Improved Energy Efficiency: Vital for Energy Transition and Stimulus for Economic Growth

by Jürgen Blazejczak, Dietmar Edler, and Wolf-Peter Schill

As part of the energy transition process, the German government has set far-reaching energy efficiency targets, including doubling the annual rate of building renovation to upgrade energy performance from one to two percent. DIW Berlin has estimated the additional energy-savings-related investment required to meet these targets and analyzed the impact this could have on the economy. In the long term, the savings on household energy bills far exceed the additional investment. This, combined with further measures to increase energy efficiency in other sectors, substantially reduces energy consumption and greenhouse gas emissions. Even allowing for some elements of uncertainty, these measures to improve energy efficiency have a positive impact on income and domestic demand. They could also result in significantly positive effects on employment, depending on the ratio of productivity gains and new jobs. Nevertheless, the most recent savings are not nearly enough to achieve the German government's energy efficiency targets. Clear and reliable framework conditions are needed soon to increase the number of buildings being renovated to upgrade energy performance. Given the present analyses, which indicate that forcing the pace of energy efficiency improvements has a positive impact on German economic growth and employment, the government's hesitation seems even less justified.

According to the European Energy Efficiency Directive,[1] energy efficiency is defined as the ratio of output of services and goods to input of energy. From a macroeconomic perspective, the aim of an increase in energy efficiency is to achieve a higher contribution to wealth per unit of energy used. Indicators of an increase in energy efficiency are a rise in energy productivity (economic output per unit of energy used) or a fall in energy intensity (energy use per unit of economic output), and can refer to both primary and final energy. The development path of energy efficiency has a directly impact on the correlation between economic growth and energy consumption. To decouple economic growth and energy consumption requires an increase in energy efficiency for the economy as a whole.

In Germany, energy productivity relative to GDP has increased at a somewhat faster rate since 1990 than GDP itself.[2] Primary energy productivity improved by an average of 1.7 percent per year between 1990 and 2013.[3] Consequently, despite increasing economic output (1.4 percent per year on average) a slight reduction in primary energy consumption (–0.3 percent per year) was possible (see Figure 1). However, the improvement in efficiency has slowed in recent years: primary energy productivity grew by an annual average of 2.2 percent between 1990 and 2000, but only by 1.3 percent between 2000 and 2013.

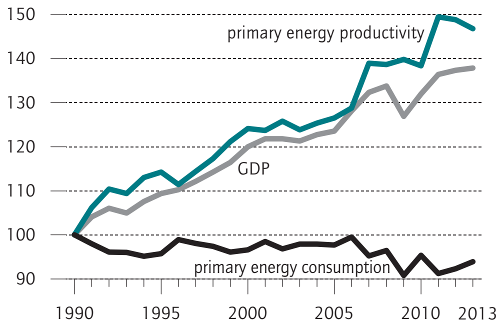
1 Directive 2012/27/EU of the European Parliament and of the Council of October 25, 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

2 Non-temperature-adjusted calculations by DIW Berlin based on data from the Working Group on Energy Balances (AGEB) and the German Federal Statistical Office.

3 No data on final energy consumption for 2013 are available yet. Between 1990 and 2012 final energy productivity improved by an average of 1.7 percent per year and primary energy productivity by an average of 1.8 percent per year. The slightly higher increase in primary energy efficiency can be attributed, inter alia, to the expansion of renewable energy sources, which has reduced primary energy consumption relative to final energy consumption.

Figure 1

Primary Energy Consumption, Primary Energy Productivity,[1] and GDP[2]
Index 1990 = 100[3]



1 Primary energy productivity (= GDP per unit of primary energy consumption) and primary energy consumption are not temperature adjusted.
2 In 2005 prices. 1990 estimated.
3 Provisional values for 2012 and 2013.
Sources: Arbeitsgemeinschaft Energiebilanzen; Federal Statistical Office; calculations by DIW Berlin.

Energy productivity increased slightly more sharply than GDP.

German Government's Efficiency Targets Are Far Reaching

In its 2010 Energy Concept, the German government formulated detailed and far-reaching targets to enhance energy efficiency.[4] For instance, with economic output continuing to increase, the aim is to reduce primary energy consumption by 20 percent by 2020 compared to 2008 and by 50 percent by 2050 and to increase final energy productivity by 2.1 percent per year.[5] The latter corresponds to a 0.4-percent rise in comparison to the average for the years 1990 to 2012.

A separate savings target of ten percent by 2020 and 25 percent by 2050 compared to 2008 was set for power consumption. In the transport sector, around ten percent of final energy consumption is to be saved by 2020 and around 40 percent by 2050 in comparison to the base year 2005. In the building sector, the objective is to achieve a virtually climate-neutral building stock by 2050. A further target is to double the rate of building renovation to upgrade energy performance from approximately one percent[6] to two percent per annum thus reducing the heat requirements of buildings by 20 percent by 2020 in comparison to 2008 and primary energy demand by as much as 80 percent by 2050.

Increasing energy efficiency—together with greater use of renewable energy sources in all areas of application—is considered to be a pillar of the energy transition.[7] The development of energy efficiency plays a crucial role in achieving the German government's climate policy targets. A high proportion of overall energy consumption contributed by renewable energy sources can be more easily achieved with a marked increase in energy efficiency.

Heat Sector of Particular Importance

In 2011, the industrial share of final energy consumption was around 30 percent (see Figure 2) and that of the transport sector was almost as high (29 percent).[8] Consumption by households accounted for 26 percent and consumption by trade, commerce, and the service sector for the remaining 15 percent. Accordingly, all sectors are expected to contribute to achieving the German government's far-reaching efficiency targets. The heat sector is of particular importance here. Space heating and hot water supply together accounted for over 30 percent of total final energy consumption in 2011. Mechanical energy, used mainly in the transport sector, also contributed a high share. Lighting as well as information and communication technology, often associated with power-saving measures in households, together accounted for a good six percent of final energy consumption.

4 BMWi and BMU, Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung (Berlin: Federal Ministry for Economic Affairs and Energy, Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, September 28, 2010).

