\,\alpha_{COA} + \gamma_{COACOA}\,log\left(\frac{PE_{COA}}{PE_{ELD}}\right) + \gamma_{COAOIL}\,log\left(\frac{PE_{OIL}}{PE_{ELD}}\right) + \gamma_{COAGAS}\,log\left(\frac{PE_{GAS}}{PE_{ELD}}\right) + \gamma_{COAREN}\,log\left(\frac{PE_{REN}}{PE_{ELD}}\right) + \rho_{tCOA}$$

$$s_{OIL} = [\,\alpha_{OIL} + \gamma_{OILCOA}\,log\left(\frac{PE_{COA}}{PE_{ELD}}\right) + \gamma_{OILOIL}\,log\left(\frac{PE_{OIL}}{PE_{ELD}}\right) + \gamma_{OILGAS}\,log\left(\frac{PE_{GAS}}{PE_{ELD}}\right) + \gamma_{OILREN}\,log\left(\frac{PE_{REN}}{PE_{ELD}}\right) + \rho_{tOIL}$$

$$s_{GAS} = [\,\alpha_{GAS} + \gamma_{GASCOA}\,log\left(\frac{PE_{COA}}{PE_{ELD}}\right) + \gamma_{GASOIL}\,log\left(\frac{PE_{OIL}}{PE_{ELD}}\right) + \gamma_{GASGAS}\,log\left(\frac{PE_{GAS}}{PE_{ELD}}\right) + \gamma_{GASREN}\,log\left(\frac{PE_{REN}}{PE_{ELD}}\right) + \rho_{tGAS}$$

$$s_{REN} = [\,\alpha_{REN} + \gamma_{RENCOA}\,log\left(\frac{PE_{COA}}{PE_{ELD}}\right) + \gamma_{RENOIL}\,log\left(\frac{PE_{OIL}}{PE_{ELD}}\right) + \gamma_{RENGAS}\,log\left(\frac{PE_{GAS}}{PE_{ELD}}\right) + \gamma_{RENREN}\,log\left(\frac{PE_{REN}}{PE_{ELD}}\right) + \rho_{tREN}$$

$$s_{REN} = 1 - s_{COA} - s_{OIL} - s_{GAS} - s_{REN}$$

Table 2: Estimated parameters of interfuel substitution by translog function

	Parameter	Sectors													
		Iron , Steel, Metallic Minerals	Chemical and Petro-chemical	Non Ferrous Metals	Transport Equipmen	Machinery	Mining and Quarrying	Food Tobacco and Beverages	Pulp Paper and Print	Wood and Wood Products	Constructio n	Textiles and Leather	Non Specified Industry	Commercial and Public Services	Agriculture
	α0	-0.01	0.07	0.01	-0.01	-0.02	-0.18	0.00	0.02	0.04	-0.11	-0.03	-0.07	0.07	-0.03
	αCOA	0.15													
	αOIL			0.22				0.13				0.09		0.17	0.59
	αGAS	0.57	0.39	0.52	0.32	0.37		0.58	0.28	0.46	0.45	0.51	0.23	0.31	
	αREN		0.14						0.32		0.13		0.06	0.04	0.19
Compensated Price Elasticities	γcoa_coa	0.07													
	γOIL_OIL			0.04				0.05				-0.16		-0.04	0.18
	γGAS_GAS	0.16	0.12	0.34	0.11	0.10		0.31	0.15	0.35	0.15	0.07	0.08	0.29	
	γREN_REN		0.06						0.21		0.05		0.16	0.04	0.13
	γCOA_OIL														
	γCOA_GAS	-0.01													
	γCOA_REN														
	γOIL_GAS			-0.14				-0.06				0.15		0.06	
	γOIL_REN													0.05	-0.05
	γGAS_REN		0.00						-0.07		0.09		-0.06	-0.10	
	ρCOA	0.00													
	ρOIL			-0.01				0.00				0.00		0.00	-0.01
	ρGAS	-0.01	0.00	0.00	0.00	0.00		0.00	0.01	-0.02	-0.01	-0.01	0.00	-0.01	
	ρREN		0.01						0.00		0.01		0.01	0.00	0.02

S: own calculations.

The energy share of ELD could be dropped due to the implementation of the homogeneity restriction in the estimation and the other input prices only enter as prices relative to the price of PE_{ELD}. Technical progress is described by the deterministic trend t.

In this table the sectors 13 (Land based transport), 14 (Internal Navigation) and 15 (Air Transport) are missing, as they mainly demand a single fuel category.

Furthermore many cells remain empty. This is due to the fact that sectors often do not demand all 5 fuel categories. Consequently some parameters cannot (do not need to be) estimated.

It can be seen that the reactions to own price changes (γ_{i_i}) are predominantly positive. This is the case because the estimated reactions are based on nominal values, i.e. if the price for coal increases, then the nominal share of coal increases too, whereas the real physical share of coal might not. Therefore the results for own price elasticites are important, as they determine the reactions of the fuel demand due to changes in prices. Some of the estimated parameters had to be restricted in order to achieve negative own price elasticies over time (global regularity). Equation (14) shows exemplarily the calculation of the own price elasticity of coal, which is a function of the estimated parameter γ_{COA} and the actual nominal share. Average values for these elasticities are shown in Table 3. Since the shares change over time, the elasticity changes as well.

$$(14)\quad \epsilon_{COACOA} = \frac{\delta log E}{\delta log PE_{Coa}} = (s_{COA}^2 - s_{COA} + \gamma_{COA})/s_{COA}$$

Table 3: Own price elasticities of interfuel substitution by translog function, sample average

Sectors	Fuel Category: Coal	Oil	Gas	Renewables	Electricity
Iron , Steel Metallic Minerals	-0,32	-1,16	-0,19		
Chemical and Petro-chemical		-1,06	-0,29		-0,47
Non Ferrous Metals		-2,31		-0,34	
Transport Equipmen		-0,5	-0,34		
Machinery		-0,62	-0,36		
Mining and Quarrying		-0,42			
Food Tobacco and Beverages		-1,56		-0,51	
Pulp Paper and Print		-2	-0,26		-0,1
Wood and Wood Products		-0,81	-0,32		
Construction		-2,57			-0,32
Textiles and Leather		-0,57	-0,41	-1,39	
Non Specified Industry		-0,65	-0,36		-0,23
Commercial and Public Services		-0,6	-0,26	-1,27	-0,27
Agriculture		-2,56		-0,13	-0,24

S: own calculations.

In order to arrive at detailed energy demand data (22 fuels x 18 sectors), real shares are calculated at the level of fuel category and then disaggregated into the original 18 fuel type structures.

2.1.2 Prices

The model contains three main price sets from which all other prices are derived. The first two are the price vectors of domestic industry's output (PQ) and the import price vector (PM). The industry output prices determine the prices of domestically produced goods (PG) via the market share matrix (D):

$$(15)\ \ PG = D * PQ$$

To identify prices for the private consumption of goods (PCP), both price vectors in combination with exogenous import shares (μ) have been applied:

$$(16)\ \ ln\,PCP = \mu * PM + (1 - \mu) * PQ$$

The third price set is the sectoral prices of energy (PE). The determination of this set has already been outlined (cf. equation (12)) within a translog estimation. The prices of carbon dioxide (CO_2) emission certificates were integrated into the fuel prices (PE_{COA}, PE_{GAS}, PE_{OIL}, PE_{REN} and PE_{ELD}) in those industries that are part of the Emission Trading System (ETS).

2.2 Final Demand

The modelling of final demand is split into private consumption and the rest of final demand categories. Private consumption is modelled according to the buffer stock model of consumption, differentiating between durable and non-durable goods. The other final demand categories are treated as exogenous and have therefore been extrapolated on the basis of historic developments and the short term forecasts of WIFO.

2.2.1 Other final demand

The categories of final demand like governmental consumption (CG), gross fixed capital formation (GFCF) and inventories (ST) are based on historic data until 2009 and thereby include the years of the economic crisis 2008/09. This data has been extrapolated including information from recent WIFO forecasts until 2013. For the period until 2030, growth rates of the world economy are assumed, which together with trends of structural change in export demand, determine the vector of exports. The equations (17) to (19) illustrate the connection between the final demand categories and the imports caused by final demand which are determined by using extrapolated import shares (μ). The final demand for domestically produced goods (FD) is then calculated by using the difference between the demand for imported goods (FM) and the total demand (F):

$$(17)\ \ F = CP + CG + GFCF + EXP + ST$$

(18) $FM = CP * \mu_{CP} + CG * \mu_{CG} + GFCF * \mu_{GFCF} + EXP * \mu_{EXP}$

(19) $FD = F - FM$

2.2.2 *Final demand of private households*

It is assumed that households behave according to the permanent income hypothesis, except for the existence of liquidity constraints and saving for uncertain events (buffer stock saving). The dynamic utility maximization is fulfilled by consuming nondurable goods and 'services' from stocks of durable goods. For this study the full version of the dynamic model has not been used. For durables, a mix of calibrated functions, considering interest rates, prices, population, income and wealth, and extrapolations, based on these variables (especially population) has been applied. The demand for the nondurable goods has been extrapolated on the basis of historic data. Furthermore, some stocks use energy inputs to provide the services demanded (e.g. gasoline for passenger car use). For these stocks energy efficiency plays a crucial role. Energy efficiency further has an impact on the cost of using this service. For example if cars consume less gasoline per distance the price for the service "driving" decreases. This differentiation allows a "service price" to be calculated which drives the demand for the service consumption and thereby for energy and goods. Consequently service prices decrease if energy efficiency increases, thereby causing the 'rebound effect' on energy demand.

For different durable stocks we model service demand separately and not (as in previous model versions, like *Kratena – Würger,* 2010) as part of non-durable consumption. These durable stocks represent electricity consuming equipment (VID), heating appliances (APP) as well as gasoline and diesel fuelled vehicles (VEH). The general formula of the demand estimation can be found in (20) where the service per unit of stock (i.e. the utilization of the stock on an annual basis) is linked to the service price and one or two stock specific parameters. The service price is calculated by the division of a capital stock specific aggregated energy price (PE_C) and an efficiency index revealing the property that service price decreases with an increase in efficiency (η).

(20) $log\left(\frac{Service}{Capital\ \ Stock}\right) = \alpha_0 + \gamma * log(P_s) + \theta_1 Param_1 + \theta_2 Param_2$ [3]

(21) $where\, P_S = \frac{PE_C}{\eta}$

[3] The estimations are normalized to service per capital unit. I.e. per vehicle, per heating system and per electricity installment

Table 4: Estimated parameters for energy service demand

		Electricity Service		Heating Service		Transport Service Gasoline	Diesel
α0	Constant	-3.207	Constant	-3.083	Constant	-6.73	-5.068
γ	Compensated price elasticity	-0.033	Compensated Price elasticity	-0.192	Compensated Price elasticity	-0.221	-0.147
Θ 1	heating degree days	0.597	heating degree day	0.59	Vehicles per capita	-3.477	-1.797
Θ2	-	-	Correction	0.127	Trend	0.029	0.016

S: own calculations.

Table 4 shows the estimated parameters for all four energy consuming stocks. Negative compensated service price elasticity (γ) was found in all four estimations which consequently measure the rebound effect. Furthermore, a positive relationship between heating degree days and heating demand (non electricity based) as well as electricity services has been found.

The relationship between transport service per car and vehicles per capita is also negative. This reflects the fact that an increasing number of vehicles per household leads to less service per vehicle (i.e. less driving per car). Finally the positive trend parameter for driving displays the impact of other socio-demographic changes (for example urban sprawl) on the demand for driving services.

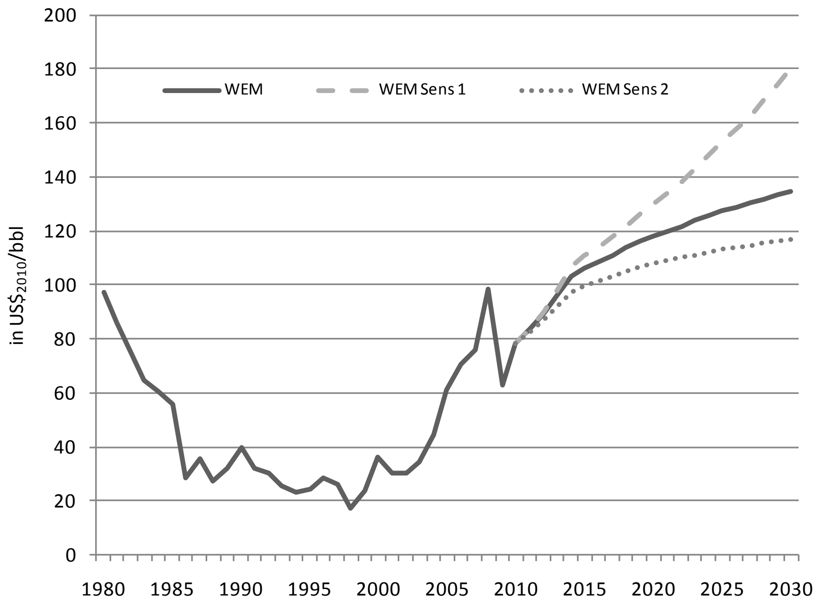
3. Framework conditions for the energy use scenarios

Future trends in energy demand are determined by a number of interplaying factors and most of these factors are difficult to predict accurately. This holds true in particular for the long run perspective of two decades that the present study encompasses. GDP as a measure of economic growth is considered one of the main drivers of energy demand and GHG emissions. Economic growth in turn is influenced *inter alia* by demographic developments, technological progress and deployment, in particular with respect to energy efficiency, and energy prices such as the price for crude oil. These data are exogenous to the present model of Austria's economic growth and energy demand. The following sections give an overview of the exogenous data used to model the WEM scenario family in the DEIO top-down model as well as in the bottom-up models of the project consortium.

