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Energy Scenarios 2030

A Basis for the Projection of Austrian Greenhouse Gas Emissions

Kurt Kratena, Ina Meyer

Research assistance: Katharina Köberl

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Abstract

In this project energy scenarios up to the year 2030 representing economic trends and impacts of climate and energy policies are developed. These provide a basis for the reporting duties "monitoring mechanism" of the Federal Environmental Agency regarding the UNFCCC. For this purpose the dynamic econometric Input-Output (DEIO) model of the WIFO is used. It represents energy demands of 59 NACE 2-digit sectors, and the household sector in relations to energy prices, technical and socio-demographic variables such as stock of dwellings and energy efficiency explaining economic developments. The DEIO model is linked to three partial bottom-up models of other research groups, which describe the heating system, electricity demand and power generation and the transport sector. Scenario results are presented according to the template of the aggregated energy balance of Statistics Austria with regard to 1. the reference, with-measures (WM) scenario, 2. a sensitivity analysis to the reference scenario, and 3. a climate and energy policy scenario (with-additional-measures, WAM) with 4. a sensitivity analysis to the WAM scenario. The WM scenario is based on recent WIFO economic forecasts and focuses on the impacts of the economic crisis on energy demand. The WAM scenario is based on the Austrian Energy Strategy, reflecting the targets of the final energy consumption (1,100 PJ p.a.), the share of renewable energy according to the definition of the EU climate and energy package (34 percent) and the reduction of greenhouse gases by 16 percent within the EU "effort sharing".

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1 Introduction and methodological approach

1.1 Introduction

The present study provides energy scenarios for the Austrian economy up to the year 2030 which are developed as information basis for deriving corresponding greenhouse gas (GHG) emissions trajectories. These are a prerequisite to fulfill the reporting requirements according to the Monitoring Mechanism 2011 and to the United Nations Framework Convention on Climate Change (UNFCCC) as well as for the Austrian climate strategy 2020. For this purpose, the Umweltbundesamt (Environment Agency Austria) appointed a project team consisting of four research institutes working in different energy-economy fields with respect to scenario projections: the Austrian Institute of Economic Research (WIFO), the Austrian Energy Agency (AEA), the Energy Economics Group (EEG) at the Technical University Vienna and the Institute of Internal Combustion Engines and Thermodynamics at the Technical University Graz (TU Graz). Within this project WIFO employs a dynamic econometric Input-Output (DEIO) model in order to generate national economic and energy data, i.e. GDP and final energy demand of industries and households. The AEA (2011) analyses electricity demand and electricity and district heat generation, the EEG (2011) deals with heating, water heating and heat demand and the TU Graz (2011) provides transport scenarios including electricity demand. While the approach followed by WIFO takes a top-down perspective, the other institutions mainly employ bottom-up models to derive respective sectoral energy demand and supply scenarios. The different scenario approaches are built upon a consistent set of economic and non-economic data. The data sets are employed within both bottom-up and top-down models and are generated und used within either of the two model types so data constitute a consistent link between top-down and bottom-up spheres. The Umweltbundesamt took a coordinating function and responded to specific energy data requirements e.g. on international aviation fuels, self-producers of electricity, black liquor from pulp production, waste incineration, and, in particular, provided the frame for energy policy measures to be implemented in the policy scenario analysis.

In total, each of the project partners computed four scenarios:

With-Measures (WM): The WM-scenario serves as baseline or reference scenario. Policy measures regarding different climate mitigation targets that came into force before 2nd February 2010 are considered.

With-Measures sensitive (WMsens): The WMsens-scenario complies with the WM-scenario with respect to climate policies but shows lower economic growth with lower global energy prices.

With-Additional-Measures (WAM): The WAM-scenario is a climate and energy policy scenario that builds upon a range of policy measures across different energy using sectors in order to mitigate GHG emissions. Economic framework data is the same as in the WM-scenario.

With-Additional-Measures sensitive (WAMsens): The WAMsens-scenario follows the logic of the WMsens-scenario showing the impacts of moderate growth with lower global energy prices implementing the same energy policies as in WAM.

The design of climate- and energy-related policy measures in the WAM-scenarios takes into account the objectives of the EU climate and energy package (for details see section 3.1). Thus, three main goals to be achieved in 2020 exist (the so-called 20-20-20 targets): reducing greenhouse gas emissions by 20%, improving energy efficiency by 20%, and generating 20% of energy use from renewable energy resources. One sub-goal is to achieve a share of 10% of renewable energy in the transport sector. Within the EU climate and energy package, each EU member state has agreed upon a binding national target for renewable energy supply which reflects its relative wealth. The target share of renewable energy sources for Austria is at 34% in gross final energy consumption in 2020 (EC, 2009). Under the so-called "Effort Sharing Decision" binding GHG emission targets are set for emissions from sectors not included in the EU Emissions Trading System (ETS) such as transport, buildings, agriculture and waste. Here again, each member state contributes to this effort according to its relative wealth. The target share for emission reduction in the non-ETS sectors for Austria is minus 16% emissions with regard to the 2005 level. At the EU level, shared efforts will deliver an approximately 10% reduction of emissions from the covered sectors in 2020 compared with 2005 levels. Together with the reduction resulting from the ETS, it will accomplish the overall emission reduction goal of the EU Climate and Energy package, i.e. a 20% cut below 1990 levels by 2020. While sectors in the ETS are regulated at the Community level, it will be the responsibility of member states to define and implement policies and measures to limit emissions of sectors under the "Effort Sharing Decision".

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. Austria's NREAP indicates target paths for energy use and renewable energy deployment as a result of sector-specific policy measures, e.g. funding of renewable energy (for instance biomass) production and supply (BMWFJ, 2010a). On the basis of the EU energy and climate package, the Austrian energy strategy (BMWFJ, 2010b) was developed as a comprehensive national energy strategy pursuing three strategic goals: improving the energy efficiency of production and supply systems, developing and deploying renewable energies and enhancing the security of energy supply. The final energy consumption target is stipulated at 1.100 PJ in 2020, i.e. stabilizing final energy demand at 2005 levels. A detailed and time-specific plan of policy measures reveals the potential to reach relevant EU 20-20-20 targets. Main sectors to achieve emission reduction within the "Effort Sharing" are the transport and heat sectors, i.e. in the transport sector GHG emissions need to decline by 20% and in the heat sector by 45% in 2020 with respect to 2005 levels, reducing GHG emissions from the non-ETS sectors by more than 18% and thus 2%point more than requested by the "Effort Sharing Decision" (BMWFJ, 2010b). The selected measures implemented in the WAM-scenarios follow the Austrian Energy Strategy.

1.2 Methodological approach – the DEIO model

The energy scenarios have been carried out with a dynamic consumer optimisation model integrated into an input-output (IO) framework model. This model can be seen as a first step towards the construction of a fully fledged Dynamic Econometric IO model (DEIO), following the modelling philosophy of Dynamic Stochastic General Equilibrium (DSGE) models (Christiano et al., 2005; Smet and Wouters, 2003; Ratto et al., 2009). The objective of further development of this Austrian DEIO model is a dynamic model covering consumption, production, trade and the labour market with emphasis on energy and emissions, like the IGEM model (Goettle et al., 2007) for the U.S., that has widely been used for climate policy analysis.

The private consumption model with energy and emissions

The main features of the dynamic optimization model of households are:

(i) presence of liquidity constraints

(ii) consumption consists of durable goods (stocks) and purchases of nondurables

(iii) forward looking behaviour

In this model, households maximize expected life time utility subject to current assets, current income and expected future income. Borrowing by households does not allow for smoothing all consumption over time. Durable goods provide services which are relevant for utility and in some cases use energy input for the production of these services (appliances, vehicles). The average energy-efficiency of the durable stock is one important factor for energy demand in addition to income and prices. This demand is modelled as a service demand, depending on the price for the corresponding energy-using service (heating, electricity-using services, private transport). An important feedback effect from energy efficiency to service prices is taken into account which is responsible for the 'rebound effect' of energy efficiency improvements. In line with the philosophy in IGEM (Goettle, et al., 2007), the dynamic consumption model does not just yield a dynamic path of variables (derived from an Euler equation) but allows for deriving the demand for total nondurables, that can be directly estimated econometrically. For splitting up the total demand of nondurables across seven different consumption categories, the Almost Ideal Demand System (AIDS) is used. Total nondurable consumption consists of demand for commodities (non-energy items) and of service demand (energy items).

The demand for four different durables is modelled according to the optimal (S,s) model of households' durable purchases, where S and s represent upper and lower bounds of target durable stocks of households, so that actual stocks are adjusted in order to lie within these bounds. This type of model is usually applied at the individual level and explains changes in the distribution of durable stocks across households which in turn can explain the aggregate behaviour of households' durable purchases (Caballero, 1993; Eberly, 1994). We approximate the aggregate of this demand by a model of stock adjustment where the target stock is determined by aggregate variables measuring the wealth position of households and additionally take into account liquidity constraints. The demand for durables can be influenced by policies affecting the user costs of capital of durables at purchaser prices.

Data on private consumption (1990 to 2008) in current prices and the corresponding price indices are directly taken from private household sector data in National Accounts of Austria (in COICOP classification). These data are related to data on conversion efficiency of household appliances to derive the service price (marginal cost of service). The data on conversion efficiency comprise indices of efficiency of capital stocks for major energy-using appliances, in the sector of heating, electricity, and passenger car transport. The main data source for efficiency is the ODYSSEE database (http://www.odyssee-indicators.org), data on efficiency of the passenger vehicle fleet have been originally generated through a compilation of technological characteristics of the registered car fleet in Austria from 1990 to 2007. A detailed description of the efficiency data set for heating, electricity, and passenger cars can be found in Meyer – Wessely (2009) and Kratena et al. (2009).

The impact of efficiency improvements can be seen in Table 1 comparing the different path of energy and 'service' prices between 1990 and 2008. Especially in the period from 1990 to 2000, efficiency increases have dampened energy price increase considerably, so that 'service' prices of heating and electricity have been almost constant. These stylized facts underline the importance of an unbiased estimate of the rebound effect by using 'service' prices and estimating the 'service' price elasticity.

Table 1: Energy and service prices of fuels for private transport, heating, and electricity, 1990–2008

	Fuels for private transport		Heating		Electricity	
	Energy	Service	Energy	Service	Energy	Service
1990	70.9	86.0	81.8	99.9	84.6	94.5
1991	69.4	82.2	84.5	101.7	85.5	93.9
1992	74.0	85.7	84.6	100.4	87.1	93.7
1993	72.6	82.0	84.0	98.0	88.6	94.4
1994	74.9	83.0	83.4	95.0	89.6	94.5
1995	79.3	86.2	84.9	95.0	90.9	94.9
1996	86.3	92.0	89.0	97.8	95.9	99.3
1997	88.5	92.9	92.7	100.1	98.5	101.1
1998	83.8	86.7	88.8	93.9	98.5	100.2
1999	85.2	86.7	89.5	92.8	97.8	98.6
2000	100.0	100.0	100.0	100.0	100.0	100.0
2001	96.2	94.5	104.5	102.7	102.1	101.3
2002	93.6	89.8	102.8	99.7	99.0	97.4
2003	93.9	88.0	104.3	99.6	100.0	97.6
2004	102.0	94.8	111.1	105.3	102.7	99.5
2005	114.0	105.0	122.5	116.1	105.8	101.8
2006	122.4	111.9	130.4	122.7	109.5	104.6
2007	124.2	113.1	136.7	126.9	119.6	113.5
2008	146.2	131.9	145.8	132.8	121.7	114.7

Source: own calculations.