5 Here, the German government has assumed an average economic growth of 0.8 percent per annum. See J. Nitsch et al., Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. Final Report (German Aeronautics and Space Research Center (Deutsches Zentrum für Luft- und Raumfahrt, DLR), Fraunhofer Institute for Wind Energy and Energy System Technology (Fraunhofer Institut für Windenergie und Energiesystemtechnik, IWES), Ingenieurbüro für neue Energien (IfnE), March 29, 2012), 47. Study conducted on behalf of the Federal Environment Ministry (BMU). With higher growth rates, there would have to be a correspondingly higher increase in energy productivity in order to achieve the reduction target for primary energy demand.

6 The estimate of the current rate of renovation is based on the study by the Institute for Housing and the Environment (IWU) and the Bremer Energie Institut (BE), Datenbasis Gebäudebestand, Datenerhebung zur energetischen Qualität und zu den Modernisierungstrends im deutschen Wohngebäudebestand (Darmstadt: 2010). It is also being critically debated whether this rate is reliable enough to serve as a policy objective. On this, see the Cologne Institute for Economic Research (IW), "Energetische Sanierung: Quote ohne Aussagekraft, "Immobilien-Monitor, no. 1 (March 13, 2012).

7 See. F. Schafhausen, "Die Energiewende – Aufbruch in die Zukunft," Vierteljahrshefte zur Wirtschaftsforschung, vol. 82, no. 03 (2013): 11–28.

8 The structure of the final energy consumption by sector for 2012 is now available. According to this data, at 27 percent, households had a somewhat higher share of the final energy consumption in 2012 than in the previous year while the shares of industry and transport decreased slightly. This can, inter alia, be attributed to a weather-related higher space heating requirement.

Scenario Analyses: How Does an Increase in Energy Efficiency Impact on the Economy?

As part of the framework of a research project, DIW Berlin analyzed the economic effects of an accelerated increase in energy efficiency in households and the manufacturing industry as well as trade, commerce, and the service sector.[9] As a first step, the economic stimuli which are associated with measures to enhance energy efficiency were derived. Then, possible economic consequences were quantitatively simulated in the form of scenarios using the SEEEM modeling instrument (see Box 1). Here, the focus was on energy upgrades for existing residential buildings.

In a modernization scenario, doubling the rate of building renovation to upgrade energy performance in line with the German government targets was assumed; conversely, the rate of renovation in a reference scenario remains unchanged. In addition to a baseline version of the modernization scenario, three alternatives were also studied in order to take into account uncertainties in view of shorter periods of repayment required by investors, lower energy savings, and higher specific investment costs.

In addition, other economic measures to increase energy efficiency in households and the manufacturing industry as well as trade, commerce, and the service sector were included.[10] The economic stimuli resulting from these measures were taken from the literature. Here, it was assumed that these measures were implemented in the same way in all versions of the modernization scenario (see Box 2).

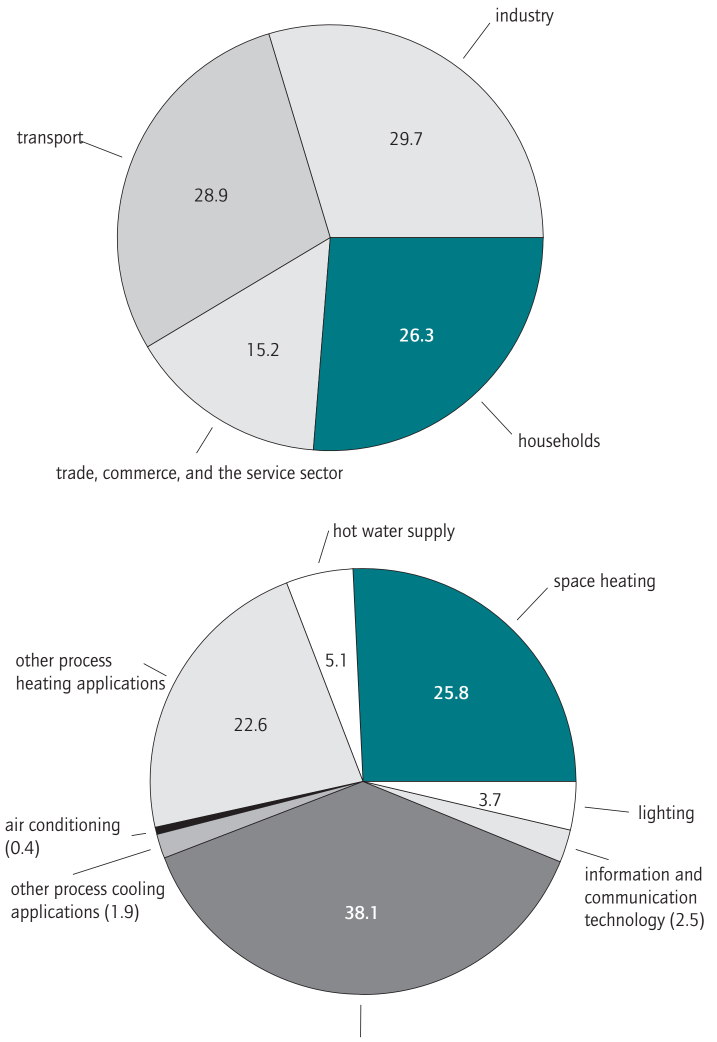
Renovation of Buildings Can Make an Important Contribution

Against the background of the targets mentioned above, energy upgrades for existing buildings can make an important contribution to the increase in overall energy efficiency. The starting point for assessing the energy-related investment in modernization in the building sector is structural information on existing residential buildings in Germany, estimates of the living space to be modernized, and information on the amount of capital expenditure needed per square meter of living space. The rate of building renovation to upgrade energy performance is used as an indicator of the scale of renovation. It is calculated as a weighted average on the basis of possible individual measures (for example, insulation

Figure 2

Final Energy Consumption by Economic Sector and Area of Energy Use 2011[1]

Share in percent



1 The structure of final energy consumption by economic sector is available for 2012 but the structure by areas of energy use is not.
Source: Arbeitsgemeinschaft Energiebilanzen.

Space heating and hot water supply constitute well over 30 percent of final energy consumption.

9 adelphi, DIW Berlin, and Fraunhofer ISI, Ökologische Modernisierung der Wirtschaft durch eine moderne Umweltpolitik. Project on behalf of the Federal Environmental Agency (UBA), project number (UFOPLAN) 3710 14 101. The final report is published by the UBA.