3.1 Energy prices

The crude oil price is considered a proxy for international energy price developments and is one of the main determinants of energy demand. Demand for energy is derived from a specific demand for energy services, e.g. kilometers travelled by passenger cars or a specific room temperature or certain hours of lighting, washing etc., or, in industry where energy demand is determined by the functional relationships with production. In real world conditions the crude oil price is influenced by a multitude of factors, i.e. supply and demand, factors relating to the structure of the crude oil market (OPEC), speculative behavior of financial market participants as well as geopolitical events such as for example the civil unrest in north Africa and the Middle East (*Breitenfellner et al.,* 2009; *IEA*, 2012b). The recent past has thus shown significant fluctuations in the crude oil price, for example as a corollary of the economic and financial crisis 2008/2009 (cf. Figure 1). Crude oil prices used to model long run scenarios are in contrast smooth. The present study employs crude oil price trajectories based on the assumptions of the International Energy Agency World Energy Outlook 2011 (*IEA*, 2011). Thereafter these price trajectories do not represent any forecasts but are a reflection of prices needed to encourage sufficient investment in supply to meet projected demand of oil over the observation period. The different future price trajectories for the scenario analysis are shown in Figure 1. The real crude oil price is assumed to rise steadily throughout the WEM, WEM Sens 1 and WEM Sens 2 scenarios. All three price trajectories show a similar pattern of elevated growth rates until 2014 from where a slower growth rate is pursued. In the WEM scenario the real crude oil price rises from 90 US$ in 2012 to 118 US$ in 2020 and 135 US$ in 2030. Thus oil prices show an average annual growth of 7.2% from 2010 to 2014 and of 1.7% from 2014 to 2030 (2.8% from 2010 to 2030). In the higher growth scenario WEM Sens 1 oil prices increase to 130 US$ in 2020 and 180 US$ in 2030 while they reach 108 US$ in 2020 and 117 US$ in 2030 in the lower growth WM Sens 2 scenario only. Accordingly average annual growth rates are higher in WEM Sens 1 (8% 2010-2014; 3.3% 2014-2030; 4.3% 2010-2030) and lower in WEM Sens 2 (5.6% 2010-2014; 1.2% 2014-2030; 2% 2010-2030).

Figure 1: Crude oil prices, real, 1980-2030



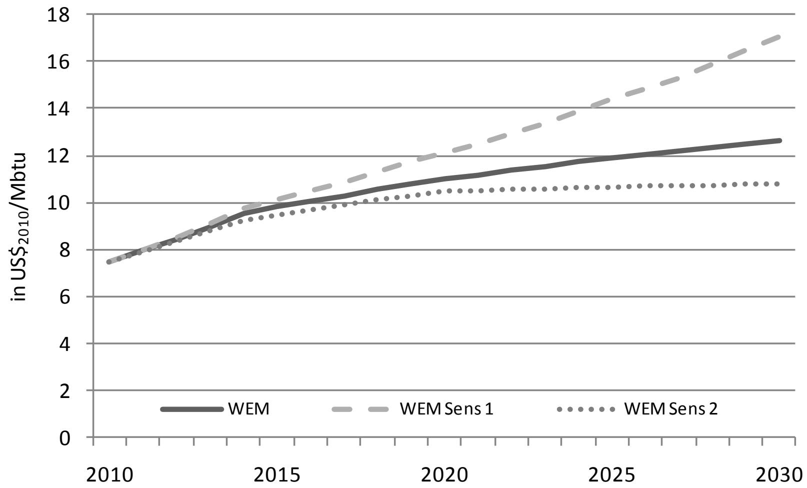
S: *IEA*, 2011: 2010-2030; BP Statistical Review of World Energy: 1980-2009, own calculations.

Historically, natural gas prices in OECD countries have moved closely in line with oil prices due to indexation clauses in long-term supply contracts or due to the competition between gas and oil products in power generation and end-use markets (*IEA,* 2011). In Europe about two-thirds of the natural gas is supplied under long-term contracts with gas prices indexed to oil prices. But there are a growing number of markets that set gas prices freely in a competitive gas market (gas-to-gas competition). The level of the gas price then depends on the supply and demand balance in each regional market and on prices of other fuels. Prices are determined this way in North America, the United Kingdom and Australia and, increasingly, in continental Europe, accounting in total for some three-quarters of the OECD gas use. Recently, gas prices set this way have been significantly lower than oil-indexed prices. such as for instance in the USA where natural gas prices have fallen relative to oil prices because of the boom in the exploitation of unconventional gas resources (*IEA,* 2011).

The development of natural gas prices in the three WEM scenarios are pictured in Figure 2. Gas prices in the WEM scenario follow the assumptions in the World Energy Outlook 2011 on gas price development of the European import price in its Current Policies Scenario (*IEA*, 2011). Thereafter, real gas prices rise to 11 US$/MBtu in 2020 and 12.5 US$/MBtu in 2030, showing an average annual growth of 6% between 2010 and 2014 and of 1.8% between 2014 and 2030 (2.6% p.a. 2010-2030). Natural gas prices are thus following the growth pattern of the crude oil price trajectory in the WEM case. Regarding the WEM Sens 1 scenario, natural gas prices are rising up to 12 US$/MBtu in 2020 and 17 US$/MBtu in 2030 also following the growth path of oil prices in the WEM Sens 1 scenario (average annual growth of 6.8% 2010-

2014, 3.5% 2014-2030, 4.2% 2010-2030). In the lower growth scenario WEM Sens 2 it is assumed that natural gas prices decouple themselves to some extent from oil price developments according to the recent trend of growing unconventional gas reserves and increasing gas-to-gas competition in some markets, particularly in North America. Thus gas prices rise to 10.5 US$/MBtu in 2020 and 10.8 US$/MBtu in 2030 only, with an average annual growth of 5.3% between 2010 and 2014 and 1% between 2014 and 2030 (1.8% over the whole period). The growth rates are therefore somewhat lower than the growth rates of the crude oil price in the WEM Sens 2 scenario due to decoupling.

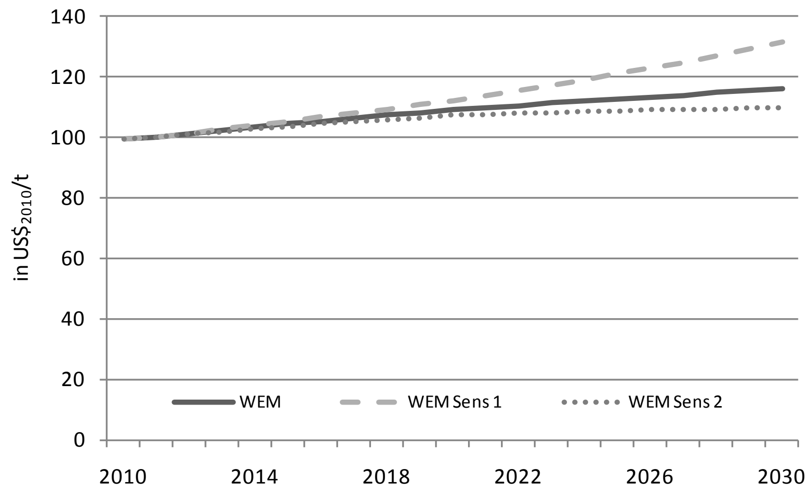
Figure 2: Natural gas prices, real, 2010-2030



S: *IEA*, 2011, own calculations.

Coal prices have fallen relative to both oil and gas prices in the decade prior to 2010. This is partly due to different market conditions and to growing environmental constraints on coal use in OECD countries but also due to stable production costs. However coal prices have recently rebounded because demand from emerging economies such as China is growing (*IEA*, 2011). Coal prices are assumed to rise gradually throughout the projection period (cf. Figure 3). The WEM coal price assumptions are like the WEM oil and natural gas price trajectories taken from the *IEA* (2011) New Policy Scenario and grow much more slowly than oil and natural gas, at an average annual growth rate of 1.1% in 2010-2014 and 0.7% in 2014-2030 (0.8% p.a. 2010-2030). In the WEM Sens 1 scenario the coal price is obviously higher reaching 112 US$/t in 2020 and 131 US$/t in 2030 (1.2% p.a. 2010-2014, 1.5% 2014-2030, 1.4% 2010-2030) while in the lower growth WEM Sens 2 scenario the coal price reaches 107 US$/t in 2020 and 110 US$/t in 2030 only (0.9 % p.a. 2010-2014, 0.4% 2014-2030, 0.5% 2010-2030).

Figure 3: Coal prices, real, 2010-2030



S: *IEA*, 2011, own calculations.

End-user price trajectories for households and industries are derived on the basis of the growth rates of fossil fuel price trajectories presented here; they are summarized in Appendix 2.

3.2 Demographic and climatic data

Future energy demand is also determined by demographic factors such as population growth or the number and structure of household development. In particular, demand for heating and cooling depends *inter alia* on the structure and growth of households. Assumptions about population and household growth are uniform throughout the WEM scenario family and are presented in Table 5. According to this information, the population in Austria will grow on average by 0.35% per year from 8.45 million inhabitants in 2012 to 9 million in 2030 (*Statistik Austria,* 2012a). This trajectory is slightly higher than in previous projections. The historic trend from 1995 to 2012 exhibits a slightly higher average annual growth rate of 0.37% (*Statistik Austria,* 2012a). The number of households is projected to increase at a rate of 0.52% p.a. from 3.67 million to 4.03 million households and hence it shows a higher growth rate than that of the population. Empirical data show a growth rate in households of 0.83% from 1995 to 2012 (*Statistik Austria,* 2012b). According to this forecast, a continuous trend towards a growing number of single-households prevails.

In addition, heating degree days are employed in the model analysis as an exogenous variable that determines heating or cooling demand and thereby energy use. The assumed trajectory of heating degree days is shown in Table 5. According to this table heating degree days are continuously decreasing throughout the projection period. This trend basically reflects the growing influence of global warming. The trend has been calculated as an average between the Holt-Winters trend extrapolation and the moving average extrapolation of heating degree days in the past.

Table 5: Population, households and heating degree days, 1995-2030

	Population	Households	Heating degree days
	in 1000		
1995	7,948	3,189	3,415
1996	7,959	3,214	3,820
1997	7,968	3,239	3,485
1998	7,977	3,261	3,309
1999	7,992	3,284	3,253
2000	8,012	3,311	2,958
2001	8,021	3,340	3,294
2002	8,064	3,380	3,191
2003	8,100	3,407	3,463
2004	8,143	3,440	3,322
2005	8,201	3,475	3,527
2006	8,254	3,510	3,315
2007	8,283	3,540	3,025
2008	8,319	3,570	3,131
2009	8,355	3,598	3,138
2010	8,388	3,621	3,557
2011	8,421	3,645	3,116
2012	8,458	3,671	3,157
2013	8,489	3,692	3,161
2014	8,523	3,715	3,139
2015	8,558	3,738	3,134
2016	8,589	3,760	3,126
2017	8,620	3,781	3,114
2018	8,651	3,803	3,106
2019	8,682	3,825	3,096
2020	8,713	3,847	3,086
2021	8,743	3,868	3,077
2022	8,773	3,887	3,068
2023	8,803	3,906	3,058
2024	8,833	3,924	3,049
2025	8,863	3,943	3,039
2026	8,890	3,961	3,030
2027	8,918	3,979	3,021
2028	8,945	3,997	3,011
2029	8,973	4,015	3,002
2030	9,000	4,033	2,992

S: *Statistik Austria*, 2012b, 2012c, own calculations.

3.3 Energy efficiency

Energy efficiency indices of the energy consuming capital stocks of households constitute a further exogenous input data to the modeling of the WEM scenario ensemble and are the output of bottom-up studies. The different energy efficiency indices of durable goods such as the passenger car fleet, the heating system and building stock or the electrical household appliances determine the specific energy service price and thereby the energy service demand of households (cf. Appendix 2.3). The relevant literature indicates that if energy efficiency increases, the per unit price of energy service decreases (c.p.) thereby causing a rebound in energy demand. The increased energy consumption partially offsets the impacts of efficiency gains (*van den Bergh*, 2011; *Sorrell*, 2009). As explained above, the present model approach does take the rebound effect into account. Energy efficiency of industries is calculated on the basis of historical trends and adopted from econometric estimations of factor demand in European industries (*Kratena – Wüger, 2012*). Average annual growth of energy efficiency in the manufacturing industries is given in Table 6. In addition, experts from the Environment Agency Austria gave their estimates on the potential for further growth in energy efficiency in the manufacturing industries. These estimates laid the groundwork for quantitative suggestions on future efficiency improvements in the WAM scenario.

Table 6: Improvements of energy efficiency in manufacturing industries in WEM and efficiency potential, 2012-2030

Clusters	Manufacturing sectors	Efficiency improvement WEM 2012-2030 ø % p.a.	Potential for efficiency improvements in qualitative terms
1	Iron and steel & non metalic minerals	0.86	-
1	Chemical and petrochmical	1.94	+
1	Non ferrous metals	-0.52	-
2	Transport equipment	0.13	+
3	Machinery	2.37	++
3	Mining and quarrying	3.24	+
2	Food, tabacco and beverages	3.21	+
1	Pulp, paper and print	1.00	+
2	Wood and wood products	2.62	+
3	Construction	-0.39	++
3	Textiles and leather	6.05	+
3	Non specified industries	-1.38	++

S: DEIO Model (*Kratena – Wüger*, 2012), Environment Agency Austria.