The aggregate of total nondurables is the starting point of a demand system that describes the consistent splitting up across different consumption categories. This is consistent with a two step interpretation of the intertemporal optimization problem: in a first step the consumer decides how to allocate expenditure across time periods, and in a second step, she allocates the expenditure in each time period to different consumption categories. This second step in allocation depends on the vector of prices of consumption categories, and the level of total non-durable expenditure. Therefore we proceed by applying the cost function of the Almost Ideal Demand System (AIDS). The AIDS model represents a flexible functional form consistent with restrictions on demand in microeconomic theory (Deaton – Muellbauer, 1980).

The commodity classification i in this model includes:

(i) food, and beverages, tobacco, (ii) clothing, and footwear, (iii) services for private transport (via input of gasoline/diesel), (iv) services for heating (via input of solid fuels, oil, gas, district heating), (v) services for electricity using appliances (via input of electricity), (vi) public transport services, (vii) operation of vehicles (other than fuel), and (viii) other (non-energy) commodities and services.

The estimated parameter values together with the data for the budget shares are used to calculate expenditure elasticities and compensated price elasticities.

Table 2 shows the values for the calculated elasticities applying the sample mean of the budget shares. All own price elasticities show the expected negative sign and are below unity except for clothing and footwear and for public transport services. For the energy commodities the estimated service price elasticities are in the range as reported in the literature, except for fuels for private transport, which show a relatively high own price elasticity (-0.45). The direct rebound effects which can be expected from our model, therefore also lie within the bounds in the literature (Greening and Greene, 1997; Greening et al., 2000). It must be noted, however, that these direct price-induced rebound effects are only one aspect of the overall model impacts and are based on ceteris paribus assumptions. If all commodity prices and total nondurable expenditure change, the overall feedback effect on energy consumption will be significantly different from the direct rebound effect.

Table 2: Compensated price and expenditure elasticities

	Food, beverages, tobacco	Clothing, footwear	Fuel for private transport	Public transport services	Electricity	Heating
			Compensated price elasticities			
Food, beverages, tobacco	**- 0.0137**	0.0506	0.0020	0.0344	- 0.0070	0.1394
Clothing, footwear	0.1028	**- 1.0102**	- 0.0834	0.1938	0.0897	0.1259
Fuel for private transport	0.0087	- 0.1793	**- 0.4504**	0.0685	0.0929	0.2127
Public transport services	0.3688	0.9995	0.1631	**- 1.1479**	- 0.3014	0.5319
Electricity	- 0.0564	0.3499	0.1671	- 0.2272	**- 0.1725**	- 0.0274
Heating	0.8678	0.3774	0.2939	0.3086	- 0.0212	**- 0.3412**
			Expenditure elasticities			
	0.6979	- 0.4818	1.3239	2.4494	1.6710	1.2111

Source: own calculations.

The cross price elasticities between the energy commodities partly have positive signs (fuels for transport vs. electricity and vs. heating), indicating a substitutive relationship, and partly negative signs (electricity vs. heating), indicating a complementary relationship. The substitutive relationship between fuels for transport and heating as well as electricity implies that higher expenditure for private transport ceteris paribus leads to lower expenditures for the other energy commodities. This is the 'normal' case within any pair of goods in household theory. The complementary relationship between heating and electricity can be explained by a technological relationship in the development of heating appliances leading to increasing amounts of electricity for system regulation. The cross price elasticity between fuels for private transport and public transport services is positive, indicating a substitutive relationship, as expected. Note that the cross price elasticities are not symmetric, as they are linear combinations of symmetric cross price parameters with different budget shares.

The expenditure elasticities shown in

Table 2 are positive for all commodities, except for clothing and footwear. This is due to a very pronounced decrease of the budget share in the observation period. For energy commodities all expenditure elasticities are above unity indicating that energy reacts above average to overall nondurable expenditure in the observation period in Austria. The expenditure elasticity for public transport services is 2.45, which is the highest value of all commodities.

The consumption model yields results for a vector of expenditure in current prices as well as constant prices, comprising the vector of non-energy nondurables, of energy nondurables, and of durable expenditure. The energy nondurables consist of fuel for private transport, heating, and electricity. At this aggregate level of energy demand, a fully consistent link between expenditure data and (physical) energy NAMEA data, both from National Accounts, is achieved. The core variables of this link are prices of these energy demand categories, which partly come as deflators from the COICOP National Accounts data and partly have been derived by combining expenditure data and physical data. Additionally, the price information from OECD (Energy Prices and Taxes) and other national sources have been taken into account. The combination of expenditure and physical data yields prices per unit of energy content (million €/TJ). The final link between the two data sets is achieved by equations relating the deflators from the COICOP National Accounts data to the prices per unit of energy content.

The NAMEA energy data set differentiates between 19 energy inputs and contains physical energy input (in TJ) for each of the 19 energy sources in the household sector, including private transport. The aggregates of the energy demand categories 'fuel for private transport', 'heating', and 'electricity' in energy units are further split up into the 19 energy inputs by applying fixed subshares. These subshares can be extrapolated into the future for reference scenarios or changed for the purpose of simulations.

The input-output model with energy and emissions

The private consumption model determines the vector of private consumption for 12 consumption categories (in COICOP classification) which is transformed into a vector of private consumption used in an input-output model by applying a bridge matrix. The link of the consumption model to the input-output model (in NACE 60 classifiaction) is similar to the one proposed in Mongelli et al. (2010) and comprises three interfaces: (i) consumption demand by commodities derived from the consumption model, (ii) consumer prices by categories derived from the input-output price model, and (iii) value added and household income derived from the input-output model.

The consumption model block as well as the input-output model are complemented by an energy and environment-satellite based on NAMEA data. Actually it includes detailed energy accounts (in energy units for 19 types of energy) which are linked to consumption and production activities. In the private consumption model a fully consistent link between energy demand in energy units and expenditure for energy commodities is in place, based on price links. For production, energy inputs in energy units by unit of output are used.

2 Macroeconomic framework data

Future energy trends will be the result of a number of different interplaying factors and most of these factors are hard to predict accurately. The financial and economic crises of the year 2008/2009 highlight this fact in particular regarding the accurate forecast of economic growth. GDP as measure of economic growth is yet considered one of the main drivers of energy demand and thus GHG emissions. Economic growth, in turn, is influenced *inter alia* by demographic trends and energy price developments such as the price for crude oil. The recent oil price surge caused by the turmoil in Libya and other Arabic states refers to the sensitivity of the crude oil price to unforeseen political events and its related price fluctuations. These examples reveal the difficulties of predicting (smooth) oil price developments that are, however, a major input to modelling future energy demand. Due to inherent uncertainty with respect to oil price developments, the project applies a sensitivity analysis to the energy demand scenarios with respect to oil price trajectories (see 2.2).

This section gives an overview of input data used to model relevant scenarios and exhibits price assumptions that determine household and producer behavior.

2.1 Demographic and climatic boundary conditions

The structure and level of future energy use is significantly determined by population growth and household development. In particular, demand for heating and cooling is dependent on the structure and growth of households. We use the same assumptions about population growth for each scenario. They are presented in Table 3. Thereafter, the population in Austria grows by an average of 0.3% per year from 8.4 mill. inhabitants in 2010 to 8.8 mill. in 2030. In the same time the number of households rises at a slightly higher average annual rate of 0.5% from 3.6 mill. households to 3.97 mill. households according to the population forecast by Statistik Austria (2006). This indicates a continuous trend towards smaller, i.e. single-households that prevailed throughout recent decades.

In addition, heating degrees days employed in the model analysis of each scenario are exhibited in Table 3 and Figure 1. Two different methodologies have been applied for smoothing the heating degrees time series and extract a long-term trend from the data: the

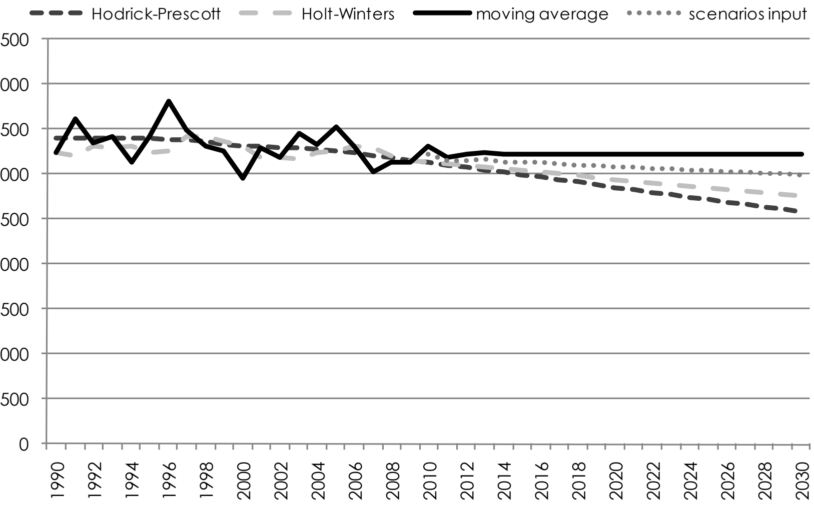
Hodrick-Prescott filter and the exponential smoothing methodology according to Holt-Winters. As can be seen from Figure 1, the Hodrick-Prescott filter predicts a more pronounced negative trend for heating degree days than the methodology of exponential smoothing (Holt-Winters). Both predict a decrease and therefore capture a global warming trend compared to the straight line of constant heating degree days (moving average extrapolation). As input for the scenarios we calculated an average between the Holt-Winters trend extrapolation and the moving average extrapolation of heating degrees days.

Table 3: Population, households and heating degrees days, 2010-2030

	population	households	heating degree days
ø	0,26	0,48	
2010	8.397.256	3.602.903	3.227
2011	8.427.318	3.627.271	3.156
2012	8.456.265	3.651.740	3.157
2013	8.484.098	3.676.374	3.161
2014	8.510.861	3.701.174	3.139
2015	8.536.606	3.726.141	3.134
2016	8.561.351	3.749.615	3.126
2017	8.585.170	3.768.950	3.114
2018	8.608.059	3.788.386	3.106
2019	8.630.010	3.807.921	3.096
2020	8.650.995	3.827.557	3.086
2021	8.671.561	3.846.292	3.077
2022	8.692.003	3.860.757	3.068
2023	8.712.187	3.875.276	3.058
2024	8.732.064	3.889.850	3.049
2025	8.751.421	3.904.478	3.039
2026	8.770.252	3.918.616	3.030
2027	8.788.372	3.930.241	3.021
2028	8.805.763	3.941.900	3.011
2029	8.822.460	3.953.593	3.002
2030	8.838.399	3.965.322	2.992

Source: Statistics Austria, 2006, WIFO - own calculations.

Figure 1: Heating degrees days



Source: Own calculations.

