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20% by 2020? Economy-wide impacts of energy efficiency improvement in Germany

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1 INTRODUCTION AND BACKGROUND

Energy efficiency has been an issue on the political agenda for the last years and also the latest World Energy Outlook (WEO 2010) stresses the necessity of increased policy support for energy efficiency. The public debate on mitigating climate change and its impact on the global economy, the scarcity of resources and the growing dependence of some countries on imported fossil fuels and on the goodwill of the resource owners have spurred the interest in decoupling of economic growth and energy consumption. Fluctuations in energy prices from the all-time high of more than $140 per barrel in 2008 down to the low prices in 2009 and the rises in 2010 have certainly contributed.

Europe has committed itself to a 20% reduction of total primary energy supply (TPES) by 2020 compared to a business-as-usual development (COM(2006)545, COM(2005)265, COM(2008) 772). This efficiency target is part of a comprehensive energy concept (COM(2008) 30). In January 2008 the commission passed a note to the EU parliament with the title „20, 20 and 20 by 2020", which includes the commitment for a reduction of GHG to 20% below the 1990 level and a 20% share of renewable energy in total energy consumption by 2020. These targets are intertwined, since the share of renewable energy depends on the denominator and the reduction of GHG is strongly dependent on energy consumption. Therefore, energy efficiency is a key to reach these goals as has been pointed out by the Communication by the Commission to the European Parliament "Energy 2020" (COM 2010). While the political agenda seems set, the effectiveness of policy incentives for efficiency measures is still well disputed.

Energy efficiency plays a very important role in the development and potential reduction of final energy use. Taylor et al. (2010) show the historic development in IEA countries. For the future, the IEA (Jollands et al. 2010) recommends energy efficiency policies in 25 fields as part of the G8 Gleneagles Plan of Action, which could make a very significant contribution to energy savings and global carbon emission reductions. The authors highlight key barriers that prevent the implementation of economic, i.e. cost-effective measures and necessary conditions to fully exploit them. The barriers to exploit these potentials have been traced back to lack of information, lack of financing instruments, transactions costs, low priority of energy issues, incomplete markets for energy efficiency and others. National studies show positive economy-wide effects of energy efficiency measures (see e.g. Wei et al. 2010 for the US and Kuckshinrichs et al. 2010 for Germany).

In the literature, several attempts have been made to estimate the potential for energy saving. The IPCC (Intergovernmental Panel on Climate Change, 2001) found that cost-effective energy efficiency, i.e. efficiency measures with pay-back periods smaller or equal to the lifetime of the equipment could half the GHG emissions by 2020. A wide range of technologies and options has been identified: for instance the general use of fluorescent lamps could save approximately 2 880PJ and 470 MtCO_2 emissions in 2010. For heating and cooling of buildings, the potential cost-effective savings are estimated at 20EJ per year by 2030.

However, the economy-wide perspective of energy efficiency measures is still an open question (Guerra and Sancho 2010). Could the so-called rebound effect work partly or fully against the energy savings? As early as 1865 Jevons claimed for the iron industry that increased coal efficiency will lead to increased production and thus to an increased use of coal. His basic idea led to an ongoing debate about rebound effect. The work of Khazzoom (1980) and Brookes (1990) led to the postulate that “with fixed real energy prices, energy efficiency gains will increase energy consumption above what it would be without the gains” (Saunders 1992). Birol and Keppler (2000) trace the difference between political targets such as the above mentioned European target and economic results back to the “engineering view” and the economists’ view of the world.

More recent literature reviews (Greening et al. 2000, UKERC 2007) distinguish the direct rebound effect from the increased demand for specific energy services resulting from efficiency improvements of this very service, e.g. increases in transport as a result from increasing fuel efficiency; the indirect rebound effect from increasing budgets and increasing economic activity due to energy savings and the economy wide rebound effect, which reflects the compound impacts of energy efficiency policies on the economy. The direct rebound effect at the level of consumers or single industries has been analyzed in great detail from empirical data (cf. UKERC chap. 3 for an overview). The literature finds some empirical evidence for a very large rebound effect which counterbalances the original energy saving (backfire) especially for the direct rebound effect for single consumer goods (such as cars, refrigerators etc.) (Saunders 1992). However, even though increasing fuel efficiency for instance with vehicles has found to be paralleled by increasing demand for transport, the causality direction remains open. Small and van Dender (2005) conclude that though more fuel efficient cars might trigger more driving also the reverse can be true: the demand for more fuel efficient cars could stem from changed lifestyles that include more driving. Estimates for industry proved difficult. DeCanio (1997) showed that the possibility of a rebound effect strongly hinges on the existence of the so called efficiency gap, i.e. a gap between the efficient production of a good or service in energy terms and the real production conditions. Laitner (2000) provides historical evidence for the existence of an energy efficiency gap from US data since 1973.

Indirect rebound effects either stem from the energy required to produce energy saving technologies or go back to a shift in demands due to increasing budgets or price changes of energy intensive goods and as a consequence price changes of other goods, too.