The clusters 1 to 3 are grouped according to the industry sectors mostly covered by the EU ETS (1), partly covered by the EU ETS (2) and not covered by the EU ETS (3). Assumptions on efficiency improvements in the three industry clusters – given by expert judgments from the Environment Agency Austria – suggest a growth in efficiency in manufacturing of about 7,374 TJ for cluster 1, 2,578 TJ for cluster 2 and 4,174 TJ for cluster 3 until 2020 compared to WEM. These efficiency gains are derived on the basis of the requirements of the Energy Efficiency Directive that involves a rate of 1.5% average annual efficiency improvements for the Austrian economy. Given early action, this figure reduces to about 1.125% p.a. efficiency gains. Table 7 shows the efficiency gains implemented in the WAM scenario in industrial sectors.

Table 7: Efficiency gains in manufacturing sectors in the WAM scenario, 2014-2020

	2014	2015	2016	2017	2018	2019	2020
Cluster 1				in TJ			
WEM	194,137	195,707	198,031	200,633	203,569	206,746	210,702
WAM	191,740	192,574	194,125	195,924	198,019	200,322	203,328
Efficiency gains (WEM-WAM)	2,397	3,133	3,905	4,710	5,549	6,424	7,374
Cluster 2							
WEM	48,843	48,368	48,019	47,728	47,468	47,221	47,076
WAM	48,077	47,348	46,726	46,144	45,576	45,005	44,499
Efficiency gains	766	1,019	1,293	1,584	1,892	2,216	2,578
Cluster 3							
WEM	63,089	63,404	63,722	64,170	64,718	65,342	66,317
WAM	61,702	61,633	61,533	61,534	61,604	61,717	62,143
Efficiency gains	1,386	1,771	2,189	2,636	3,114	3,625	4,174

S: Own calculations, Environment Agency Austria.

Due to the efficiency improvements and thus a lower demand for relevant energy products in the industry, real output production from energy sectors decreases. These sectors are mining (NACE 10), coke and refined petroleum (NACE 23) as well as electricity, gas, steam and hot water supply (NACE 40) where production deviates from the WEM level by -1.5%, -0.7% and -1.6% respectively in 2020. These output changes from the macroeconomic top-down model are employed as input in the bottom-up models.

3.4 Climate and energy policy

The following table provides a summary of climate and energy policy implemented in the WEM scenario ensemble. These policy measures are thus taken into account in the macroeconomic top-down and in the bottom-up models.

Table 8: Climate and energy policy considered in the WEM scenario ensemble

Electricity generation
Green Electricity Act 2011
Water Framwork Directive (2000/60/EU)
Optimising existing hydroelectric power plants
Heat-Power-Cogeneration Act (BGBl. I Nr. 111/2008)
Expansion of photovoltaic technology (Klima- und Energiefonds)
Emission Trading (100% auctioning in electricity generation)
Heat and warm water (houholds and services)
New buildings and heating systems
Thermal building insulation (0.7% until 2030, constant quality)
Boiler exchange
Promotion of renewable energy
Promotion of district heat and local heat
Transport
EU Biofuel Directive and national Fuel Regulation (7.34% share)
Greening of NOVA (car registration tax)
Klima:aktiv mobil program
Fuel saving initiative
Telematics systems Danube
Increase of mineral oil tax 2011
Promotion of public transport and mobility management
Speed limit (Technical Instruction for protection of the air, IG-L)
Promotion of connecting railways in freight transport
Greening of truck toll scheme
Industsry
Efficiency improvements by technological developments
EU Emission Trading System

S: Own illustration.

4. Energy Use Scenarios

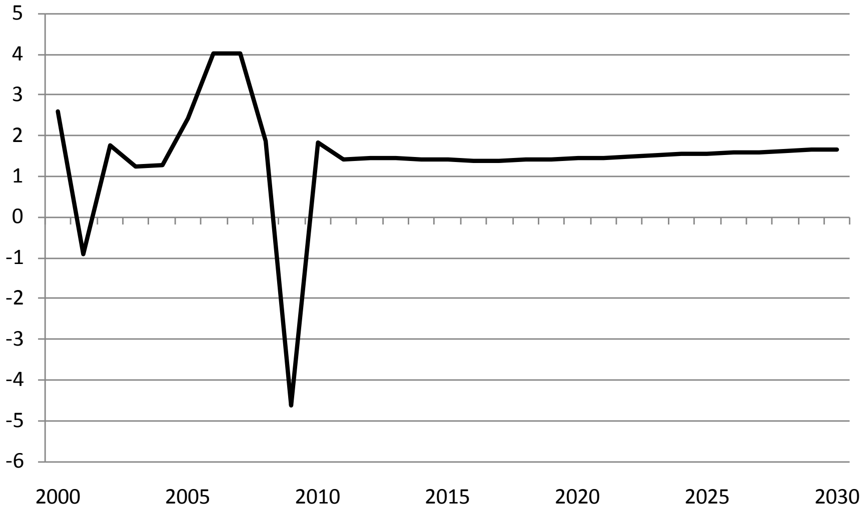
4.1 The WEM scenario

Modeling the WEM scenario requires specific energy prices for households and industries as input data. These price trajectories are calculated from price elasticities relating to the crude oil price. Household and industry energy prices take account of taxes, excise duties and carbon dioxide emissions pricing as well as subsidies, if applicable. Taxes and excise duties on fuels are assumed to remain unchanged as the WEM scenario abstracts from further climate and energy policies. Household energy prices for transport fuels, electricity and other fuels are depicted in Appendix 2.1. Household fuel price developments are provided by the TU Graz. Price increases are depicted as an index development. According to this the price for diesel rises by 75% and that for gasoline by 79% between 2010 and 2030 at current prices. In real terms, these growth rates translate to 11% for diesel and 13% for gasoline (Figure 24). Among the other household energy prices heating oil shows the strongest growth (+179% in current terms) followed by electricity (+75%), fuelwood (64%), natural gas (+49%) and biomass (+12%, cf. Figure 25). Industry energy prices are summarized in Appendix 2.2. While transport fuels show a moderate growth, i.e. the price of kerosene grows by 66% from 2005 to 2030 at current prices, diesel by 51% and gasoline by 35%, fuel oil shows the highest increase (+337%), followed by gasoil (+270%), electricity (+154%), coal (+145%), coke (+120%), gas and gas products (+85%), district heat (+ 55%) and renewables (+42%).

4.1.1 Economic growth

The economic performance measured as GDP or value added of a country is a key driver of energy demand and thus strongly correlated with energy demand and GHG emissions. The close link between the growth of GDP and GHG emissions was clearly visible as a result of the financial and economic crisis of 2008/09 when GHG emissions dropped sharply with the slump in GDP. The total growth in GDP is derived as the sum of the value added of the economic sectors. The GDP projection for 2012-2030 in the WEM scenario is pictured in Figure 4. According to this illustration the economy grows by 1.5% on average per year between 2012 and 2030, with an average annual growth rate of 1.4% from 2012 to 2020 and 1.6% from 2020 to 2030. The GDP growth path constitutes an exogenous input data for the bottom-up models of the consortium partners.

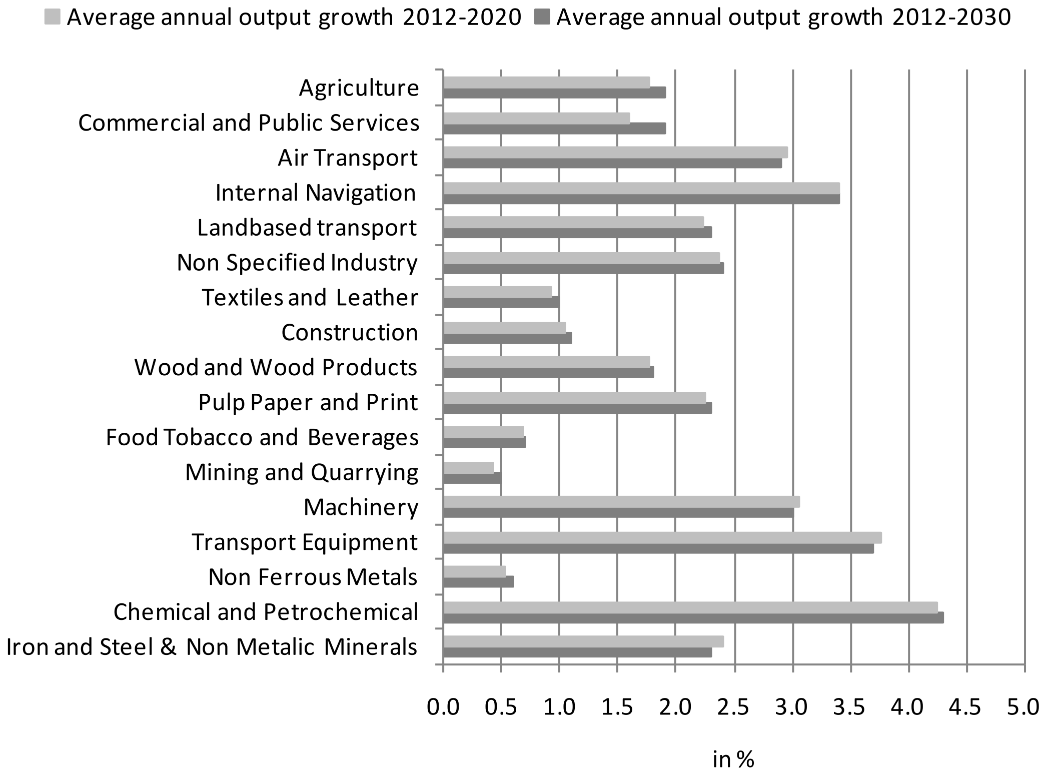
Figure 4: GDP growth in WEM, real, 2000-2030



S: *Statistik Austria*, own calculations.

Average annual growth rates of the economic sectors of the Austrian economy are displayed in Figure 5 for two periods of time, from 2012-2020 and from 2012-2030. Growth is highest in the chemical and petrochemical sector (4.2% on average p.a. from 2012-2020), the transport equipment industries (3.7%), internal navigation (3.4%), the machinery (3%) and the air transport sector (2.9%). Growth in iron and steel industries (2.3%), pulp and paper industries (2.3%), land based transport (2.3%) and the non specified industries sector (2.4%) demonstrate above 2% average annual growth. For the period 2012-2030 average annual growth is slightly higher by about 0.1 percentage points. This is due to the somewhat higher growth impetus in the second decade that *inter alia* stems from a lower growth rate in energy prices after 2014. In sum, production in the economic sectors is more dynamic than total GDP growth, in particular transport related industries as well as the petrochemical sector show a significant growth dynamic.

Figure 5: Average annual growth in economic sectors, real, WEM, 2012-2030

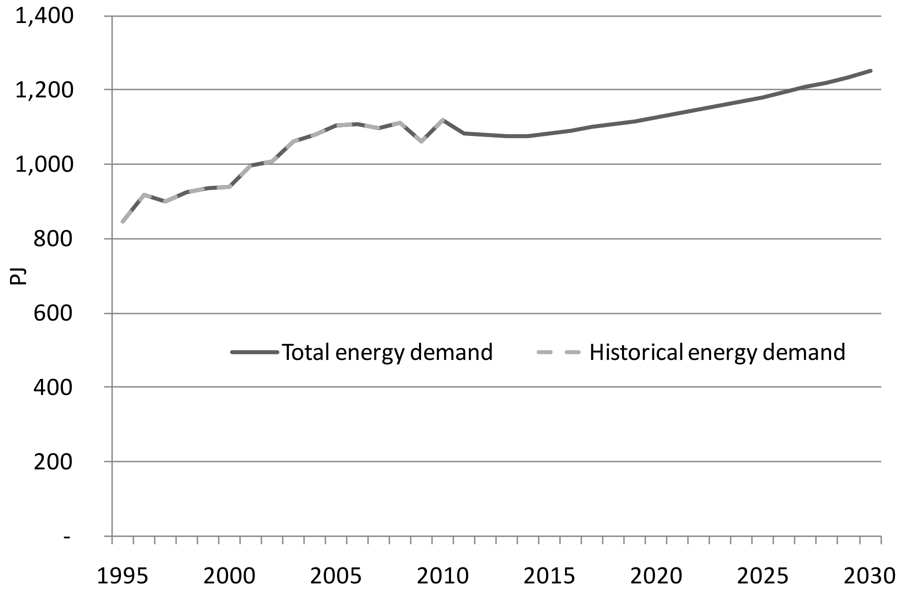


S: own calculations.

4.1.2 Final energy demand

Influenced by the structural economic growth pattern, total final energy demand rises by 4.5% in the first decade (2012-2020) and by 11% in the second decade (2020-2030) increasing in total by 16% from 2012-2030 (cf. Figure 6). The slower growth in energy demand until 2020 is, on the one hand, explained by higher oil price growth that generally has a more dampening effect on energy demand, and, on the other hand, by the impact of the underlying climate and energy policies targeted towards the year 2020. These effects peter out in the second decade as policies are targeted towards 2020. In addition, GDP growth is slightly higher in the second decade which also contributes to a rise in energy demand after 2020. Total final energy demand achieves 1,127 PJ in 2020. Energy demand of the WEM scenario thus slightly exceeds the 1,100 PJ-target stipulated by the Austrian energy strategy (see above).

Figure 6: Total final energy demand in Austria, WEM, 1995-2030



S: own calculations.

