

## German Energy Transition: Investment Needed



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**Volume 3, No 9**  
27 September, 2013  
ISSN 2192-7219

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# Energy Transition Calls for High Investment

by Jürgen Blazejczak, Jochen Diekmann, Dietmar Edler, Claudia Kemfert, Karsten Neuhoff, and Wolf-Peter Schill

Achieving the objectives of the German governments 2010 Energy Concept and the accelerated phase-out of nuclear energy will require significant investment in restructuring energy supply. In particular, this includes investment in installations for the use of renewable energy sources in the power and heating sector, as well as in the infrastructure, such as power grids. In addition, substantial investment is needed to improve energy efficiency, for example, by insulating buildings.

Model calculations by DIW Berlin show that the transformation of the energy sector is likely to have a sustained positive effect on added value in Germany. Furthermore, this investment will lead to substantial savings of primary fossil energy sources. This is also accompanied by a reduction in energy-related greenhouse gas emissions. The existing framework for investment in renewable power generation and electricity grids is largely appropriate and should, in principle, be maintained in the near future. Accelerating the rate of the energy-efficient building refurbishment, however, will require additional incentives.

The German government's 2010 Energy Concept outlines the country's long-term strategy for future energy supply.<sup>1</sup> The Concept proposes to increase the share of renewables in gross final energy consumption from 11 percent in 2010 to at least 18 percent by 2020. This target is in line with the EU Directive 2009/28/EC and Germany's obligations on the promotion of the use of energy from renewable sources in Europe.<sup>2</sup> The Directive requires the proportion of energy consumption produced by renewable sources to reach 60 percent by 2050.<sup>3</sup> The Energy Concept envisages a share of renewables in gross electricity consumption of at least 35 percent by 2020 and the target for 2050 is 80 percent. In 2012, the corresponding figure was almost 23 percent. At the same time, energy consumption should be significantly reduced in the long term. By 2050, primary energy consumption should be 50 percent lower than 2008 levels. In the buildings sector, the aim is to reduce primary energy needs by 20 percent by 2020 and 80 percent by 2050.

In order to meet these targets, significant investment is needed in various areas. In particular, this includes investment in installations for the use of renewables in the power and heating sector, and in other parts of the energy infrastructure. In addition, substantial investment is necessary for energy-efficient building refurbishment. The present article discusses future investment needs and the potential macroeconomic effects of this investment, as well as the framework required.

<sup>1</sup> German Federal Ministry of Economics and Technology (Bundesministerium für Wirtschaft und Technologie), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit), *Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung* (September 28, 2010). The Energy Concept was supplemented with resolutions from the Energy Package of June 6, 2011. A particularly important element of this was a complete nuclear phase-out by 2022.

<sup>2</sup> J. Diekmann, "Renewable Energy in Europe: Strong Political Will Required for Ambitious Goals". DIW Berlin Weekly Report 5 (2009), 36, 242-250.

<sup>3</sup> Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, *Erneuerbare Energien in Zahlen. Internet-Update ausgewählter Daten* (December 2012).

## Energy Transition Investment Needs Until 2020

Against the backdrop of previous investment activity, the following outlines investment needs until 2020, in order to implement the Energy Concept. The article distinguishes between different sectors: installations for the use of renewables in electricity and heat generation, power grids, energy storage systems and other installations for the system integration of renewable energy, and also energy-efficient building refurbishment.

## Electricity and Heat Generation from Renewables

Table 1 shows the development of investment in installations for using renewables in electricity and heat generation until 2012. Starting at a low level in 2000, investment increased dramatically to 27 billion euros in 2010.<sup>4</sup> Since then, installation volume has remained

<sup>4</sup> Here and throughout the text, only real investment figures are given based on 2012 prices. This means that it is not necessary to forecast general future price developments.

Table 1

### Investment in Renewables and Their Share of Macroeconomic Investment

Year	Investment in renewable energy	Share of equipment investment	Share of capital investment
	In billion euros	In percent	In percent
2012	19.5	11.1	4.2
2011	23.5	12.8	5.0
2010	27.0	15.8	6.2
2009	22.7	14.6	5.5
2008	17.2	8.6	3.7
2007	14.4	7.4	3.2
2006	13.6	7.6	3.2
2005	11.6	7.2	3.0
2004	9.5	6.2	2.5

Based on 2012 prices.

Sources: Federal Statistical Office, Working Group on Renewable Energy Statistics (AGEE-Stat); calculations by DIW Berlin.

virtually constant but a slight decrease in investment has been observed as a result of falling prices, particularly of solar power (photovoltaics).<sup>5</sup>

According to data from the Federal Environment Ministry's (BMU) "2011 Lead Study,"<sup>6</sup> from 2013 to 2020, annual investment of between 17 and almost 19 billion eu-

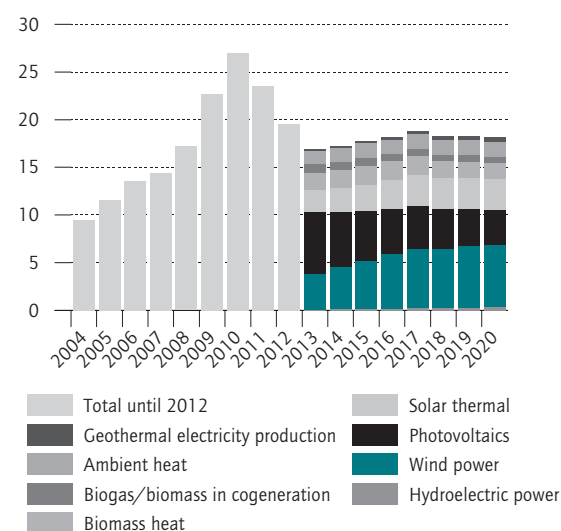
<sup>5</sup> J. Diekmann, C. Kemfert, and K. Neuhoﬀ, "The Proposed Adjustment of Germany's Renewable Energy Law: A Critical Assessment". DIW Economic Bulletin 2 (2012), 6, 3-9. T. Grau, "Targeted Support for New Photovoltaic Installations Requires Flexible and Regular Adjustments" DIW Economic Bulletin, 6 / 2012, 11-15.

<sup>6</sup> 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), Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. Final Report (March 29, 2012). The study which is often referred to as the "2011 Lead Study" maps a development path that is consistent with the German government's resolutions on the implementation of the energy transition. Here, the scenario being referred to is "2011A".

Figure 1

### Annual Investment in Power and Heat Generation from Renewables Until 2020

In billion euros



Based on 2012 prices. Excluding investment in local heat networks and energy imports.

Sources: German Federal Statistical Office, Working Group on Renewable Energy Statistics (AGEE-Stat), German Aeronautics and Space Research Center (DLR), Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), Ingenieurbüro für neue Energien (IfnE), Langfristszenarien und Strategien (2012); calculations by DIW Berlin.

Up until 2010, investment in renewable energy steadily increased but has slightly declined since then.

Investment plateaus at a high level.

Table 2

**Investment in Power Grids, 2007 to 2012**

In billion euros

	Transmission grids			Distribution grids			Overall total
	New construction / upgrade / expansion	Maintenance / renewal	Total transmission grids	New construction / upgrade / expansion	Maintenance / renewal	Total distribution grids	
2007	0.4	0.1	0.5	1.2	1.0	2.2	2.8
2008	0.6	0.2	0.8	1.3	1.2	2.5	3.3
2009	0.4	0.1	0.5	1.3	1.3	2.6	3.2
2010	0.5	0.1	0.6	1.6	1.7	3.3	3.9
2011	0.5	0.1	0.6	1.6	1.4	3.1	3.7
2012	0.6	0.2	0.7	1.6	1.4	3.0	3.8

Based on 2012 prices. 2012 values are planned figures.

Source: German Federal Network Agency (Bundesnetzagentur) and German Competition Authority (Bundeskartellamt); calculations by DIW Berlin.

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Recent annual investment in power grids has amounted to almost four billion euros.

ros will be necessary (based on 2012 prices).<sup>7</sup> The data shows an increase in the significance of investment in wind energy as well as heat generation from renewables by 2020 (see Figure 1). According to the study, the expansion of renewables requires that the high level of investment of recent years largely be sustained up until 2020. However, investment in photovoltaics is likely to fall since the cost per installation has plummeted and the total output of subsidized photovoltaic plants has been capped. At the same time, however, it can be assumed that investment in other technologies will increase. To a certain extent, the aforementioned investment substitutes replacement and new investment in conventional power and heat generation.<sup>8</sup>

**Power Grids**

The German electricity networks can be distinguished according to their voltage levels. The distribution grids comprise low, medium, and high voltage levels (0.4, 10–30, and 110 kilovolt), and the transmission networks have the highest voltage levels (220 to 380 kilovolt). Table 2 shows annual investment in power grids since 2007. Total investment over the last few years was between just under three and almost four billion euros and has recently followed an upward trend.

<sup>7</sup> In 2012, actual investment was higher than the figures used in the 2011 Lead Study, particularly for photovoltaics.

<sup>8</sup> The specific investment costs for renewable energy technologies are, however, generally considerably higher than those of conventional power plants; at the same time, renewables usually only clock up a minimal number of full load hours. Thus, power and heat generation using renewable sources requires significantly more investment than conventional supply.

Table 3

**Additional Annual Investment in Power Grids Until 2020**

In billion euros

Transmission grids		Distribution grids			Total
Onshore	Offshore	Low voltage	Medium voltage	High voltage	
2.1	2.2	0.3	0.5	1.0	6.1

Based on 2012 prices. Distribution grid investment needs according to the dena Distribution Grid Study, NEP B 2012 Scenario. Transmission network investment needs according to current Network Development Plan drafted by network operators, Scenario B 2023, including starter network. Investment for whole period evenly distributed across individual years.

