

ENVIRONMENTAL TARGETS, ECONOMIC EFFECTS AND SOCIAL IMPACTS– HOW SUSTAINABLE IS THE GERMAN WAY FROM A FOSSIL TO A RENEWABLE ENERGY SUPPLY SYSTEM?

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1 Introduction

The German government is keen to provide international leadership in climate protection and the establishment of a renewable energy supply system. Therefore in September 2010 an energy strategy, the *Energy Concept*, was approved which required a fundamental restructuring of the German energy supply system during the period until 2050: the main objective is a comprehensive replacement of fossil by renewable energy sources. At the same time affordable energy prices for consumers and a high level of economic competitiveness and development have to be maintained (BMWi 2010). Thus, the establishment of a sustainable energy supply system involves environmental, economic and social issues, which have to be considered simultaneously.

One aspect of the implementation of the *Energy Concept* was the extension of the operating lifetime of German nuclear power plants by an average of 12 years to reach the environmental goal to reduce CO₂ emissions. But, the nuclear accident in Fukushima, in March 2011, changed the government's energy strategy to include the elimination of nuclear power by the year 2022, starting with the immediate closure of the eight oldest plants. The revised energy policy, commonly known as *Energiewende*, also includes measures to support renewable energy, grid expansion and promote energy efficiency (BMWi 2016).

These changes are being implemented alongside major changes in the coal policies. The European Council of Ministers introduced (stepwise) reductions in hard coal subsidies from 2011 to 2018 that are expected to end German hard coal production. At the same time energy generation using brown coal has to be reduced. In 2015 the government decided to close 2.7 GW of brown coal power plants by 2020. The combined impact of the nuclear and coal policies is that at least 40 % of established energy sources have to be replaced, predominantly by renewable energy sources, by 2022 (BMWi 2013).

This study analyses the environmental, economic and social impacts of the nuclear phase out, the abolition of the hard coal subsidies, the reduction of energy generating capacities of brown coal and the simultaneously increase of renewable energy on the economy in Germany.

The analyses are conducted using a comparative static single country Computable General Equilibrium (CGE) model. The model is an extension of the STAGE model (McDONALD 2007) that encompasses a detailed energy production and CO₂ emissions module and nested utility functions, so as to capture the environmental, economic and social effects of the energy policy in Germany.

In the energy modules the electricity sector encompasses existing technologies (nuclear, coal, gas, oil, etc.) and new technologies (wind, solar, biofuels and biomass) that use new energy sources and/or existing energy sources with different cost structures. This formulation requires addressing the

problems presented by a homogenous product – electricity – being produced by different technologies with different cost structures.

Because of relevant differences of the income structure and the historic importance of combined heat and power systems based on brown coal plants in former East Germany, households are disaggregated on the basis of income and residential location.

The model is calibrated with a new Social Accounting Matrix (SAM) for Germany, which includes disaggregated data for the energy sectors and households, and detailed satellite accounts for energy and emissions.

The paper is structured as follows. The first chapter gives an overview of the current energy policy and taxation in Germany. An introduction into the energy supply and use structures in the German economy is presented in chapter 2. Additionally a special focus is on the differences of heat production and use as well as the historically founded distinctions of household income and energy use. After this thematic background the model database is described in chapter 4 and base information about the STAGE model and model adoptions regarding this analysis are given in chapter 5. The computed scenarios and appropriate results are content of chapter 6 and conclusions about the sustainability of the German energy policy are drawn in chapter 7.

2 Energy policy in Germany

The current German energy policy captures several goals. Behind the big declared topics, the granting of the economic efficiency, the security of energy supply and climate protection, a multitude of objectives are in the focus of German government. Economic efficiency covers market structures and competition in the energy markets, but also the securing of growth and competitiveness of the German industrial sector in total, as well as appropriate consumer prices for energy.

For Germany, a country poor in natural resources and dependent on energy imports, the security of energy supply has priority. Security shall be reached by a diversification of energy sources and reduction of energy demand by the increase of energy savings and energy efficiency.

Increasing energy savings and energy efficiency are all requests in the context of climate protection. Next to this the importance of renewable energy sources are supposed to be increased and in doing so, green house gas emissions reduced. (BMW 2014).

The implementation of these complex objectives is laid out in two comprehensive programs: The Energy Concept of 2010 and the Energy Package of 2011, described in the following chapter.

2.1 The Energy Concept 2010

With the *Energy Concept*, determined on 28th September 2010, the Federal Government established guidelines for the implementation of ambitious economic, energy and climate political objectives. The aim is to implement a long-term, integrated strategy until 2050. The transformation sets out to increase energy efficiency, to expand renewable energy sources and to reduce GHGs and includes the extension of the run-time of nuclear power plants by an average of 12 years.

The objective to reduce greenhouse gas (GHG) emissions is determined by 40 % in 2020 and by at least 80 % in 2050. Renewable energy sources should be developed to become a cornerstone of energy supply. The aim is to increase the renewables share in gross energy consumption from around 10 % in 2010 to 60 % in 2050. The energy strategy considers a sustainable energy supply of electricity, heat and mobility, which shall be ensured by renewable energy sources. This includes wind, biomass hydropower, solar power, geothermal and ocean energy, which will serve as an alternative to fossil (oil, coal, natural gas) and nuclear energy. The share of renewable energy in electricity generation shall be increased from 35 % in 2020 up to 80 % in 2050.

Simultaneously, the aim is to reduce energy consumption in the long term. By 2020, primary energy consumption is intended to decline by 20 % and in 2050 by 50 % compared to 2008. It requires annual increases in energy productivity by an average of 2.1 % based on total energy consumption.