10 Improvements in efficiency in the transport sector which are undoubtedly necessary and beneficial were not studied as part of DIW Berlin's sub-project. On current developments in road transport, see U. Kunert and S. Radke, "Nachfrageentwicklung und Kraftstoffeinsatz im Straßenverkehr: Alternative Antriebe kommen nur schwer in Fahrt," Wochenbericht des DIW Berlin, no. 50 (2013).

Box 1

The SEEEM Modeling Instrument

DIW Berlin's Sectoral Energy-Economic Econometric Model (SEEEM) is used for the quantitative scenario analysis. This is based on the macroeconomic multi-country model of the National Institute Global Econometric Model (NiGEM) developed by the British National Institute of Economic and Social Research and was expanded at DIW Berlin by adding a sectoral submodel for Germany.

The equations of this neo-Keynesian model are theoretically consistently derived and include parameters which are estimated econometrically using error correction specifications. The model makes it possible to study the macroeconomic and sectoral knock-on effects of economic stimuli and permits to map out both short- and long-term effects. After exogenous shocks, there is a gradual shift toward long-term equilibriums in the model.

SEEEM has been used in the past to analyze the economic effects of expanding renewable energy sources in Germany.[1]

In the present study, it is used to examine the effects of various energy efficiency paths. Here, the direct economic stimuli associated with different scenarios to increase energy efficiency are fed into the model as exogenous parameters. The differences between various scenarios can be interpreted as effects of the change in stimuli.

For 2030 to 2050, the long-term effects of the stimuli from previous years and the effects of further stimuli were evaluated on the basis of the model results up until 2030. As a rule, all models used to estimate the effects of environmental policy strategies and other strategies are based on the assumption that key behavioral patterns and structures of the past also remain valid in the future. The further into the future these estimates extend, the less likely it is that this prerequisite is fulfilled. Therefore, assessments of the long-term effects of measures to enhance energy efficiency are subject to distinctly increasing uncertainties.

1 See J. Blazejczak, F.G. Braun, D. Edler, and W.-P. Schill, „Ausbau erneuerbarer Energien erhöht Wirtschaftsleistung in Deutschland," Wochenbericht des DIW Berlin, no. 50 (2010); and J. Blazejczak, F.G. Braun, D. Edler, and W.-P. Schill, „Economic Effects of Renewable Energy Expansion: A Model-Based Analysis for Germany," DIW Discussion Paper no. 1156 (2011).

of outer wall, insulation of roof/top floor ceiling, insulation of floor/cellar roof, or window replacement), with the weighting reflecting the heating energy saving resulting from the individual measures.[11]

Energy Upgrades of Living Space Must Be Doubled

In order to achieve the above-mentioned targets of the energy concept targets, a significant acceleration of activities in the field of building renovation to upgrade energy performance is required, so that ultimately the energy upgrades to existing buildings will be doubled from around one percent to date to two percent in future.

According to information provided by the Institute for Housing and the Environment (IWU) for 2011,[12] there were around 18 million residential buildings in Germany (up to construction year 2009), made up of 39.4 million homes with 3.415 billion square meters of living space. Around 36 percent of single- and multi-family houses as well as a good 30 percent of apartment blocks were built after the introduction of the first Thermal Insulation Ordinance of 1977 and consequently already met certain minimum standards regarding energy consumption at the time of construction.

11 For details of the methods of calculating the renovation rate, see the Institute for Housing and the Environment (IWU) and the Bremer Energie Institut (BE), Datenbasis Gebäudebestand. Individual measures related to energy upgrades on existing buildings are carried out significantly more frequently than full refurbishments to improve energy performance. Individual measures are carried out on around three percent of the residential building stock each year, also taking modernization of heating systems into account.

12 See the Institute for Housing and the Environment (IWU), Basisdaten für Hochrechnungen mit der Deutschen Gebäudetypologie des IWU: Neufassung (August 2011). According to more recent data which are also based on analysis of the 2011 Census, the benchmark figures have changed slightly. The building stock is now estimated at 18.2 million residential buildings, encompassing 39.2 million homes with a living space of 3.552 billion m^2. On this, see the Institute for Housing and the Environment (IWU), Basisdaten für Hochrechnungen mit der Deutschen Gebäudetypologie des IWU (2013): revised version, October 2013.

Box 2

Further Measures to Enhance Energy Efficiency

In addition to energy upgrades to buildings, there is further potential to increase energy efficiency in households. Some examples are energy saving through technical improvements to household appliances and lighting. There is considerable potential to save energy in trade, commerce and the service sector through energy upgrades to non-residential buildings as well as in areas of technology such as efficient lighting, office equipment, or improved refrigeration and freezer systems. In the industrial sector there is a particularly broad and diverse potential for fuel- and electricity-specific energy-saving technologies. These include both technologies that can be used in many sectors (cross-sectional technologies), and technologies for application in individual sectors, for example, in energy-intensive fields such as the chemicals industry or the paper industry.

Due to the large number of technologies that must be taken into consideration, no independent detailed assessment of investment in modernization and the associated energy savings was included. Instead, existing studies were evaluated,[1] in which measures to increase energy efficiency, excluding energy upgrades to residential buildings, were examined in detail. According to these analyses, there is a huge potential in the industrial sector for efficiency measures which can be developed at a low cost but which are subject to high return requirements with short repayment periods. Measures in this field are therefore assumed to be characterized by rather lower investment and relatively high energy savings.

In the areas summarized, excluding energy upgrades to residential buildings, investment in measures to enhance energy efficiency in 2020 amount to 4.2 billion euros. This is expected to increase to 4.7 billion euros in 2030 and subsequently remain constant in real terms. Approximately half of this figure is made up of investment in energy upgrades to non-residential buildings and half is investment in other—mainly electricity-related—measures. The energy cost savings in 2020 are anticipated to amount to 6.4 billion euros and are expected to rise by 2050 to 14.5 billion euros. The estimates for both investment and energy cost savings for the sectors considered collectively here are subject to greater uncertainties than the corresponding estimates for energy upgrades to residential buildings.