2.2 Energy prices

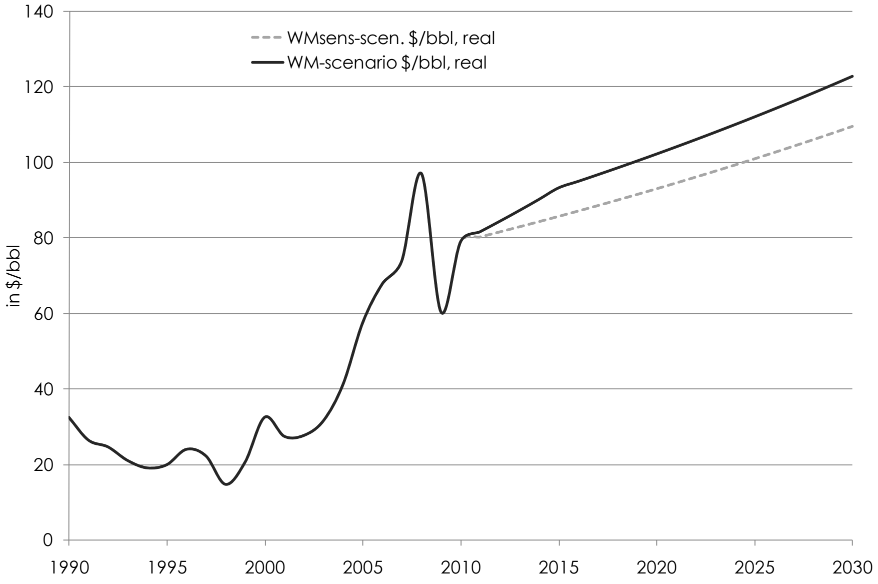
In addition to demographic and climatic framework conditions, energy price developments are assumed to be exogenous. Energy prices play a crucial role with respect to energy-using sectors and households and thus have an impact on related energy demand and GHG emissions. Demand for a specific energy service (transport, heat, electricity) depends on the service price which reflects the price of both the fuel and the technology used to produce the energy service.

The crude oil price is considered a proxy for international price developments (IEA, 2010). The development of the crude oil price until the year 2030 for the 2 scenarios WM and WMsens (WAM and WAMsens respectively) is listed in nominal and in real terms in Table 4, oil price scenarios are delineated in Figure 2. In the WM-scenario the oil price rises from about 80 US$/bbl in 2010 to about 120 US$/bbl in 2030 in real terms while in the WMsens-scenario the price increase is more moderate, growing to about 110 US$ in 2030 only. These two price trajectories are in the order of magnitude of the price trajectory given by the World Energy Outlook 2010 (IEA, 2010) being at 99 US$/bbl in 2020 (at constant 2009 US$) and 113 US$/bbl in 2035. The global oil price in the WM-scenario is thus assumed to lie continuously above the oil price scenario of the WMsens-scenario. Here, additional demand from higher global economic growth that leads to higher economic growth in Austria, leads to higher international energy prices. Thus, crude oil prices rise by 55% (130% nominal) in the WM-scenario and by 39% (104% nominal) in the WMsens-scenario. This equals an average annual price increase of 2.2% in real terms with respect to the WM-scenario and of 1.7% in real terms with respect to the WMsens-scenario. The price trajectories for crude oil remain the same within the WAM-scenario-set, i.e. a higher price increase in the WAM-scenario as in the WAMsens-scenario.

Natural gas prices historically have moved rather close with oil prices because of indexation clauses in European and Asian markets. Another reason is the competitive or substitutive relationship of gas and oil products in power generation and end-use applications. In recent years, gas prices tended to decouple from oil prices due to relatively abundant supplies and because demand for gas was dropping significantly during the recession (IEA, 2010). However, the potential for substitution between oil and gas will ensure that changes in the price of one resource will continue to affect the price of the other to a certain degree. The development of the relative price of gas to crude oil is pictured in Figure 3 together with the price scenario until 2030. It is assumed that the ratio of the gas price to the price for crude oil remains unchanged until 2030 at a level slightly below the average prices between 1990 and 2010.

Coal prices have fallen due to a declining demand and reduced prices for gas which is the main competitor to coal, in particular in the power generating sectors. According to the IEA (2010), coal prices increase less in percentage terms than oil or gas prices. This is because production costs remain stable and demand for coal is assumed to level off by 2020, see Figure 2 for the coal price development with respect to oil price growth and related scenario assumptions until 2030.

Figure 2: Crude oil price scenarios, real, 1990-2030



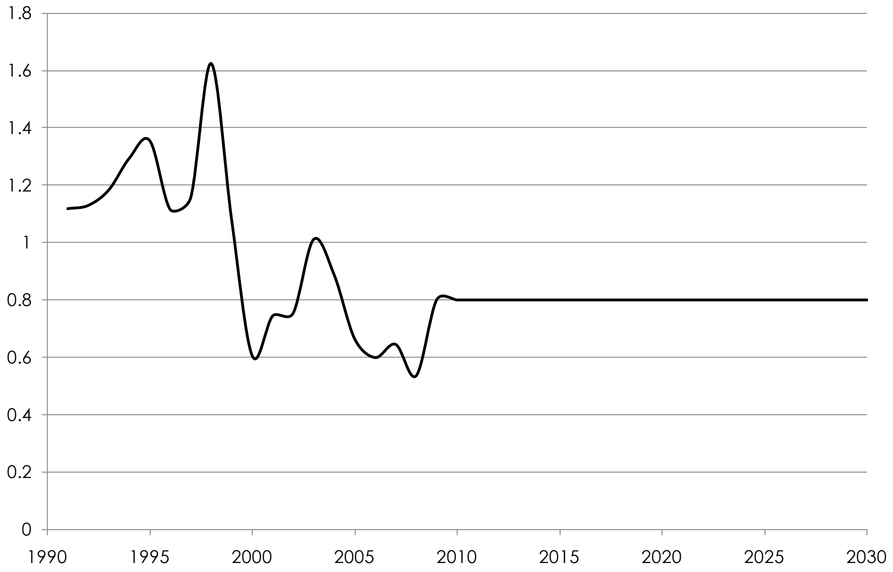
Source: own calculations.

Table 4: Crude oil price scenarios, nominal and real, 2010-2030

	WM-Scenario				**WMsens-Scenario**			
		BRENT				BRENT		
	$/bbl, nominal	$/bbl, real	€/$	€/t	$/bbl, nominal	$/bbl, real	€/$	€/t
2010	80.00	78.98	0.74	444.44	80.00	78.98	0.74	444.44
2011	84.06	81.64	0.74	466.98	82.68	80.28	0.74	459.32
2012	88.57	84.39	0.74	488.44	85.69	81.60	0.74	472.57
2013	93.33	87.24	0.73	510.91	88.82	82.95	0.73	486.23
2014	98.34	90.18	0.72	534.44	92.06	84.31	0.72	500.31
2015	103.62	93.21	0.72	559.09	95.41	85.70	0.72	514.83
2016	107.61	94.94	0.71	576.47	98.89	87.11	0.71	529.79
2017	111.75	96.70	0.71	598.66	102.50	88.55	0.71	549.11
2018	116.05	98.48	0.71	621.71	106.24	90.00	0.71	569.14
2019	120.52	100.31	0.71	645.65	110.11	91.49	0.71	589.90
2020	125.16	102.16	0.71	670.51	114.14	93.00	0.71	611.45
2021	129.98	104.05	0.71	696.32	118.30	94.53	0.71	633.75
2022	134.98	105.98	0.71	723.13	122.61	96.09	0.71	656.86
2023	140.18	107.94	0.71	750.97	127.09	97.67	0.71	680.81
2024	145.58	109.93	0.71	779.88	131.72	99.28	0.71	705.64
2025	151.18	111.97	0.71	809.91	136.52	100.92	0.71	731.38
2026	157.00	114.04	0.71	841.09	141.50	102.58	0.71	758.05
2027	163.05	116.15	0.71	873.47	146.66	104.27	0.71	785.70
2028	169.33	118.30	0.71	907.10	152.01	105.98	0.71	814.35
2029	175.84	120.49	0.71	942.02	157.56	107.73	0.71	844.05
2030	182.61	122.72	0.71	978.29	163.30	109.50	0.71	874.83

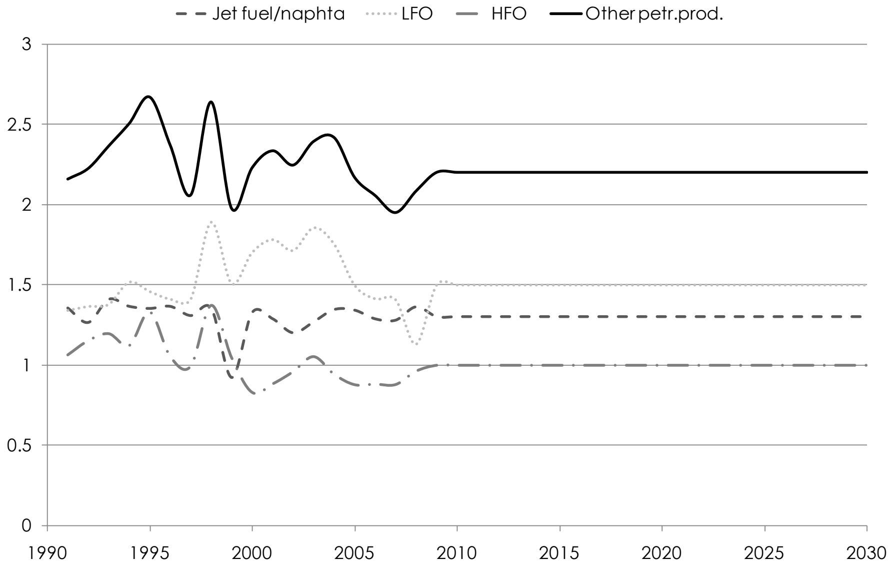
Source: own calculations.

Figure 3: Relative price: natural gas to crude oil, 1990-2030



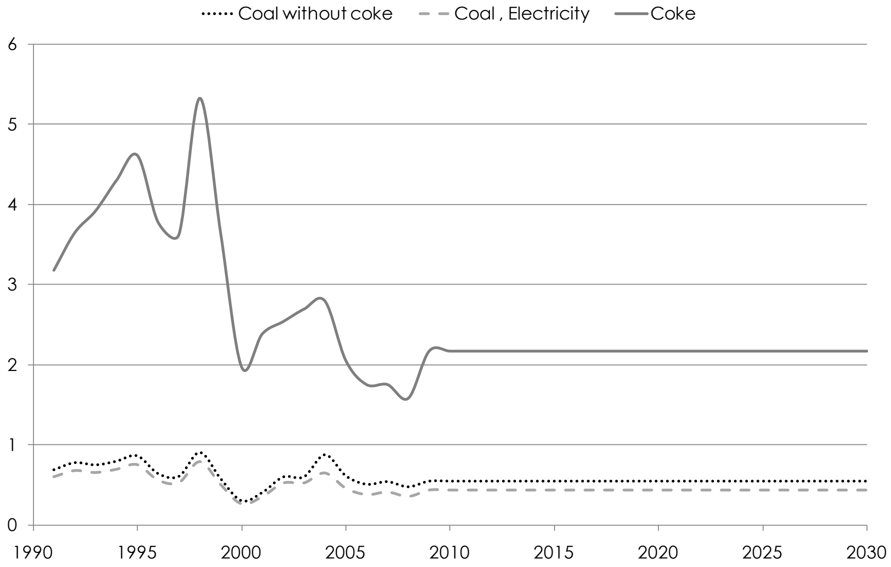
Source: own calculations.