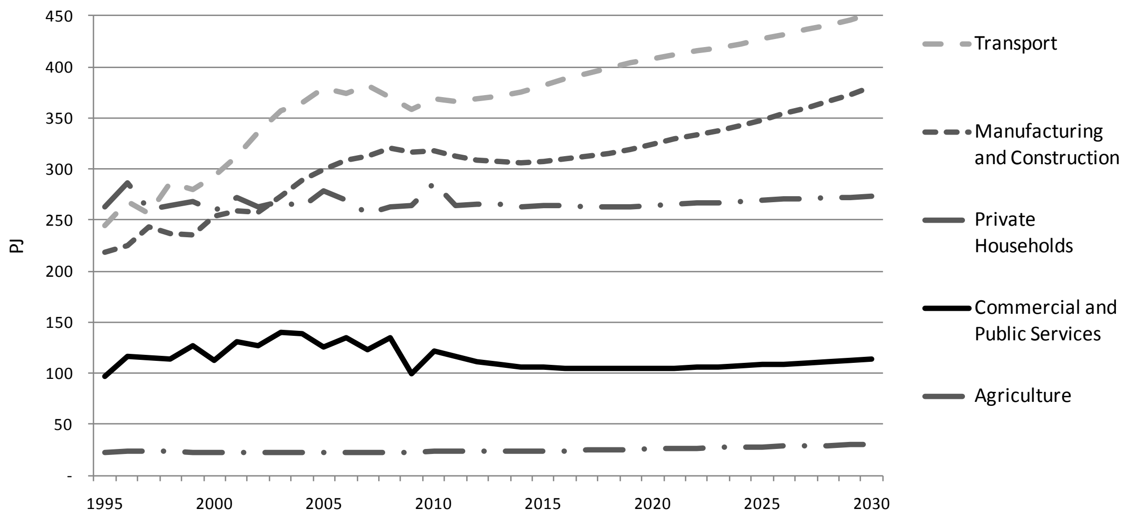
Sector-wide energy demand is shown in Figure 7 and Table 9. In the first decade (2012-2020), growth in energy demand is moderate in the manufacturing and construction sector and negative in the commercial and public service sector as well as in the private household sector while energy demand rises by around 11% in the transport and the agricultural sector. After 2020 energy demand increases substantially in the manufacturing and construction sector (+17.4%) as well as in agriculture (+16.5%) while growth in the transport and private household's sectors is at around 10%. Given these patterns in energy demand and given the long term strategy of decarbonizing the energy sector by 80%-90% (*European Commission*, 2011; *Kettner et al.,* 2012), manufacturing and construction, transport and agriculture emerge as sectors that need to be addressed by future climate and energy policy as they show substantial growth potential in energy demand if this is not addressed by political regulation.

Table 9: Growth in energy demand by sectors, WEM, 2012-2030

	2012-2020	2020-2030	2012-2030
		in %	
Manufacturing/Construction	4.8	17.4	23.0
Transport	10.7	10.9	22.7
Commercial/Public Services	-0.5	3.7	3.1
Private Households	-6.0	9.3	2.7
Agriculture	10.5	16.5	28.8
Total	4.5	11.1	16.1

S: own calculations.

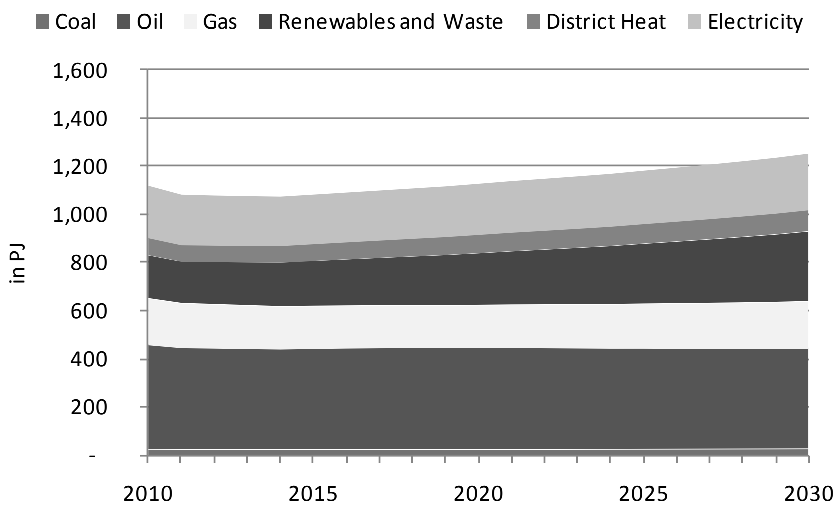
Figure 7: Energy demand by sectors, WEM, 1995-2030



S: own calculations.

Final energy demand by energy sources between 2012 and 2030 shows a substantial growth in renewable energy sources (+65.7%), district heat (+25.8%), coal demand (+16,2%) and electricity (+12.9%) while demand for natural gas increases moderately (+7,5%) and demand for oil even declines (-1%; cf. Figure 8, Table 10).

Figure 8: Final energy demand by energy sources, WEM, 2010-2030



S: own calculations.

Table 10: Growth in energy demand by energy source, WEM, 2012-2030

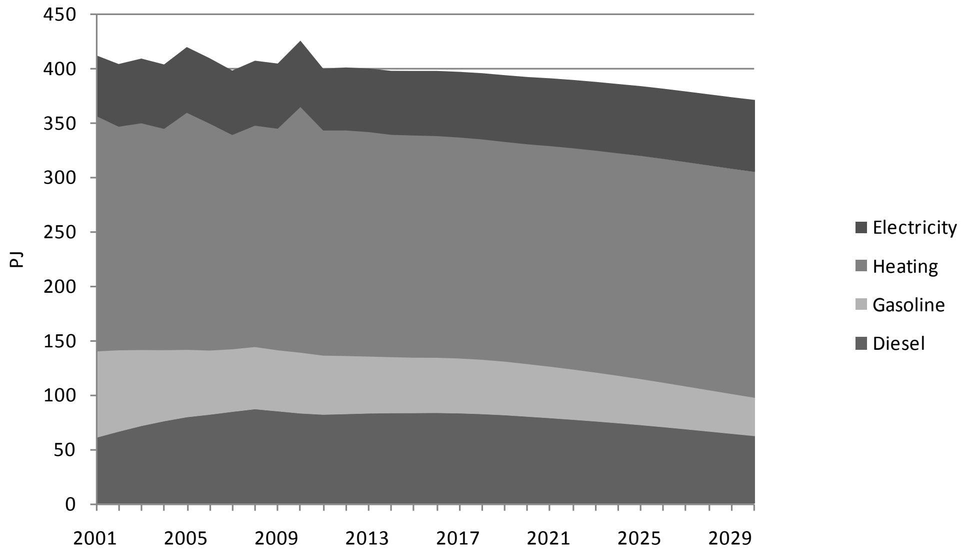
	2012-2020	2020-2030	2012-2030	2012	2020	2030
		in %			share (in %)	
Coal	3.8	11.9	16.2	1.9	1.9	1.9
Oil	0.4	-1.4	-1.0	39.3	37.7	33.5
Natural Gas	-3.3	11.2	7.5	16.7	15.5	15.5
Renewables and Waste	22.8	34.9	65.7	16.3	19.2	23.3
District Heat	10.9	13.4	25.8	6.5	6.9	7.0
Electricity	2.0	10.7	12.9	19.3	18.8	18.7
Total	4.5	11.1	16.1	100.0	100.0	100.0

S: own calculations.

The structure of the energy mix in total final energy demand is shifting, with the share of renewable energy sources and waste growing substantially from 16% in 2012 to 19% in 2020 and 23% in 2030 showing an increase of 66% from 2012 to 2030. The share of coal remains rather constant throughout the projection period and the share of oil declines from 39% in 2012 to 37.7% in 2020 and 33.5% in 2030. The share of natural gas is slightly reduced from 16.7% in 2012 to 15.5% in 2020 and 2030 with natural gas demand on the rise by 7.5%. The share of electricity is rather constant (19.3% in 2012, 18.7% in 2030) with a moderate growth of 13% (2012-2030). Demand for district heat is growing by 26% (2012-2030) with a slight increase in the share of the energy mix.

Total household energy demand as part of Austria's final energy demand declines from 401 PJ in 2012 to 392 PJ in 2020 and 371 PJ in 2030 (cf. Figure 9). This trajectory includes the assumed increase in energy productivity (cf. Appendix 2: Input Data.3) and rebounds in energy demand. Demand for diesel declines strongly by 22% in the second decade with an overall decline of 24% (2012-2030). Gasoline demand shrinks even more strongly by 27% from 2020 to 2030 and by 34% between 2012 and 2030. The share of diesel and gasoline in the household's energy mix thus shift from 20% diesel and 13% gasoline in 2012 to 17% diesel and 9.5% gasoline in 2030 (cf. Table 11).

Figure 9: Total household energy demand by fuel, WEM, 2001-2030



S: own calculations.

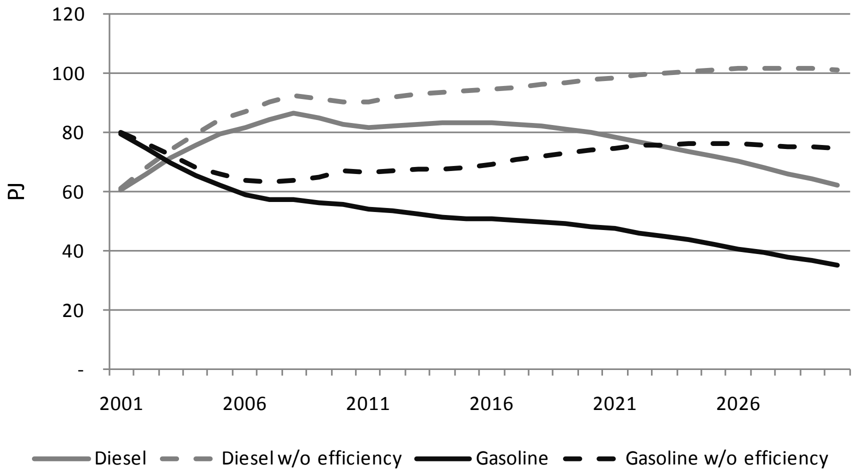
Table 11: Growth in household energy demand by fuel, WEM, 2012-2030

	2012-2020	2020-2030	2012-2030	2012	2020	2030
		in %			share (in %)	
Electricity	6.9	7.0	14.4	14.5	15.9	18.0
Heat	-2.6	2.6	0.0	51.6	51.4	55.8
Diesel	-2.9	-22.2	-24.5	20.5	20.3	16.7
Gasoline	-9.5	-27.1	-34.1	13.3	12.3	9.5
Total	-2.2	-5.4	-7.5	100.0	100.0	100.0

S: own calculations.

Figure 10 summarizes energy consumption from passenger car service demand by households. The upper dotted lines reflect household transport service energy demand, i.e. driving a particular distance; the straight lines show the resulting energy demand by diesel and gasoline car fleets considering efficiency improvements as set out in the appendix. In the model the demand for transport service is implemented as a function of a service price (fuel price divided by efficiency index). Transport service demand increases as the service price (due to the efficiency improvement) decreases. Thus efficiency gains lead to a rebound effect.

Figure 10: Household transport service energy demand, WEM, 2001-2030

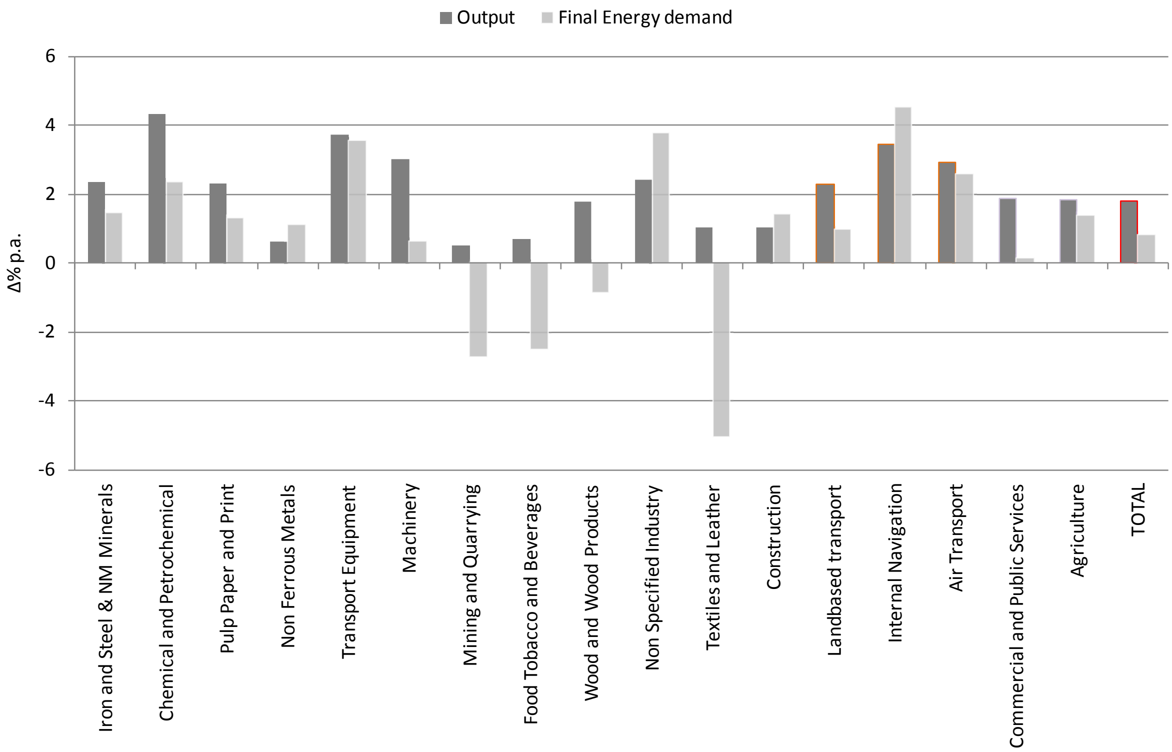


S: own calculations.