1 See WWF Germany, Modell Deutschland, Klimaschutz bis 2050: Vom Ziel her denken, a study by Prognos and Öko-Institut on behalf of the WWF (Berlin, Basel: 2009),; and M. Pehndt et al.: Energieeffizienz: Potenziale, volkswirtschaftliche Effekte und innovative Handlungs- und Förderfelder für die Nationale Klimaschutzinitiative, final report for the project "Wissenschaftliche Begleitforschung zu übergreifenden technischen, ökologischen, ökonomischen und strategischen Aspekten des nationalen Teils der Klimaschutzinitiative," (Heidelberg, Karlsruhe, Berlin, Osnabrück, and Freiburg: IFEU, Fraunhofer ISI, Prognos, GWS et al., 2011).

The future demand for buildings[13] essentially depends on demographic trends and household structure, particularly average household size. Although a marked decrease in the population of Germany is highly probable in the long term,[14] an increased demand for living space is anticipated up until 2030, followed by a decrease.[15] Living space is expected to increase to 3.7 billion square meters by 2030 and then drop again slightly to 3.6 billion square meters in 2050.

Renovation work on existing buildings varies according to the age and type of building. In addition, it has to be taken into account that the rates of renovation change over time. Very little modernization is required for new buildings; as buildings become older, the rate of renovation increases. As regards buildings which are already old now, the share of renovations carried out on them is initially high but the rate of renovation decreases in the long term. In the reference scenario, the rate of renovation for the entire building stock remains constant over time at well over one percent (see Table 1).

13 In the following, all modernization work refers to the building stock available in 2009. However, the modernizaton rates reported refer to the relevant total building stock. Physical depreciation or obsolescence from the existing building stock is not modeled here.

14 According to various versions of the 12th coordinated population projection by the Federal Statistical Office, the population of Germany is likely to drop from a good 80 million people at present to 77 to 79 million in 2030 and 69 to 73 million in 2050.

15 A crucial factor affecting this development is the significantly increasing proportion of one-person households of the total number of households, which leads to an increase in the per capita demand for living space.

Table 1

Rate of Building Renovation to Upgrade Energy Performance in the Reference and Modernization Scenarios
In percent

	Completion of building					
	Before 1957	1958–1983	After 1983	Before 1957	1958–1983	After 1983
	Single and multi-family houses			Apartment blocks and large apartment blocks		
Reference scenario						
2020	1.3	1.1	0.1	1.3	1.3	0.8
2030	1.1	1.0	0.5	1.3	1.2	1.0
2050	0.8	0.8	1.3	0.9	1.1	1.3
Modernization scenario						
2020	2.6	2.2	0.2	2.6	2.6	1.6
2030	2.3	2.0	1.0	2.6	2.4	2.0
2050	1.7	1.6	2.6	1.8	2.1	2.6

Source: calculations by DIW Berlin.

Renovation rates vary considerably depending on building type and age.

Table 2

Additionally Modernized Living Space with Doubled Rate of Building Renovation to Upgrade Energy Performance
Differences between modernization and reference scenario

	2020	2030	2050
In million m^2			
Modernized residential space per annum	35.7	37.6	36.1
Existing modernized residential space	247.1	614.4	1,349.5
In percent			
Modernized residential space as share of total existing housing	7.0	16.7	37.3

Source: calculations by DIW Berlin

The total modernized residential space is expected to increase substantially over time.

In the modernization scenario, following an initial phase,[16] the rate of renovation remains permanently doubled in comparison to the reference scenario at around two percent. Growth of this magnitude results in a significant increase in the living space that has been renovated to upgrade energy performance (see Table 2). The annual additionally modernized living space in the modernization scenario amounts to a good 35 million square meters. The total area of additionally modernized living space in 2030 is 614 million square meters, while the corresponding figure for 2050 is 1.3 billion square meters. Measured in terms of building stock in the relevant year, compared to the reference development, an additional almost 17 percent of buildings will be modernized in 2030 and a good 37 percent in 2050.

Accelerated Pace of Energy Upgrades to Buildings Requires Considerable Additional Investment

The annual additional investment required for an accelerated pace of energy upgrades to buildings is calculated on the basis of the additionally modernized area and the specific costs of energy upgrades to buildings per unit of area. The specific renovation costs take the energy-related additional costs into account rather than the full costs (see Box 3). Due to the diversity of the different renovation projects and the dependence of the specific costs on the type of building,[17] the individual modernization costs can generally only be estimated with a degree of uncertainty. Based on the evaluation of numerous studies,[18] depending on the type and age of the building, specific energy-related additional costs are calculated here as between 160 and 220 euros per square meter. In real terms, this means that relative to the general price development in the economy, a cost increase of 1.5 percent per year from 2020 and of 2.5 percent from 2030 is assumed, since buildings that require more specific and costly renovation work are increasingly being upgraded in the course of time. Therefore, it is presumed that from about 2020 onwards the particularly low-cost renovation options will be increasingly exhausted and technological progress will not be sufficient to meet the increased modernization requirements. On this basis, the annual additional investment in energy

16 In the initial phase of accelerated energy upgrades to existing buildings, consideration must also be given to making the expansion of the necessary capacities in the building construction and finishing trades as smooth as possible. Observations by DIW Berlin have shown that considerable efforts and a well-timed phase of expansion of capacity are necessary for this. On this, see M. Gornig, H. Hagedorn, and C. Michelsen, "Bauwirtschaft: Zusätzliche Infrastrukturinvestitionen bringen zunächst keinen neuen Schwung, " Wochenbericht des DIW Berlin, no. 47 (2013).

17 The specific costs are, for example, lower for multi-family houses than for single-family houses and other building characteristics also play a crucial role.

18 See the Institute for Housing and the Environment (IWU), Wirtschaftlichkeit energiesparender Maßnahmen im Bestand vor dem Hintergrund der novellierten EnEV (Darmstadt: 2008); Dena, dena-Sanierungsstudie. Teil 1: Wirtschaftlichkeit energetischer Modernisierung im Mietwohnungsbestand. Begleitforschung zum dena-Projekt „Niedrigenergiehaus im Bestand" (Berlin: 2010); empirica, LUWOGE consult, Wirtschaftlichkeit energetischer Sanierungen im Berliner Mietwohnbestand (Berlin, Ludwigshafen: 2010); Arbeitsgemeinschaft, ed., Wohnungsbau in Deutschland 2011 – Modernisierung oder Bestandsersatz. Studie zum Zustand und der Zukunftsfähigkeit des deutschen „Kleinen Wohnungsbaus" (Kiel: 2011); the Cologne Institute for Economic Research (IW), Energetische Modernisierung des Gebäudebestandes: Herausforderungen für private Eigentümer, study conducted on behalf of Haus & Grund Deutschland (Cologne: 2012); prognos Ermittlung der Wachstumswirkungen der KfW-Programme zum Energieeffizienten Bauen und Sanieren, study conducted on behalf of the KfW Bankengruppe (Berlin, Basel: 2013).