It is envisaged that electricity consumption will be reduced by 25 % by 2050 compared with 2008. Final energy consumption in the transport sector is expected to decline in 2050 by about 40 % compared to 2005. Furthermore, the rate of renovation of buildings from the current approximately doubled each year to be 2 % of the total building stock.

On top of this, an immediate action program has been declared consisting of ten so called urgent measures. The immediate action program focuses in particular on the expansion of offshore wind power and the expansion/upgrading of power grids (BMWi 2012).

Table 1: Objectives of the energy concept

	2012	2020	2030	2040	2050
Reduction in GHGs (base: 1990)	-27%	-40%	-55%	-70%	-80%
Share of renewable energies in total final energy consumption	10%	18%	30%	45%	60%
Share of renewable energies in electricity consumption	20%	35%	50%	65%	80%
Reduction of primary energy consumption (year: 2008)	-5%	-20%			-50%
Reduction of electricity consumption (base: 2008)	-1%	-10%			-25%
Reduction of final energy consumption in transport sector (base: 2008)		-10%			-40%

Source: BMU (2012)

2.2 The Energy Package 2011

Following the Fukushima Daiichi nuclear accident in March 2011, the federal government reconsidered the long-term role of nuclear power, with the result to phase-out the use of nuclear power for commercial electricity generation at the earliest possible time. On 30 June 2011, the *Bundestag* passed the Thirteenth Act amending the Atomic Energy Act (*Dreizehntes Gesetz zur Änderung des Atomgesetzes*). This act entered into force on 6 August 2011. In order to phase-out nuclear power more quickly, the process of reorganizing German energy supply at a fundamental level needed to be substantially accelerated. This process is known as the *Energiewende* (Energy Shift). So the Federal Cabinet, the *Bundestag* and the *Bundesrat* adopted a comprehensive so-called *Energy Package*, in June and July 2011. This *Energy Package* consists of seven acts and one ordinance, e.g. on expanding renewables, expanding the grid, energy efficiency and on the funding of the reforms. The Energy Package marked a second significant step by the federal government towards the restructuring of the energy supply. An important aim of the legislative package was to ensure that the nuclear phase-out could proceed as fast as possible, with the eight oldest nuclear power plants not being reconnected to the grid. Shortly afterwards, the Federal Council followed the *Bundestag*'s vote and approved the energy legislation. The key elements of the *Energy Package* 2011 adopted in July 2011, based on the *Energy Concept* of 2010 are:

- Act to Accelerate the Expansion of Electricity Networks (NABEG): acceleration of spatial planning;
- Energy Industry Act (EnWG): transposition of Third Internal Market Directive;
- Renewable Energies Act (EEG): cost-efficient expansion of renewables;
- Nuclear Energy Act: phase-out of German nuclear power plants until 2022;
- Energy and Climate Fund Act;
- Act to Strengthen Climate-compatible Development in Cities and Municipalities;
- Act on Tax Incentives for Energy-Related Modernisation of Residential Buildings;
- Ordinance on the Award of Public Contracts (BMW 2012).

2.3 The Hard Coal Financing Act

The extraction of hard coal in Germany is not competitive in the international context; therefore hard coal extraction has been subsidized since 1974.

In February 2007 a coal policy agreement was reached between the government, the hard coal industry and the coal-mining Länder. The agreement "Terminating subsidised hard coal production in Germany in

a socially acceptable manner” contents the details of the phase-out process until the year 2018. The corresponding Act “The Act to Finance the Termination of Subsidised Hard Coal Production by the Year 2018” (Hard Coal Financing Act, *Steinkohlefinanzierungsgesetz*), entered into force on 28 December 2007. Subsidies will be reduced annually. Appropriate to the agreement, the government and the coal-mining Länder grant the financial support for sales, mine closures and liabilities needed in the period 2009-19. The industry has to contribute to the costs from 2012 onwards.

Beyond the German act, operational aid of hard coal extraction from 2018 onwards is permitted by a European Council Regulation, which came in force in January 2011 (BMWi 2007, IAE 2013).

2.4 Energy and Electricity Taxation in Germany

The tax revenues from energy comprised 39.3 bn € and for electricity tax 6.9 bn € in the year 2012. This come up to 7.7 % of the country’s total tax revenues in this year (Statistical Office 2013).

The Petroleum Tax Act and the Electricity tax Act have been introduced in Germany on 1 April 1999 within the framework of ecological tax reform. These acts organized the energy and electricity taxation on petroleum (products) in Germany.

Due to the requirement of the EU Energy Tax Directive from 2003 (European Commission 2003) a harmonisation of minimum taxation on electricity and energy products from other energy sources than petroleum was necessary. On 1 August 2006 the Energy Tax Act replaced the previously Petroleum Tax Act. The Electricity Tax Act has been adopted.

The Energy Tax Act

The Energy Tax Act (EnergieStG 2006) regulates the taxation on energy products used as transport and heating fuels in Germany. These includes fuels of fossil origin and renewable energy products. The energy tax is a federally implemented excise tax containing a number of different tax rates on energy sources. The reason for these different tax rates is due to the fact that energy products are taxed depending on their use and because of their contribution on climate protection.

There also exist a number of exceptions. Depending on their use, energy products can be tax free or tax relieved. Tax exemptions are granted for example for air and water transport, as well as for the production of energy products. Tax reliefs are possible for energy-intensive enterprises in the agricultural and forestry sector and the base as well as energy-intensive manufacturing industries. In addition, manufacturing companies can receive repayments from paid electricity and energy taxes in the so-called tax cap. These regulations were introduced by the government in 2000 in the context of a

Climate Agreement with the industry to ensure the international competitiveness of these industries. The European Commission has recognized the tax benefits until the end of 2012. Since the 6 August 2013 the receipt of the tax cap is linked to the establishment of an energy management system according to ISO 50001 or an environmental management system according to EMAS established. The intention of introducing these management systems are a systematically capture of energy consumption by the companies, the identification of potential savings and a specified reduction of energy use by 1.3 % until 2015 and 1.35 % from 2018 onwards.