The analysis of the economy wide rebound effect tries to capture all direct and indirect effects and estimate the net economic effects. Few studies have been devoted to this analysis as of yet. Koomey et al. (1998) analyze a technology led investment strategy for the US and find positive overall effects, Schipper and Grubb (2000) analyse the feedback between energy intensities and energy use for IEA countries. Computable general equilibrium (CGE) modeling experiments have been undertaken for several countries such as Sweden, China, Kenya, Sudan, Scotland, UK and Japan. Rather recent findings for Scotland are presented by Hanley et al. (2009), who apply a CGE model and find high rebound effects growing into backfire. Guerra and Sancho (2010) propose an unbiased measure for the economy-wide rebound effect combining input-output analysis and CGE modeling. Barker et al. (2007) present results for UK. They use a times-series econometric model and find moderate rebound effects. Our findings show similar effects for the German case study using a very similar modeling approach.

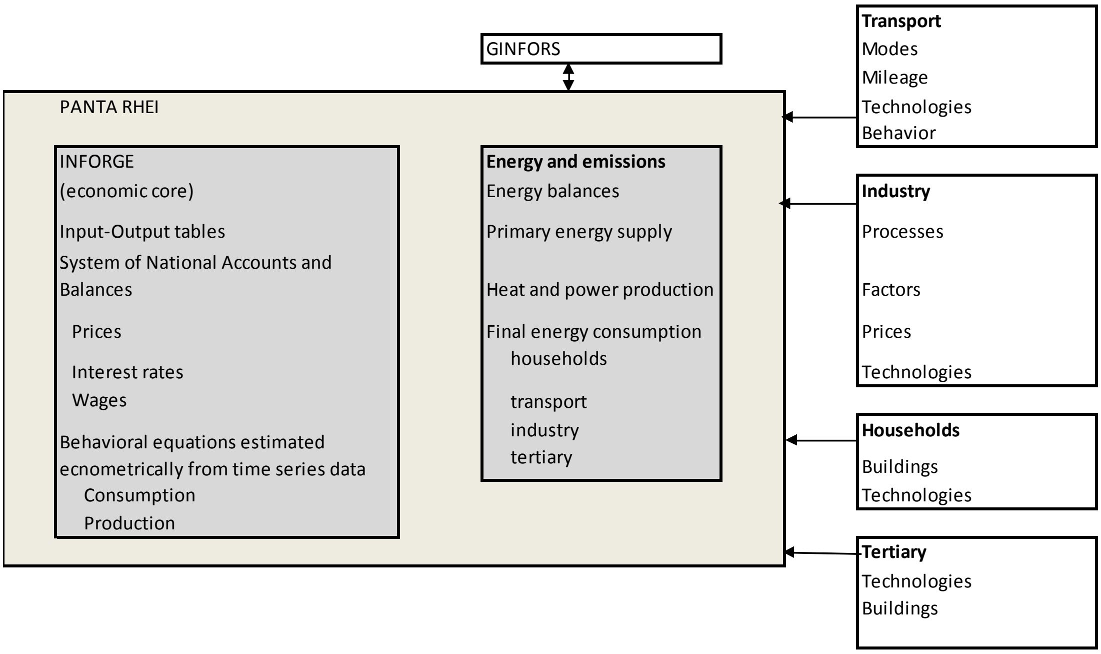
Overall economic effects of energy efficiency policies are important in the evaluation of policies to reach e.g. the European targets. Hanley et al. (2009) interpret their results not as a point against efficiency measures, but postulate a combination of taxes and efficiency measures. Our research shows that the rebound effects are small for the German case.

This contribution is organized as following. The introduction is followed by a description of our modeling approach and section 3 discusses the framework of our case study. Section 4 gives results and views them in the light of the literature, section 5 concludes.

2 THE MODELING FRAMEWORK

The main challenge of the modeling approach is to consider the overall economy wide effects of improved energy efficiency together with a detailed analysis of the technical change that drives the energy efficiency improvements. Traditionally, models are specialized on one of these aspects. Either they consider economy wide effects and relations (top-down models) or they are explicit about the technologies and their dynamics (bottom-up models). As a result of the shortcomings of both approaches, hybrid models that combine both aspects are increasingly used in recent years. These can be bottom-up models that are extended to model economy wide dynamics (Jaccard 2005; Murphy et al. 2007) or top-down models that explicitly consider certain technologies (Laitner & Hanson 2006; Schumacher & Sands 2007). Also, a combination of top-down and bottom-up models has been suggested (Barker et al. (2007)).

Figure 1: Modeling approach



In our study, we follow this approach. To model the effects of increasing energy efficiency we use a bottom-up modeling approach within each sector (households, tertiary sector, transport and industry) and integrate the results more into the environmental economic model PANTA RHEI (Figure 1) to show the economy-wide impacts.