Box 3

Concepts for Assessing the Costs of Measures for Energy Upgrades to Buildings

With regards to costs of energy upgrades to buildings, a distinction should always be made between full costs and energy-related additional costs. As a rule, comprehensive energy upgrades are only carried out in combination with other renovation work on the building shell (coupling principle), partly because this is a decisive factor in the microeconomic profitability of the work. The energy-related additional costs comprise only costs which are incurred for measures in addition to pure maintenance work (for example, costs of thermal insulation to exterior walls or intermediate floors, including fixing). What is not taken into consideration are costs that would be incurred anyway (for example, costs of the required construction site facilities, scaffolding costs, repainting, etc.), i.e., costs which, although necessary for carrying out the modernization work, are not directly connected with energy saving. Because of the many possible constellations of renovations, the ratio of energy-related additional costs to full costs fluctuates considerably. After evaluating a large number of cost estimates, a metastudy comes to the conclusion that the proportion of energy-related additional costs to full costs ranges from 30 to 60 percent.[1] According to these observations, assuming energy-related additional investment amounting to 7.4 billion euros, in the modernization scenario in 2020, full investment costs could range from 12.3 to 24.7 billion. However, calculations made on the basis of the DIW Berlin's construction volume calculation suggest that the upper limit of the cost estimate, i.e., with a proportion of energy-related additional costs of around 30 percent of the full costs, should be considered to be the more realistic version.

1 See the Cologne Institute for Economic Research (IW), Energetische Modernisierung.

upgrades of residential buildings is expected to amount to 7.4 billion euros in 2020,[19] increasing to 9 billion euros in 2030 and 14 billion euros in 2050.

Sharp Increase in Energy Cost Savings in Residential Buildings Over Time

The energy cost savings resulting from the investment in modernization depend on the existing modernized living space, the specific energy savings, and the assumptions relating to energy price development. The specific energy savings can only be estimated with a degree of uncertainty due to the numerous factors which have an impact: depending on building type and age, specific final energy savings of 120 to 200 kilowatt-hours per square meter are taken as a basis.[20] With respect to the energy costs, an average price of seven cents for final energy used per kilowatt-hour is assumed for 2010. The further price development is based on the fuel price paths in Scenario A of the long-term scenarios for 2011,[21] so that this represents an increase in energy prices by 2050 that is twice as high as the increase in general prices. Based on these considerations, the energy costs saved for residential buildings will amount to 3.8 billion euros in 2020, while 11.1 billion euros will be saved in 2030 and 32 billion euros in 2050.[22]

Further Efficiency Measures in Other Sectors Require Additional Investment

Together with further additional investment and energy savings in other sectors (see Box 2), the estimated additional investment needed to accelerate the pace of energy upgrades for buildings and the energy costs saved results in all the economic stimuli studied in the baseline scenario of the modernization scenario. The additional investment required for energy efficiency in 2020 will amount to 11.6 billion euros, offset by total energy costs saved of 10.2 billion euros in the same year (see Table 3).[23] There is a significant rise in the energy costs

19 Unless otherwise stated, all information in the following refers to 2000 prices.

20 The specific energy savings can be derived from the studies quoted in footnote 18. See also F. Schröder et al., "Universelle Energiekennzahlen für Deutschland – Teil 1: Differenzierte Kennzahlverteilungen nach Energieträger und wärmetechnischem Sanierungsstand," Bauphysik 31, no.6 (2009): 393–402; and M. Greller et al., "Universelle Energiekennzahlen für Deutschland – Teil 2: Verbrauchskennzahlentwicklung nach Baualtersklassen," Bauphysik 32, no. 1 (2010): 1–6.

21 See Nitsch et al., Langfristszenarien.

22 With owner-occupied housing, both the costs (in the form of funding energy-saving modernization) and the returns (in the form of energy costs saved) belong to the same economic unit. With rented housing, the owner bears the costs while the occupier profits (user/investor dilemma). In this case, the costs of energy-saving modernization must be recuperated from increases in the basic rent (not including utilities). Whether or not the necessary increase in this rent is feasible also depends, inter alia, on local rental market conditions.

23 If energy costs fall as a result of investment in energy efficiency, this may give energy consumers an incentive to use more energy. The size of this rebound effect is difficult to determine empirically. This effect is ignored in the present analysis.

Table 3

Investment for Accelerated Increase in Energy Efficiency and Additional Energy Cost Savings

Differences between modernization[1] and reference scenarios in billion euros[2]

	2020	2030	2050
Energy upgrades to residential buildings			
Investment	7.4	9.0	14.0
Energy cost savings	3.8	11.1	32.0
Measures in other sectors			
Investment	4.2	4.7	4.7
Energy cost savings	6.4	9.3	14.5
Total			
Investment	11.6	13.8	18.7
Energy cost savings	10.2	20.4	46.5

1 In the baseline version.
2 At 2000 prices.
Source: calculations by DIW Berlin.

There will be a much sharper increase in additional energy cost savings than additional investment.

saved over time because the stock of buildings on which efficiency measures have been carried out is constantly increasing. The investment needed also increases over time, albeit at a considerably slower rate. Investment in energy efficiency in 2030 is expected to amount to 13.8 billion euros, while the total energy cost savings in the same year are anticipated to be 20.4 billion euros. In 2050, energy cost savings of 46.5 billion euros are still only expected to be offset by additional investment of 18.7 billion euros.

Efficiency Measures Result In Significant Energy Savings and Reductions in Greenhouse Gas Emissions

The investment stimuli discussed earlier will result in significant energy savings. For 2020, savings of approximately 120 terawatt-hours are anticipated, compared to the reference scenario. The corresponding figure for 2030 is 214 terawatt-hours and 2050 will see savings of almost 400 terawatt-hours (see Table 4). Relative to Germany's total final energy consumption in 2012, these figures equate to additional savings of five percent in 2020, nine percent in 2030, and 16 percent in 2050.