Sources: German Energy Agency (dena), Ausbau und Investitionsbedarf (2012), 50Hertz et al., Netzentwicklungsplan Strom (2013) (2013a and b); calculations by DIW Berlin.

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Additional expansion needs amount to a total annual investment sum of six billion euros.

The power generation capacity of renewable energy is geographically dispersed and the power supply from wind energy and photovoltaics is subject to significant fluctuations. Therefore, alongside adjustments to power supply operation, the expansion of renewables increasingly also needs to include expanding and upgrading transmission and distribution grids. The lion's share of power from renewable sources is fed into the distribution grids while the transmission grids facilitate long-distance electricity transmission.

According to calculations by the German Energy Agency (Deutsche Energie-Agentur, dena), between 2010 and 2020, the distribution grids will require a total investment of 18.4 billion euros.<sup>9</sup> If this investment is more or less equally distributed over the individual years, it becomes apparent that an additional almost two billion euros a year will be needed to fund network expansion (see Table 3).

A multistage process was recently implemented by the transmission network operators to calculate the expansion requirements of the transmission grids and this information was then formalized by the legislature in the form of a Federal Requirements Plan (Bundesbedarfsplan).<sup>10</sup> Including network expansion projects that are already underway (five billion euros), onshore investment needs are expected to be 21 billion euros through 2023.<sup>11</sup> An equivalent offshore network development plan is being created for the grid connection of offshore wind farms. Including investment for starter grid lines that are already in the planning or construction stages (12 billion euros), additional annual investment needs of 22 billion euros up until 2023 are anticipated.<sup>12</sup> This corresponds to an average annual investment of 2.1 billion euros onshore and 2.2 billion euros offshore.

The expansion needs calculated by the transmission network operators should largely be viewed as additional investment requirements generated by the energy transition. However, it is not yet apparent whether all planned projects will actually be implemented within the envisaged timeframe. Delays will result in investment being postponed.<sup>13</sup> In this respect, the figures for expected investment are likely to be liberal estimates.

<sup>9</sup> German Energy Agency (Deutsche Energie-Agentur, dena), dena-Verteilnetzstudie: Ausbau und Innovationsbedarf der Stromverteilnetze in Deutschland bis 2030 (Berlin: December 11, 2012). Information is based on framework data from the middle scenario B in the 2012 Network Development Plan compiled by the transmission grid operators. An additional scenario implies significantly higher investment needs of almost 27 billion euros.

<sup>10</sup> For details on this process, see C. Gerbaulet, F. Kunz, C. von Hirschhausen, and A. Zerrahn, "German Electricity Transmission Grid Remains Robust," DIW Economic Bulletin, no. 20/21 (2013): 3–12.

<sup>11</sup> 50Hertz, Amprion, TenneT, TransnetBW, Netzentwicklungsplan Strom 2013. Erster Entwurf der Übertragungsnetzbetreiber (March 2, 2013). Figures from B 2023 Scenario (2013a).

<sup>12</sup> 50Hertz, Amprion, TenneT, TransnetBW, Offshore-Netzentwicklungsplan 2013. Erster Entwurf der Übertragungsnetzbetreiber (March 2, 2013) (2013b).

<sup>13</sup> A recently published study by DIW Berlin discusses the methodology used by the government for requirement planning and comes to the conclusion that actual expansion needs until 2020 have been overestimated. Delays in grid expansion would not in fact jeopardize the energy transition. Gerbaulet et al. "German Electricity Transmission Grid" (2013).

## System Integration of Renewable Energy

Due to the variable power generation of wind energy and photovoltaics in Germany, and the fact that the shares of these technologies in total energy production are increasing, additional measures will be required for the system integration of these energy sources. These include the flexibilization of thermal power plants, energy storage systems, demand-side measures, and active feed-in management for power generators using renewable energy sources. Measures such as this usually have investment implications which can vary dramatically depending on technology and field of application. However, in recent years, there has been no significant investment in the construction of power storage systems or other installations for the system integration of renewables in Germany.

According to forecasts for up to 2020, estimated investment needs for the aforementioned measures are generally much lower than requirements for electricity generation and grids.<sup>14</sup> With regard to power storage, a series of large pump storage projects are currently in the planning stages with investment of over five billion euros. The developers of all these projects have substantiated their investment with the need to integrate renewables (see Table 4). In the light of current price developments on the electricity exchange and long approval processes, from today's perspective it appears unlikely that these projects will actually be completed by 2020.

For the period after 2020, energy storage systems—not only electricity, but also heat and gas storage—will be needed. In addition, other measures for the system integration of renewables will be necessary with the aim of improving the flexibility of thermal power plants or for the system integration of future electric vehicle fleets, the scale of which cannot yet be accurately quantified. Therefore, even prior to 2020, relevant research, development, and demonstration projects are needed. These are also likely to have certain investment implications. Overall, annual investment of approximately one billion euros should be anticipated for this purpose.

## Energy-Efficient Building Refurbishment

Based on definitions used in the system of national accounts, in 2011, gross investment in the residential cons-

<sup>14</sup> Association for Electrical, Electronic and Information Technologies (Verband der Elektrotechnik, Elektronik, Informationstechnik, VDE), ETG-Task Force Energiespeicherung, Energiespeicher für die Energiewende. Speichungsbedarf und Auswirkungen auf das Übertragungsnetz für Szenarien bis 2050 (Frankfurt: 2012). Also Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Erneuerbare Energien in Zahlen, (2012)

Table 4

**Pump Storage Projects in Germany**

Company	Project	Output in GW	Planned commissioning	Investment in billion euros
Schluchseewerke AG	Atdorf	1.4	2018	1.4
Donaukraftwerk Jochenstein AG	Jochenstein / Energiespeicher Riedl	0.3	2018	0.4
Trianel Power	Simmerath / Rursee	0.6	2019	0.7
Trianel Power	Nethe/Höxter	0.4	2019	0.5
Stadtwerke Trier	Schweich	0.3	2019/2020	0.5
Stadtwerke Mainz	Heimbach	0.4–0.6	2019	0.5–0.7
Trianel Power	Gotha/Talsperre Schmalwasser administrative district	1.0	2019	1.1
Energieallianz Bayern	Jochberg/Walchensee	0.7	No data available	0.6
EnBW AG	Forbach (expansion)	0.2	No data available	No data available
Stadtwerke Ulm	Blautal	0.1	No data available	No data available
Total		5.4–5.6		5.6–5.8

Source: List of power plants from the German Association of Energy and Water Industries (BDEW); research by DIW Berlin.

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Currently, investment of between five and six billion euros is planned for pump storage projects.

truction sector was at least 145 billion euros, and in 2012 the corresponding figure was 150 billion euros. Both of these figures represent almost a third of the total gross fixed capital investments in Germany. This demonstrates the high quantitative importance of residential construction investment for the Germany economy.<sup>15</sup>

The construction volume calculation by DIW Berlin includes detailed information on the structure of residential construction activity.<sup>16</sup> According to the calculation, in 2011, residential construction investment and non-investment construction activity amounted to 166 billion euros. Of the total volume, construction work on existing buildings accounted for 125 billion euros and new builds almost 41 billion euros.

From an environmental and climate policy perspective, investment aimed at improving energy

efficiency is of particular importance.<sup>17</sup> According to estimates from DIW Berlin's construction volume calculation, based on investment enquiries made by building owners and property developers, in 2011, at least 38 billion euros were spent on energy-efficient refurbishment. However, this figure also includes investment in photovoltaic plants and the non-investment share of these construction measures.<sup>18</sup> If an appropriate sum is deducted, for 2011, the estimated relevant expenditure for energy-efficient refurbishment is then approximately 25 billion euros.<sup>19</sup> However, this data not only refers to energy-related incremental costs but also to other additive refurbishment costs. The share of total investment (full costs) attributed to energy-related incremental costs is likely to be between 30 and 40 percent for the majority of construction projects.<sup>20</sup> Accordingly, energy-related

<sup>15</sup> Further, in 2012 an additional 110 billion euros were invested in non-residential construction projects. Apart from investment in non-residential buildings, this figure also includes investment in the transport infrastructure. For more on this, see U. Kunert and H. Link, "Verkehrsinfrastruktur: Substanzerhaltung erfordert deutlich höhere Investitionen," Wochenbericht des DIW Berlin, no. 26 (2013): 32–38.

<sup>16</sup> M. Gornig, B. Gözrig, H. Hagedorn, and H. Steinke, "Strukturdaten zur Produktion und Beschäftigung im Baugewerbe – Berechnungen für das Jahr 2011," analysis commissioned by the German Federal Ministry of Transport, Building and Urban Development (Bundesministerium für Verkehr, Bau und Stadtentwicklung) and the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (Bundesinstitut für Bau-, Stadt- und Raumforschung), BMVBS-Online-Publikation, no. 21 (Berlin: 2012). The construction volume calculation also includes non-investment measures, divided into new and existing buildings.

<sup>17</sup> The following sections do not factor in the new build sector; it is to be assumed that a certain level of additional investment to improve energy efficiency is also required for new builds to ensure that the Energy Concept targets are met.

<sup>18</sup> On this, see Heinze GmbH, "Struktur der Investitionstätigkeit in den Wohnungs- und Nichtwohnungsbeständen," report by Heinze GmbH commissioned by the German Federal Institute for Building, Urban Affairs and Spatial Development (Celle: 2011), eds. S. Hotze, C. Kaiser, and C. Tiller.