The Electricity Tax Act

The Electricity Tax Act (StromStG 1999) regulates the taxation of consumption of electricity. It is an indirect excise tax, accrued by the electricity supplier, if electricity is used by the last consumer. The energy tax is passed to the consumer by electricity prices. The amount of electricity tax is 2.05 ct/KWh since 2003.

There exist different tax exemptions and tax abatements, for example reduced tax rates for the manufacturing industries or the abolition of electricity taxes on electricity produced from renewable resources.

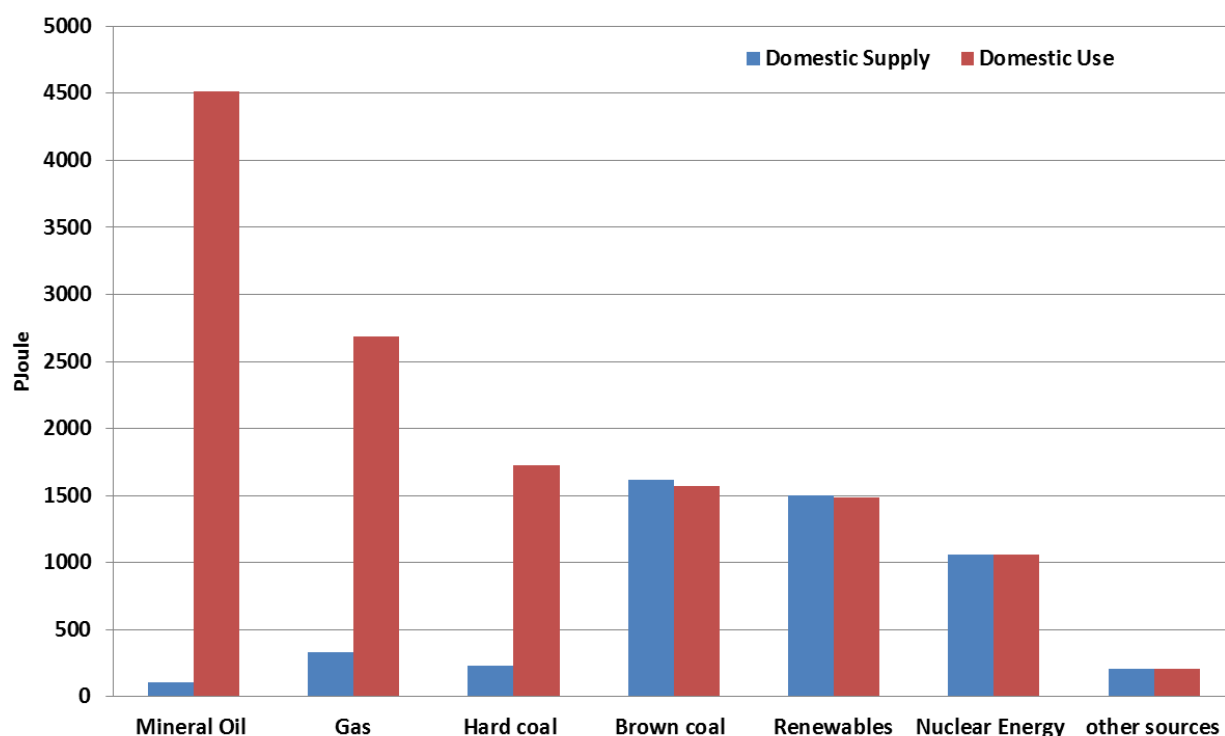
Further information and detailed tax rates can be found at the homepage of the Federal Ministry for Economic Affairs and Energy (www.bmwi.de) and the Ministry of Finance (www.zoll.de).

3 The Energy sector in Germany – An overview

Within the European Union (EU) Germany is the biggest user of energy with a primary energy consumption of 13,132 PJoule in 2014 (AGEB 2015). The main reason for this high energy demand is due to the fact that Germany is one of largest countries in the EU in terms of population and energy intensive industries. Round about 50 % of Energy is used for heat, 30 % for Transport and 20 % for electricity generation (BMU 2013).

For getting an impression of the German energy supply and use structure, Figure 1 shows this differentiated by energy sources for the year 2014. The red bars show the domestic energy use of the particular energy source for heat, transport and electricity in Germany. The blue bars show the supply of energy based on domestic resources.

Figure 1: Supply and use of primary energy in Germany (2014)



Source: AGEb 2015

Germany represents a resource-poor country. Only the amount of energy of 3,992.5 PJoule, what represents 30 % of energy use, is produced by domestic resources. Therefore almost 70 % of energy sources are imports. 98 % of mineral oil and 87 % of natural gas are imported energy sources, but also 82 % of hard coal. Energy from brown coal and renewable is based on domestic resources. Nuclear power has been produced continuously over years from nuclear fuel rods and can be seen as a medium-term domestic resource (AGEb 2015).