Household electricity demand grows by around 7% in both decades such that the total increase in electricity is at 14% and the share in the energy mix of households rises from 14.5% in 2012 to 18% in 2030. Heat demand by households remains constant over the trajectory as it declines in the first decade and increases after 2020 by the same amount. Due to the strong decline in the demand for transport fuels, the share of heat in the household energy mix rises from 52% in 2012 to 56% in 2030 and thus constitutes the majority share of energy demand by households. Demand dynamics for heat remain low but the level in heat demand, or the share in households energy demand, is rather high. The heating sector is thus a central sector when considering climate and energy policy. Reductions in transport energy demand by households appear to be rather pronounced for a business-as-usual scenario given historical trends in passenger transport-related energy demand. Therefore, it appears to be important to reconsider existing transport policies to see whether they may indeed generate the assumed efficiency improvements of car fleets.

The average annual change in output and in energy demand in sectors is displayed in Figure 11. The difference in growth rates of output and energy demand can be explained by historical trend developments in energy productivity as well as by structural changes within these industries.

Figure 11: Average annual change in output and energy demand in sectors, WEM, 2012-2030



S: own calculations.

4.2. The WEM Sens 1 and WEM Sens 2 scenarios

In addition to the main WEM scenario, two sensitivity scenarios WEM Sens 1 and WEM Sens 2 are computed based on alternative assumptions of world economic development and fossil fuel prices. The WEM Sens 1 scenario represents a world with higher economic growth and thus higher crude oil and natural gas prices than the benchmark (WEM). The WEM Sens 2 scenario describes a world of lower growth and lower energy prices.

The sensitivity scenarios WEM Sens 1 and WEM Sens 2, like the WEM scenario, require specific energy price data as inputs to model energy demand (see section 3.1). These household and industry price trajectories are calculated on the basis of price elasticities relating to the relevant crude oil price trajectories (cf. Figure 1). Since the deviations of the household and industry energy prices from the crude oil prices correspond to the difference between the crude oil price and the household and industry prices in the WEM scenario (cf. Appendix 2.1 and 2.2), the energy price trajectories for the WEM Sens 1 and WEM Sens 2 scenarios are not reproduced here.

Additionally, a slight decoupling of gas prices from crude oil prices is assumed to occur in WEM Sens 2 (cf. Table 1). The decoupling of crude oil and gas prices leads, in principle, to fuel substitutions in industry sectors and households to the extent that the (production or service) technology in use allows for different fuel types. The demand for energy is then shifted towards the more competitive natural gas. However, the effects of decoupling oil and gas prices are minor.

As an example, interfuel substitution resulting from a 15% reduction in the natural gas price is shown for the sector group chemical and petrochemical (cf. Table 12). This analysis is a ceteris paribus calculation with all other prices remaining constant. The share in natural gas products shifts from 32.8% to 34.5% in 2030 as a reaction to the price reduction. This example shows that the reaction is rather limited which can be explained by low elasticities.

Table 12: Interfuel Subsitution in sector group chemical and petrochemical, 2030

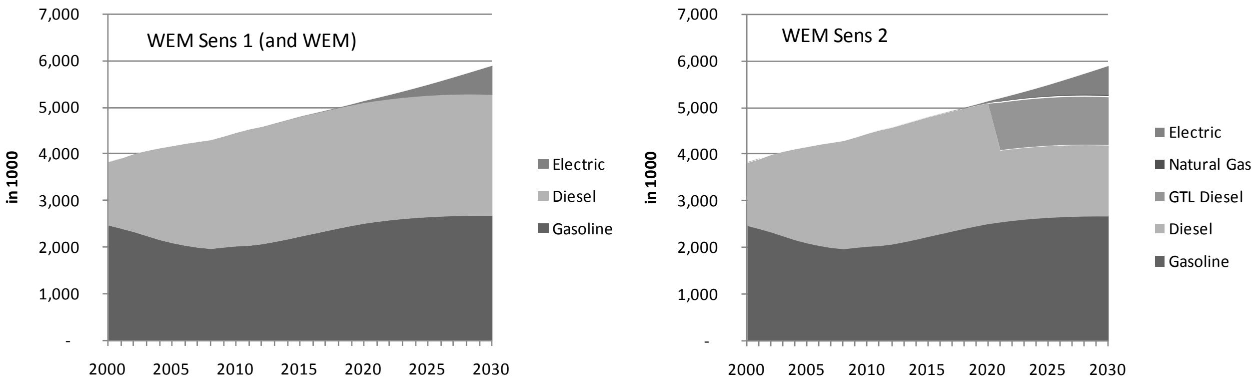
		Reference	-15% Gas price
	2010	2030	2030
		in %	
Coal Products	0.9	1.2	1.2
Oil Products	3.2	3.0	3.0
Gas Products	37.3	32.8	34.5
Renewables	20.2	34.2	32.5
Electricty and District Heat	38.4	28.8	28.8

S: Own calculations.

Further research should, however analyze, the impact of a more profound price spread between oil and natural gas than those assumed here. Firstly it should be noted that natural gas prices in the United States have already achieved a level of 70% below the European natural gas import prices (*Kemfert*, 2013) because of the growing supply of natural gas from fracking and the exploitation of unconventional gas reserves. These developments will certainly also influence European import prices. Second, European import prices are expected to fall irrespective of whether the technology of fracking is considered for the EU (there are many doubts as to the sustainability of this method in particular with respect to water pollution, landscape degradation and public health), because EU gas import contracts that control gas price to oil price developments are becoming less and less stringent (*IEA*, 2012a).

Against this background of gas prices slightly decoupling from oil prices, the WEM Sens 2 scenario assumes that a gas-to-liquid (GTL) plant will be installed by 2020 in Schwechat, Austria. This assumption leads to about 1 million diesel cars substituting diesel for GTL. The composition of passenger car fleets in WEM Sens 1 and 2 are summarized in Figure 12. In both cases car fleets grow to 5.8 million cars in 2030 (5.1 million in 2020). While the share of gasoline driven cars grows to a peak of 49% in 2020 (45% in 2012 and 2030), the share of diesel fuelled cars declines from 55% in 2012 to 44% in 2030. Electric cars rise to a share of about 10% in 2030 (1% in 2020) in both scenarios.

Figure 12: Passenger Car Fleets in WEM, WEM Sens 1 and Sens 2, 2000- 2030

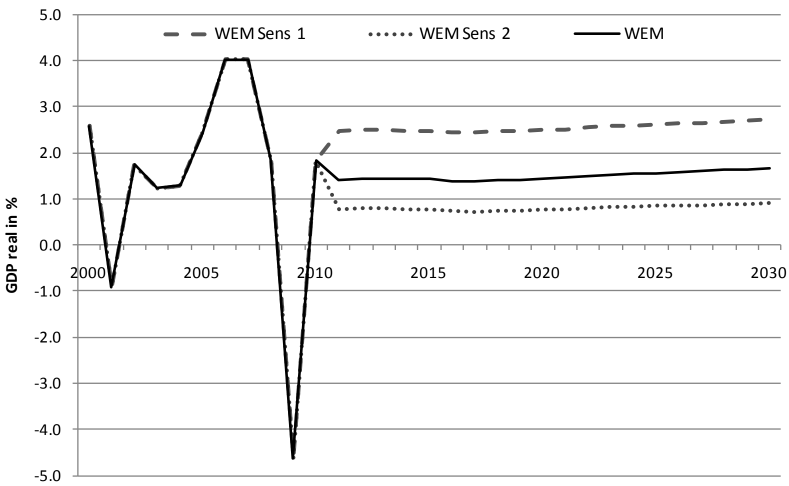


S: Prof. *Hausberger*, TU Graz, own representation.

4.2.1 Economic growth

Based on the differing energy price assumption in WEM Sens 1 and Sens 2 the economic performance of Austria in terms of GDP growth deviates as well from the WEM scenario (cf. Figure 13). The total growth in GDP is again derived from the sum of the value added of the economic sectors. Thereafter the economy grows on average by 2.5% per year between 2012 and 2030 in WEM Sens 1 and by 0.8% on average per year in WEM Sens 2. Average annual growth between 2012 and 2020 is again slightly lower than the average growth in the period 2020 to 2030, namely 2.4/2.6 in Sens 1 and 0.7/0.8 in Sens 2.

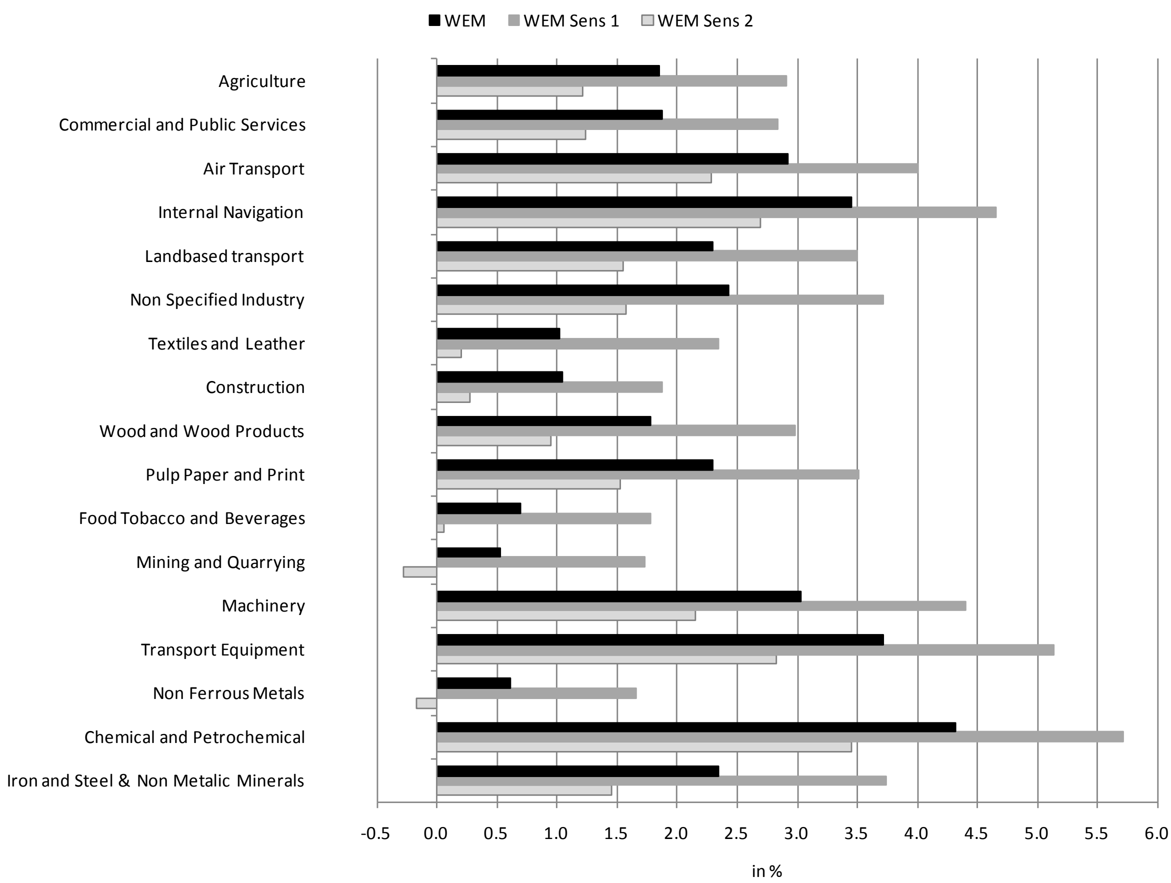
Figure 13: GDP growth in WEM, WEM Sens 1 and Sens 2, real, 2000-2030



S: Own calculations.

Average annual growth rates of the economic sectors of the Austrian economy in the period 2012-2030 are displayed in Figure 14. According to this diagram growth patterns of the scenarios follow the GDP growth pattern with higher average annual growth in WEM Sens 1 and lower growth in WEM Sens 2 with respect to WEM. Growth is again highest in the chemical and petrochemical sector (5.7% Sens 1, 3.5% Sens2), the transport equipment industries (5.1%/2.8%) and internal navigation (4.7%/2.7%), followed by machinery (4.4%/2.2%) and the air transport sector (4.0%/2.3%). In the WEM Sens 2 scenario average annual growth becomes negative for mining and quarrying and non ferrous metals. Interestingly, the commercial and public service sector incurs more than 50% of output production (about 56%-57% throughout all scenarios in 2020). The production share of the chemical and petrochemical sector lies at about 4.4%, machinery has a share of around 4% and land based transport of around 2.7%.

Figure 14: Average annual growth in production by sectors, WEM, WEM Sens 1 and Sens 2, 2012-2030

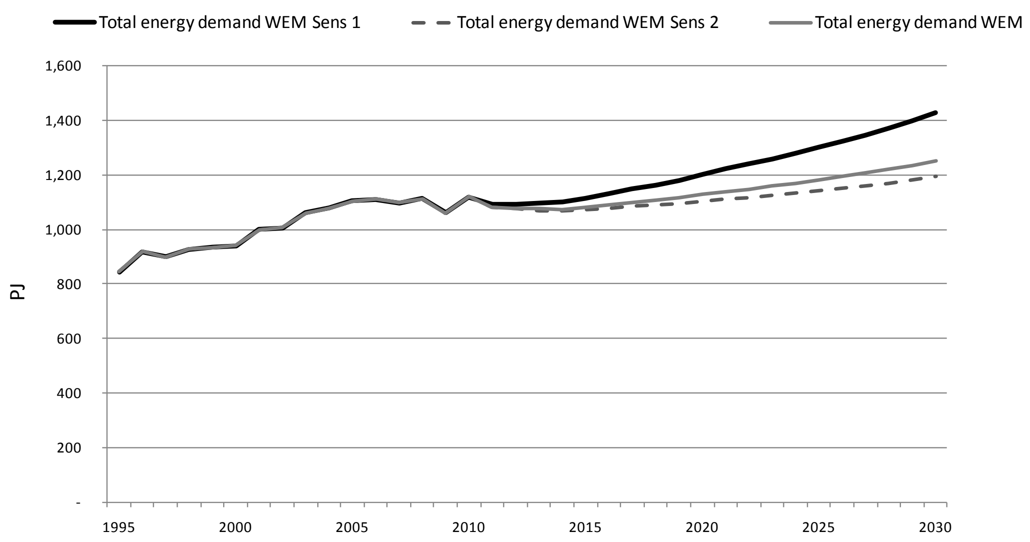


S: Own calculations.