Figure 4: Relative prices: oil products to crude oil, 1990-2030



Source: own calculations.

Figure 5: Relative prices: coal to crude oil, 1990-2030

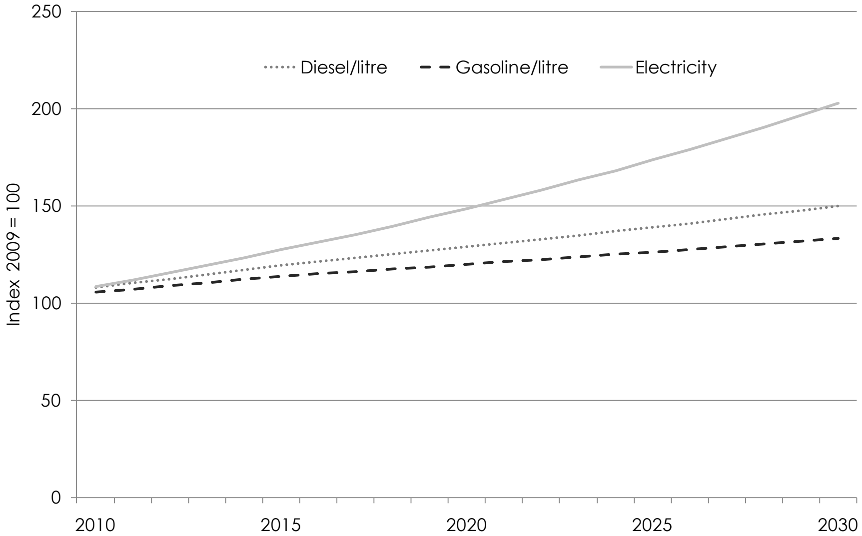


Source: own calculations.

On the basis of the crude oil price projections and the relative price projections of the other energy sources (see also Figure 4 for oil products), energy prices for industrial sectors are derived in €/TJ serving as model input. Energy input prices for the industrial sector such as for coal, light and heavy fuels, natural gas and other petroleum products are assumed to rise by 120% in nominal terms between 2010 and 2030 in the WM scenario which is equivalent to an average price increase of 3.8% per year. The difference in the price increase between different industry energy prices and the price increase of crude oil is mainly the result of the altered ratio of exchange rates between the euro and the dollar (see Table 4). Thereafter the increase in the crude oil price calculated in dollar is slightly higher than the increase in industrial energy prices calculated in Euro because of the assumed slight devaluation of the dollar. Industrial energy prices for the WMsens/WAMsens-scenarios are calculated equivalently.

In contrast, automotive (net) fuel price developments are calculated on the basis of dynamic econometric equations that estimate the price elasticity for diesel and gasoline fuels in relation to the crude oil price using data from 1991 to 2008. Correlated price increases are depicted as index development in Figure 6. The long term price elasticity for diesel fuel is at 0.53 and that for gasoline fuel much lower at about 0.4. Higher (gross) price increases are derived for electricity, i.e. prices are assumed to increase by about 100% within the projection period. The electricity price is adopted as input from the EEG, TU Vienna. Energy prices are used as input to the DEIO model.

Figure 6: Energy prices for households, 2010-2030



Source: own calculations.

2.3 Economic growth and structure

The economic performance measured as GDP or value added of a country is a key driver of energy demand and thus strongly correlated with 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 ff. when GHG emissions dropped sharply with the slump in GDP, i.e. GHG emissions fell by 8% and real GDP by almost 4% between 2008 and 2009 (WIFO database). The decline in emissions was especially pronounced in the domestic goods production and in freight transport (Kratena, 2010; Kletzan et al., 2009).

The total growth in GDP is derived as the sum of the value added in the economic sectors. The value added of the domestic goods production sectors as well as the derived GDP is summarized in Table 5 for the WM- and the WMsens-scenarios. These data are results of the solution of the DEIO model and feed as inputs into the bottom-up models of the project partners.

The economy grows on average by 2% per year in the WM-scenario and by 1.5% per year in the WMsens-scenario. The difference in overall economic performance is mirrored in the sectors of the domestic goods production, being higher in the WM-scenario. The calculation of GDP growth figures takes into account the impacts of the economic and financial crisis in 2009, i.e. remarkable drops in production are considered in particular with respect to the domestic manufacturing sectors and freight transport. In addition, the medium-term economic forecast by WIFO is implemented in the modelling of future GDP growth patterns. According to that, growth in Austria recovers quickly profiting from expansive monetary and fiscal policies in major world economies and the strong economic recovery in the economies in transition. The medium-term economic forecast suggests a real average annual growth of 2.2% for Austria in the period 2011/2015, i.e. a GDP growth of a quarter percentage point lower than during the last 10 years is expected (Baumgartner et al., 2011). Within this period an annual average growth of 4.5% is expected for the world economy such that Austria's export is growing on average by 6.2% per year which represents about the rates that prevailed during the last 10 years before the crisis. With a lower increase in imports and an average growth of 5.6% per year the strong trade balance supports the economic development in Austria. This stands in contrast to domestic consumption which grows only moderately. Detailed growth rates of private consumer demand (in nominal and real terms), final demand, imports and GDP are summarized in Table 6 for the WM-scenario. Private consumption shows an average annual growth of only 1.13% in real terms from 2012 until 2030. The WMsens-scenario (not listed) constitutes a sensitivity analysis on the WM-scenario with an overall lower growth pattern (real private consumption: 1.11%; final demand (nominal): 3.05%).

Table 5: GDP and value added in domestic goods production sectors, WM and WMsens

		WM	WMsens
	Ø growth in %	2012-2030	2012-2030
	GDP, total	2,08	1,51
15	manufacture of food products and beverages	1,51	0,95
16	manufacture of tobacco products	-1,46	-2,21
17	manufacture of textiles	1,83	-0,13
18	manufacture of wearing apparel	1,08	-0,50
19	manufacture of leather and related products	-0,31	-2,74
20	manufacture of wood and of products of wood and cork, except furniture	2,71	1,99
21	manufacture of paper and paper products	-0,20	-1,90
22	printing and reproductin of recorded media	3,94	3,45
24	manufacture of chemicals and chemical products	2,17	0,71
25	manufacture of rubber and plastic products	3,51	3,32
26	manufacture of non-metallic mineral products	1,56	0,35
27	manufacture of basic metals	0,04	-0,61
28	manufacture of fabricated metal products, except machinery and equipment	2,23	1,19
29	manufacture of machinery and equipment	2,60	0,89
30	manufacture of computer, electronic and optical products	-0,23	-0,24
31	manufacture of electrical equipment	5,08	3,39
32	radio, television and communication equipment and apparatus	2,17	0,37
33	medical, precision and optical instruments, watches and clocks	3,54	1,84
34	manufacture of motor vehicles and transport equipment	3,35	2,86

Source: own calculations.

Table 6: GDP, private consumption and final demand, WM-scenario

	private consumption nominal	consumer prices	private consumption real (2005)	final demand nominal	imports	GDP nominal	GDP real
2009	0,75	-0,13	0,89	-4,55	-8,87	-2,28	-4,41
2010	0,73	1,95	-1,20	5,58	7,93	4,44	1,99
2011	3,18	1,15	2,01	4,57	6,55	3,54	1,58
2012	2,44	1,33	1,10	3,45	3,61	3,36	1,87
2013	2,40	1,40	0,99	3,46	3,99	3,18	1,76
2014	2,75	1,40	1,33	3,54	4,17	3,20	1,82
2015	2,73	1,61	1,11	3,56	3,89	3,38	1,98
2016	2,75	1,64	1,09	3,58	3,54	3,60	2,15
2017	2,84	1,62	1,20	3,59	3,78	3,49	2,05
2018	2,92	1,63	1,28	3,63	3,94	3,45	2,03
2019	2,92	1,66	1,25	3,64	3,90	3,50	2,10
2020	2,97	1,67	1,28	3,81	4,00	3,70	2,26
2021	2,87	1,74	1,11	3,65	3,79	3,57	2,14
2022	2,91	1,71	1,18	3,65	4,08	3,40	2,03
2023	2,91	1,75	1,14	3,66	4,08	3,42	2,06
2024	2,88	1,81	1,05	3,66	3,88	3,54	2,11
2025	3,06	1,80	1,24	3,71	4,08	3,50	2,10
2026	2,93	1,89	1,02	3,70	3,84	3,61	2,19
2027	3,01	1,84	1,15	3,71	4,05	3,50	2,12
2028	2,90	1,94	0,95	3,70	3,83	3,63	2,22
2029	3,02	1,95	1,05	3,73	3,85	3,66	2,26
2030	2,98	2,03	0,94	3,74	3,69	3,76	2,33
2012-2030	2,85	1,71	1,13	3,64	3,89	3,50	2,08

Source: own calculations.

3 Energy scenarios and quantification of effects from policies

3.1 Description of policy scenarios

3.1.1 Climate and energy policies in the WM-scenarios (with measures)

Within the WM-scenario set different climate and energy policies are considered that were implemented until the 2nd February 2010. This concerns the industrial and energy supply sectors, the sector heating and other small-scale energy consumption as well as the transport sector. The relevant national policies are induced by a number of European directives that were transferred into national laws. Among these, Austrian policies apply, for example, financial assistance to environmental projects (Umweltförderung Inland, UFI), financial assistance from the climate and energy fund (kli:en), other national programs like "klima:aktiv Mobilität" as well as programs on the level of federal states such as financial assistance to biomass utilities (for an overview of directives and national policies see Table 7).

Table 7: Climate and energy policies in WM-scenario set

EU-Regulations	EC Directive
Kyoto Protocol project mechanisms	2004/101/EC
Renewable energy	2001/77/EC
Promotion of Cogeneration	2004/8/EC
Taxation of energy products and electricity	2003/96/EC
End-use efficiency and energy services	2006/32/EC
Eco-management and audit	Reg. 761/2001
Ecodesign requirements	2005/32/EC
	2009/125/EG
Energy labelling for households appliances	2003/66/EC
	2002/40/EC
	2002/31/EC
	99/9/EC
	96/89/EC
	96/60/EC
	92/75/EC
Energy labelling for office equipment	Reg. 2422/2001
Energy labelling for fluorescent lighting	2000/55/EG
EURO Classification	1999/96/EG
Correlated national policy measures	
climate protection programmes of states	
klima:aktiv	
long distant heating system law	
kli:en-projects	
Domestic environmental subsidies	
Energy efficiency plan	
Biofuels directive	
Mobility management	
Fuel saving initiative	
Mineral oil tax 2007	
Ecologizing of Nova	
Road charge	

Source: own illustration.

3.1.2 Climate and energy policies in the WAM-scenarios (with additional measures)

Additional policy measures to model the impacts of a more stringent climate- and energy policy approach mainly recur to the Energy Strategy Austria (BMWFJ, 2010b) but also refer to the Monitoring Mechanism 2009. They encompass above all measures dealing with the energy efficiency of buildings, the transport and industrial sectors as well as with measures tackling the energy supply industry. An overview of additional measures implemented in modelling the impacts on energy demand is given in Table 8. In particular, climate and energy policy measures which are implemented in detail in the bottom-up models of the project partners result in improved energy efficiency indicators that are, in turn, implemented as input data into the DEIO model. For instance, the efficiency index for the energy service heating results as model output from the ERNSTL buildings model of the EEG TU Wien. Necessary correlated investments in energy-efficiency refurbishing are implemented into the DEIO top-down model, in the WAM-scenario, 1.2 mill square meters of dwelling area are refurbished additionally at an investment cost of 900 mill € on average. For details refer to EEG (2011).