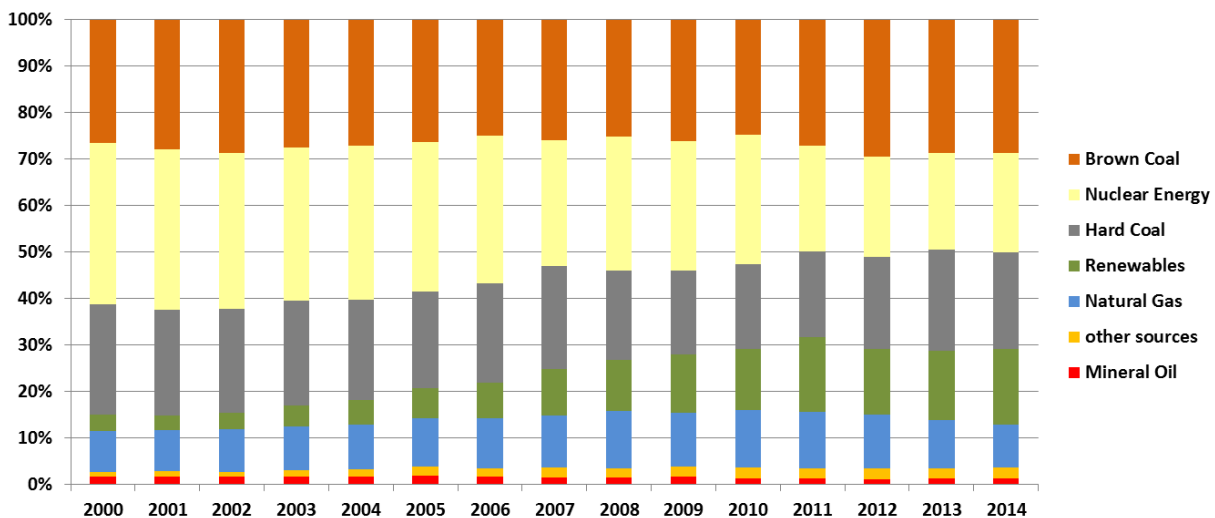
The use of energy is dominated by mineral oil, with a share of 34 %. Until today, oil based products cover almost the total requirements in the transport sector. Other important energy sources in Germany are hard and brown coal with shares of 13 % and 12 % as well as natural gas, with 20 %. Here brown and hard coal are predominantly used for electricity generation and gas is mostly used for heat generation. The share of nuclear power on primary energy consumption adds up to 8 % in 2012. Beyond that, renewable energy sources became increasingly important. Water and wind power in addition with the use of biomass produced together 11.2 % of the primary energy consumption in 2014 (AGEb 2015).

The main objective of this paper is to discuss and to analyze the phase-out of nuclear power and the increasing use of renewable energy source accompanied with the phase-out of hard coal production and reduction of brown coal use. With this focus the next section will be on electricity generation and use in Germany.

3.1 Electricity generation in Germany

In 2014 627.8 bn kWh of electricity have been produced in Germany. Figure 2 presents the development of shares of energy resources for gross electricity generation in Germany between the years 2000 and 2014.

Figure 2: Shares of electricity generation by energy source between 2000 and 2014



Source: AGEb 2015

Before the implementation of the German energy policy, electricity generation based on nuclear energy, brown and hard coal have been the fundament of electricity supply, with shares of 35 %, 27 % and 24 %. Brown and hard coal are still in 2014 the most important sources for electricity production with shares of 29 % and 21 %, respectively. Especially on the background of the Fukushima accident and the immediate closure of the eight oldest plants in 2011, coal had an important function to support the German electricity supply system. Although the use of renewable resources increases, there are still problems with the fluctuating production of wind and solar based electricity. This can be seen as one challenge in the implementation of the political objective to reduce CO₂ emissions. Coal is a resource with high CO₂ emissions, but it is a domestic resource and stabilises the supply system.

Since the political decision to phase-out from hard coal production, the extractions have been reduced slightly. Nevertheless the share of hard coal on gross electricity production is relatively stable.

Brown coal does not depend on subsidies and is available in sufficient quantities. Germany is the biggest extractor of brown coal worldwide. In 2012 two new power plants with a capacity of 2,875 MW have put into operation (AGEB 2014). Electricity generation based on brown coal increased by 2 %.

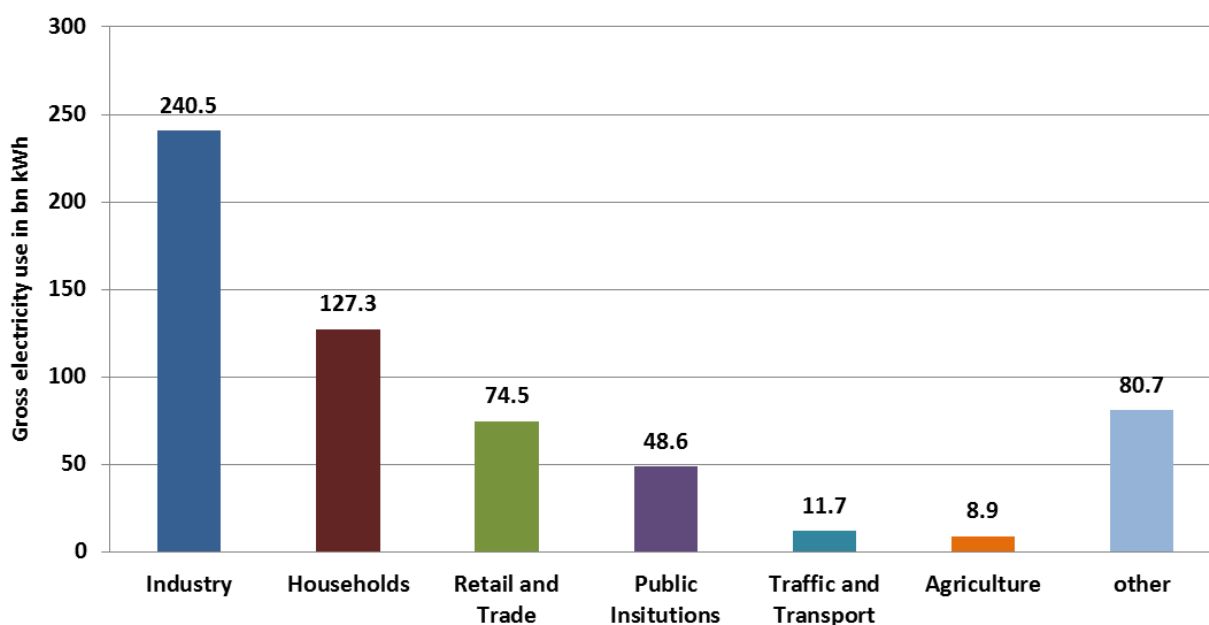
As already mentioned, the nuclear power is used less since the shutdown of the eight oldest plants. In 2014 21 % of electricity generation was based on this resource.