<sup>19</sup> Prognos AG estimates the 2010 market volume to be considerably lower. Based on funded measures covering full budgetary costs, the volume of energy-efficient refurbishment is estimated at 12.5 billion euros. See Prognos AG, "Ermittlung der Wachstumswirkungen der KfW-Programme zum Energieeffizienten Bauen und Sanieren," report commissioned by the KfW banking group, (Berlin/Basel: 2013), eds. M. Bömer, N. Thamling, M. Hoch, and G. Steudle.

<sup>20</sup> IW Köln, "Energetische Modernisierung des Gebäudebestandes: Herausforderungen für private Eigentümer," analysis commissioned by Haus & Grund Deutschland, (Cologne: 2012).



additional costs for construction work conducted in 2011 would amount to between seven and ten billion euros.

A further indicator for assessing the scale of energy-efficient refurbishment is the investment contributed by the German Investment and Development Bank (Kreditanstalt für Wiederaufbau, KfW) under the auspices of its funding programs. In 2010, in the field of residential refurbishment, KfW either funded or approved funding for investment in energy-efficient refurbishment to the sum of seven billion euros. In 2011, the volume of funded investment fell<sup>21</sup> to 3.9 billion euros.<sup>22</sup> There is, however, no reliable data available concerning funded investment as a share of total investment for energy-efficient refurbishment.

The future investment need for energy-efficient refurbishment measures in the building sector is considerable. The actual amount invested up until 2020 will be heavily dependent on future measures and regulations for the implementation of climate policy targets. For existing buildings, the previous energy-efficient refurbishment rate will need to be doubled from approximately one percent to two percent per annum. Thus, every planned refurbishment project will have to include energy efficiency components and these should be more comprehensive and ambitious than has usually been the case to date.

According to approximate model calculations by DIW Berlin based on the estimated future area of residential buildings requiring refurbishment and the trend of the specific refurbishment costs, between approximately seven and 13 billion euros in additional annual investment will be needed for the energy-efficient refurbishment of residential buildings up until 2020 (see Figure 2).<sup>23</sup> This sum primarily covers the energy-related incremental costs of these construction projects.

<sup>21</sup> This could be attributed to an anticipatory effect in 2010 and also discussions at the time regarding possible improvements in funding conditions (special tax breaks). Bearing this in mind, the 2011 decline might have simply been a one-off atypical development.

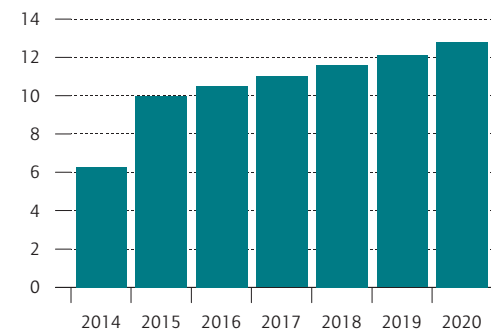
<sup>22</sup> Institute for Housing and Environment (Institut Wohnen und Umwelt, IWU) and Bremer Energie Institut, "Monitoring der KfW-Programme „Energieeffizientes Sanieren“ 2010 und „Ökologisch/Energieeffizient Bauen“ 2006–2010," analysis commissioned by the KfW banking group, (Darmstadt and Bremen: 2011). The Institute of Energy and Climate Research – Systems Analysis and Technology Evaluation (Institut für Energie- und Klimaforschung Systemforschung und Technologische Entwicklung (IEK-STE)) at the Forschungszentrum Jülich, "Wirkungen der Förderprogramme „Energieeffizient Bauen“, „Energieeffizientes Sanieren“ und „Energieeffiziente Infrastruktur“ der KfW auf öffentliche Haushalte: Förderjahr 2011," STE Research Report 07 (2012).

<sup>23</sup> This is based on the assumption that the refurbishment rate will increase linearly from one to approximately two percent between 2013 and 2015 and, thereafter, will continue to grow slightly, partially to offset the accrued backlog of refurbishment work. There is also investment for improving energy efficiency in new builds and other non-residential buildings which is not considered here.

Figure 2

### Additional Investment in Energy-Efficient Building Refurbishment

In billion euros



Based on 2012 prices.

Source: calculations by DIW Berlin.

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Significant additional investment is required in the field of energy-efficient building refurbishment.

However, it is to be assumed that—due to the existing backlog of energy-efficient refurbishment projects—by 2020, the implementation of these projects will be accelerated, which, to a limited extent, will also result in the early implementation of general refurbishment projects.

### Total Annual Investment: 31 to 38 Billion Euros

In summary, the expansion of renewable electricity and heat generation will involve annual investment of approximately 17 to 19 billion euros up until 2020. For power grids, the corresponding figure is around six billion euros and for additional investment in energy-efficient building refurbishment, it is between six and 13 billion euros. Around another billion euros will be required for the system integration of renewable energy sources, such as electricity storage systems, measures for the flexibilization of thermal power plants or for the system integration of future electric vehicle fleets. Thus, overall, from 2014 to 2020, these sectors will require annual investment of approximately 31 to 38 billion euros, the lion's share of which can be considered as additional investment resulting from the energy transition (see Figure 3).<sup>24</sup>

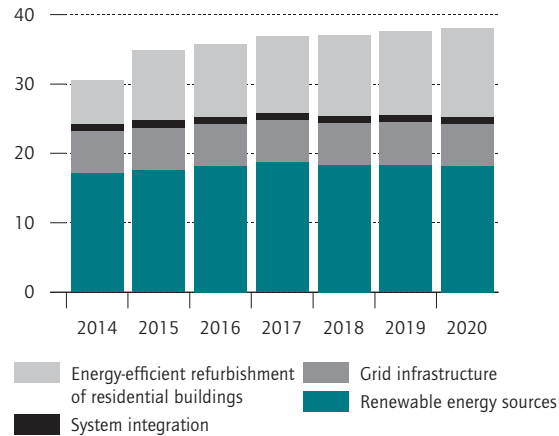
<sup>24</sup> Particularly with regard to renewable power and heat generation, this additionality only applies on the assumption that previous funding measures will be largely discontinued.



Figure 3

### Investment in the Implementation of the Energy Transition by Field of Activity

In billion euros



Based on 2012 prices. System integration includes energy storage and the flexibilization of power plants.

Source: calculations by DIW Berlin.

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The total investment needs for restructuring energy supply will be between 31 and 38 billion euros a year until 2020.

## Macroeconomic Effects of Investment in Renewables

The following will look at different examples of the macroeconomic effects of investment in renewables. As a result of the significant expansion of renewables, in Germany, in the last few years, employment in this sector has dramatically increased. Gross employment in the sector has grown from 160,000 jobs in 2004 to almost 380,000 in 2012, i.e., almost doubled during this period (see Figure 4).

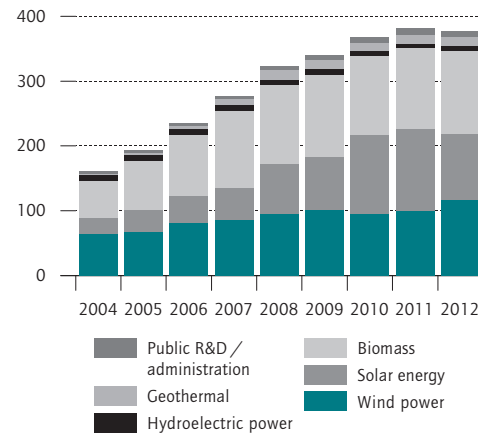
This section considers the possible net effects on the national economy of investment stimuli resulting from the expansion of renewables in electricity and heat generation. DIW Berlin has already analyzed the impact of the expansion of renewable energy based on a model developed specifically for this purpose, SEEEM (Sectoral Energy-Economic Econometric Model).<sup>25</sup> SEEEM is

<sup>25</sup> J. Blazejczak, F. Braun, D. Edler, and W.-P. Schill, "Economic Effects of Renewable Energy Expansion: A Model-Based Analysis for Germany," DIW Discussion Paper 1156 (2011); Also J. Blazejczak, F. Braun, D. Edler, and W.-P. Schill, "Economic Opportunities and Structural Effects of Sustainable Energy Supply," DIW Economic Bulletin, no. 20 (2011): 8–15; and J. Blazejczak, F. Braun, D. Edler, and W.-P. Schill, "Ausbau erneuerbarer Energien erhöht Wirtschaftsleistung in Deutschland," Wochenbericht des DIW Berlin, no. 50 (2010): 10–16.

Figure 4

### Gross Employment due to Renewable Energy in Germany

Number of employees in thousands



Sources: German Aeronautics and Space Research Center (DLR), Institute of Economic Structures Research (GWS), Center for Solar Energy and Hydrogen Technologies Research (ZSW), DIW Berlin.

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Since 2004, gross employment in the renewable energy field has more than doubled.

a macroeconometric multi-country model consisting of detailed representations of individual industries. It can be used to simulate the dynamic effects of economic stimuli (or shocks) both at the macroeconomic level and also with regard to their impact in the individual industries. The following presents updated findings based on more recent data.