In the transport sector; the efficiency of the passenger vehicle fleet is enhanced by the introduction of cars with alternative power trains such as natural gas, biogas, fuel cells, e-vehicles and the introduction of lower speed limits on motorways. These measures imply an increase of energy efficiency of the vehicle fleet (technological change). Additionally, measures that mainly influence the energy service demand in transport are implemented. The most relevant of these measures is the stepwise increase of the mineral oil tax. This tax is increased by 4/5 cents per liter of gasoline/diesel in 2011 and further by 5/5 cents per liter of gasoline/diesel in 2015. Other measures influencing the energy service demand are:

- development of public transport services (multi-modal systems)
- mobility management by mobility consultants
- support of bicycle use
- optimization of spatial planning.

Related investments and operating costs of these measures amount to 50 mill € per year until 2020 for 1000 mobility consultants and 36 mill € per year until 2020 for the enhancement of bicycle infrastructure. Unfortunately, detailed cost estimates for the other measures were not available and, therefore, could not be implemented. The freight transport sector is covered by measures that address modal shift such that average kilometer travelled by freight vehicles decrease by 3% compared to the WM-scenario. For further details reference is made to TU Graz (2011).

With regard to electricity use, we directly apply the consumption of electricity by industry from AEA (2011).

Table 8: Additional climate and energy policies in WAM-scenario set

Buildings	DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings Code of the Austrian Institute of Construction Engineering housing subsidies according to new standards UFI and kli:en
Transport	promoting energy efficient vehicles and alternative drive trains (e-vehicles, hybrids etc.) promotion of renewable energy sources (e.g. biofuels) promotion of public transport (quality and frequency enhancement) promotion of energy efficient modes in goods transport reduction of goods transport through logistics mobility management by mobility consultant spatial planning and organisation of transport small ecological tax reform
Industry	new guidelines for emission trading (auctioning, reduced emissions allowances, etc.) promoting energy efficiency in the use of electricity
Energy supply	Eco electricity act (Ökostromgesetz) Domestic environmental subsidies (UFI) kli:en etc.

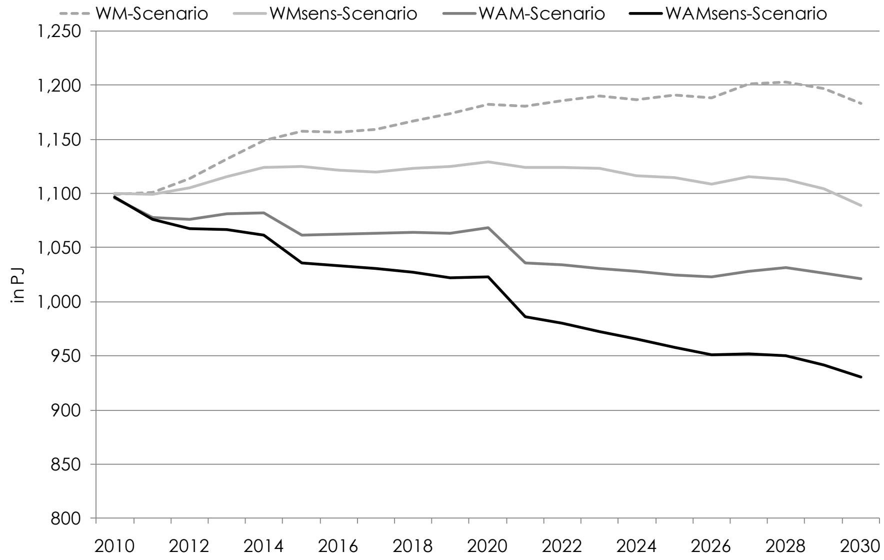
Source: own illustration.

3.2 Final energy consumption

In order to achieve the 20/20/20-targets of the EU climate and energy package and, in addition, ensure a secure and affordable energy supply to private households and industries, the final energy consumption in Austria should stabilize at 1100 PJ in 2020 according to the Austrian Energy Strategy (BMWFJ, 2010b). Final energy consumptions derived in the four scenarios are depicted in Figure 7 and Table 9. The WM-scenario shows – according to assumptions on GDP and crude oil price developments - the highest final energy demand, growing from about 1,100 PJ in 2010 to 1,183 PJ in 2020, thereby rising final energy demand by 7.5% until 2020 (+7.6% until 2030). Considering a lower increase in crude oil prices, the WMsens-scenario is growing from 1,100 PJ in 2010 to 1,129 PJ in 2020, increasing by 2.6% until 2020 (-1% until 2030) with respect to 2010. The long term development of the WM-scenario set shows a decline in final energy consumption due to climate and energy policies already implemented. The drop is, of course, more pronounced in the WMsens-scenario due to lower

GDP growth. Climate and energy policies taken into consideration mainly gain momentum through the positive effect on the energy efficiency of the relevant capital stocks that deliver energy services. This effect is becoming more pronounced in the long run when most of the capital stock will be replaced by energy efficient devices.

Figure 7: Total final energy consumption, 2010-2030



Source: own calculations.

Table 9: Total final energy consumption 2010, 2020, 2030

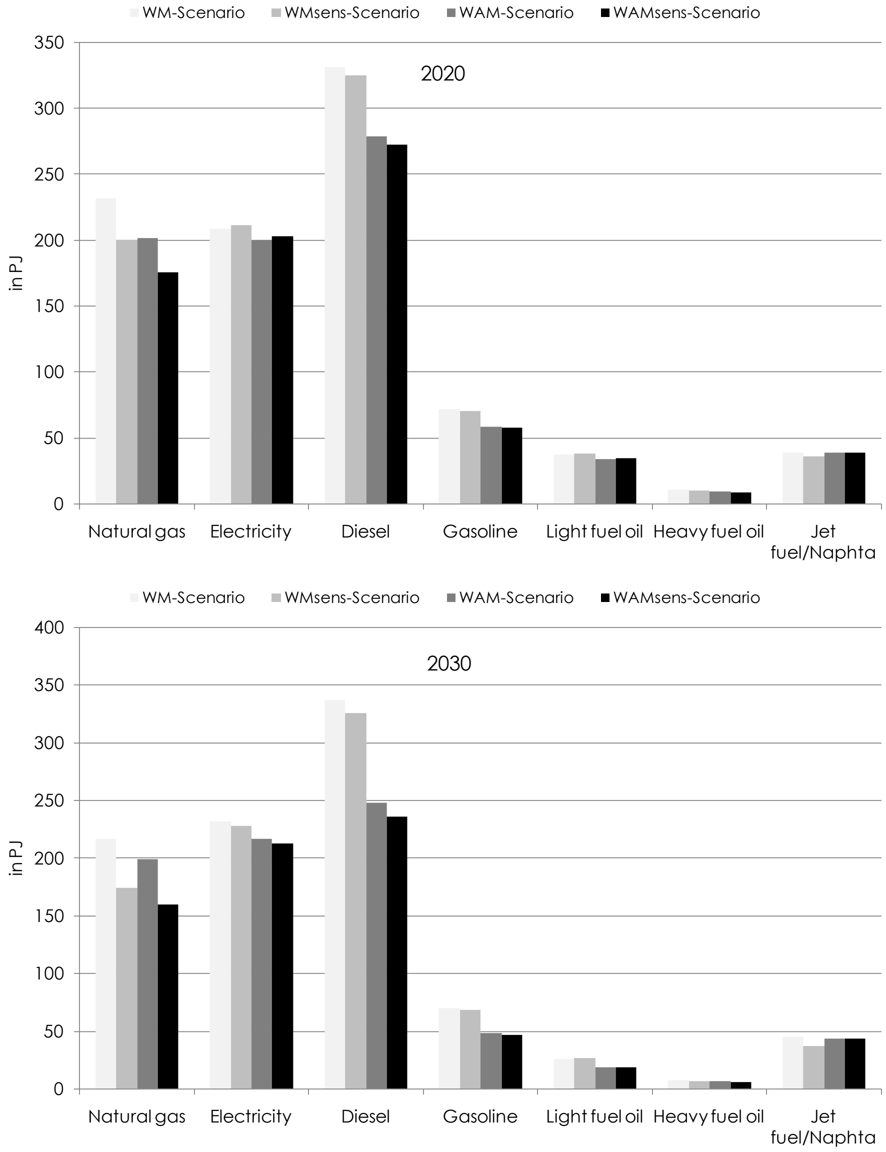
	2010	2020	2030	2010-2020	2010-2030	2010-2020	2010-2030
		in TJ		in %		Ø in %	
WM	1,099,388	1,182,109	1,183,267	7.52	7.63	0.73	0.37
Wmsens	1,100,052	1,128,945	1,088,947	2.63	-1.01	0.26	-0.05
WAM	1,095,734	1,068,415	1,020,909	-2.49	-6.83	-0.25	-0.35
WAMsens	1,096,398	1,022,830	930,702	-6.71	-15.11	-0.69	-0.82

Source: own calculations.

The WAM-scenarios follow the pattern of the WM-scenarios, with the WAM-scenario being the high growth scenario resulting in higher levels of final energy consumption compared to WAMsens. Due to the enhanced climate and energy policy measures taken into account, the overall energy demand, however, reaches significant lower levels. In 2020, final energy consumption is at 1,070 PJ (at 1,022 PJ for WAMsens), thus falling below the target of 1,100 PJ stipulated by the Austrian Energy Strategy. Results show a significant different energy consumption pattern between the WM and the WAM-scenarios, i.e. while final energy demand increases on average by 0.7% p.a. until 2020, the policy case exhibits negative growth in final energy demand of -0.25% p.a. until 2020 and even -0.35% until 2030 in the WAM case. The impact of climate policies is highest in the WAMsens case, i.e. in the low growth scenario the decline in energy demand lies at -15% until 2030 with respect to 2010 or at an average of -0.8% p.a. (2030).

Final energy consumption by energy sources in the WM and WAM-scenario sets is summarized in Figure 8 as well as in Table 10 for the years 2020 and 2030. Most of the energy carriers depicted follow the same scenario pattern as total final energy demand in Figure 7, i.e. a subsequent decline in energy consumption from the WM-scenario to the WAMsens-scenario. However, the consumption of natural gas brakes this rule as it is higher in the high growth policy-scenario (WAM) than in the low growth WMsens-scenario (for 2020 and 2030). This result can be explained by the fact that lower economic growth in the WMsens-scenario is driven by lower output growth of export-intensive industrial sectors that in turn reduce their natural gas consumption. In addition, supplementary measures regarding the ETS sectors of the economy are not included in the analysis and hence there is no extra climate policy effect on the industrial sectors. The same holds for jet fuel. At this point, the significance of economic growth with respect to energy consumption becomes apparent in relation to the effects of climate policies: Economic growth can outpace ambitious climate policies in terms of energy consumption.

Figure 8: Final energy consumption by energy sources, 2020, 2030



Source: own calculations.