4.2.2 *Final energy demand*

Influenced by the structural economic growth patterns presented above, total final energy demand rises to 1,202 PJ in 2020 in WEM Sens 1 and to 1,102 PJ in 2020 in WEM Sens 2, exceeding the 1,100 PJ-target of the Austrian energy strategy in the high growth scenario WEM Sens 1. Only the low growth scenario WEM Sens 2 is able to achieve the 1,100 PJ-target without any need to enact further climate and energy measures (cf. Figure 15). Final energy demand thereby grows by 9.8%/2.5% between 2012 and 2020 (Sens 1/Sens 2), by 18.9%/8.2% between 2020 and 2030, and by 30.6%/11% between the whole projection period of 2012 and 2030. The slower growth in energy demand until 2020 is again explained by higher oil price growth in the first decade as well as by the impact of climate and energy policies targeted towards the goals for the year 2020. This pattern is in line with the respective GDP growth rates which are slightly higher in the second decade as well.

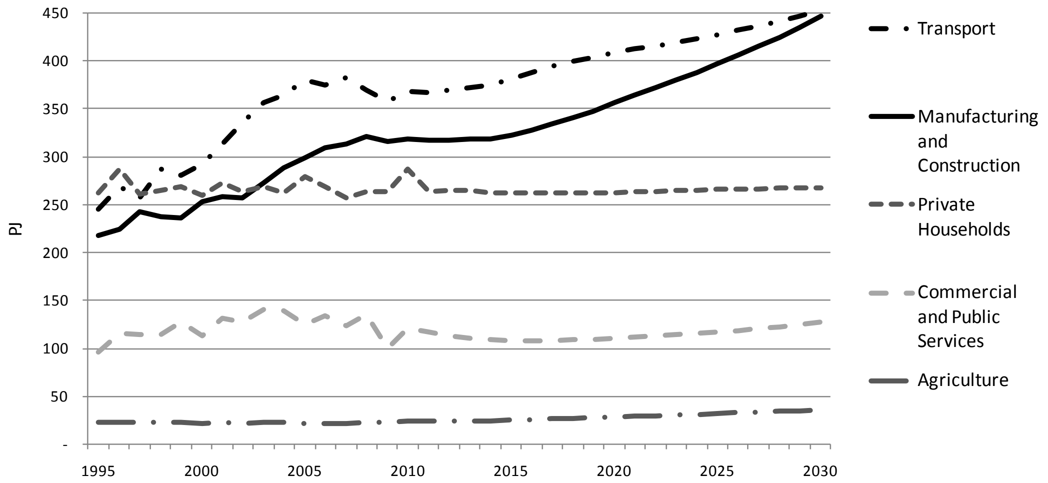
Figure 15: Total final energy demand in Austria in WEM, WEM Sens 1 and Sens 2, 1995-2030



S: Own calculations.

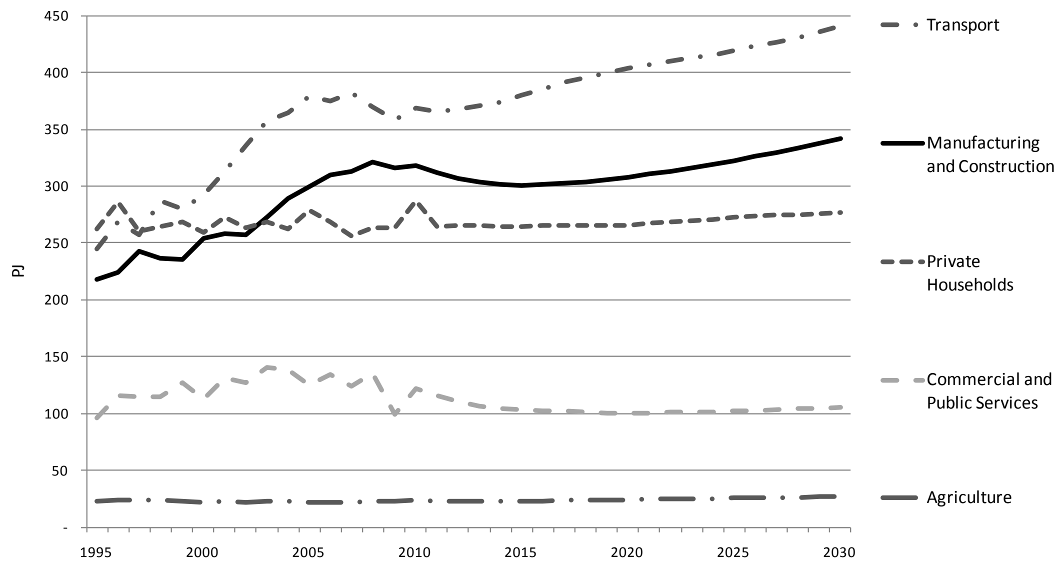
Sector specific energy demand is depicted in Figure 16 and Figure 17. Sectoral growth in both scenarios is also summarized in Table 13. Growth in WEM Sens 1 is strong in transport, agriculture, manufacturing and construction while it is lower in the commercial and public services and almost zero in the private household sector. In WEM Sens 2 the overall growth figures remain low.

Figure 16: Energy demand by sectors, WEM Sens 1, 1995-2030



S: Own calculations.

Figure 17: Energy demand by sectors, WEM Sens 2, 1995-2030



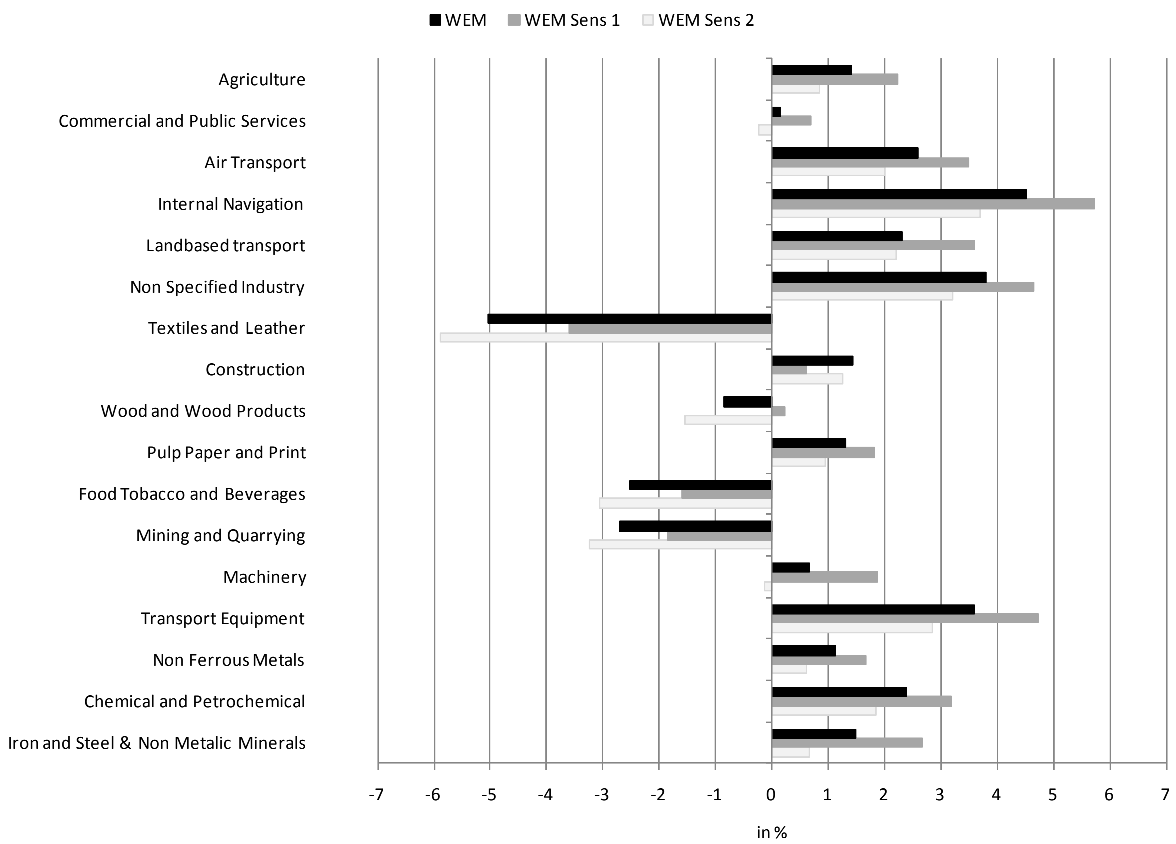
S: Own calculations.

Table 13: Growth in energy demand by sectors, WEM Sens 1 and Sens 2, 2012-2030

	2012-2020		2020-2030		2012-2030	
	WEM Sens 1	WEM Sens 2	WEM Sens 1	WEM Sens 2	WEM Sens 1	WEM Sens 2
			in %			
Manufacturing and Construction	12.2	0.3	25.4	11.0	40.7	11.3
Transport	18.6	9.7	24.0	9.2	47.1	19.8
Private Households	-1.2	-0.1	2.2	4.3	1.0	4.2
Commercial and Public Services	-2.2	-8.9	15.4	5.2	12.9	-4.2
Agriculture	19.5	5.5	24.9	10.2	49.2	16.3
Total	9.8	2.6	18.9	8.2	30.6	11

S: Own calculations.

Figure 18: Average annual growth in final energy demand by sectors, WEM, WEM Sens 1 and Sens 2, 2012-2030



S: Own calculations.

Average annual growth of energy demand across production sectors is pictured in Figure 17. According to this diagram, internal navigation shows the highest average annual growth of 5.7% in WEM Sens1 and 3.7% in WEM Sens 2, followed by transport equipment (4.7%/2.8%) and the non specified industries (4.7%/3.2), land based transport (3.6%/2.2%) and air transport (3.5%/2%). A couple of sectors show negative average annual growth in energy demand such as textiles and leathers (-3.6%/-5.9%), mining and quarrying (-1.9%/-3.3%) and food, tobacco and beverages (-1.6%/-3.1%). Given the average annual production growth (Figure 13) and the average annual growth in energy demand (Figure 17), the difference in growth rates could be explained by historical trends in energy productivity as well as by structural changes within these industries. Absolute energy demand in industrial sectors is summarized for 2020 and 2030 (cf. Figure 19, Figure 20).

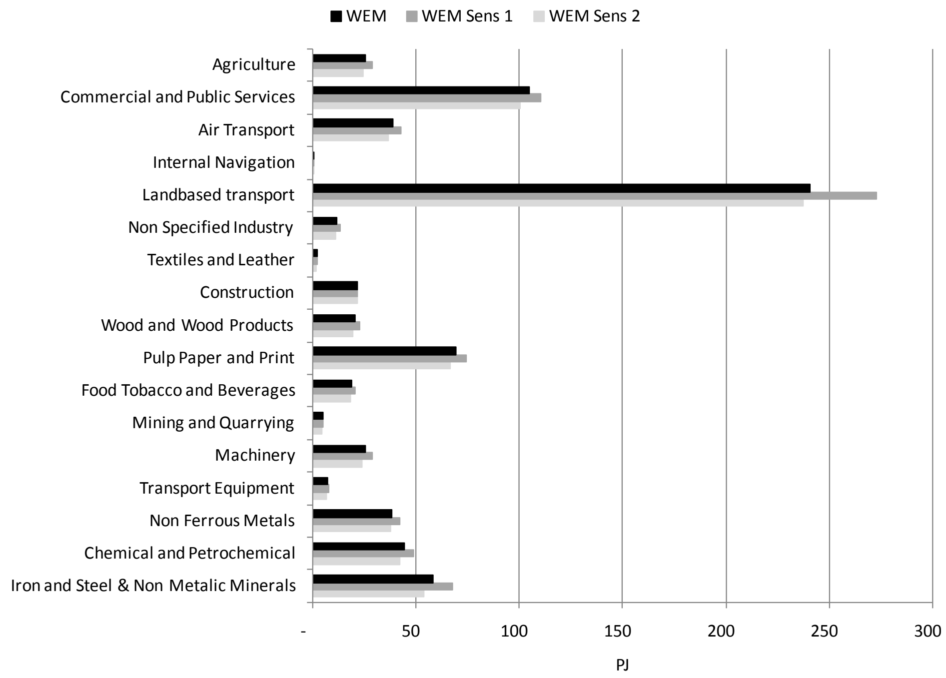
Final energy demand by energy source for WEM Sens 1 and Sens 2 is depicted in Figure 21, and Figure 22, and summarized in Table 13. It is obvious that growth is rather different in the two sensitivity scenarios, e.g. renewables increase by 29% in WEM Sens 1 while they increase by only 20.7% in WEM Sens 2 until 2020. Coal, natural gas and oil decline altogether until 2020 in WEM Sens 2 while these sources grow considerably in the high growth scenario WEM Sens 1.