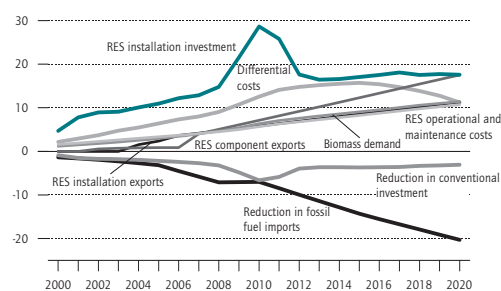
The economic effects are determined by comparing a policy scenario that draws on both current and planned investment, and a hypothetical "zero scenario" that assumes no investment in renewables from the year 2000. Based on this method, a share of the resulting positive effects is attributed to the expansion of renewables in Germany to date. The aforementioned 2011 Lead Study, which describes a possible path towards achieving the targets in the government's Energy Concept, acts as the policy scenario.<sup>26</sup> As well as investment, further economic stimuli that form the basis of the model are: operational costs, a reduction in fossil fuel imports, and also exports of components and installations. Other

<sup>26</sup> German Aeronautics and Space Research Center (DLR), Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), Ingenieurbüro für neue Energien (IfnE), Langfristszenarien und Strategien (2012).

Figure 5

### Economic Stimuli in Expansion Scenario 2000 to 2020

In billion euros



Based on 2012 prices. RES: renewable energy sources.  
Sources: German Aeronautics and Space Research Center (DLR), Institute for Wind Energy and Energy System Technology (IWES), IfnE, Langfristszenarien und Strategien (2012); calculations by DIW Berlin.

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As well as investment, other stimuli are also factored into the model.

stimuli factored into the model are a reduction in investment in the conventional power industry and also the additional costs (differential costs) of expanding renewables (see Figure 5).

### Investment in Renewables Generates Sustained Increase in GDP

The model calculations indicate that the additional investment in expanding renewable energy sources in Germany, combined with exports of installations and components result in a sustained increase in added value. In the policy scenario, in 2010, GDP is 2.1 percent higher than in the zero scenario, and in 2020, it is 2.8 percent higher (see Table 5).

The employment effects that accompany this development largely depend on the scale of productivity growth acceleration. In 2010, per capita labor productivity was two percent higher than in the scenario with no expansion of renewables, and in 2020, the corresponding figure was almost three percent. A similar increase in added value and productivity creates merely a slight change in employment; only initially is employment slightly higher (by around 43,000 jobs). The model demonstrates that, in the long term, employment and production develop at the same pace. If the model were based on alternative assumptions, larger net employment effects might be

Table 5

### Impact of Expansion of Renewable Energy

Deviations from zero scenario

	2010	2020
	In percent	
GDP	2.1	2.8
Private consumption	1.1	2.2
Private capital investment excluding investment in residential construction	13.5	10.0
Export	1.0	1.2
Import	1.6	0.9
Per capita productivity	2.0	2.8
	In thousands	
Employees	43.0	14.0

Source: calculations by DIW Berlin.

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The expansion of renewables results in increased growth as compared to the zero scenario.

observed.<sup>27</sup> Depending on labor market conditions, there could also be higher growth in employment even if productivity were to accelerate more slowly, particularly if suitable additional labor could easily be mobilized.

Initially, private capital investment (excluding residential construction) is, in real terms, at least 13 percent higher than without the expansion of renewables and in 2020, the corresponding figure is still as high as ten percent. This also reflects the increased investment activity in other branches of the economy as a result of an overall increase in economic activity. This additional investment also contributes to productivity growth. Increased income also facilitates increased private consumption, which, in 2010, was 1.1 percent higher than in the zero scenario, and 2.2 percent higher in 2020.

The expansion of renewables in Germany improves the global market position of German renewable energy companies. In real terms, total exports are approximately one percent higher than in the zero scenario.<sup>28</sup> At the same time, however, imports are also increasing. The relatively significant increase in imports observed in 2010 can be explained by the fact that use of renewable energy is still relatively restricted, resulting in only a marginal reduction in imports of fossil fuels; si-

<sup>27</sup> For sensitivity calculations, see Blazejczak et al. "Economic Effects" (2011).

<sup>28</sup> This is slightly less than the stimulus for the export of renewable energy plants and components. The observed lessening of the export stimulus can be attributed to the fact that a change in the relative prices resulted in fewer exports of other goods.

Table 6

**Loans Granted by KfW Renewable Energy Program (New Approvals)**

Program	Number (in thousands)					Volume (in billion euros)				
	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012
Standard	26.0	36.6	63.2	34.9	25.7	2.8	4.6	8.9	6.5	7.6
Supplementary	–	0.0	0.0	–	–	–	0.6	0.4	–	–
Premium	0.4	2.1	2.3	2.8	2.7	0.0	0.3	0.3	0.5	0.4
Offshore wind energy	–	–	–	0.0	–	–	–	–	0.5	–
Total	26.5	38.7	65.5	37.7	28.4	2.8	5.5	9.6	7.6	7.9

Sources: KfW, Funding Report by KfW Banking Group (2013). Reporting date: December 31, 2012; calculations by DIW Berlin.

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The KfW loan programs represent an important source of financing for renewable energy.

multaneously, the consumer import demand has a relatively high elasticity. Due to dynamic adjustment effects, at the end of the period examined, the external contribution is about the same as in the zero scenario, despite significant stimuli for the export of renewables and import of fuels.

Sensitivity calculations indicate that, even using alternative assumptions, for example, with regard to the development of the German economy's competitive capacity on global markets, additional investment could still result in positive net macroeconomic effects.<sup>29</sup> One reason for this is that, to a great extent, investment in renewables means that Germany can avoid importing fossil fuels while, at the same time, increasing its domestic economic activity.

Similar effects to those generated by investment in renewables can also be expected with regard to other types of investment. Energy-efficient refurbishment is a prime example of this. Investment is offset by future energy savings and thus also reduced energy imports. However, it can be assumed that the weighting of the effects varies. While technology content and thus also export opportunities presumably have less of an impact, the high share of domestic added value and the high labor intensity in the finishing construction sector are likely to result in stronger positive effects.

### Stable Framework Necessary

The following section discusses the existing framework conditions as well as those that will be required in fu-

ture to enable the aforementioned investment to be implemented. In all three areas, the focus is basically on mobilizing long-term private investment by creating a suitable framework. In future, institutional investors, such as pension providers, which, across Europe, are currently looking for large-scale long-term investment opportunities,<sup>30</sup> could play a bigger role.

### Maintain Investment Framework for Renewables

To ensure that the targets for the expansion of renewable energy in Europe are met, a general framework is set out in the EU Directive 2009/28/EG. According to the subsidiarity principle, the choice of specific promotion programs and mechanisms are left up to the individual member states. In Germany, use of renewable energy is supported using a series of different measures. Apart from funding for research and development, the most important mechanism in the electricity sector is the German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG) which provides for guaranteed feed-in and fixed tariffs. In the heating sector, the expansion of renewables is primarily fostered through government subsidies (for measures in existing buildings and market incentive programs) and via regulatory provisions (mandatory use of renewables in new buildings and the German Renewable Energies Heat Act (Erneuerbare-Energien-Wärmegesetz, EEWärmeG)). The use of renewables in the transport sector, however, is primarily supported by way of biofuel quotas. These and similar measures will continue to be essential in future to ensure that the expansion targets are met. In

<sup>29</sup> Blazejczak et al. "Economic Effects" (2011).

<sup>30</sup> House of Lords, European Union Committee, "No Country is an Energy Island: Securing Investment for the EU's Future," 14th Report of Session 2012–2013 (May 2, 2013).

Germany, investment in installations for the use of renewable energy sources is also promoted by KfW loan programs (see Table 6).

The feed-in tariff (EEG) is of particular importance for the expansion of renewables. It has proven to be an effective instrument in fostering electricity generation from renewable energy sources and its basic structure has been adopted by a large number of other countries. The role of the EEG is shifting more and more from an instrument to subsidize renewables to an instrument to secure revenue streams to facilitate investment in renewables. This is reflected in falling generation costs from renewables and correspondingly dramatic reductions in tariffs.

The importance of the EEG as a financial instrument is particularly apparent in the field of wind and solar energy—two technologies where the cost of power generation is dominated by capital costs. Without EEG support, plant operators would be particularly exposed to the risks of the liberalized electricity market. Thus, for example, the economic crisis led to a decline in energy demand, bringing falling electricity prices in its wake. This effect is exacerbated by the currently very low and also unstable price of CO<sub>2</sub> emission certificates. The energy transition has also resulted in other uncertainties. New technologies with a modified cost structure result in new market prices that are difficult to forecast. In the transitional period, the accelerated deployment of renewables reduces generation scarcity and thus also wholesale prices.

Against the backdrop of these uncertainties, a key advantage of the EEG becomes apparent. For investors, the feed-in tariff that is guaranteed for 20 years alleviates the impact of future regulatory decisions regarding the expansion of renewables and the power grids, but also of market design or the EU Emissions Trading System. The long-term social contract between producers and consumers implied in the EEG minimizes market risks on both sides. This safeguards long-term private investment and significantly reduces costs for financing power plants. Ultimately, this also leads to a reduction in overall costs.<sup>31</sup>

To date, investment required for the energy transition has been made largely by private households by virtue of the framework created by the EEG. Approximately 40 percent of the total investment in renewables originated from private households and a further 11 percent

from farmers.<sup>32</sup> The number of energy cooperatives has increased particularly rapidly. However, without major investors, it will not be possible to successfully implement the energy transition.<sup>33</sup> These investors also need a stable framework in order to be able to make investments with a moderate minimal share of “own capital” and a predominant share of “borrowed capital” (up to 80 percent). Without borrowed capital, even the major energy suppliers would not be in a position to finance extensive investment in renewable energy projects, and would only be able to justify the remaining investment if they could expect significantly higher returns.

The further expansion of renewables also requires a stable framework for investors which can be provided by retaining the feed-in tariff system. Prudent adjustments are, however, necessary here to ensure that a balance is maintained between an acceptable financial burden for energy consumers and sufficient prospects of a sustained high level of investment. This would create a basis for further development of the value chain and also stimuli for further innovations.