Table 10: Final energy consumption by energy sources

Natural Gas	2020	2030
	in TJ	
WM-Scenario	231,717	216,585
WMsens-Scenario	200,195	174,543
WAM-Scenario	201,594	198,907
WAMsens-Scenario	175,748	159,813
Electricity	2020	2030
	in TJ	
WM-Scenario	208,448	232,054
WMsens-Scenario	211,074	227,965
WAM-Scenario	200,033	216,990
WAMsens-Scenario	202,658	212,906
Diesel	2020	2030
	in TJ	
WM-Scenario	331,145	337,123
WMsens-Scenario	324,642	325,359
WAM-Scenario	278,886	247,591
WAMsens-Scenario	272,638	236,206
Gasoline	2020	2030
	in TJ	
WM-Scenario	71,863	70,329
WMsens-Scenario	70,577	68,733
WAM-Scenario	58,613	48,067
WAMsens-Scenario	57,497	46,719

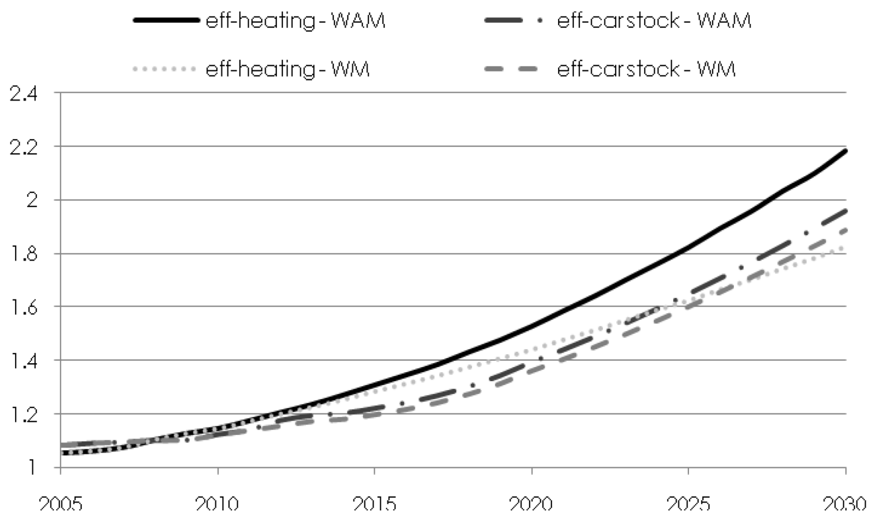
Source: own calculations.

The effectiveness of the climate and energy policies is revealed when comparing the WM with the WAM-scenario. Accordingly, energy consumption is reduced by 13% (2020; 8% in 2030) with natural gas, -4% (2020; -6,5% in 2030) with electricity, -16% (2020; -27% in 2030) with Diesel fuels and -18% (2020; -32% in 2030) with Gasoline. These figures reveal a particularly high sensitivity towards climate and energy policies with respect to transport fuels. This reaction is -to a great extent- due to the stepwise increase of the mineral oil tax (for details see section 3.3). This measure not only impacts on domestic fuel demand (via the service price of fuel) but also reduces the difference in the price of domestic and foreign fuels. It thus shows a dampening effect on fuel exports which substantially contributes to the domestic GHG balance (Molitor et al., 2009). The relationship of energy consumption between the WMsens and the WAMsens-scenarios is in a similar order of magnitude.

3.3 Household energy demand

The interface of modelling the impacts of climate and energy policies between the bottom-up and the top-down models lies in the energy efficiency of household capital stocks. Due to climate and energy policy measures, the efficiency of the household energy-using capital stocks, i.e. electrical appliances, heating equipment and the passenger car stock, is increasing thereby reducing the energy intensity of the relevant energy service (see Figure 9). For a detailed exposition of the policies considered to trigger energy efficiency improvements reference is made to the project reports of the research partners. The improvement of the energy efficiency of the heating systems figures highest in 2030, closely followed by the efficiency of the passenger car stock. The improvement of efficiency of electrical appliances is relatively low and not pictured.

Figure 9: Energy efficiency of households' capital stock, WM and WAM



Source: own calculations.

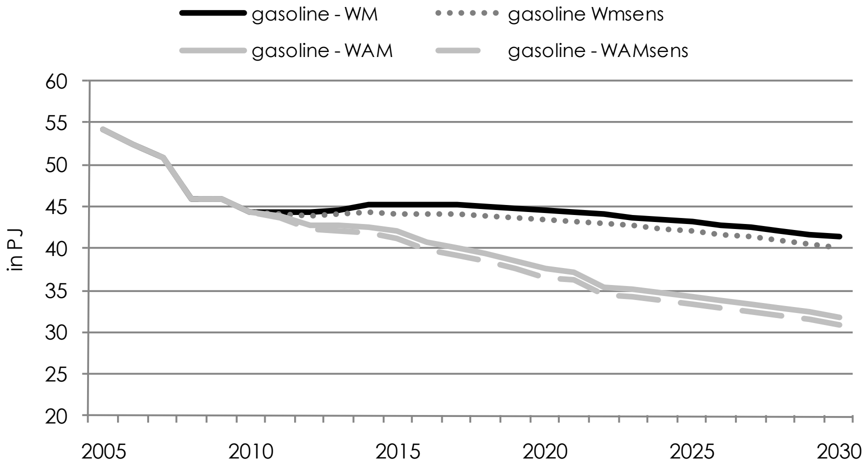
The household passenger car stock efficiency improvement in the WAM-scenario is induced by several policies such as the introduction of alternative powertrains and the stepwise increase of the mineral oil tax (plus 4/5 cent, nominal, gasoline/diesel in 2011, plus 5/5 cent in 2015 and plus 10/7 cent in 2020). Other transport-related climate and energy policy measures implemented comprise tempo limits, mobility management, the promotion of cycling, the expansion of public transport systems and altered spatial planning strategies (for details also refer to Arbeiterkammer (2007)). These measures impact on the household service demand via increased efficiency of the vehicle stock in use and due to reduced person kilometers travelled in the WAM-scenario set. The combined effect with respect to energy consumption of household transport demand is illustrated in Figure 10. Policy efforts to reduce fossil energy consumption in the household transport sector have a substantial impact, i.e. gasoline demand is reduced by 16% (2020; 23% in 2030) and diesel demand by 16% (2020; 22% in 2030) with respect to the WM-scenario. The difference in energy demand between the sensitivity scenarios WMsens and WAMsens is in the same order of magnitude as in the WM/WAM case.

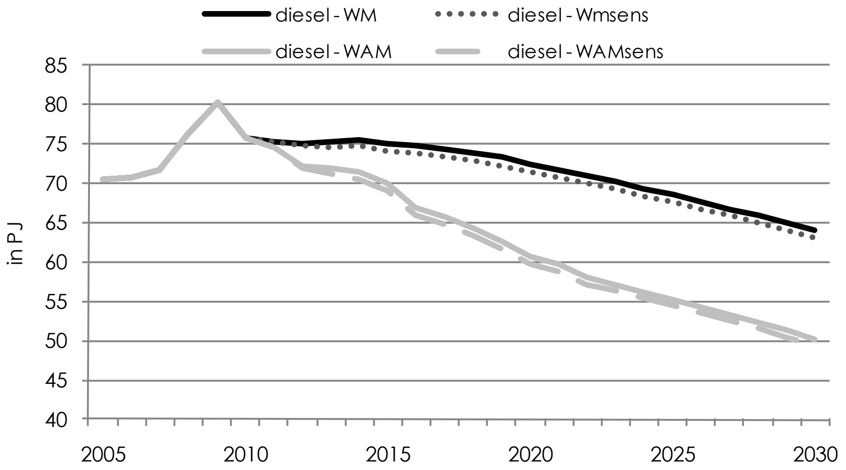
In the household heating sector two climate and energy policy measures are combined. First, a slight increase in efficiency of boilers is assumed, in particular the efficiency of pellets and firewood furnaces as well as of heat pumps is improved. Second, 1.2 mill m^2 of living space are refurbished on average per year in the period until 2030 in order to reduce heating energy demand. The outcome with respect to energy efficiency improvements of heating systems is depicted in Figure 9, the resulting energy demand in Figure 11. A reduction in energy demand of 2% in 2020 and 13% in 2030 comparing the WM and the WAM–scenarios derives. The same order of magnitude in the decline of energy demand is calculated for the WMsens and WAMsens-scenarios. Here again it is visible that the transformation of energy-related capital stocks towards lower carbon energy consumption is feasible only in the middle to long term.

With respect to the efficiency of household electrical appliances, an efficiency increase of 1% p.a. was assumed for both scenarios (WM and WAM). The modelling results for the scenarios show that electricity demand is higher in both scenario comparisons (WAM vs. WM and WAMsens vs. WMsens, see Figure 11). This can be explained by feedback loops in demand that are triggered by respective climate and energy policy measures and lead to indirect positive effects on electricity demand, part of which are direct rebound effects.

Figure 12 and Figure 13 highlight these effects showing the difference in household energy demand between the WM and the WAM-scenarios, on the one hand, and energy demand when service demand is held constant (equal to WM-scenario), on the other hand. The result for the WAM-scenario thus represents the efficiency improvement induced by climate and energy policies but without considering effects on the service demand itself. The effects are shown for the heating and the transport sector as the effects in the electricity sector are negligible.

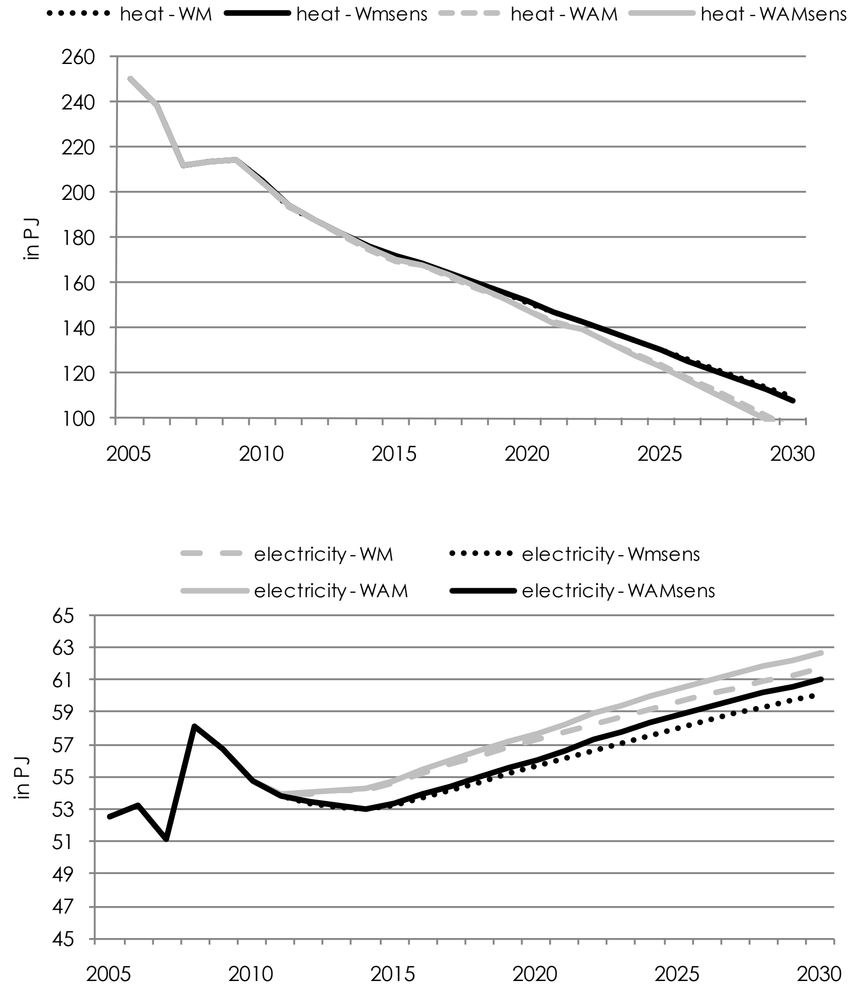
Figure 10: Development of household energy demand for transport fuels, 2020, 2030