In the other hand the use of renewable energy sources experienced a significant upturn, because of political support programs. In the year 2000 only 3 % of electricity generation was based on renewables. In the year 2014 the share is around 16 %. The most important developments could be observed in the use of wind power, solar energy and biogas.

3.2 Electricity use in Germany

The gross electricity consumption in 2014 comprehended 592.2 bn kWh. The biggest user of electricity is the industry, which includes the mining and manufacturing sectors (see Figure 3) with 240.5 bn kWh, which correspond to 40.6 %. 21.5 % of electricity is used by households. Retail trade, public institutions, transport and the agricultural sector belong to the biggest users of electricity.

Figure 3: Electricity use in Germany in the year 2014



Source: BMWi 2016

3.2.1 Energy use in German households

The development of the amount of energy used in households in Germany is influenced by two factors: a) the trend for more households with fewer members, but more living space and b) the increase of efficiency of energy use. The biggest part of energy used by households is used for heating, with nearly 70 %. Energy for hot water claims around 15 %, cooking 6%, refrigerating and technology for communication both 4 %, energy for light 2 % and other electronic features 1 %. Altogether the energy use had an amount of 2.4 Petajoule in 1990. The use of energy increased up to 2.6 Petajoule in the year 2000. As one effect of the energy change policy, but also because of technological progress, the energy use by households today has an amount of 2.2 Petajoule.

The structure of energy use by resource of German households was influenced over time especially by two determining factors: the reunification of Germany and the current energy change policy.

Table 2 represents the energy use partitioned as shares of energy sources of households directly after reunification in the year 1990, the year 2000, which can be seen as the beginning of the energy change policy of the government and in the year 2014.

One outstanding result of the German reunification was the reduction of coal use, especially brown coal, by almost 14 % between 1990 and 2000. In the former GDR brown coal was one of the main resources for heating. The substitute for brown coal was natural gas. Therefore the use of natural gas increased by nearly 10 % in the same time. Today, natural gas is the main energy source in German households.

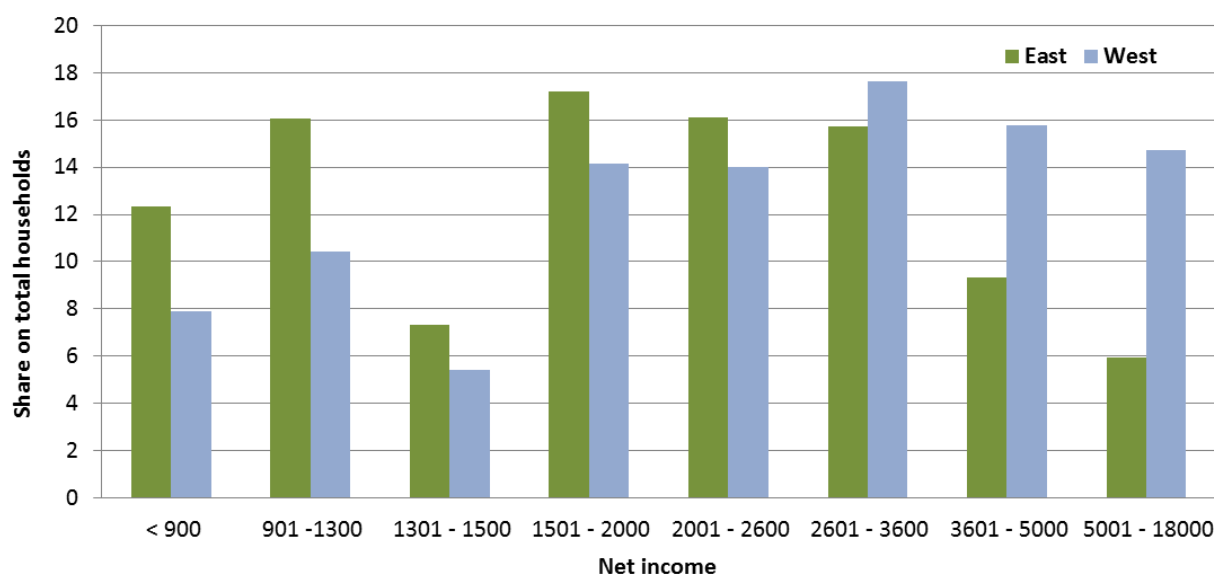
The effect of the energy change policy with the objective of the replacement of fossil by renewable fuels, which was implemented with the Renewable Energy Act in the year 2000, an increase of renewable energy use in households, can be observed. Since the year 2000 the use of renewables nearly doubled up to 12 % and the use of mineral oil decreased by 8 %. Renewable energy source used in households are wood, solar heat, geothermal energy and heat pumps (UBA 2015, <https://www.umweltbundesamt.de/daten/private-haushalte-konsum/energieverbrauch-der-privaten-haushalte>).