### Sufficient Investment in Power Grids

German national power grids are owned by private companies. Of the four transmission networks, the TransnetBW network is however owned by the federal state of Baden-Württemberg and the TenneT network is owned by the Netherlands.

The German Federal Network Agency (Bundesnetzagentur) is the regulatory authority that oversees network operators within the framework of incentive regulation. In particular, the Agency limits maximum permissible revenues with the aim of preventing network operators from taking advantage of their natural monopoly at the expense of the customer. At the same time, network operators are given incentives to improve quality and reduce costs. Linking incentives with future revenues, however, also results in uncertainty for investors. Therefore, a regulatory regime needs to achieve a balance between cost reduction incentives and adequate investment incentives. The introduction of incentive regulation meant that the focus was initially on developing cost reduction potential in power supply operation. With investment in maintenance and expansion increasing,

<sup>31</sup> L. Butler and K. Neuhoﬀ, “Comparison of feed-in tariff, quota and auction mechanisms to support wind power development,” *Renewable Energy* 33 (8), (2008): 1854–1867.

<sup>32</sup> German Renewable Energies Agency (Agentur für Erneuerbare Energien, AEE), *Energie in Bürgerhand* (Berlin: October 20, 2011).

<sup>33</sup> C. Kemfert and D. Schäfer, “Financing the Transformation of the Energy System in Times of Great Instability of Financial Markets,” *DIW Economic Bulletin*, no. 31 (2012): 3–14.

the reduction of regulatory uncertainty and thus also investment risks is becoming increasingly important.<sup>34</sup>

This is reflected in questions surrounding the longer term approach to investment projects. The Federal Network Agency (Bundesnetzagentur) evaluates investment projects and determines whether it is permissible for the costs to be passed on to the final energy consumer. Currently, a return on equity of 9.05 percent before corporate tax (10.48 percent before corporate and commercial tax) is guaranteed on new and or expansion investments.<sup>35</sup> However, in each case, the decision to expand the grid only applies to the current regulatory period (five years) and can also include the next regulatory period (investment budgets). Thus, despite the government decision to expand the grid, medium-term risks arise relating to the extent to which the costs of these various power lines will be accepted and at what rate of return.

This is one of the factors explaining why, as in the rest of Europe, network operators in Germany only borrow approximately two euros for every euro of own capital despite apparently secure investment opportunities in a government-guaranteed infrastructure.<sup>36</sup> On the one hand, this increases the financing costs and, on the other hand, means that growth in own capital is essential to finance grid expansion. However, public-sector owners are hesitant about providing more capital themselves, yet, at the same time, are reluctant to accept additional owners. This is why the Federal Network Agency has recently been calling for a reduction in regulatory risks for investors. In this context, for example, improved liability regulations have been introduced for connecting offshore wind farms to the grid.

### Additional Incentives for Investment in Energy-Efficient Building Refurbishment

Since the introduction of the German Energy Saving Ordinance (Energieeinsparverordnung, EnEV) in 1979, the heating requirements of new buildings have been reduced by a factor of three. This development can be attributed to a combination of standards and funding programs. Many of the components contributing to im-

proved energy efficiency in new builds have also been adopted in the energy-efficient refurbishment of existing buildings.

The energy-related investment needs of existing buildings are far greater than in new buildings. However, investors often lack the capital and long-term planning perspective for and also interest and confidence in energy-efficient refurbishment. Further obstacles include the “owner-user dilemma” in the refurbishing of rental properties and the unique nature of the complex investment decision that has to be made by the proprietors of owner-occupied detached or semi-detached properties.

However, to date, financial incentives, combined with existing complementary measures (such as information provision, certification, and training) have not been sufficient to ensure that the Energy Concept targets are met. Therefore, in 2011, the German government proposed an additional tax incentive, which, however, was ultimately not approved by the Bundesrat (upper house of German parliament) due to the issue of cost sharing between the national government and the Länder. A political agreement on rapidly effective measures for existing buildings is urgently required since, without a dramatic improvement in energy efficiency, the targets for the entire energy transition will be jeopardized.

### Conclusion and Economic Policy Implications

As outlined above, significant investment is required to meet the targets set out in the German government’s 2010 Energy Concept and to implement the accelerated nuclear phase-out. This applies to installations for the use of renewable energy sources in the electricity and heating sector as well as infrastructure such as power grids, and also, in future, energy storage systems and other measures for the system integration of renewable energy sources. Significant investment is also needed to improve energy efficiency, for instance using heat insulation for buildings. Without a considerable increase in energy efficiency, the energy transition targets simply will not be met. In the aforementioned areas, between 2014 and 2020, annual investment of between 31 and 38 billion euros will be required.

Model calculations by DIW Berlin use examples to illustrate that the expansion of renewables could have a lasting positive effect on macroeconomic development in Germany. This stems from additional domestic investment and the knock-on reduction in imports of primary fossil fuels, the additional demand for biomass fuels, and also the possible development of further export poten-

<sup>34</sup> European Commission, Green Paper on the long-term financing of the European economy, (Brussels: March 25, 2013), COM (2013) 150 final.

<sup>35</sup> German Federal Network Agency (Bundesnetzagentur) press release, November 2, 2011. In practice, however, this figure is not often reached. U. Büdenbender, Die Angemessenheit der Eigenkapitalrendite im Rahmen der Anreizregulierung von Netzentgelten in der Energiewirtschaft (Düsseldorf: 2011).

<sup>36</sup> For a detailed discussion, see K. Neuhoﬀ, R. Boyd, and J. M. Glachant, European Electricity Infrastructure: Planning, Regulation, and Financing, workshop report (2012).

tial in the renewable energy sector. At the same time, it will also lead to a considerable reduction in energy-related greenhouse gas emissions.

The existing framework for investment in renewable electricity and heat generation is largely appropriate. In the electricity sector, the Renewable Energy Sources Act (EEG) is particularly central, and it is suggested that the law will, in essence, be retained in the foreseeable future. The fixed prices stipulated by the law provide security for private investors and thus also ensure low financing costs. Due to declining tariff levels, the additional financial burden borne by energy consumers is lower for new plants than for existing ones.

With regard to the power grids, the existing refinancing options for investments that are part of the incentive regulation framework are essentially adequate. A gradual reduction in regulatory risks would lead to a further reduction in own capital requirements for investors and thus also financing costs in the medium term.

Contrary to investment in renewables where the prevailing framework is, in essence, likely to be retained, there is a need for urgent action with regard to energy-efficient buildings refurbishment if government targets are to be met. The aim of accelerating the rate of refurbishment requires additional financial incentives for example through KfW funding programs. Further development of the qualification and certification processes for consultants and tradesmen is also needed here.

Fundamentally, all investment in the energy sector requires a reliable and long-term framework. This also implies making use of the possibilities available within the European framework and integrating longer term targets for emission reductions, improvements in efficiency, and the use of renewable energy beyond legislative periods. The European Commission has launched the debate on this subject with its Green Paper on a 2030 framework for climate and energy policies.<sup>37</sup> This should aim to create stable conditions for companies making investment decisions for the European market.

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**JEL:** Q42, Q43, Q48, Q52

**Keywords:** Energy transition, investment, renewable energy, energy efficiency

First published as »Energiewende erfordert hohe Investitionen«, in: DIW Wochenbericht no. 26/2013.

<sup>37</sup> European Commission, Green Paper: A 2030 Framework for Climate and Energy Policies (Brussels: March 27, 2013), COM(2013) 169 final.





Prof. Dr. Claudia Kemfert, Head of the Department of Energy, Transportation, Environment at DIW Berlin

## SIX QUESTIONS TO CLAUDIA KEMFERT

# »Investment in Energy Transition Has Unequivocally Positive Impact on Economy«

1. Professor Kemfert, the Federal Environment Ministry anticipates that, over the next ten years, approximately 200 billion euros in investment will be needed for renewable energy sources alone. Will this be sufficient to increase the share of renewables to 18 percent by 2020? Yes, absolutely. We are well on schedule to achieve this. The share of electricity produced from renewables was already as high as almost 22 percent in 2012. Now the focus should be on maintaining investment in sustainable electricity and heat generation and also in fuels. Another important aim should be to improve the energy efficiency of buildings, which has unfortunately been somewhat neglected in energy policy to date.
2. How much needs to be invested over the next few years? According to our estimates, up to 20 billion euros a year are invested annually in renewables, approximately six billion euros in the power grids, and a somewhat smaller sum of up to one billion euros in system integration, such as energy storage. An additional investment of up to 13 billion euros is required for building refurbishment.
3. What are the macroeconomic effects emanating from investment in renewable energy sources? The macroeconomic impact is unequivocally positive. Based on a model developed for this purpose, we have calculated that investment in all the areas mentioned will result in a sustainable increase in GDP which, in turn, will bring positive employment effects in its wake.
4. How significant is the impact on the market position and competitiveness of German technology providers? We anticipate that competitive capacity will be boosted

as a result of investment in innovative technologies, whether in the field of renewables, energy efficiency, or innovative power networks. Further, improving energy efficiency will also significantly reduce energy costs. This gives the German economy a considerable competitive edge.