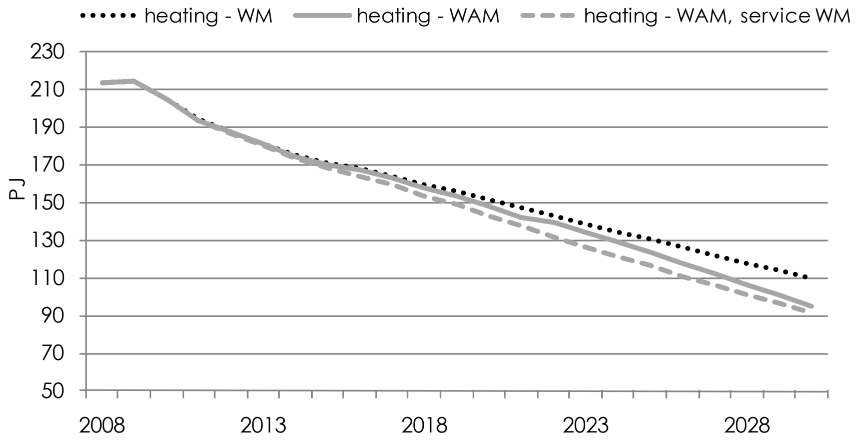
Source: own calculations.

Figure 11: Development of household energy demand for heat and electricity, 2020, 2030



Source: own calculations.

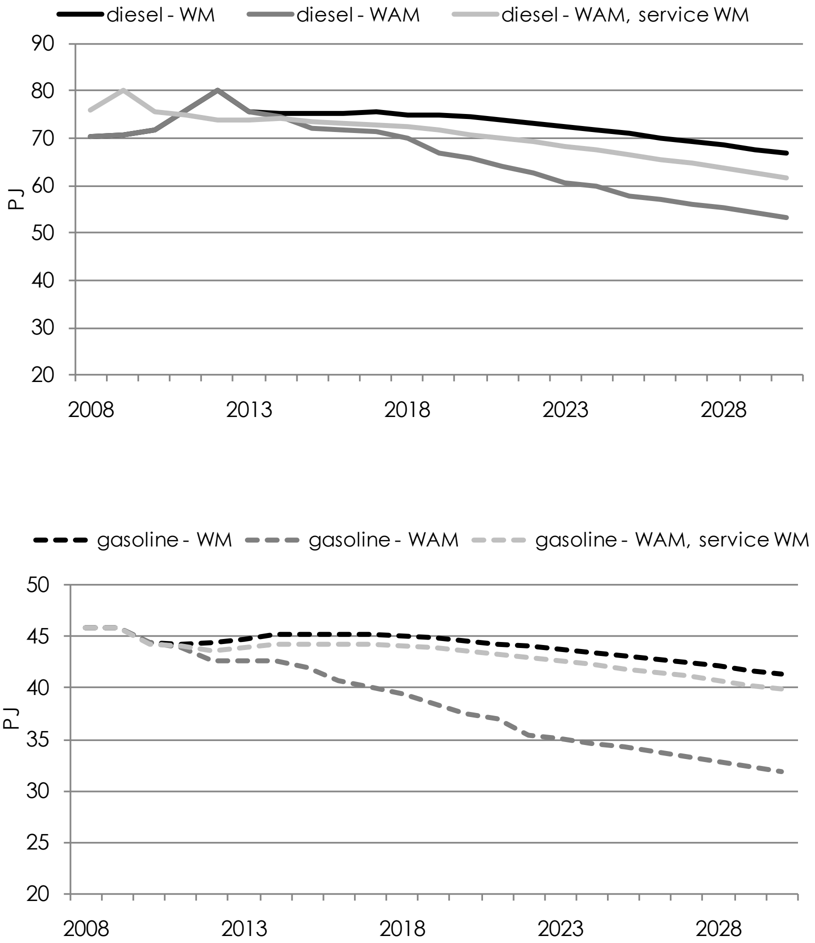
Figure 12: Development of household energy demand for heat with rebound effect



Source: own calculations.

Figure 12 shows the effects for energy demand for heating with respect to the rebound effect. The energy demand in the WAM-scenario is higher than in a fictitious WAM-scenario with constant service demand. This means that due to service price variations stemming from higher energy efficiency of buildings and heating systems, demand actually shows a rebound. Figure 13, in contrast, shows that the implemented climate and energy policies in the transport sector are effective in preventing a rebound effect in the service demand, or, put differently, that the considered policies are effective in reducing the service demand, e.g. due to modal shift policies etc. Here, the energy demand is lower for both gasoline and diesel in the WAM-scenario in relation to the fictitious WAM-scenario with constant service demand. Climate and energy policies thus need to be comprehensive in order to effectively reduce energy demand.

Figure 13: Development of household energy demand for fuels with rebound effect



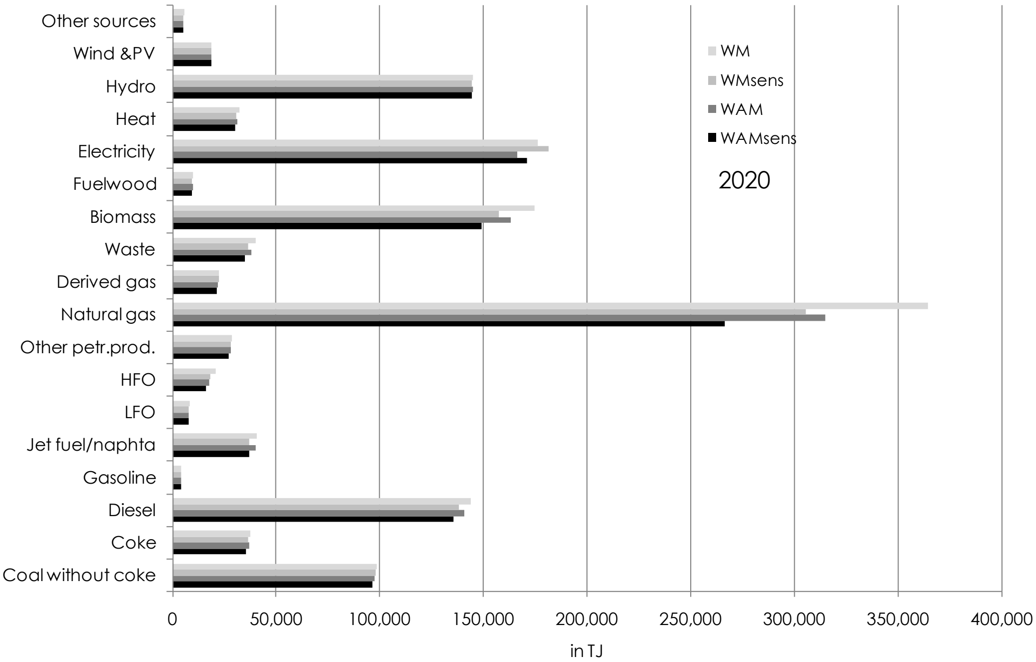
Source: own calculations.

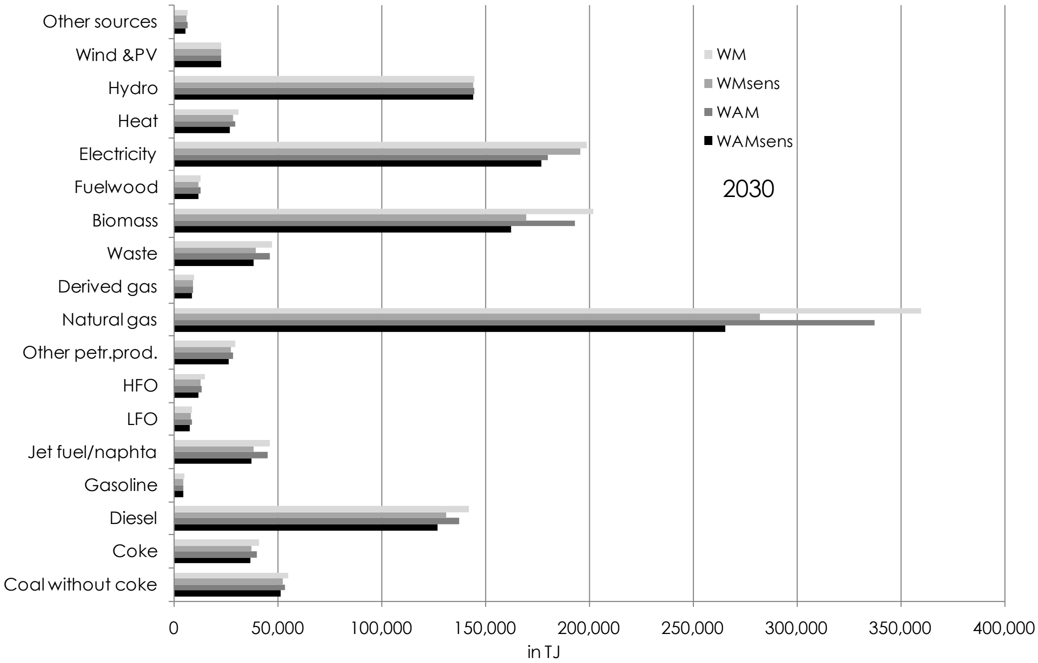
3.4 Energy use by industry

The energy use by industry sectors is depicted in Figure 14 with respect to specific energy resources in the WM and WAM-scenarios. Table 11 quantifies the relevant variations in energy use by different energy resources. The decline in energy demand by industrial sectors is highest with respect to heavy fuel oils (HFO, -14% in 2020, -9% in 2030) and natural gas (-14% in 2020, -6% in 2030). Reductions in energy use are also substantial with respect to biomass (-6% in 2020, - 5% in 2030), electricity (-6% in 2020, - 9% in 2030), waste (-5% in 2020, - 3% in 2020) and oil (-3% in 2020, - 3% in 2030). These reductions mainly stem from the energy sectors (power and heat generation, oil industry), which are affected by lower final energy demand due to the measures implemented in the WAM scenario. The lower demand of households for gasoline and diesel in the WAM scenario dampens the output (and therefore also the input) of refineries and the lower electricity demand of different industries mainly leads to a reduction of thermal power generation. That mainly affects natural gas, but also biomass and waste input of industrial autoproducers.

In contrast to the household energy demand there is barely a reduction in diesel and gasoline use in the industrial sectors. This highlights the fact that most of the climate and energy policy measures in transport impact on the household sector (see Table 8).