Savings in the field of space heating applications are expected to be comparatively low initially. However, since it is anticipated that a constant building renovation rate of two percent will be maintained, this will lead to significant and constant growth in savings over time.[24] In other areas of energy use, on the other hand (particularly trade, commerce, and the service sector as well as industry) it is forecast that considerable energy savings potential will be realized as early as 2020 but that the growth of energy savings in this field will level off in the future.

Energy savings are accompanied by a reduction in greenhouse gas emissions. These are calculated on the basis of specific emission factors attributed to final energy consumption. For 2010, an emission factor of 0.28 kg CO_2 per kilowatt-hour of final energy consumption was assumed for heat energy consumption of residential buildings.[25] This factor is anticipated to improve to a value of 0.12 kg CO_2 per kilowatt-hour by 2050 due to a less emissions-intensive energy mix.[26] The same factor was also used to estimate the reduction in greenhouse gas emissions produced by fuel consumption in trade, commerce, and the service sector, and in industry. Electricity use is assigned a specific emission factor, which—particularly as a result of increased use of renewables—is expected to improve from around 0.6 kg CO_2 per kilowatt-hour in 2010 to 0.34 kg CO_2 per kilowatt-hour in 2030, and to continue to decline subsequently.[27]

It is envisaged that the investment stimuli modeled could result in an additional 45 million tonnes of CO_2 savings in 2020, compared to the reference scenario (see Table 4). The equivalent saving in 2030 would be 59 million tonnes and 74 million in 2050. Relative to total greenhouse gas emissions in 2012, this corresponds to a saving of five percent by 2020, six percent by 2030, and eight percent by 2050.[28] Initially, savings predominantly result from more efficient electricity usage in trade, commerce and the service sectors, and in industry. However, over time, there is an increase in the significance of savings made in the space heating of households due to the constantly growing number of existing residential buildings that are upgraded. As far as power is concerned, a drop in annual emission reductions is recorded over time as the electricity mix produces significantly fewer emissions.

24 Based on the assumption that the specific energy savings in kWh/m^2 remain constant over time.

25 Here and in the following, always CO_2 equivalent.

26 See IW Köln, Energetische Modernisierung des Gebäudebestandes (2012).

27 Shell, ed., Shell Hauswärme-Studie – Nachhaltige Wärmeerzeugung für Wohngebäude. Fakten, Trends, Perspektiven (Hamburg: 2011).

28 In the long-term, the relative savings in greenhouse gases should be lower than savings in energy consumption since, as renewable energy sources are used increasingly, the CO_2 intensity of energy supply will significantly decline over time.

Table 4

Energy Saving and Reduction in Greenhouse Gas Emissions

Differences between modernization[1] and reference scenarios

	2020	2030	2050
Energy in terawatt-hours(TWh)			
Residential space heating	39	96	206
Other forms of energy	80	117	186
Fuels	33	52	82
Electricity	48	65	103
Total	**119**	**214**	**391**
Greenhouse gas emissions in million tons of CO_2			
Residential space heating	10	24	43
Other forms of energy	34	35	31
Fuels	9	13	17
Electricity	26	22	14
Total	**45**	**59**	**74**

1 In the baseline version.
Source: calculations by DIW Berlin.

The energy savings and reduction in greenhouse gas emissions will be significant.

Table 5

Economic Effects of Additional Measures to Enhance Energy Efficiency

Differences between modernization[1] and reference scenarios in percent[2]

	2020	2030	2050
GDP	0.5	0.7	1.0
Private consumption	0.3	0.4	0.9
Private capital investment (excluding residential construction investment)	0.5	0.4	0.3
Investment in residential construction	7.2	7.4	9.6
Public investment	3.3	3.3	2.8
Exports	0.0	0.0	0.0
Imports	0.3	0.0	−0.1

1 In the baseline version.
2 Calculated on the basis of constant prices.
Source: calculations by DIW Berlin.

GDP is consistently higher when measures to enhance energy efficiency are implemented.

Positive Income and Employment Effects

Measures to enhance energy efficiency result in reduced greenhouse gas emissions and primary energy savings and cut external costs. In addition, these measures might also exert a positive impact on income and employment.

Through the network of interdependencies represented in the SEEEM modeling instrument used (see Box 1), the economic stimuli resulting from the increase in energy efficiency will have an impact on the income of the economy and how this income is used (see Table 5). The rise in residential construction investment, private fixed investment, and public investment combined (almost one billion euros in 2020)[29] is expected to be slightly higher than the increase in direct investment expenditure for further measures to enhance energy efficiency.

This can be explained by the fact that the additional investment results in expansionary effects that are greater than the damping effects that also occur. Expansionary effects mainly evolve as a result of multiplier and accelerator effects. The former occur because the additional income generated in producing the additional investments will then be spent again which, in turn, further increases demand. The latter are a result of companies investing in the capital goods necessary to increase their output capacity. Damping effects can be caused, for example, by financial or real crowding out effects occurring when high borrowing requirements lead to deteriorations in credit conditions or shortages in personnel or equipment.

The additional income generated by higher output leads, in turn, to greater private consumption. Initially, the effect on imports will be dominated by the expansion of domestic demand, and the savings in energy costs and resultant reduction in imports are likely to remain minimal in 2020. Later, once the energy cost savings are higher due to a larger number of upgraded buildings, on balance, the imports are likely to be slightly less than in the reference scenario. Essentially, the reduction in fuel imports will be substituted by higher imports of other goods, however. There will be little change in exports.

After 2030, the stimuli which, on balance, have expansive effects will continue to increase due to the additional investment in enhancing energy efficiency and to energy cost savings. Consequently, the positive impact on income and consumption is also greater. In 2050, with further measures to improve energy efficiency, in real terms, GDP is anticipated to be around one percent higher than in the reference scenario.

One decisive factor for increases in income is that, in combination with measures to enhance energy efficien-

29 Unless otherwise stated, the following figures refer to the difference between the modernization scenario (baseline version) and the reference scenario.

cy, additional economic resources could be mobilized to create additional value-added. This could either be generated by activating additional labor or by accelerating productivity gains.[30] Additional labor can either be drawn from the ranks of the unemployed or the non-working population. If there is a risk of wage increases due to structural discrepancies between labor supply and demand, this might encourage companies to make better use of the potential for productivity growth. In the longer term, a simultaneous increase in output and productivity can be expected by the accelerated diffusion of innovations that occurs when growth is higher.