5. How great is the risk that investment plans will not come to fruition by 2020 and what ramifications would this have? The risk of projects not being implemented due to insufficient investment, at least on the scale required, is definitely very real. This is due to the fact that the German government is fomenting anxiety and thus deterring investors. A stable political framework is required in the longer term to attract rather than deter investors. There is certainly sufficient available capital.
6. What are the most important tools for securing the long-term financing of the energy transition? It is important to retain the German Renewable Energy Sources Act (EEG). One or two amendments to the Act would be acceptable, but the current debate about abolishing or radically changing it and introducing a completely new system is not constructive. This simply deters investors. With regard to electricity grids, regulatory risks should be minimized. When it comes to improving energy efficiency in the buildings sector, the aim should be to create real financial incentives, both in terms of direct financing and tax breaks, and also when it comes to the professional qualifications of those carrying out energy-efficient refurbishment. This would facilitate a successful energy transition.

Interview by Erich Wittenberg.



# European Electricity Generation Post-2020: Renewable Energy Not To Be Underestimated

by Christian von Hirschhausen, Claudia Kemfert, Friedrich Kunz, and Roman Mendelevitch

In its Green Paper on a 2030 framework for climate and energy policies, the European Commission calls for a framework for the future development of environment and energy policy beyond 2020. However, much like the Energy Roadmap 2050 adopted by the Commission in December 2011, the Green Paper is based on scenario assumptions that are, to a great extent, not up-to-date. The European Commission would need to provide updated model calculations rapidly to enable energy policy decisions to be taken on the basis of transparent and comprehensible scenarios.

A comparison of recent estimates conducted by DIW Berlin indicates that the Commission systematically underestimates the cost of nuclear power and carbon capture, transport, and storage (CCTS), while the cost of renewables tends to be overestimated. In particular this applies to photovoltaics where current capital costs are, to a certain extent, already lower than the Commission's estimates for 2050. In contrast to renewables, neither nuclear energy nor carbon capture, transport, and storage are cost efficient enough to play a central role in the future European electricity mix. It is therefore vital for Europe to continue to focus on the further development of renewables. This requires the setting of ambitious renewables targets for 2030 as well as clear emissions reduction and energy efficiency targets.

In 2009, the European Commission agreed on a package of directives for energy and climate conservation<sup>1</sup> which contained specific targets for the year 2020 (known as 20-20-20 targets). The objectives were a 20 percent reduction in greenhouse gas (GHG) emissions by 2020 (compared to 1990 figures), a 20 percent improvement in energy efficiency over current forecasts and an increase in the proportion of renewables in overall energy consumption (gross final energy consumption for electricity, heat and transport) to 20 percent. To achieve these targets, the intention was to reform emissions trading as a key instrument for reducing greenhouse gases and to set national targets for increasing the share of renewable energies.<sup>2</sup> These energy efficiency targets were agreed in the Energy Efficiency Directive<sup>3</sup> and the Energy Efficiency Plan.<sup>4</sup>

Targets for 2020 have so far been achieved to varying degrees. The EU's emission reduction targets, for example, have already been almost fully achieved. In 2011, emissions were only about two percentage points above the reduction target.<sup>5</sup> The EU has certainly made progress on the renewables target and has increased the share of renewable energies in gross final consumption from 8.5 percent in 2005 to 13 percent in 2011.<sup>6</sup> However, there are still concerns about whether the overall target for 2020 will be achieved. To do this, renewables in Euro-

<sup>1</sup> European Climate and Energy Package of 2009. This includes Directives 2009/28/EC on renewable energies, 2009/29/EC on emissions trading, 2009/31/EC on CO<sub>2</sub> storage and Decision 406/2009/EC on effort sharing.

<sup>2</sup> Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources.

<sup>3</sup> Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency.

<sup>4</sup> European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Energy Efficiency Plan, 2011 (Brussels: March 8, 2011) COM (2011) 109 final.

<sup>5</sup> European Environment Agency (EEA), Annual European Union greenhouse gas inventory 1990–2011 and inventory report 2013 (Technical report no. 8/2013). (Copenhagen: 2013).

<sup>6</sup> Eurostat, Europe 2020 indicators (2013).

pe would have to grow by an average of more than six percent per annum.<sup>7</sup> In terms of the efficiency target, the consensus here is that increased efforts are necessary to achieve the 20 percent target.

### Green Paper 2030: EU Launches Debate on Energy and Climate Strategy

The European Union and the 28 member states which are responsible for the national energy mix under Article 194 of the EU Treaty<sup>8</sup> will soon have to make strategic decisions about the future structure of power generation beyond the year 2020. With its Green Paper on “a 2030 Framework for Climate and Energy Policy”,<sup>9</sup> the European Commission is launching a discussion on the direction of European energy and climate policy beyond the year 2020. In consultations on the Green Paper 2030, questions were asked about experience gained from the energy and climate policy framework up to 2020 and further developments in the coming decade. The reasons for compiling the roadmap up to 2030 at this early stage are the length of investment cycles and the need for fixed framework conditions. In addition, existing long-term targets must be substantiated by binding intermediate targets. Consequently, both the climate roadmap and the Energy Roadmap 2050 contain explicit reductions in GHG emissions by 2050 of 80 to 95 percent compared to 1990; these figures assume a far-reaching decarbonization of the power sector.<sup>10</sup>

The Green Paper builds on the long-term targets of the European energy and climate policy: the European Union has committed itself to reducing GHG emissions significantly and to increasing the share of renewables. At the same time, the competitiveness of the European economy should be improved, while increasing security of energy supply, and ensuring affordability of energy in the internal energy market. In particular, the EU plans to reduce GHG emissions by 80 to 95 percent. To achieve this, it will be necessary to establish binding GHG reduction targets for 2030. The European Com-

mission has proposed introducing an interim reduction target of 40 percent by 2030.

Going beyond the issue of target setting, the Green Paper also highlights the problem that two important policy instruments currently show very little impact towards the creation of a sustainable energy mix. These instruments are the emissions trading scheme, and promoting schemes for the carbon capture, transport, and storage (CCTS) technology. Emissions trading leads to insufficient price signals because there are too many surplus certificates on the market and limits on the number of emissions were not consistently adjusted downward.<sup>11</sup> As a result, the very low CO<sub>2</sub> price (currently at three to five euros per ton) fails to set the necessary signals required for long-term innovation in the field of low-CO<sub>2</sub> power generation technologies.<sup>12</sup> Furthermore, the EU's efforts to develop the CCTS technology have come to nothing because neither the energy industry nor national governments have made corresponding efforts to implement the technology.<sup>13</sup>

### Green Paper 2030 Based on Outdated Assumptions and Puts Renewables at a Disadvantage

When the Green Paper was compiled by the Commission, there were no updated model runs and scenarios available, so it had to rely on cost assumptions that were up to four years old. In particular, it failed to take into account the most recent development in costs of renewable energies.<sup>14</sup> As a result, neither the European Commission nor the member states, nor citizens who were also called on to participate were able to form their opinion based on current and transparent calculations.

In particular, the Green Paper neglected to factor in recent sharp reductions in the production costs of renewable energy. Moreover, the development of costs of

<sup>7</sup> Germany has committed to a national target of 18 percent, in 2011, according to Eurostat, the share of renewables in final energy consumption was 12.3 percent.

<sup>8</sup> According to Article 194 of the EU Treaty, energy policy is a shared competence of the European Union and the member states. In particular, member states still have sole decision-making authority over the energy mix. Nevertheless, specific EU measures and other stimuli are of great importance. As a result, the efficiency of almost all power generation technologies is directly influenced by European directives or regulations.

<sup>9</sup> European Commission, Green Paper: A 2030 framework for climate and energy policies (Brussels: March 27, 2013), COM (2013) 169 final.

<sup>10</sup> European Commission, Energy Roadmap 2050 (2011), COM (2011) 885 final, and European Commission, A Roadmap for moving to a competitive low carbon economy in 2050 (2011), COM (2011) 112 final.

<sup>11</sup> K. Neuhoﬀ and A. Schopp, “Europäischer Emissionshandel: Durch Backloading Zeit für Strukturreform gewinnen,” Wochenbericht des DIW Berlin, no. 11 (2013).

<sup>12</sup> See open letter to Chancellor Angela Merkel on European emissions trading, dated 18 March 2013, and J. Diekmann, “EU-Emissionshandel: Anpassungsbedarf des Caps als Reaktion auf externe Schocks und unerwartete Entwicklungen?,” report commissioned by the Federal Environment Ministry, Climate Change, no. 17 (Dessau/Berlin:2012).

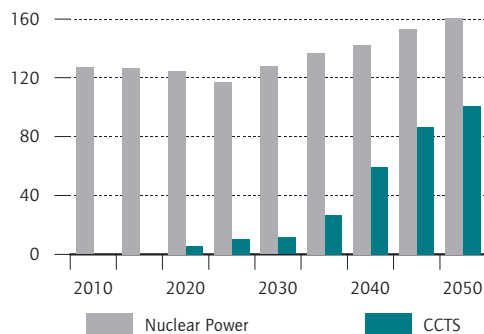
<sup>13</sup> In this regard, the Green Paper 2030 refers to two simultaneous consultations on i) international negotiations on a new legally binding agreement on climate protection and ii) a concept for demonstrating technologies for CO<sub>2</sub> capture, transport and storage.

<sup>14</sup> In addition, the responsible Directorate-General for Energy still has not presented the “Reference and Policy Scenarios 2050” from that time which, in addition to European level model calculations, also contain results for each member country.

Figure 1

### Installed Capacity of Nuclear Power and CCTS According to the Energy Roadmap<sup>1</sup>

In gigawatts



<sup>1</sup> Based on the reference scenario.

Source: Prepared by DIW Berlin based on European Commission (2011).