2.1 BOTTOM-UP ANALYSIS

The bottom-up analysis is conducted on a sectoral basis, because the sectors show a rather different technology structure and dynamics. Here, we will only discuss the industry sector in detail, but use similar instruments for the other sectors, too. The bottom-up analysis aims at calculating the additional energy savings in the "energy efficiency scenario" in comparison to the business-as-usual (BAU) scenario - as well as the related additional investment. These two variables are then used as exogenous input in the environmental economic model PANTA RHEI.

The industrial sector was modeled using the bottom-up model ISIndustry. It explicitly considers about 50 of the most energy intensive processes (like oxygen steel, paper making, aluminum production or clinker burning), which together account for more than half of the industrial fuels consumption and more than 30% of the electricity consumption. In order to also consider the remaining energy consumption - in less energy intensive sectors – the models also considers so called cross-cutting technologies like motor or lighting systems, which are found across all industrial branches. For both, the cross-cutting technologies and the process technologies, saving options[1] are modeled. These are described by a saving potential, investment and running costs as well as a lifetime. By diffusing through the technology stock, they reduce the energy consumption of the related processes.

In order to calculate the additional saving potential beyond the BAU scenario, we implemented two exogenous technology diffusion paths for each saving option: one path that represents rather a continuation of the past trends and a second more optimistic path regarding efficiency increases. However, also the optimistic path is constrained to cost-effective technologies and excludes pre-mature technology replacement.

Consequently, the difference between both diffusion paths represents the no-regret potential that is not exploited in the reference scenario due to the presence of various barriers.

Thus, the model does not optimize the firms' investment behavior and instead works with exogenous assumptions on the presence of barriers to technology diffusion[2]. The empirical basis for the technology data is taken from different technology specific engineering studies that were conducted in the last years (examples are Almeida et al. 2008; European Commission 2001; IEA 2006; Radgen 2002; Radgen, Blaustein 2001; Schmid et al. 2003; Vogt et al. 2008).

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[1] Examples are efficient motors, new paper drying techniques or heat exchangers in various processes

[2] We use exogenous input here, because firms' investment decision parameters are manifold as well as the different barriers which makes it very difficult to endogenously model the diffusion of more than 200 technologies

2.2 MACRO-ECONOMIC FRAMEWORK: PANTA RHEI

PANTA RHEI is an environmentally extended version (cf. Lehr et al. 2008, Meyer et al. 2007a, Lutz et al. 2007; 2005) of the macro-econometric simulation and forecasting model INFORGE of the German economy. It is based on official statistics. INFORGE consistently describes the annual inter-industry flows between the 59 sectors, their contributions to personal consumption, government, equipment investment, construction, inventory investment, exports as well as prices, wages, output, imports, employment, labor compensation, profits, taxes, etc. for each sector as well as for the macro economy (Meyer et al. 2007b, Ahlert et al. 2009).

The economic part of the model also contains a complete system of national accounts to calculate the aggregated variables and the income redistribution between the government, households, firms and the rest of the world. For these institutional sectors, their disposable income and flow of funds can be estimated and the budget of the government, including fiscal policy and the social security system, is depicted endogenously. In this way the model provides a consistent framework for the analysis of market-based climate change policies, as indirect effects in other industries are captured and additional tax revenues are adequately accounted for.

In the behavioral equations decision routines are modeled that are not explicitly based on optimization behavior of agents, but are founded on bounded rationality. The parameters in all equations in PANTA RHEI are estimated econometrically from time series data (1990 – 2008). Producer prices are the result of mark-up calculations of firms. Output decisions do not stem from an optimization process but follow observable historic developments, including observed inefficiencies.

The energy module captures the relations between economic development, energy input and CO_2 emissions. It contains the full energy balance with primary energy input, transformation and final energy consumption for 20 energy consumption sectors and 30 different energy carriers (AGEB 2010). It is fully integrated into the economic part of the model.

Final demand is determined from the disposable income of private households, the interest rates and profits, the world trade variables and the relative prices for all components and product groups of final demand. For all intermediary inputs, imports and domestic origins are distinguished. Given final and intermediary demand, final production and imports are derived. Employment is determined from the production volume and the real wage rate in each sector, which in return depends on labor productivities and prices.

To examine the economic effects of additional efficiency measures in Germany our analysis applies PANTA RHEI to two scenarios: a business as usual scenario without additional efficiency measures and an efficiency scenario, which includes measures in the household sector, the tertiary sector, industry and transport[1]. The efficiency scenario can be characterized as “technology oriented”. Both scenarios are implemented in the macro-econometric model PANTA RHEI. The respective differences in economic indicators, such

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[1] We did not consider the energy sector, shifts in fuels, urban planning measures or shifts in the modal split.

as employment, GDP etc. can then be attributed to the increased efficiency efforts included in the efficiency scenario, since all other factors have been held equal. Changes in volumes and prices are fully accounted for.

3 EFFICIENCY IN GERMANY - A CASE STUDY

The case study analyses the impact of additional efficiency measures on the German economy. For this purpose, we identified a set of efficiency measures and their additional costs and compare this efficiency scenario with a business as usual scenario (BAU). The efficiency-scenario includes a set of 33 additional measures accounting for about 10% of final energy consumption in 2020; i.e. measures not included in the business as usual that are cost-effective. These measures consist of a combination of attainable energy reduction and the necessary investment in more efficiency (for a similar approach see Sorrell 2009 and Jollands et al. 2010).