Should neither an increase in labor productivity nor the mobilization of additional labor be possible, thus preventing an increase in value-added, then—as long as foreign trade remains unchanged—additional investment to enhance energy efficiency would only be possible at the expense of other investment or private consumption.

Employment Effects Depend on Labor Market Conditions

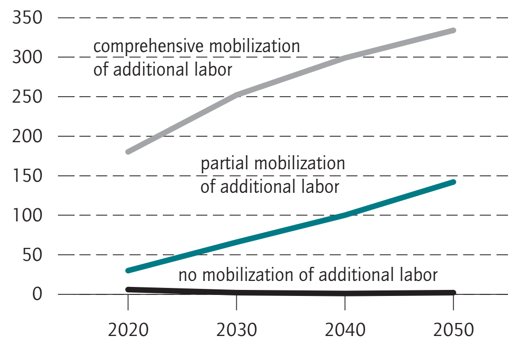
If productivity increases at the same pace as value-added, accelerated energy efficiency measures are unlikely to have any appreciable impact on net employment. If, however, value-added is not only facilitated by productivity gains but, to a certain extent, also by the mobilization of additional labor, palpable employment effects are possible. This would create around 30,000 more jobs in 2020 and 66,000 in 2030 (see Figure 3). In the period that follows, the employment effects could continue to grow, particularly if, over the course of time, more additional labor can be mobilized and the potential for further productivity growth decreases.

If there is no potential for productivity gains but, at the same time, there is unlimited availability of suitable additional labor[31] (and there are no feedback effects either due to rates of pay or foreign trade, for example), with identical stimuli and comparable effects on GDP, there could be an increase in employment of up to 180,000 people in 2020 and approximately 250,000 by 2030. In the long term, in this extreme case, the employment effect might even increase to over 300,000 people.

Figure 3

Possible Employment Effects of Further Measures to Enhance Energy Efficiency

1,000 people[1]



1 Differences between the modernization and reference scenarios based on different assumptions regarding the recruitment of additional labor. All variants are based on identical economic stimuli and comparable effects on GDP.
Source: calculations by DIW Berlin.

Significant positive employment effects are possible.

Positive Economic Effects Even Under Different Conditions

The economic effects depend on a series of external conditions, the future development of which is uncertain. This applies in particular to the repayment periods required by investors, achievable energy savings, and to specific investment costs. First, it is unclear whether the repayment period of 20 years assumed in the baseline version provides enough incentives for investment in energy efficiency in residential buildings. If the investor intends to amortize his additional investment in energy efficiency within a ten-year period,[32] the capital costs would initially exceed the energy savings. Only from 2030, when a larger share of the investments will have already been amortized, are net cost savings likely to be higher than in the baseline version. The initially higher costs will be borne by households; consequently, purchasing power will be transferred to companies in the residential construction sector, which will then not be available for private consumption. For this reason, to begin with, shorter repayment periods result in growth in private consumption that is lower than in the baseline version, whereas it is subsequently higher (see Table 6). Imports demonstrate a very elastic response to changes in private consumption. Foreign goods account

30 What is meant here is per capita productivity; this increases in line with the average working hours or productivity per working hour.

31 For qualification requirements in the field of building renovation to upgrade energy performance see F. Mohaupt et al., " Beschäftigungswirkungen sowie Ausbildungs- und Qualifizierungsbedarf im Bereich der energetischen Gebäudesanierung," Reihe Umwelt, Innovation, Beschäftigung des BMU und UBA, no. 1/11 (Berlin and Dessau: 2011).

32 With a real annual interest rate on residual debt of 2.5 percent (unchanged compared to the baseline version).

for a significant share of the increase or decrease in consumption. The changes in consumption therefore only result in increases or decreases in domestic value-added to a limited extent; the effects on GDP and employment only vary slightly with different repayment periods.

The magnitude of energy savings that can be achieved with a specific investment sum is also uncertain. If energy savings and the resultant reduction in fossil fuel imports in the housing sector is only half the level assumed in the baseline version (keeping investment levels the same), on balance, this would lead to increased costs over the entire period analyzed in comparison to the reference scenario. This, in turn, would lead to a marked reduction in the potential for additional consumption available to households. In contrast to the model with shorter repayment periods, the initially lower private consumption (compared to the baseline version) is not offset by higher consumption in later years. The knock-on effect on domesctic value-added and employment is cushioned by the highly elasticity of imports in relation to private consumption: although the increase in GDP is lower than in the baseline version, the difference is not as significant as with private consumption.

The effect is similar when energy upgrades to existing residential buildings result in higher costs. Assuming that specific investment costs are double those in the baseline version, this would result in a decline in disposable income and would also dampen private consumption, albeit to a lesser extent than the original stimulus. The reason for this is the multiplier effects of higher investment. Here, too, some of the additional demand (compared to the reference scenario) is satisfied by imports; this attenuates the impact on GDP and employment.

The size of the increase in income and employment also depends on other circumstances, such as fiscal policy. The higher income resulting from enhancing energy efficiency initially leads to additional tax revenue. In the versions of the modernization scenario described, it is assumed that the government will reduce taxes to offset this effect to the extent that its fiscal balances remain unchanged. Should the additional tax revenue be used to consolidate the national budget instead, the increase in income and private consumption would be lower.

Conversely, there could be a stronger increase in income if policy-makers based their decisions on past developments rather than available information about future developments, as is assumed here.[33]

Table 6

Economic Effects Based On Alternative Assumptions

Differences between modernization and reference scenarios in percent[1]

Assumptions		2020	2030	2050
Baseline version	GDP	0.5	0.7	1.0
	Private consumption	0.3	0.4	0.9
Shorter repayment periods	GDP	0.4	0.7	1.1
	Private consumption	0.1	0.5	1.3
Lower energy savings	GDP	0.4	0.5	0.7
	Private consumption	0.1	0.1	0.4
Higher investment costs	GDP	0.5	0.7	1.0
	Private consumption	0.1	0.0	0.3

1 Calculated on the basis of constant prices.
Source: calculations by DIW Berlin.

Even allowing for considerable elements of uncertainty, positive economic effects prevail.