Table 2: Energy use by resource of German households

	1990	2000	2014	1990/2014
	%			
Hard coal	1.6	1.1	0.3	-1.3
Brown coal	14.7	0.8	0.7	-14.1
Mineral oil	31.1	31.6	23.5	-7.6
Natural gas	26.6	36.7	35.5	9.0
Electricity	17.7	18.2	21.1	3.4
District heat	6.7	5.1	6.8	0.1
Renewable energy	1.6	6.6	12.1	10.5

Source: AGEb 2015

The share of expenditure for energy on the total expenditures of households increased over time from 6.3 % in the year 2000 up to 7.3 % in 2014 (AGEb 2016). There exists no official statistic about the expenditure share for energy related to different income groups. But due to the increasing energy prices and the costs of the energy change policy, especially households with less income pay a higher share for energy costs compared to high income households. Figure 4 shows the shares of households in different income groups with a differentiation between Eastern and Western Germany. Also 25 years after the reunification it is observable, that there are considerable differences in net income between East and West. More than 50 % of Eastern households have a net income less than 2,000 €. In the West this share is 38 %. In the higher income classes the share on western households is higher (Destatis 2008).

Figure 4: Shares of Households in net income groups in East and West Germany (2008)

Source: Destatis 2008

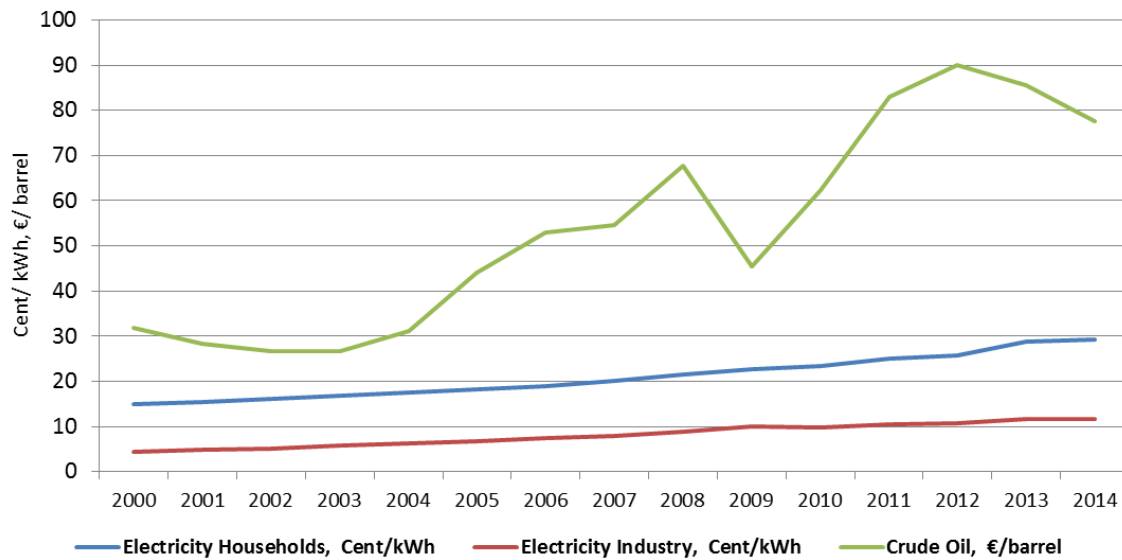
It can also be observed, that energy prices in the eastern part of Germany are higher than in the west (DESTATIS 2016). The reason for the difference is a higher grid fees in the east. Over the last years higher investments in the development of the grid have been necessary in east Germany. The amount of grid fees but also the faster development of renewable energy with the

Alltogether with regard to energy households in the East have to carry a double burden: the level of income is lower and the prices for energy higher than in the West.

3.3 Energy prices

Figure 5 shows the development of electricity prices of households and the industry, as well as the price of crude oil between the years 2000 and 2014. Prices for energy are influenced by developments on the world markets as well as national energy policy and appropriate taxation.

Generally the development of the oil price is affected by the supply and demand. Oil supply is predominantly determined by the member states of the Organization of the Petroleum Exporting Countries (OPEC) and big oil exports as the USA, Russia and UK. Oil demand is influenced by the amount of energy used for electricity, heat and fuels. Worldwide the amount of oil demanded depends heavily on the economic development in emerging economies, the political situation in important oil production countries and the fact that oil is a non-renewable resource. The global economic growth, but especially the growth in China resulted in increasing oil prices until the financial crisis in 2008. But also after this crisis the price for oil remained on a high level because of the forecasted shortage of crude oil in the future, what caused investments in new technologies. Due to the new technology “fracking” the USA increased the domestic oil production and the global oil supply increased; with the consequence of decreasing prices. Usually OPEC member states reduce oil production in times of decreasing prices. Actually they keep their amount of oil production because of strategic reasons of the competition with the new and more costly technology of fracking. The price of crude oil decreases since 2012.

Figure 5: Development of Electricity and Oil prices in Germany

Source: BMWi (2016)

The prices for electricity increased over time for all consumers. The prices for households almost doubled between 2000 and 2014. But also the industry had to pay more. The price increased by 76 % in the same time. Reasons for the rising prices can be seen in the higher resource demand by financial investors and the crisis in Middle East. The difference between private households and the industry is caused by the diverse taxation of the electricity tax and the EEG surcharge. The industry also profits from lower wholesale prices and the possibility to purchase electricity at the electricity exchange (Destatis 2014).

4 Database

The database used in this paper, is compiled as a Social Accounting Matrix (SAM). A SAM represents social and economic data for an economy in the form of a square matrix, for usually one year. It represents the income generation by activities during production and the distribution and redistribution of income between all social and institutional protagonists of an economy. In a SAM receipts are captured in the row accounts and expenditures in the column accounts, which have to be equal in their sum. Further information on the basic structure and characteristics of a SAM can be found in Pyatt (1991) and Round (2003).