The main climate change mitigation and sustainability targets in Germany are:

- Renewable energy share (RES): energy from renewable sources has to contribute 30% to total electricity generation by 2020. The European target of 18% RES in final energy demand also has to be reached by 2020.
- CO_2 emissions: the national goal is set at a 40% reduction by 2020 compared to 1990.
- Efficiency: In the German sustainable development strategy, a doubling of energy productivity, i.e. the ratio between GDP and primary energy, is set for 2020 compared to 1990. This translates into a 3% annual increase in productivity from today until 2020.

The first two targets, of course, also depend on future efficiency development.

3.1 THE BUSINESS AS USUAL (BAU) SCENARIO

Scenarios provide a structured description of possible future development paths, depending on current and future framework conditions. The BAU scenario is based on the literature (Prognos and EWI 2007)[1]. Table 1 gives a few key data of this projection.

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[1] The BAU scenario does not include the 2009 crunch. However, since the efficiency scenario is based on this BAU scenario and the economic effects are considered in terms of differences between two simulation runs, this should not alter the main effects.

Table 1: Key data of the reference scenario

	Unit	2005	2010	2020	2030
Oil price	USD/bbl	55	72	81	128
Population	1000	82,464	82,402	81,425	79,524
Households	1000	39,178	39,631	39,994	39,909
GDP	bill. Euro	2,123	2,312	2,700	3,099
Production	bill. Euro	3,864	4,191	4,957	5,886
Total Primary Energy Supply (TPES)	PJ	14,690	14,427	13,352	12,890
Final Energy Consumption (FEC)	PJ	9,141	9,300	9,020	8,954
Households	%	29	29	27	25
Tertiary sector	%	16	16	15	14
Industry	%	27	27	29	30
Transport	%	28	28	29	31
Electricity generation	TJ	2,234	2,341	2,345	2,399
TPES/cap	GJ/cap	178	175	164	162
GDP/TPES	Euro/GJ	145	160	202	240
Production/FEC	Euro/GJ	423	451	549	657
CO_2 emissions	MtCO2	833	824	741	692

Own calculations

The German population is expected to shrink by almost 3 million people by 2030. However, since the average household size also decreases, the number of households is expected to rise. Total primary energy supply (TPES) is projected to decrease from more than 14,000 PJ to less than 13,000 PJ, a decrease of more than 10% in 20 years. The scenario includes phasing out nuclear energy[1] and a clear shift towards renewable energy (RES) in the overall energy mix. Efficiency gains and increases in RES yield a decrease in CO_2 emissions by 17% between 2005 and 2030. The reference scenario does contain several efficiency measures and political instruments to support efficiency increases. Thermal insulation of buildings, for instance, has been supported with a program for soft loan conditions and allowances. Car taxes depend on vehicles size and emission category, eco-taxes signal scarcity of energy and labeling is mandatory for certain household appliances. However, energy efficiency does not get as much notice as other environmental issues such as renewable energy.

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[1] The September 2010 decision to postpone the phase out, could not be included in scenarios.

3.2 THE EFFICIENCY SCENARIO – RESULTS FROM BOTTOM-UP ANALYSIS

In the following we focus on economic efficiency potentials, i.e. no-regret measures, which are cost-effective over the lifespan of the equipment. This definition includes the necessary investment for fuel efficient technologies, new motors etc.

This efficiency scenario is constructed bottom up for households, the tertiary sector, industry and transport (on bottom-up modeling cf. section 2.1). Each sector will be described in turn in the following.

3.2.1 EFFICIENCY IN HOUSEHOLDS

Energy consumption of private households is dominated by energy for heat. 80% of total household energy consumption are attributed to this purpose, 10% go to electricity and hot water each. Therefore, the efficiency scenario for households includes all feasible measures of insulation of buildings' elements (walls, roofs, ceilings) concerning the building stock and newly built houses plus changes to a more efficient heating system. Fuel switch to renewable energy is not considered, the effects thereof can be found in (Lehr et al. 2008).

Concerning electricity consumption, the scenario includes the reduction of stand-by and/or operational energy consumption of consumer electronics – entertainment products and household products. Efficient lighting has been analyzed separately. Overall, the fields analyzed cover up to 80% of total household electricity consumption. All measures together lead to additional energy savings of 254 PJ (10.4% of TFEC), with electricity savings of 86 PJ and fuel savings of 168 PJ by 2020. These savings compare well to other studies in the literature, for instance 11% with a similar set of measures in Oikonomou et al. (2007) for UK, and up to 15% savings until 2020 in the US (Soratana and Marriott 2010). The suggestions for instruments in the literature reach from obligations to certificates.

We assume that the more efficient – and initially more expensive – appliances and insulation works are bought by consumers from their savings and that the energy saving pays back roughly during the lifetime of the device. This lowers the direct effects, because lighting or heating has not become cheaper by the measure and also the budget effects is lowered.