Construction Industry Accounts for Lion's Share of Increased Output

The different sectors of the economy are affected to varying degrees by measures to enhance energy efficiency (see Figure 4).[34] The construction industry accounts for the largest share of output effects—anticipated to be almost 35 percent of the total additional gross output in 2020; this reflects the importance of energy upgrades as one of the measures to increase energy efficiency. However, over time, the contribution made by the construction industry will decline because households' energy cost savings noticeably increase the demand for other private consumption goods. Nonetheless, in 2050, the construction industry is expected to still account for more than a quarter of the additional gross output.

The manufacturing industry (excluding construction) accounts for the second highest share of growth effects—around 27 percent of gross output in 2020. However, relative to the significance of this sector for the economy, the impact on this branch is considerably weaker than on the construction sector. The manufacturing industry profits directly from increasing capital investment to improve energy efficiency outside the housing sector, but, since it supplies the intermediate inputs, it also benefits indirectly from increases in output in other branches of the economy. However, the share of

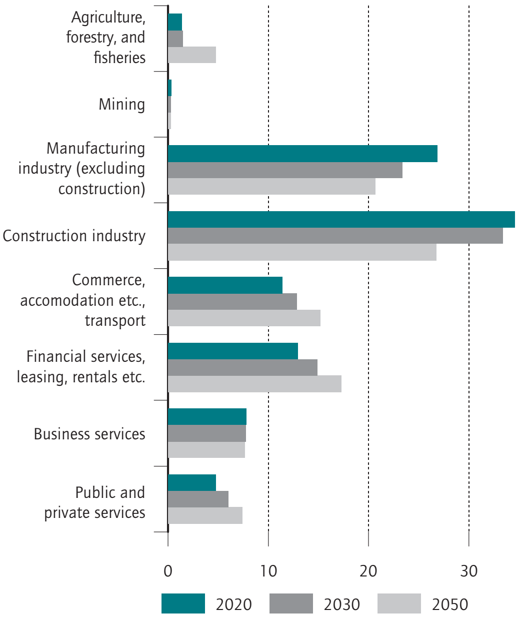
33 The SEEEM model enables us to depict both forward- and backward-looking expectation formation. A simulation based on the assumption of *backward-looking expectations* shows that the effect on GDP, particularly initially, is significantly greater than with *forward-looking expectations*; over time, developments in both scenarios converge to the results obtained under *forward-looking expectations*.

34 The following figures are taken from the baseline version.

Figure 4

Sectoral Distribution of Output Effects[1] of Further Measures to Enhance Energy Efficiency

Share of total output effect accounted for by respective sectors, in percent



1 Differences between the modernization scenario in the baseline version and the reference scenario.
Source: calculations by DIW Berlin.

The construction industry in particular has profited.

gross output gains accounted for by the manufacturing industry will decrease over time. The service sector increasingly profits from modernization over time as the second-round effects of the energy efficiency measures gain significance.

Conclusion and Implications for Economic Policy

Since 1990, Germany has enhanced energy efficiency: with rising GDP, primary energy consumption has declined slightly. However, in order to meet the German government's far-reaching energy saving and emissions reduction targets, as well as bring about the planned increased use of renewables, the previous rate of energy efficiency improvement is far from sufficient. Therefore, the German government aims to achieve a rise in the final energy productivity rate by an average of 2.1 percent per annum. Meeting this target will require the involvement of every sector of the economy. In the long-term, the renovation of existing residential buildings is of particular significance; the government aims to double the rate of building renovation to upgrade energy performance from one percent at present to two percent in the future.

Taking into account the different renovation requirements (depending on building age and type), it is possible to estimate the additional investment required for energy efficiency measures: the volume of investment is expected to be well over seven billion euros in 2020, nine billion euros in 2030, and 14 billion in 2050, all at 2000 prices. The extra investment consists of additional expenditure exclusively for energy upgrades to buildings. This would enable households to save almost four billion euros on their energy bills in 2020 (at 2000 prices). A saving of 11 billion euros is expected in 2030 and the corresponding figure for 2050 is 32 billion.

This, combined with further measures to improve energy efficiency in households, industry as well as trade, commerce, and the service sector could reduce energy consumption by 120 terawatt-hours by 2020 in comparison to the reference scenario, and the corresponding figure could be as high as almost 400 terawatt-hours by 2050. Compared to the reference scenario, greenhouse gas emissions could decline by 45 million tons by 2020 and this figure could be as high as 74 million tons by 2050.

Stimuli, in the form of additional investment and energy cost savings, resulting from measures to accelerate energy efficiency could have a positive impact on income and domestic demand, should it be possible to achieve additional production capacity through productivity gains or the mobilization of previously unemployed labor. GDP will increase by half a percent in 2020 and one percent in 2050, compared to the reference scenario. Most of the additional output is accounted for by the construction industry. This could result in significantly positive effects on employment, depending on the ratio of productivity gains and new jobs.

Slightly more limited but still positive income and employment effects will remain even with the requirement for shorter repayment periods for investments in energy upgrades to residential buildings, lower energy savings with the same investment requirements, or higher investments resulting from the same targeted increases in energy upgrades.

To date, policy-makers have not taken adequate account of the importance of enhancing energy efficiency for the success of the energy transition. If the government does not succeed in moving Germany onto a more ambitious energy efficiency path through additional incentives and measures, the existing climate targets and the renewable energy expansion targets (formulated as shares of energy consumption) will become much less achievable. The lack of success with regard to building renovation to upgrade energy performance is a particular problem area. Against a background of necessary capacity adjustments in the construction industry (and its supply sectors) as well as the advanced planning required for these adjustments, an acceleration of activities has to be gradual if friction and price increases are to be avoided. This underlines how important it is to create a clear and dependable framework soon to increase the number of buildings being renovated to upgrade energy performance. Any further hesitation will only increase the risk of tentativeness in investment decisions and diminish the window of time available for meeting the government's targets. Given the present analyses which indicate that forcing the pace of energy efficiency improvements has a positive impact on German economic growth and employment, the hesitation at the policy level seems even less justified.

Finally, measures to accelerate energy efficiency improvements—along with other elements of the energy transition,[35] measures to maintain an efficient transport infrastructure,[36] and increased investment in education[37]—are expected to contribute to increasing investment activity in Germany, thus closing the existing investment gap. This would strengthen German economic growth and also provide momentum for an upturn of the European economy.[38]

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