Table 14: Growth in energy demand by energy source, WEM Sens 1 and Sens 2, 2012-2030

	2012-2020	2020-2030	2012-2030	2012	2020	2030
WEM Sens 1		in %			share (in %)	
Coal	12.8	19.6	34.9	1.9	2.0	2.0
Oil	5.8	7.0	13.2	39.2	37.8	34.0
Natural Gas	1.9	17.6	19.9	16.8	15.6	15.4
Renewables and Waste	29.0	45.2	87.4	16.3	19.2	23.4
District Heat	13.3	17.0	32.6	6.5	6.7	6.6
Electricity	7.2	17.7	26.2	19.3	18.8	18.6
Total	9.8	18.9	30.6	100.0	100.0	100.0
WEM Sens 2						
Coal	-1.4	5.6	4.1	1.9	1.8	1.8
Oil	-0.4	-3.2	-3.6	39.4	38.2	34.2
Natural Gas	-6.3	7.9	1.0	16.7	15.2	15.2
Renewables and Waste	20.7	31.8	59.2	16.3	19.2	23.4
District Heat	9.2	10.7	20.8	6.5	6.9	7.1
Electricity	-0.8	6.8	5.9	19.2	18.6	18.3
Total	2.6	8.2	11.0	100.0	100.0	100.0

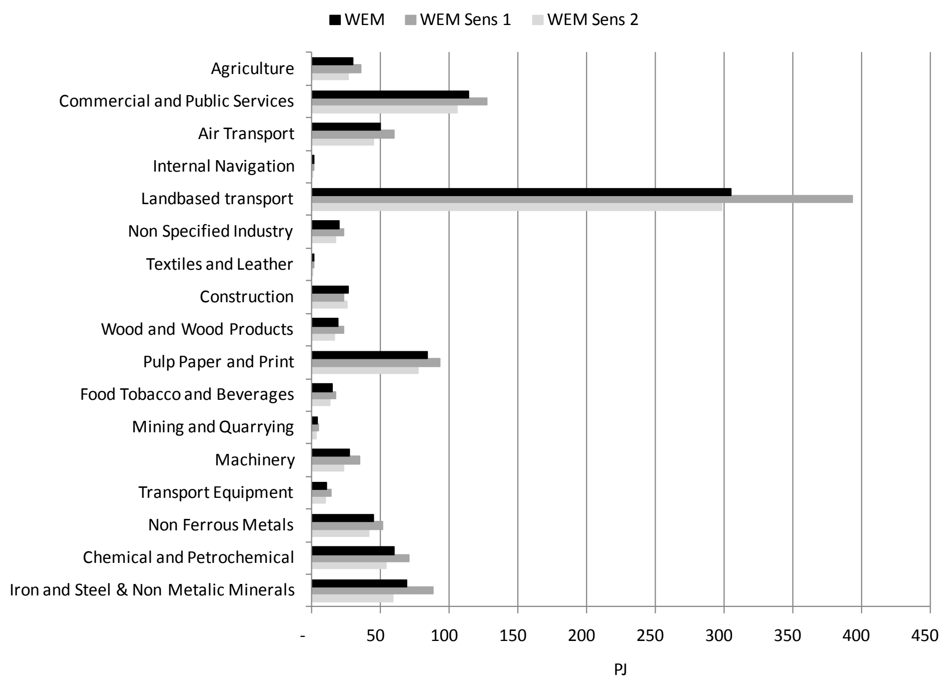
S: Own calculations.

Figure 19: Energy demand by sectors, WEM, WEM Sens 1 and Sens 2, 2020



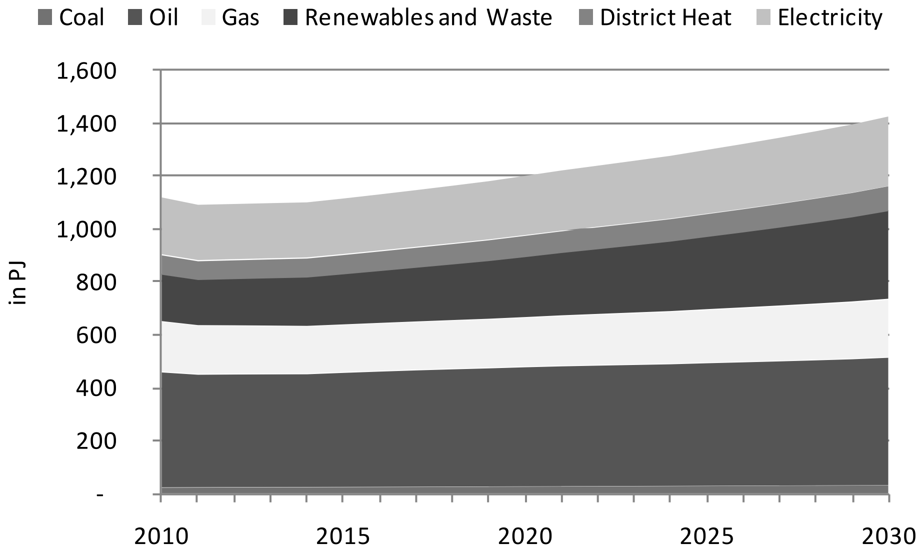
S: Own calculations.

Figure 20: Energy demand by sectors, WEM, WEM Sens 1 and Sens 2, 2030



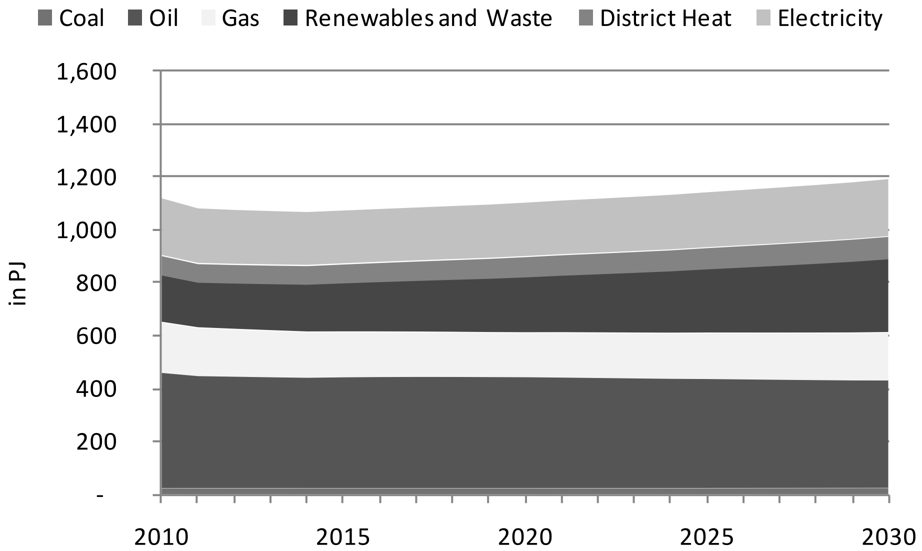
S: Own calculations.

Figure 21: Final energy demand by energy sources, WEM Sens 1, 2010-2030



S: Own calculations.

Figure 22: Final energy demand by energy sources, WEM Sens 2, 2010-2030



S: Own calculations.

5. Conclusions

The main results of the energy scenarios 2030 regarding the growth of GDP and final energy demand in the WEM scenario family from 2012 to 2030 are summarized in Table 15. The table illustrates that the WEM and the WEM Sens 2 scenarios almost reach the 1,100 PJ target of the Austrian Energy Strategy. It is thus possible – according to the model and the assumptions – to reach this 2020 target even if the economy were to follow a different growth path for GDP and energy demand. Both an annual average growth of 1.5% in GDP with an average annual growth in energy demand of 0.8%, or a much lower average annual growth in GDP of 0.8% with an average growth in energy demand of 0.6% produce a final energy demand of close to 1,100 PJ. The WEM scenario thus attests to a higher energy efficiency (energy use per unit of GDP) which is the result of higher international energy prices in WEM. In the long-term, both scenarios are characterized by further growth in energy demand reaching 1,252 PJ in WEM and 1,193 PJ in WEM Sens 2 in 2030. By contrast, the high growth WEM Sens 1 scenario with an average annual growth in GDP of 2.5% overshoots the 1,100 PJ-target in 2020 by about 100 PJ which grows further to 1,429 PJ in 2030.

Table 15: GDP and final energy demand in WEM, WEM Sens 1, Sens 2, 2012-2030

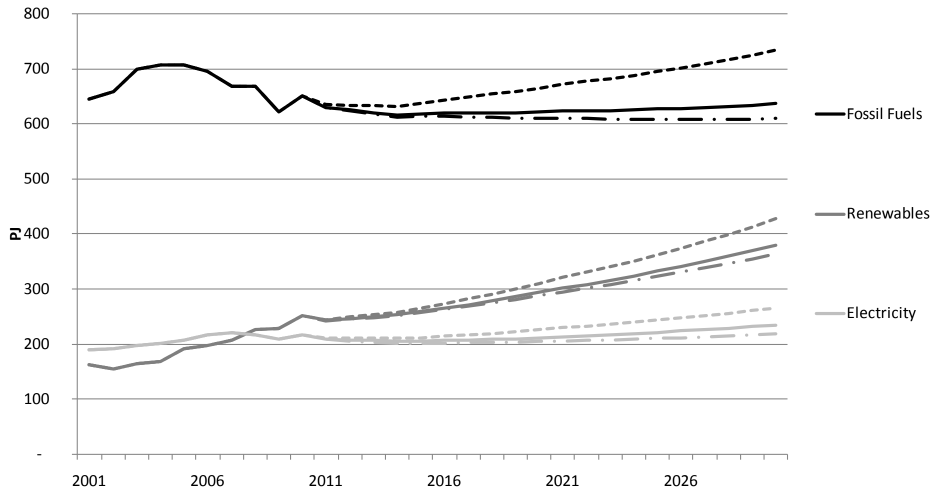
	GDP	Final Energy Demand		
	2012-2030	2012-2030	2020	2030
	ø % p.a.		PJ	
WEM	1.5	0.8	1,127	1,252
WEM Sens 1	2.5	1.5	1,202	1,429
WEM Sens 2	0.8	0.6	1,102	1,193

S: Own calculations.

Thus economic growth above around 1% p.a. would require additional intervention in terms of enacting further climate and energy policy measures to keep final energy demand strictly below 1,100 PJ by 2020. In any case the long-term outlook for 2030 (and beyond) demands the implementation of further climate and energy measures. Given the fact that energy-relevant capital stocks have long life-times, the transition to a low-carbon structure must be planned and executed in good time so that it can actually be effective in 2030.

The various scenario results of energy demand by sectors (Table 9 and Table 13) reflect *inter alia* the state of current climate and energy policies implemented in Austria, i.e. the structure and sectoral relevance of ongoing mitigation activities, as well as the assumed technological progress in energy efficiency. For instance, low growth in energy demand by private households might be evidence of the success and comprehensiveness of climate policies already implemented in this area dealing *inter alia* with thermal insulation, boiler exchange and the promotion of district heat. By contrast, the strong growth in energy demand in transport, manufacturing and construction as well as in agriculture – although the latter is small in terms of its overall share – brings to light that these sectors are not sufficiently covered by existing measures. In particular the strong growth in transport final energy demand indicates the need for comprehensive measures to be enacted in this area.

Figure 23: Energy demand by energy source categories in WEM, WEM Sens 1 and WEM Sens 2, 2001-2030



S: Own calculations.

The various scenario results of energy demand by energy source (cf. Table 10 and Table 14) are summarized in Figure 23. They show that the level of fossil fuel remains rather constant with the exception of the high growth scenario WEM Sens 1. Renewable energy demand including district heat grows substantially in all three WEM scenarios while electricity demand increases only moderately. Emphasis in climate and energy policy should be laid on the reduction of fossil fuel use.

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Appendix 1: Classifications

1.1 Final Demand Sectors and Fuels

Table 16: Final demand sectors and fuels of the energy balance

	Final Demand Sectors		Fuels
1	Iron and Steel & Non Metalic Minerals	1	Hard coal
2	Chemical and Petrochemical	2	lignite
3	Non Ferrous Metals	3	Brown coal briquette (BKB)
4	Transport Equipment	4	Peat
5	Machinery	5	Coke
6	Mining and Quarrying	6	Gasoline
7	Food Tobacco and Beverages	7	Kerosine
8	Pulp Paper and Print	8	Diesel
9	Wood and Wood Products	9	Gasoil
10	Construction	10	Fuel oil
11	Textiles and Leather	11	LPG
12	Non Specified Industry	12	Other Oil Products
13	Landbased transport	13	Refinery gas
14	Internal Navigation	14	Natural gas
15	Air Transport	15	Blast Furnace Gas
16	Commercial and Public Services	16	Coke oven gas
17	Private Households	17	Waste
18	Agriculture	18	Fuelwood
		19	Biofuels
		20	Ambient Heat
		21	District Heat
		22	Electricity

S: Statistik Austria.