3.2.2 EFFICIENCY IN THE TERTIARY SECTOR

The largest share of energy consumption in the tertiary sector comprises of the supply of heat, with the problems and the potential similar to those discussed above. In contrast to the household sector, the tertiary sector not only needs energy to heat buildings, but also for certain processes such as washing, drying or food processing. The next largest application is powering pumps, fans and motors. 6% of total energy consumption goes into office electronics and air conditioning. Also, lighting consumes with 11% a rather large share.

Compared to the household sector, the coverage of the rather general measures suggested is smaller, since the tertiary sector has more specialized energy consuming processes and needs more detailed measures. However, the measures suggested in Table 2 still result in energy savings of 68 PJ or 5% of final energy consumption in the sector .

At least the public energy services such as traffic lights will not be increased from the installations of energy saving technologies. Also street lights should be provided roughly by the same amounts. Savings from other activities on the other hand could lead to increases in output and therefore will contribute to the overall rebound effect.

Table 2: ***Energy savings in the tertiary sector by 2020*** **[PJ]**

	Savings compared to BAU
Sum (% of final energy consumption in the sector)	**68 (5%)**
Buildings and efficient heat (stock and newly built)	10
Optimizing ventilation and air conditioning	10
Efficient cooling	3
Efficient lighting	33
Efficient office electronics	6
Streetlight	5
LED lighting	1

Own calculations.

3.2.3 EFFICIENCY IN INDUSTRY

With 2444 PJ industry contributes more than 30% to final energy consumption in Germany. The main potentials are found across all industries in the fields of process heat, mechanical uses and lighting. These potentials are cost efficient in most cases. Cost efficiency is defined as the positive returns from the investment over the lifetime of the appliance. In other words: the investment plus interest is covered by the gains from energy saving. Furthermore, we assume that there will be no pre-mature replacement of technologies. Thus, we only consider the differential costs between a standard appliance and an energy efficient appliance. It further follows that the technology stock turnover sets the limit for the diffusion of new energy efficient technologies.

Especially electricity consumption can be reduced by large amounts through the optimization of cross-cutting technologies like pumps, ventilation systems, compressed air systems and lighting. These fields contribute roughly 75% to total energy consumption. 60% of total fuel consumption also go into uses, which are identical across all industries. Process heat, i.e. steam systems, drying processes, ovens and the heating of buildings are the major heat applications.

Table 3 gives an overview. Total savings come up to 212 PJ in 2020 and account for about 8% of final energy demand in the BAU scenario in 2020. Additional potential lies in optimization of processes and the introduction of new technologies in energy intensive sectors such as steel and iron, paper production, concrete and glass production as well as chemicals production.

Table 3: **Energy efficiency potentials in industry by 2020 [PJ]**

	Savings compared to BAU
Sum (% of final energy consumption in the sector)	**212 (8.1%)**
Optimization of electric motors systems (pumps, ventilation, cooling, compressed air, etc.)	101
Efficient lighting	13
Efficient steam generation and distribution	24
Efficient drying	29
Efficient industrial ovens	40
Efficient caloric value boilers (natural gas)	5
Own calculations.	

Policies to exploit these saving potentials are partly already in place or foreseen. Examples are minimum standards (the EU Ecodesign Directive), energy efficiency audit programmes or the EU emissions trading scheme, which also sets incentives for technologies like industrial ovens or drying in very energy intensive firms. However, as the largest part of the saving potentials is hidden in system optimization, which also experiences a huge variety of different and complex barriers. Relevant policies to foster system optimization and overcome the barriers are the mentioned energy audit programme - which still runs on a relatively low level - or energy management systems in companies.

3.2.4 EFFICIENCY IN TRANSPORT

Energy for the transport of people or freight holds a 30% share of final energy consumption in Germany. More than 85% of energy consumption in the transport sector goes into road traffic. Therefore, most measures suggested in the following focus on road traffic.

There is a wide body of literature on efficiency increases in the transport sector. The suggestions reach from behavioral change, e.g. switch from cars to bicycles, or walk for short distances, and technological improvements, such as an increase mileage of cars, to infrastructural improvements (e.g. improvements of public transportation). For a rather recent overview of a wide set of measures cf. European Commission (2009).

The measures suggested here cover mileage improvement, modal shift and efficient driving. Total savings of 300 PJ are attainable by 2020. The largest part with 175 PJ is contributed by efficient cars and trucks. Efficient driving and efficient tires and oils contribute 100 PJ. The costs of the measures can be recovered during the life span of the measures through energy savings.

Obviously, the potential for energy saving in the transport sector exceeds the measures suggested here by far. However, the cost effectiveness of measures such as a severe shift in modal split, changes in infrastructure of cities etc. depend on the political instruments used for financing these measures. From the bottom-up approach the efficiency scenario for all sectors is constructed carefully to avoid double counts. It comprises of 33 single technological and sometimes behavioral (transport) changes with different impacts on energy efficiency.