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The Energy Roadmap forecasts a sharp rise in the output of CCTS power plants by 2050.

thermal power generation after the nuclear accident in Fukushima and the persistent lack of operating CCTS demonstration projects must be taken into account. For technical and economic reasons, third-generation nuclear power plants and CCTS technology are unlikely to play a major role in the future energy mix of the EU. Although neither technology is available on an operational level yet, significant cost reductions have been predicted. As a result, some scenarios anticipate that, by 2050, both technologies become the cornerstones of European electricity supply (see Figures 1 and 2).

In the reference scenario capacity of nuclear power plants increases from the current 127 gigawatts to 161 gigawatts by 2050. Power plant capacity with CCTS technology, which is currently not available in demonstration plants in Europe or anywhere in the world, will jump from zero to over 100 gigawatts by 2050. In the following the plausibility of these results is scrutinized and the assumptions behind them are challenged.

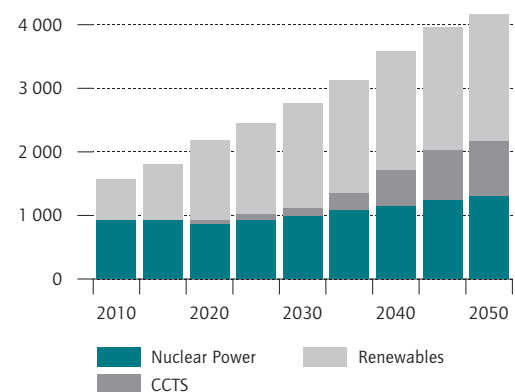
### Literature Study by DIW Berlin on Current Cost Trends

As a basis for the development of its electricity market model (ELMOD), DIW Berlin conducted a systematic survey of the costs of renewable and conventional power

Figure 2

### Electricity Production from Nuclear Power, CCTS and Renewable Energy Sources According to the Energy Roadmap<sup>1</sup>

In terawatt-hours



<sup>1</sup> Based on gross power generation in the reference scenario.

Source: Prepared by DIW Berlin based on European Commission (2011).

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According to the Energy Roadmap, nuclear power and CCTS are the cornerstones of power supply.

generation.<sup>15</sup> Here, investment costs for a wide range of production technologies were quantified and own analyses of operating costs were conducted, based on exogenous parameters such as fuel costs. The study also discusses the differences between various quantification approaches and develops plausible development paths from today's perspective. Selected results of this analysis are used as an aid in the following discussion of future scenarios for European energy supply, particularly in comparison with figures contained in the Energy Roadmap 2050.

The use of a comprehensive cost concept depends on the inclusion or non-inclusion of relevant cost factors. While a private investor is primarily focused on private production costs, the government's energy and environmental policies should take into account all costs, including social environmental and transaction costs (see box).

<sup>15</sup> A. Schröder, F. Kunz, J. Meiss, R. Mendelevitch, and C. von Hirschhausen, "Current and Prospective Costs of Electricity Generation until 2050," Data Documentation, no. 68, DIW Berlin (2013). In the following, all details relate to this data documentation unless otherwise stated. The authors would like to thank Mr. Schröder for his assistance with the literature and data research conducted in preparing this weekly report.

## Box

**Cost Components**

The development of power generation costs is an important indicator for assessing future developments in the energy system. However, there are methodological and practical differences in quantifying power generation costs that can lead to varied and controversial assessments. Therefore it is necessary to take account of the assumptions made in determining current and future cost structures and to depict cost categories transparently.

In principle, a distinction should be made between *private* and *social* costs: private costs refer to costs incurred by the power producer, while social costs also take into account costs borne by society, such as the cost of environmental pollution.

Furthermore, a distinction should be made between production and *transaction* costs:

- Production costs are the costs of generating electricity directly incurred in the production process, which consist of investments, fixed operating and maintenance costs, and CO<sub>2</sub> allowance costs;
- Transaction costs include the provision of the necessary framework, for example within the company, in terms of market infrastructure or in terms of the overall energy policy framework.

A largely neglected category of transaction costs is risk costs, which include the costs of unforeseeable events borne by the investor, society or other stakeholders. These events can be "normal" risks, such as market and regulatory risks, but also technological risks, such as a serious accident. Risk costs can accrue explicitly in the form of insurance costs but can also occur implicitly by increasing the capital costs of financing. In the case of major uninsured risks, society bears the risk costs, for example, of major nuclear power plant accidents. The risk costs incurred here can be considerable, but are often erroneously neglected in quantitative investment appraisals.

Furthermore, it is common to make a distinction between the timing of the costs: Variable costs are short-term costs dependent on production quantities (operating costs), whereas fixed costs are short-term but do not depend on production; in the long term all costs are variable and subsumed under the term "standardized average costs" (levelized cost of electricity, LCOE). Additional aggregates can be analyzed beyond the specific costs of individual technologies, for example, energy system costs or macroeconomic effects.<sup>1</sup>

<sup>1</sup> M. Pahle, B. Knopf, O. Tietjen, and E. Schmid, "Kosten des Ausbaus erneuerbarer Energien: Eine Metaanalyse von Szenarien," *Climate Change*, no. 23 (Dessau/Berlin: Federal Environment Agency, 2012).

## Costs of Nuclear Energy Prohibitively High

Right from the beginning, the use of nuclear power for civilian purposes was never really exposed to market competition. After World War II, some countries developed nuclear power generation with military objectives in mind. Either government-owned enterprises were entrusted with the task (such as in the UK and France) or private businesses were given government grants or guarantees to encourage them to develop nuclear energy (for example, in Germany and the US).<sup>16</sup>

A detailed survey of the total cost of power generation from nuclear power plants is particularly difficult. Costs are incurred in research and development, the construction, operation and decommissioning of the power plant. Fuel costs and other variable costs as well as the

costs of possible accidents (cost of risk) should also be taken into account.

Due to technical uncertainties and the increasing safety requirements of nuclear power the technology has not become cheaper over the decades—in contrast to all other power generation technologies—but rather its capital costs have increased many times over. For example, the output-specific investment per kilowatt in France in 1980 was approximately 1,000 euros, in 1990 it was between 1,300 and 1,600 euros, and in 2000 it was between 1,500 and 3,000 euros (see Figure 3).<sup>17</sup> In the US, too, output-specific investment rose significantly from 1973 (ca. 1,000 US dollars/kilowatt) to 1990

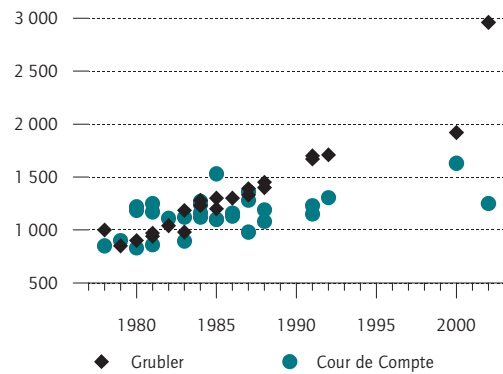
<sup>16</sup> J. Radkau and L. Hahn, *Aufstieg und Fall der deutschen Atomwirtschaft* (Munich: 2013). In socialist countries like the Soviet Union, the GDR or China, or in emerging countries such as Iran, the development of nuclear power had already extended beyond any economic considerations.

<sup>17</sup> Based on 2010 prices. See L. Rangel and F. Lévêque, "Revisiting the cost escalation curse of nuclear power. New lessons from the French experience," Working Paper 12-ME-08, Interdisciplinary Institute of Innovation, (Paris: 2012), and A. Grubler, "The cost of the French nuclear scale-up: A case of negative learning by doing," *Energy Policy* 38 (2010): 5174-5188. Rangel and Lévêque refer to Grubler and to cost data from the French Court of Auditors (Cour de Comptes).

Figure 3

### Historic Specific Investment Costs<sup>1</sup> for French Nuclear Power Plants

In euros per kilowatt



<sup>1</sup> Based on 2010 prices. Figures related to "second generation" nuclear power plants. Projections by Grubler and the French Court of Auditors (Cour de Compte).

Source: Prepared by DIW Berlin based on Rangel and Lévêque (2012).

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New nuclear power plants are becoming increasingly expensive over time.

(ca. 5,000 US dollars/kilowatt).<sup>18</sup> The reasons for this are, in particular, more stringent safety regulations, changing standards, and a lack of continuity in the construction of nuclear power plants.

Past experience of rising capital costs appears to apply to the current stage of development for the "Third Generation" (European Pressurized Reactor, EPR) of nuclear power plants. The cost estimates for the two nuclear power plants currently under construction in Olkiluoto (Finland) and Flamanville (France) are continually increasing. In 2006, the original estimate was 1,500 euros per kilowatt. Since then it has risen to 4,500 euros per kilowatt (mid-2008)<sup>19</sup> and has recently climbed to 5,100 euros per kilowatt (December 2012).<sup>20</sup> Reasons for this include planning errors, problems with the automatic control systems, and also revised safety requirements.<sup>21</sup>

The planned construction of a new nuclear power plant in the UK also underlines the high costs of nuclear power. Negotiations are currently being held between the

government and the French state company EdF on the level of financial security the latter should receive to build a new third-generation nuclear power plant. It is becoming apparent that the potential investor is not keen on making market-based investments, and is also calling for a very high price guarantee.<sup>22</sup> In the discussion, a "strike price" (equivalent to the German feed-in tariff) is somewhere in the region of 100 pounds sterling (about 116 euros) per megawatt-hour over 40 years plus government guarantees to secure against various risks. By way of comparison, this is roughly the same as the "strike price" for onshore wind turbines in the UK, but this is only granted for 15 years.