Due to the lack of an actual existing SAM for Germany a new SAM has been compiled. The SAM is based on Supply- and Use Tables and other data sources from the German Statistical Office for the year 2007. The base SAM involves 71 commodities and 59 activities, 2 capital accounts, 1 labour account, 1 private

household and 1 government account, 2 accounts for enterprises, 3 tax accounts, 1 investment and 1 stock changes account, 1 account for the rest of the world. Because of the high aggregation level of the base SAM, a SAM was developed, which reflects the complex structure of energy supply and use. Therefore different commodities and activities have to be disaggregated. The development of the energy SAM for Germany is described in the following chapter.

4.1 The German Energy SAM 2007

The approach taken for the analysis of this paper is guided by the principle that the model and the database, i.e. the SAM, must be configured in such a way that both reflect the policy environment which is supposed to be analysed. As such the alternative of adapting the SAM to the CGE model is rejected and instead the choice is made to adapt the model to the 'reality' that should be reflected in the structure and reported transactions in the SAM. In order to follow the logic of this principle it is first necessary to determine the range of agents/accounts and policy instruments that need to be included within the SAM. However even a cursory review of the available databases indicates that the published degree of detail with respect to the energy sector and policy has limitations.

This requires additional disaggregation of inputs - intermediate use and final demand, outputs – joint- and by-production within the energy sector and its use for further processing. Additionally energy policy instruments, as well as the final use of energy in households had to be implemented and disaggregated. To capture the environmental impacts of the energy policy, also carbon emissions by energy source have been added in the database.

The main challenge is the further disaggregation of the whole energy sector in the base SAM for Germany. Moreover, the energy policy environment in Germany is such that policy instruments impact upon decision making with respect to different commodities and different types of activities.

In order to reflect the influence of different policy instruments on the decisions made by different protagonists of the energy sector the SAM for this study is based on the Supply and Use tables i.e., the commodity and activity accounts are potentially different. This distinction allows for the inclusion of policy instruments that impact on commodities, e.g., electricity taxes, carbon tax etc., and those that impact upon different activities, e.g., hard coal subsidies. In the published SUT energy resources are recorded in different commodities and activities. Often different energy sources are aggregated into a single account. Thus energy is less disaggregated than required for the analysis here. The disaggregation draws heavily on the data collated by the Federal Statistical Office and the Federal and the

Arbeitsgemeinschaft Energiebilanzen (AGEB). Next to the energy sector, the households had to be splitted into a useful disaggregation level, which shows regional and income differences. To capture also the social effects of the energy change policy, the disaggregation of households was necessary. Although the reunification was 25 years ago, there is still a distinctive difference in the incomes of households in the East and the West of Germany.

Therefore the compilation of an extended SAM faces a number of methodological and data-handling challenges. Table 3 shows the disaggregation of the original data from the SUT to the SAM database used in STAGE.

DRAFT

Table 3: SAM Disaggregation for modeling energy change policy in STAGE

Energy				Households	
<u>Commodities</u>		<u>Activities</u>			
cargas	Crops for biogas	adark	Mining dark coal	hinc9_w	Net income < 900_West
cfuel	Crops for biofuel	abrown	Mining brown coal	hinc13_w	Net income 901 - 1300_West
cdark	Dark coal	acokeman	Manufacture of coke	hinc15_w	Net income 1301 - 1500_West
cbrown	Brown coal	apetro	Manufacture of petroleum	hinc20_w	Net income 1501 - 2000_West
ccrudeoil	Crude oil	adiesel	Manufacture of diesel	hinc26_w	Net income 2001 - 2600_West
cnatgas	Natural gas	abiodie	Production of biodiesel	hinc36_w	Net income 2601 - 3600_West
ccok	Coke	abioeth	Production of bioethanol	hinc50_w	Net income 3601 - 5000_West
cpetro	Petrol	anucl	Manufacture nuclear fuels	hinc180_w	Net income 5001 - 18000_West
cdiesel	Mineral diesel	agas	Gas supply	hinc9_e	Net income < 900_East
cbiodiesel	Biodiesel	awater	Steam and hot water supply	hinc13_e	Net income 901 - 1300_East
cbioethanol	Bioethanol	aelblack	Electricity supply from dark coal	hinc15_e	Net income 1301 - 1500_East
cnucl	Nuclear products	aelbrown	Electricity supply from brown coal	hinc20_e	Net income 1501 - 2000_East
celectricity	Electricity	aeloil	Electricity supply from oil	hinc26_e	Net income 2001 - 2600_East
cdist	Distric heat	aelgas	Electricity supply from gas	hinc36_e	Net income 2601 - 3600_East
		aelnucl	Electricity supply from nuclear fuels	hinc50_e	Net income 3601 - 5000_East
		aeloth	Electricity supply from other sources	hinc180_e	Net income 5001 - 18000_East
		aelwind	Electricity supply from wind		
		ael solar	Electricity supply from solar		
		aelbio	Electricity supply from biomass		
Taxes				Factors	
gvat	VAT			fcapfix	Energy capital
gtaxen	Energy tax			fcapvar	Variable capital
gtaxelec	Electricity tax			flabunskilled	Skilled labour
gcotax	Carbon tax			flabmidskilled	Mid skilled labour
gtaxcts	other taxes on products			flabskilled	Unskilled labour
gsubscs	Subsidies on products			fland	Land
gtaxtion	taxes on production				
gsubstion	subsidies on production				

Source: Own data base

5 The Model – STAGE

5.1 The basic STAGE model

The STAGE model suite falls into the class of models that follow the approach described by (Dervis, de Melo, & Robinson, 1982) and the models developed by (Robinson, Kilkenny, & Hanson, 1990) and (Kilkenny, 1991). At the core of the suite is the basic STAGE model, but the basic STAGE model is not often used in practical work rather it is customised to the setting/economic environment being explored. The guiding principle is that the basic STAGE model provides a template that can support multiple variants; indeed the expectation is that for most studies it will be necessary/desirable to make changes and/or additions to the basic STAGE model.