3.2.5 SUMMARY OF BOTTOM-UP SECTOR ANALYSIS

Summing up, the efficiency scenario has the following properties:

1. Comprised of measures which predominantly are cost efficient.
2. Technology oriented.
3. Coming close to the national targets with respect to energy productivity (80% covered), emission reduction and reduction of electricity consumption. The latter target supports the RES target in electricity generation.

Additional investment of 136 billion Euro until 2020 is necessary to tap the outlined potentials. The largest part of this sum will be necessary for insulation and other improvements of buildings as well as other energy savings in the household (81 billion Euro or close to 60%). Transport takes the second largest share (30 billion Euro or 22%). Again, households contribute to this potential, but a large part of new vehicles is bought as company car or official car.

Table 4: ***Additional investment compared to BAU scenario***

	Investment until 2020 in billion Euro
Total	**136**
Private households	81
Tertiary sector	11
Industry	13
Transport	30

Own calculations.

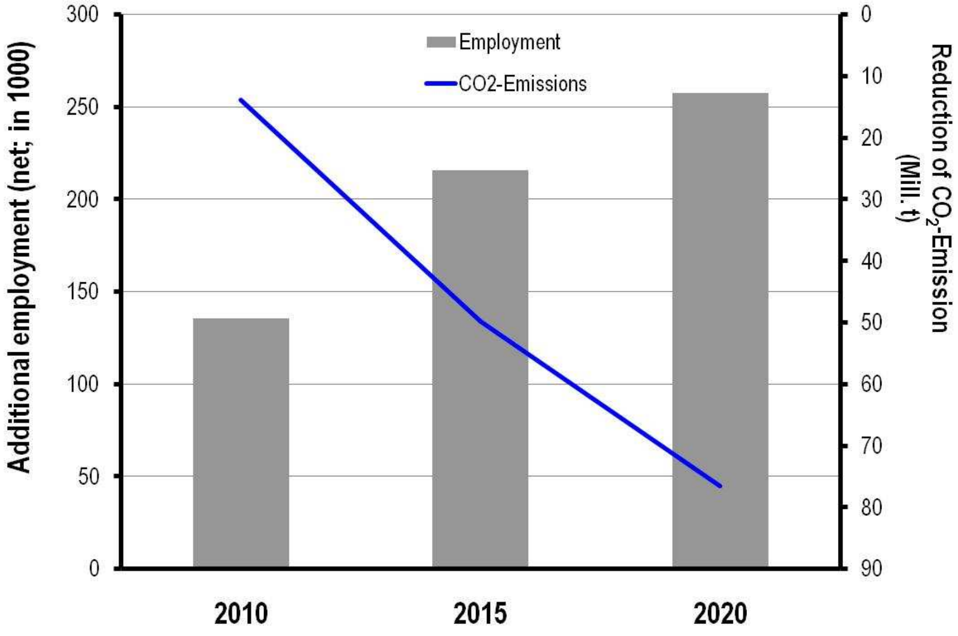
The overall economic effects of the efficiency scenario have to be compared to the respective quantities in the BAU scenario with the help of a macroeconomic model. Investments from companies and firms have impacts on the economy influence relative prices, available income, revenues, wages and savings on the expenditure for energy.

4 ECONOMY-WIDE IMPACTS OF ADDITIONAL EFFICIENCY MEASURES - RESULTS

To evaluate the impacts of political instruments or of certain measures, the results of the reference scenario are compared to the results of the efficiency scenario including additional efficiency measures. Effects on prices and quantities are taken into account. Here the additional measures consist of all cost-effective measures described in the previous chapter. The efficiency scenario is characterized by investment in improved efficiency and savings on the energy bill. The additional spending enters the model as investment on equipment, structural investment on buildings and consumption expenditure. Depreciation, annual allowances and savings reductions to finance the investment are fully included in the model. Due to the cost-efficiency of measures, additional expenditure and investment will not crowd out other investments or consumption. Energy savings and the decrease in energy costs are fully accounted for in the model.

The sum of the economy-wide net effects is positive. Gross production, GDP and its components consumption, investment and trade are higher in the efficiency scenario due to the efficiency measures over the whole simulation period (2009 – 2020). Obviously, higher production does not directly translate into higher value added, because it is partly imported and also increases imported inputs according to the German trade structure. A considerable share of the additional GDP stems from private consumption (18.3 bill. Euro). The direct effect comes from consumption of energy efficient goods, but there is a large indirect effect from additional consumption due to energy savings. The reallocation of funds from energy expenditure to consumption leads to more employment in all sectors. Employment also rises in the construction sector and in production, adding to the consumption effect.