1.2 NACE2003 Classification

Table 17: NACE 2003 Classification

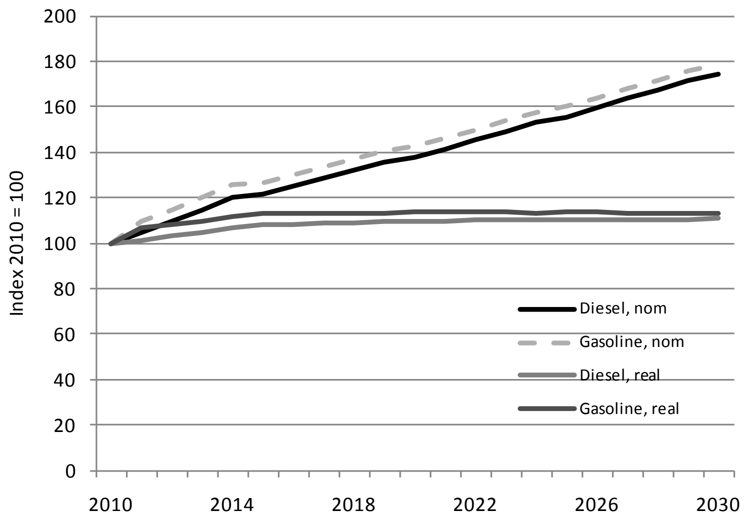
Code	NACE 2003 Sectors	Code	NACE 2003 Sectors
1	Agriculture, hunting and related service	37	Recycling
2	Forestry, logging and related service	40	Electricity, gas, steam and hot water supply
5	Fishing, operating of fish hatcheries and	41	Collection, purification and distribution of water
10	Mining of coal and lignite; extraction of	45	Construction
11	Extraction of crude petroleum and natural	50	Sale, maintenance and repair of motor vehicles and
12	Mining of uranium and thorium ores	51	Wholesale trade and commission trade, except of
13	Mining of metal ores	52	Retail trade, except of motor vehicles and
14	Other mining and quarrying	55	Hotels and restaurants
15	Manufacture of food products and	60	Land transport; transport via pipelines
16	Manufacture of tobacco products	61	Water transport
17	Manufacture of textiles	62	Air transport
18	Manufacture of wearing apparel; dressing	63	Supporting and auxiliary transport activities; activities
19	Tanning and dressing of leather;	64	Post and telecommunications
20	Manufacture of wood and of products of	65	Financial intermediation, except insurance and
21	Manufacture of pulp, paper and paper	66	Insurance and pension funding, except compulsory
22	Publishing, printing and reproduction of	67	Activities auxiliary to financial intermediation
23	Manufacture of coke, refined petroleum	70	Real estate activities
24	Manufacture of chemicals and chemical	71	Renting of machinery and equipment without
25	Manufacture of rubber and plastic	72	Computer and related activities
26	Manufacture of other non-metallic	73	Research and development
27	Manufacture of basic metals	74	Other business activities
28	Manufacture of fabricated metal	75	Public administration and defence; compulsory social
29	Manufacture of machinery and	80	Education
30	Manufacture of office machinery and	85	Health and social work
31	Manufacture of electrical machinery and	90	Sewage and refuse disposal, sanitation and similar
32	Manufacture of radio, television and	91	Activities of membership organisation n.e.c.
33	Manufacture of medical, precision and	92	Recreational, cultural and sporting activities
34	Manufacture of motor vehicles, trailers	93	Other service activities
35	Manufacture of other transport	95	Private households with employed persons
36	Manufacture of furniture; manufacturing		

S: *Statistik Austria*.

Appendix 2: Input Data

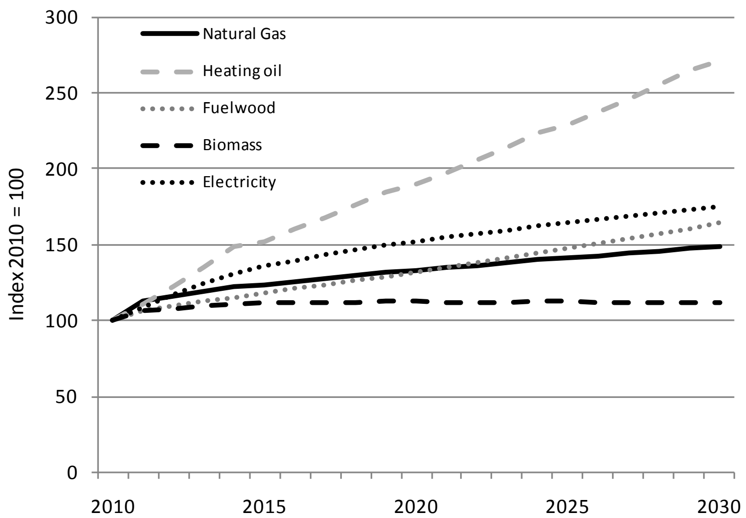
2.1 Household energy prices in the WEM scenario

Figure 24: Household price transport fuels, 2010-2030



S: TU Graz, Prof. *Hausberger*, own calculations.

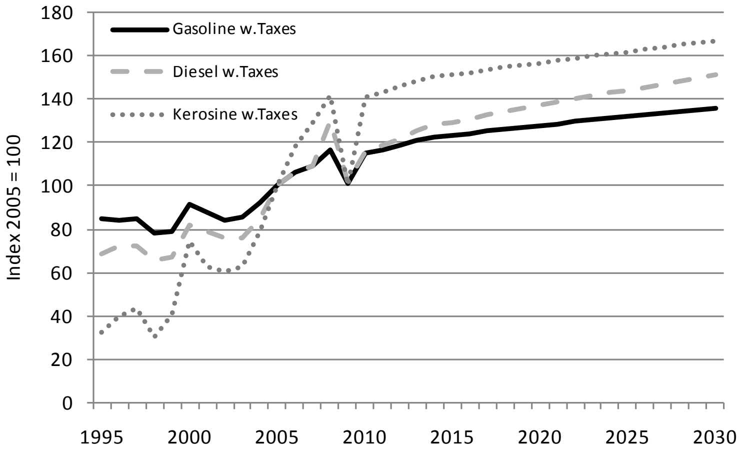
Figure 25: Household prices electricity and other fuels, nominal, 2010-2030



S: own calculations.

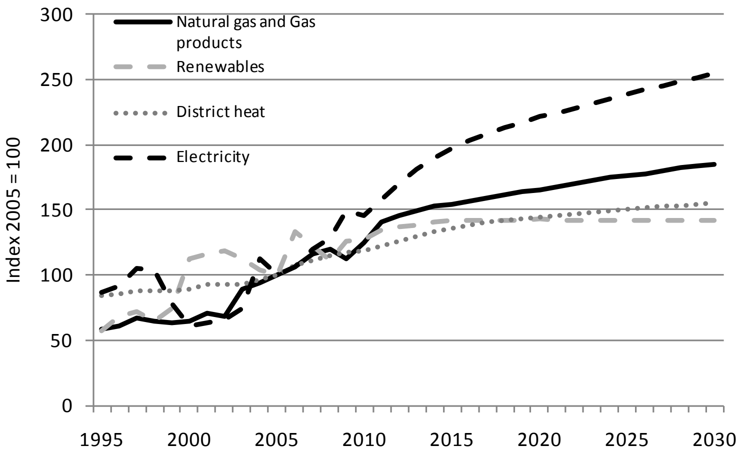
2.2 Industry energy prices

Figure 26: Industry prices transport fuels, nominal, 1995-2030



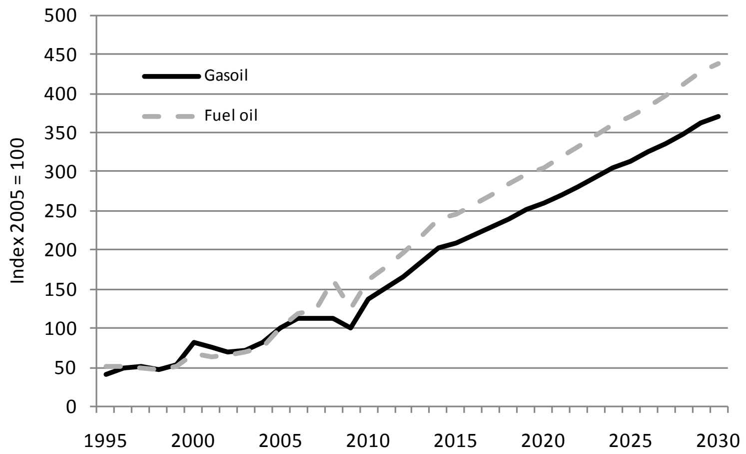
S: *IEA* energy prices, own calculations.

Figure 27: Industry prices natural gas, renewables, and electricity, nominal, 1995-2030



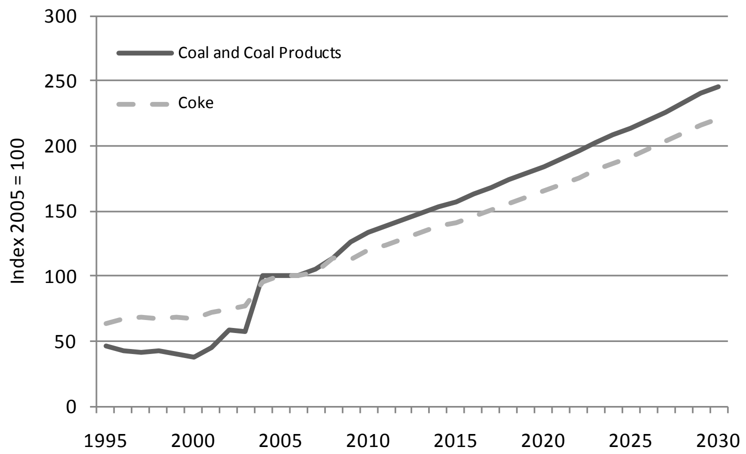
S: *IEA* energy prices, own calculations.

Figure 28: Industry prices gasoil und fuel oil, nominal, 1995-2030



S: *IEA* energy prices, own calculations.

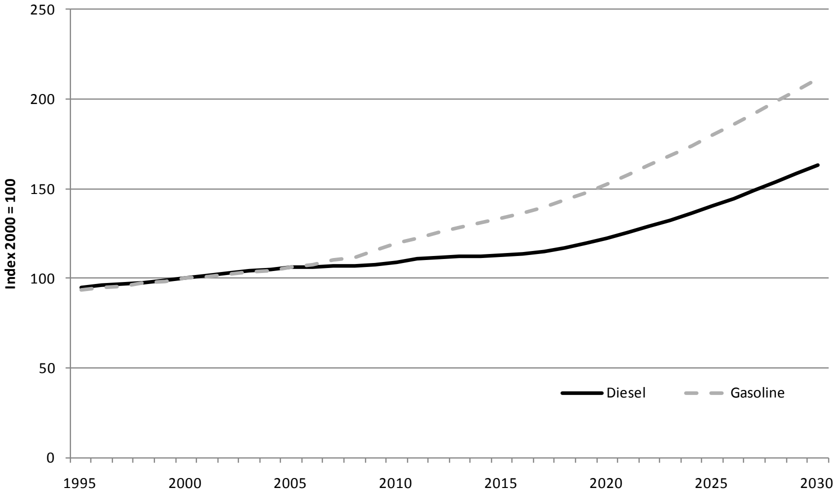
Figure 29: Industry prices coal and coal products, nominal, 1995-2030



S: *IEA* energy prices, own calculations.

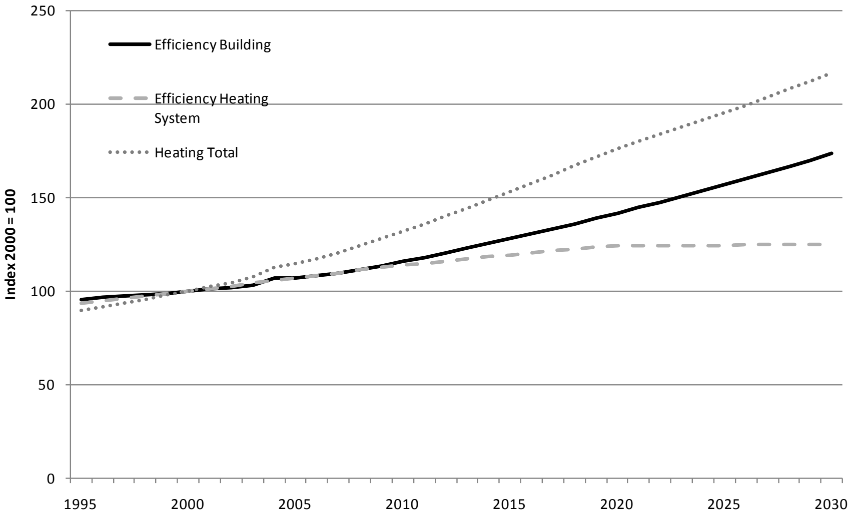
2.3 Efficiency of household's capital stocks

Figure 30: Efficiency passenger car fleets per fuel type



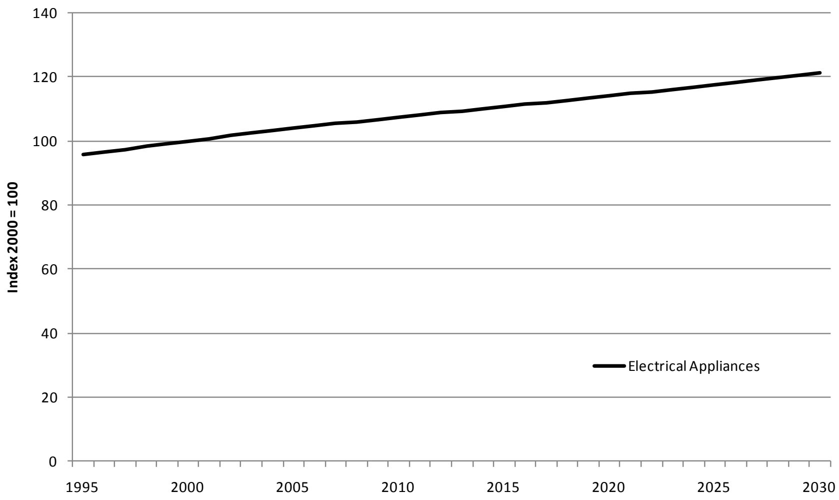
S: TU Graz, Prof. *Hausberger*

Figure 31: Efficiency heating systems and buildings



S: TU Wien, Energy Economics Group, own calculations

Figure 32: Efficiency electrical appliances



S: Austrian Energy Agency.