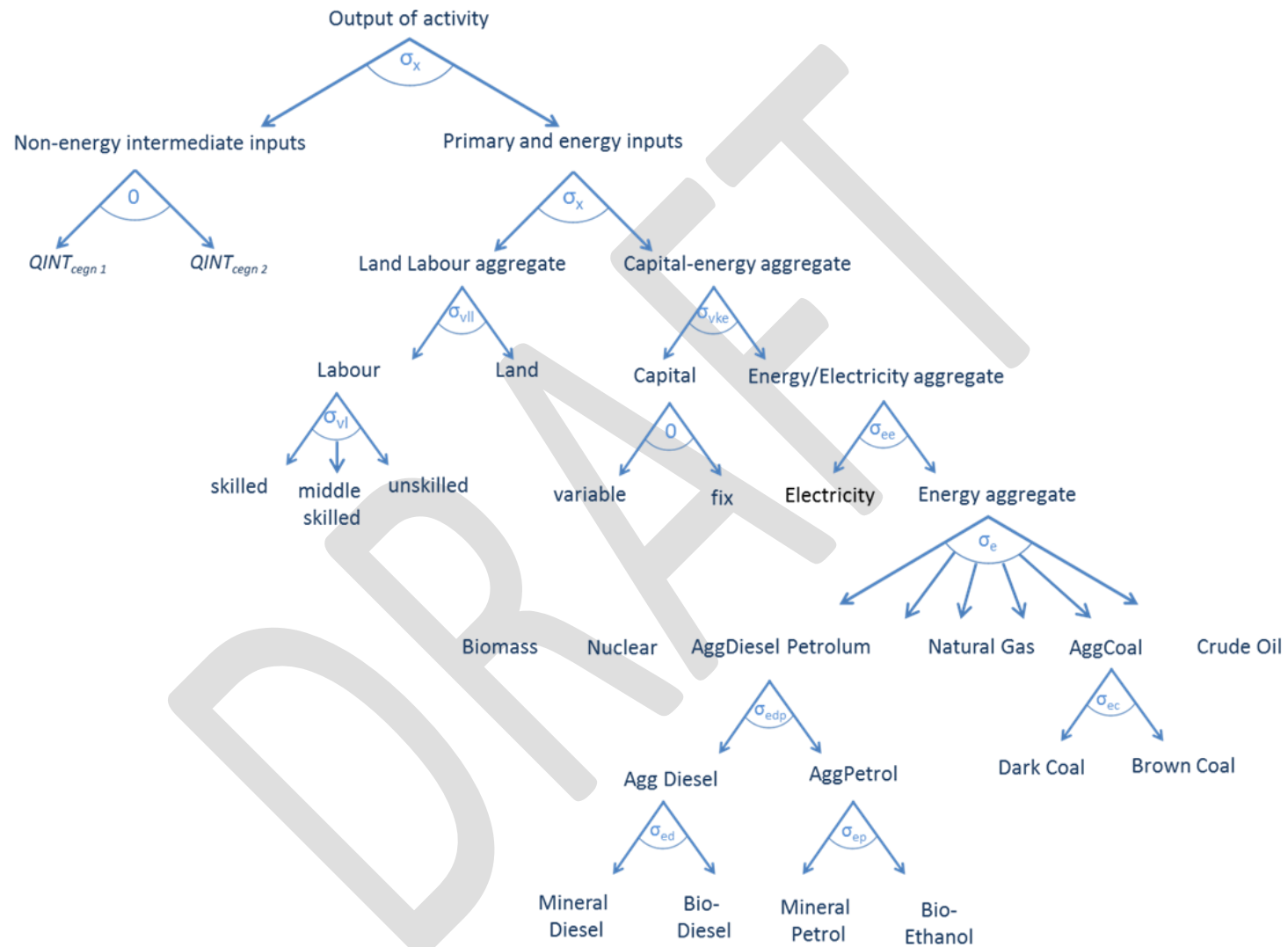
The basic STAGE model is characterised by several distinctive features. First, the model allows for a generalised treatment of trade relationships by incorporating provisions for non-traded exports and imports. Second, the model allows the relaxation of the small country assumption for exported commodities that do not face perfectly elastic demand on the world market. Third, the model allows for (simple) modelling of multiple product activities through an assumption of fixed proportions of commodity outputs by activities with commodities differentiated by the activities that produce them. Hence the numbers of commodity and activity accounts are not necessarily the same; this captures the empirical fact that real activities/industries typically produce multiple commodities/products and while for many manufacturing and services activities secondary products are relatively unimportant this is far from the case for agriculture.¹ Fourth, (value added) production technologies are specified as nested Constant Elasticity of Substitution (CES). And fifth, household consumption expenditure is modeled using Stone-Geary utility functions; these yield linear expenditure systems that allow for minimum levels of consumption of commodities, which is valuable when modelling consumption choices by households with very low incomes.

The model is designed for calibration using a reduced form of a Social Accounting Matrix (SAM) that broadly conforms to the UN System of National Accounts (SNA). This approach has been influenced by (Pyatt, 1987).

5.2 Model adoptions for energy modelling

¹ An additional advantage is that the requisite databases can be compiled from the directly observed transactions data in Supply and Use tables rather than the transformed data in Input-Output tables. Thus output composition choices are modelled explicitly rather than being subsumed into data transformation processes.

Figure 6: Modified nesting structure for modelling effect of energy policy



Source: Own illustration.

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