Figure 2: ***Employment and CO_2 emissions, difference of efficiency and reference***

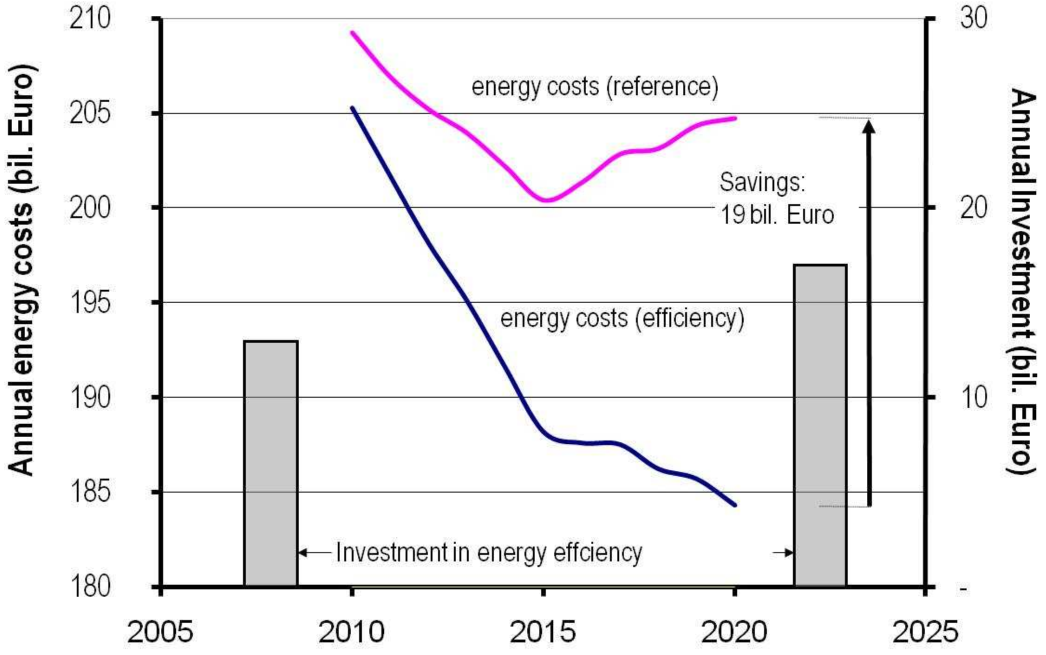


Own calculations.

Figure 2 shows the differences between the two simulation runs for two important quantities: CO_2 emissions and employment between 2010 and 2020. The efficiency scenario yields considerable CO_2 reductions and increases in employment. Additional employment reaches 257.000, plus governmental employees and self-employed the number climbs almost up to 290.000. At the same time, wages will increase due to the employment increase (+.27% in 2020). The positive employment effects are the results of different impacts:

- Additional investment yields additional production and therefore additional employment
- Energy is replaced by capital
- Imported value added (e.g. crude oil, gas) is replaced by domestic value added
- Construction and the tertiary sector are more labor intensive than the energy industry
- Energy efficiency improves economic productivity and thus competitiveness
- Short term higher demand for (efficient) investment goods and equipment improves private budgets and induces additional incomes.

Figure 3: Additional investment (annual) and energy costs for the reference and the efficiency scenario



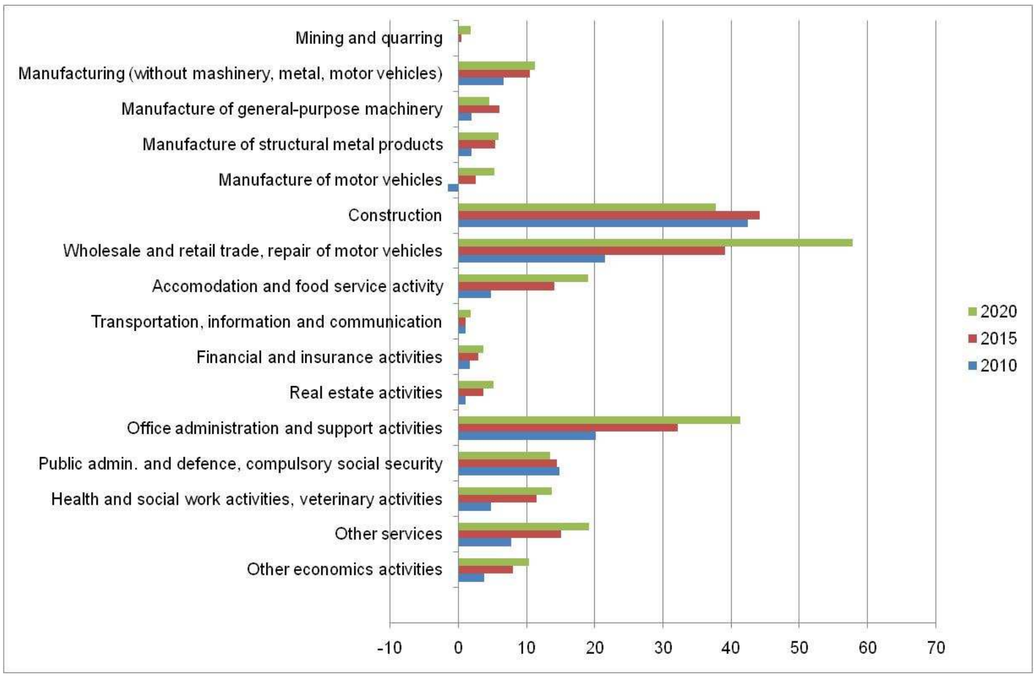
Own calculations.