Figure 14: Energy use by resources in industries, 2020, 2030





Source: own calculations.

Table 11: Difference in industry energy use by resources, WM, WAM, 2020, 2030

	2020 Difference WM/WAM	2030 Difference WM/WAM
Coal without coke	-1.24	-2.33
Coke	-1.64	-2.20
Crude oil	-2.90	-3.08
Diesel	-2.13	-3.19
Gasoline	-1.54	-2.89
Jet fuel/naphta	-0.88	-2.56
LFO	-0.95	-1.21
HFO	-13.83	-8.89
Other petr.prod.	-2.66	-3.08
Natural gas	-13.60	-6.20
Derived gas	-2.90	-3.09
Waste	-5.21	-3.04
Biomass	-6.40	-4.52
Fuelwood	-0.02	-0.18
Electricity	-5.82	-9.40
Heat	-2.40	-4.88
Hydro	0.00	0.00
Wind &PV	0.00	0.00
Other sources	-2.57	-1.59

Source: own calculations.

4. Conclusions

This study describes different energy scenarios for Austria until 2030, based on an economic top-down model for energy demand. This dynamic econometric input-output model DEIO of WIFO comprises an elaborated dynamic optimization model of household demand and an input-output model for 60 sectors. This economic model incorporates an energy satellite system with a detailed description of energy demand, based on the Austrian NAMEA energy, which can be converted into the energy balance system.

The core of the model and of the energy scenarios described here is the analysis of household energy demand for heating purposes, electricity and private transport. The main advantage of the input-output model is the quantification of all indirect effects of household activity. This is especially relevant for the WAM-scenario group, where climate and energy policy measures induce indirect energy demand effects (direct rebound effects, higher demand for household equipment, investment in refurbishment of buildings, etc.). The household sector is also fully linked to the bottom-up models used in the studies of the project partners. This mainly refers to variables for energy efficiency of the households' capital stock. The used aggregate indicators for energy efficiency in the bottom-up models as well as in the DEIO model are based on detailed data of household structures, like the structure of the building stock and of the private car fleet. In a first step, therefore, the impact of certain climate policy measures on the aggregate efficiency indicators has been calculated both in the top-down (DEIO) and bottom-up models. In a second step the aggregate efficiency indicators for all scenarios have been harmonized between the models. This exercise gave interesting insights in the functioning of the different models and revealed some important points for future research in linking bottom-up and top-down models.

The scenario analysis has shown that comprehensive climate and energy policies as formulated in the WAM-scenario are able to reduce energy consumption substantially. In 2020 final energy consumption in the WAM-scenario is at 1,070 PJ thus lower by about 9.6% compared to the WM-scenario. Austrian energy consumption in the WAM-case thus is below the target of 1,100 PJ as stipulated in the Austrian Energy Strategy.

The analysis shows that climate and energy policy measures in the WAM-scenario set are designed in a way that in those sectors with high expected rebound effects such as private transport, the reduction of energy consumption in the WAM scenario mainly results from a reduction of 'service' demand (behavioral change). In contrast, in sectors with expected lower rebound effects like heating the reduction of energy consumption in the WAM scenario mainly stem from energy efficiency improvements (technological change).

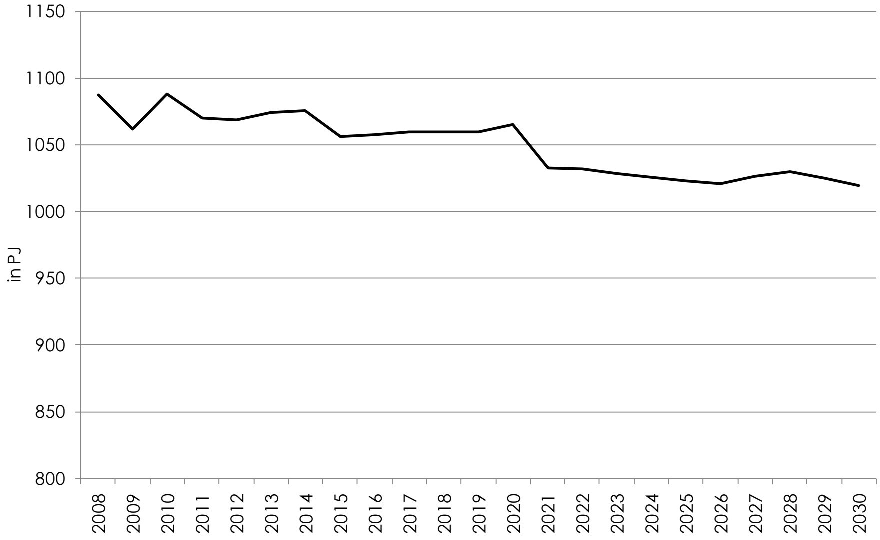
5. Annex

5.1 The scenario WAMg

Finally, a scenario **With-Additional-Measures (WAMg)** is developed which exhibits the effects of explicitly modelling the financing of implementing the relevant climate and energy policy measures. One major instrument to finance climate and energy policies that, at the same time, exerts an incentive to reduce fossil energy consumption in itself is the carbon tax. Carbon taxes raise energy prices and thus act in addition to other climate and energy policy measures. For the WAMg-scenario a carbon tax of 10 €/t CO_2 is assumed for the non-emissions trading sectors, increasing relevant fossil energy prices for household energy demand and industry energy use. In order to understand the effects of a carbon tax of 10 €/t CO_2, the impact on the price for transport fuels is calculated. As the energy content of diesel fuel is higher than the one of gasoline, the carbon tax is slightly higher per liter of diesel than per liter of gasoline, i.e. a carbon tax of 10 €/t CO_2 is equivalent to a markup of 2.8 cent per liter of diesel and 2.5 cent per liter of gasoline. This markup is, in fact, much smaller than the implemented stepwise increases in mineral oil tax of the WAM-scenario (see section 3.3). However, it is an additional measure on top of the WAM climate and energy policies.

5.1.1 Total final energy consumption and total primary energy supply

Figure 15: Final energy consumption in WAMg

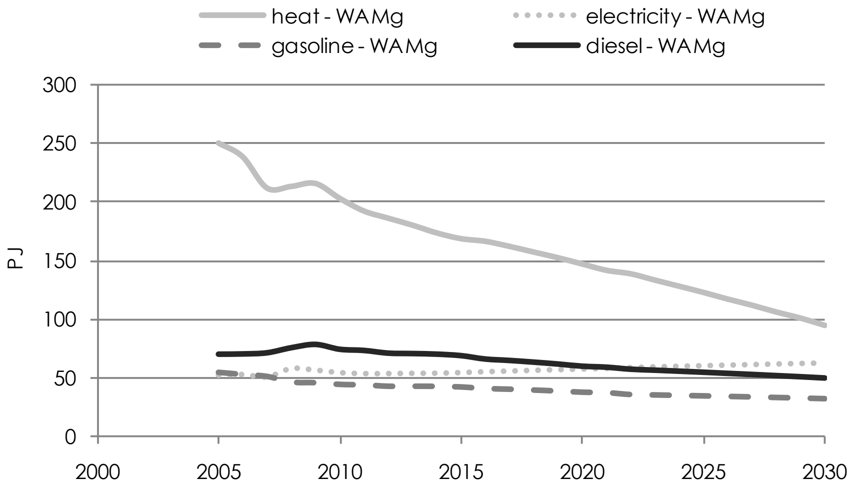


Source: own calculations

The final energy consumption in the WAMg-scenario reaches 1065 PJ in 2020 (1019 PJ in 2030) and thus is slightly below the WAM-scenario (1068 PJ in 2020, 1020 PJ in 2030, Figure 15). Thus a weak impact of the carbon tax on final energy consumption can be derived.

5.1.2 Household energy demand

Figure 16: Energy demand of households in WAMg

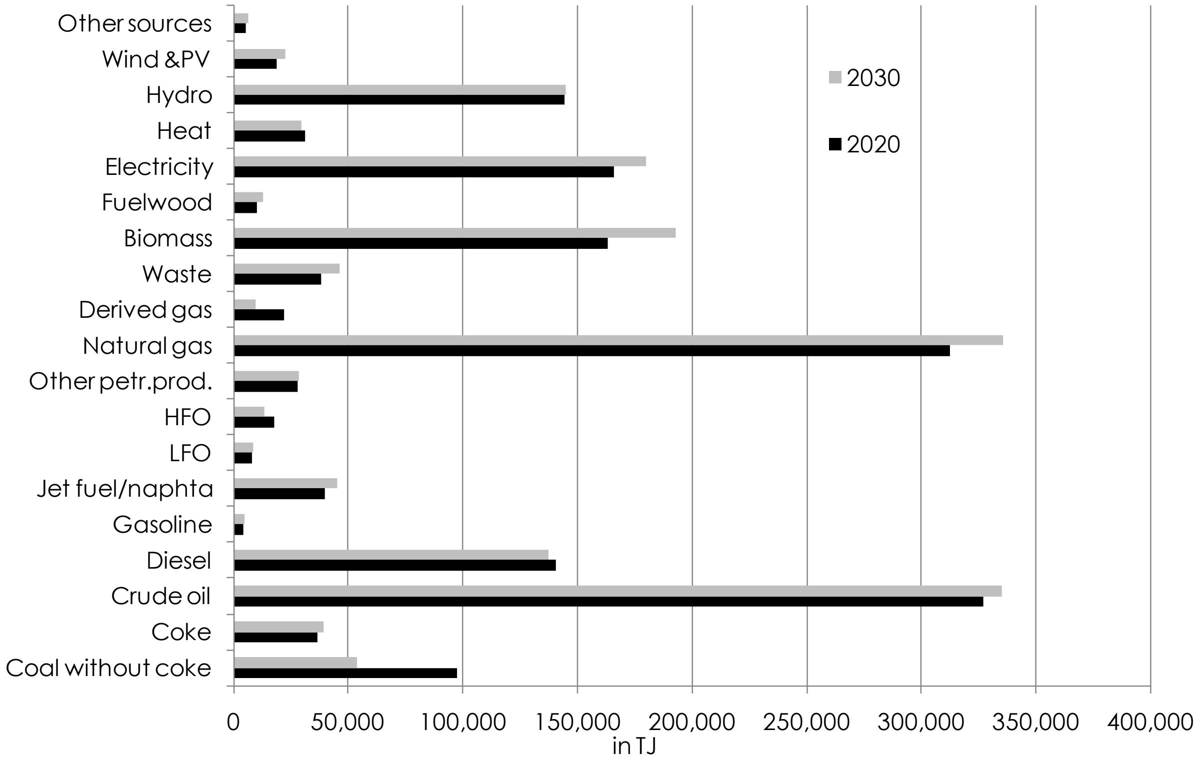


Source: own calculations

The difference between the household energy consumption in WAM and WAMg is moderate due to the moderate carbon tax, however the pattern of behavioral change is clear, a reduction in household energy demand applies. The difference between the transport fuel demand in WAM and WAMg is about 0.2 PJ for gasoline and 0.5 PJ for diesel in 2020 (0.1 PJ for gasoline and 0.2 PJ for diesel in 2030). The difference in electricity energy demand is almost zero and in energy demand for heat is 0.2 PJ in 2020.

5.1.3 Energy use in industry

Figure 17: Energy use by industries in WAMg



Source: own calculations

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