The main impact comes from additional investment, especially in the construction sector, where labor intensity is rather high. Given the work necessary for insulation, additional employment will mainly be created in small and medium enterprises. The long term effects are driven by energy savings and reductions of the energy bill.

Figure **3** shows the long term development of the energy costs for the two scenarios and contrasts investments and savings. Total savings in 2020 will be 19 bill. Euro.

Sectoral effects reflect the structure of production in the efficiency scenario. Most sectors show increasing employment. Of course, the highest effects can be seen in construction, this reflects the already mentioned labor intensity and the large investment going into this sector. But employment increases also in other sectors. Efficient appliances and efficient cars involve major inputs from the tertiary sector. The structural distribution of the additional jobs reflects the economic activity of the sectors as well as labor intensity. This shows especially in the large increases in services and the rather small increases in industry. Though for instance the vehicle industry will have turnover gains from the sales of more efficient vehicles, the majority of these gains is seen in the car sales section, since more turnover there translates into more additional employment than in the highly automated vehicle production. The same holds for other production sectors. Additional employment in the retail sectors, in food services and also in real estate, however, result from the shift from energy spending to other consumption goods as a consequence of efficiency gains.

Figure 4: ***Sectoral employment in comparison to the BAU scenario (in 1000)***



Own calculations.

The rebound effect lowers the reduction by some 17% in 2020. Also, additional employment yields additional income which is not likely to be without additional consumption. Table 5 shows the important energy quantities and their development over time including the rebound effects per sector. The least rebound is found in industry: energy efficiency is increased by 8% of which 11% of the savings are counterbalanced by increases in production – also due to increasing investment in efficient products which are produced domestically.

Households and the tertiary sector exhibit a stronger reaction. The rebound effect is close to 13% of the original energy savings in these sectors. With households, this is rather the effect of additional incomes generated by overall economic growth. The energy consumption of the tertiary sector is more closely coupled to additional output as a result of the increased demand from additional consumption and investment.

Transport is the sector with the largest rebound effect of about 27%. Mainly this originates in the transport of goods which increases with overall output increase and has not been the main target of efficiency measures suggested in the efficiency scenario. Private transport exhibits a much smaller rebound effect. Table 5 sums up the overall energy savings compared to the BAU scenario.

Table 5: *Energy data - Absolute savings compared to the BAU scenario*

		2010	2015	2020	Rebound in 2020
FEC		**108**	**418**	**693**	**17 %**
Private households	[PJ]	25	115	219	13 %
Tertiary sector	[PJ]	8	32	59	13 %
Industry	[PJ]	19	123	197	11 %
Transport	[PJ]	57	148	219	27 %
TPES	**[PJ]**	**162**	**629**	**1.027**	
Electricity production	**[PJ]**	**39**	**151**	**245**	
CO_2-Emissions	**[Mio. t]**	**13.9**	**49.8**	**76.6**	
Oil	[TJ]	67	189	287	
Natural gas	[TJ]	26	165	321	
Import savings	[Bill. €]	0.8	3.2	6.2	

Own calculations.

5 SUMMARY, POLICY CONCLUSIONS AND FUTURE RESEARCH

The paper presents results of the implementation of an efficiency strategy in Germany until 2020 which is focused on cost-effective measures. The efficiency measures are calculated in bottom-up models and translated into a top-down macro-economic model. The comparison to a business as usual simulation shows some economy-wide rebound effects of about 17% of the overall energy savings. The analysis is limited to 2020. Given that an efficiency strategy is a long-term strategy, this puts the results on the rather conservative side.

Some macroeconomic quantities have been left out in the analysis thus far. From studies on the impact of an increase in renewable energy technologies we have learned (Lehr et al. 2008) that exports of these new technologies play a major macroeconomic role. Germany is a very export oriented nation and new markets would lead to high effects for instance in the machinery and electronics sector. These topics remain for future research. Finally, Porter's hypothesis can be quoted also in this framework (Porter and van der Linde 1995): If complemented by a strict and transparent regulatory framework, climate protection and efficiency measures will not only directly reduce environmental impacts and energy imports but will also have various direct and indirect impacts on new markets for energy efficient products and may lead to increasing export chances for the respective industry.

The results clearly show that improved energy efficiency results in a variety of positive effects on the economy and the environment. These range from reduced greenhouse gas emissions to improved competitiveness of firms and budget savings for consumers to economy wide impacts like additional employment and economic growth. Even the consideration of rebound effects did not change this picture significantly. Thus, exploiting the huge potential stemming from cost-effective efficiency measures should have high priority for the design of energy and climate policies.

However, although the overall energy efficiency potential is large, it stems from completely different technologies and technology users. Consequently, also the pattern of barriers to invest in energy efficient technologies is manifold and will need a broad mix of sector and technology specific policies.

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