### Costs for Disposal and Insurance Often Neglected

The cost of disposing of spent fuel elements is still largely unknown because even after six decades of nuclear energy use there are no permanent disposal sites anywhere in the world that guarantee the safe storage of nuclear fuel rods for tens of thousands of years. In Germany, too, it is likely to take at least another 15 years before a suitable site can be identified. The concern remains that the full costs of disposal will continue to be inadequately considered in energy system models.

Another important, but often neglected, cost factor is insurance against potential major accidents. The costs of such major accidents at nuclear power plants can be extremely high and are difficult to quantify.<sup>23</sup> Currently, these costs are borne primarily by society because nuclear power plant operators are only subject to very few insurance obligations.<sup>24</sup> As a result, the government and/or uninsured private citizens bear the risk costs. Irrespective of the most economically advantageous form of insurance (public, private, or a mix of the two),<sup>25</sup> such costs must be considered accordingly in the economic evaluation.

The economic viability of nuclear power is also diminished by a further tightening of safety regulations which are currently being developed at European level. As a result of the nuclear accident in Fukushima, EU Ener-

<sup>18</sup> M. Cooper, "The Economics of Nuclear Reactors: Renaissance or Relapse?," Nuclear Monitor WISE (August 2009): 1-20.

<sup>19</sup> S. Thomas, The EPR in Crisis (London: University of Greenwich, 2010).

<sup>20</sup> EnergyMarketPrice, EDF Unveils a Sharp Rise in Costs for Flamanville Nuclear Reactor Construction (2012).

<sup>21</sup> Reuters, Finland's Olkiluoto 3 reactor delayed again (2012).

<sup>22</sup> D. Toke, "Nuclear Power: How Competitive is it Under Electricity Market Reform?" Presentation at the HEEDnet Seminar (London: July 17, 2012).

<sup>23</sup> J. Diekmann, "Verstärkte Haftung und Deckungsvorsorge für Schäden nuklearer Unfälle – Notwendige Schritte zur Internalisierung externer Effekte," Journal of Environmental Policy and Law 2 (2011): 119-132.

<sup>24</sup> In Germany, for example, 2.5 billion euros, see Diekmann, "Verstärkte Haftung" (2011).

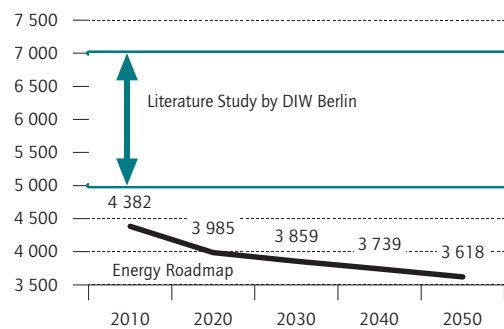
<sup>25</sup> R. Schwarze and G.G. Wagner, "Wir brauchen eine echte Atomhaftung. Mit einer Versicherungspflicht gegen Elementarschäden könnte die Welt „sicherer“ werden," Süddeutsche Zeitung, March 28, 2011.



Figure 4

### Estimated Specific Investments Costs for Future Nuclear Power Plants<sup>1</sup>

In euros per kilowatt



<sup>1</sup> Figures related to "third-generation" nuclear power plants. The cost range calculated by DIW Berlin includes construction, decommissioning, disposal, and completion risks.

Sources: European Commission (2011) and research by DIW Berlin.

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Third-generation nuclear power plants are likely to be much more expensive than assumed by the Commission.

gy Commissioner, Günther Oettinger recommended the mandatory stress testing of European nuclear power plants which revealed the urgent need for some to be retrofitted. A draft regulation will form the basis for binding rules on liability and compulsory inspection routines to be introduced in all countries.<sup>26</sup>

### Dropping Costs of Nuclear Power in the Roadmap Implausible

The cost estimates of the Energy Roadmap 2050 as well as those of other scenarios that attribute considerable importance to nuclear power as a future energy supply assume comparatively low costs and high competitiveness for the technology. Third-generation nuclear power plants currently under construction require an investment of approximately 6,000 euros per kilowatt which includes expenditure on construction, decommissioning, disposal, and completion risks. Based on past empirical evidence of increasing safety requirements, future cost reductions for this generation of power plants are not plausible; rather, constant capital costs can be assumed. In addition, there are variable operating and maintenance

costs of about 20 to 25 euros per megawatt-hour. Even these figures, which correspond to an average cost of 109 euros per megawatt-hour (MWh), show that nuclear energy is comparatively expensive. Risk costs that are largely borne by the general public add on to that.<sup>27</sup>

In contrast, the Energy Roadmap 2050 is based on significantly lower values: firstly, the starting value for the year 2010 is only 4,382 euros per kilowatt, secondly, significant cost reductions are assumed for the coming decades (see Figure 4); both of which stand in contrast to the experiences described above. These circumstances explain the surprising and systematic extra in capacity of nuclear power in the energy scenarios of the Energy Roadmap in the reference scenario from currently 127 GW to 161 GW. Given the cost estimates outlined above, such a development is somewhat unlikely.

### CO<sub>2</sub> Capture Between Hopes and Reality: No Prospects for Widespread Use in Europe

Carbon capture, transport and storage (CCTS) plays a very important role in the Energy Roadmap for the decarbonization of power generation: in the reference scenario, power plant capacity increases from zero GW to more than 100 GW by 2050; while in other scenarios the corresponding figure is up to 193 GW ("diversified supply technology scenario"); even in a scenario where the availability of the technology is delayed, the capacity of CCTS power plants is still expected to be 148 GW.<sup>28</sup>

### No CCTS Demonstration Projects To Date

These optimistic development scenarios run contrary to current developments. On a demonstration scale, there are still no production chains anywhere in the world where carbon is captured in power plants, transported downstream and then stored permanently underground. Despite efforts in some countries to develop pilot projects in the last decade, there have been no significant successes to date. In continental Europe, all demonstration projects have so far been canceled or postponed indefinitely. In Germany, both industry and policy-makers have buried their plans for the large-scale industrial implementation of CCTS technology as part of the

<sup>26</sup> European Commission, Draft proposal for a Directive amending Nuclear Safety Directive IP/13/532, June 13, 2013.

<sup>27</sup> This value is calculated assuming a lifespan of 40 years, an interest rate of ten percent, and a capacity factor of 83.3 percent; if a capacity of 50 percent is assumed, which may be quite realistic in a future with increasing feed-ins from renewable energy sources, this figure increases to 165 euros per MWh.

<sup>28</sup> European Commission, Energy Roadmap 2050 (Impact assessment Part 1) SEC Statistical annexes (Brussels: European Commission, 2011), 1565.

energy transition.<sup>29</sup> Only three countries in the North Sea region are still perusing to demonstrate the technology (the UK, the Netherlands, and Norway), but here too, the prospect of a transnational, mashed CO<sub>2</sub> infrastructure is no longer being discussed.

The current failure of CCTS technology is outlined in the recent Commission Communication on the future of carbon capture and storage in Europe.<sup>30</sup> The Commission notes that all efforts to date, despite having been afforded lucrative financial support, have not led to the construction of a single demonstration plant. The blame for this has been attributed to both the energy industry itself and the restrained policies of member states. The Communication also illustrates that of all the planned demonstration projects not one has taken the planned development path and there is little chance of a demonstration power plant being built any time soon. Discussions that could lead to an investment decision for a demonstration project within the next two years are only ongoing at locations (Rotterdam in the Netherlands and the Don Valley in the UK).<sup>31</sup>

### Large Cost Reductions Unlikely for CCTS

Given the fact that the CCTS technology has not been successfully demonstrated in any power plant with downstream carbon transport and storage, all cost estimates are speculative; in particular, long term cost forecasts be made with serious caution. The capital cost of a CCTS power plant is generally estimated at 3,000 to 4,000 euros per kilowatt. Irrespective of the selected carbon capture technology (post-combustion, pre-combustion, and oxyfuel), efficiency decreases by 21 to 33 percent compared to the reference power plant due to the additional energy demand. Overall, the carbon capture stage alone leads to an increase in power generation

costs of 50 percent.<sup>32</sup> The cost reduction potential of this part of the technology chain is estimated to be very low.<sup>33</sup>

In addition to carbon capture costs, there are also costs of transport and storage. For a large-scale deployment of CCTS technology, as envisaged in the scenarios in the Energy Roadmap 2050, a CO<sub>2</sub> transport network of many thousands of kilometers of pipeline would be required due to the distances between the emission sources and potential CO<sub>2</sub> storage sites.<sup>34</sup>

Long-term CO<sub>2</sub> storage could be done in depleted oil and gas fields or saline aquifers. The respective storage costs will vary significantly from case to case. In general, the first two options will require lower investment costs, since the subsurface will already have been extensively explored and old infrastructure could potentially be reused for constructing and operating the deep-injection facilities. Depending on the location (onshore/offshore) and geological characteristics, the average storage costs are between two and 12 euros per megawatt-hour. The technology is considered the least developed stage in the CCTS process and is associated with considerable uncertainty about effectively usable storage capacity and regulatory processes. This risk is reflected in addition burdens in financing for such projects.

In terms of future cost developments, it is unclear whether CCTS technology would have positive or negative learning rates. Analog developments in other technologies would suggest positive learning rates, that is, a gradual decrease in the average cost of power generation.<sup>35</sup>

The rather inflexible mode of operation of CCTS power plants is likely to drive costs upward. Given the increasing demand for flexibility of fossil fuel power plants in the context of the increasing share of supply from fluctuating renewable energies sources, such as solar and wind power, even adjusted cost estimates may be too low

<sup>29</sup> C. von Hirschhausen, J. Herold, P.Y. Oei, and C. Haftendorn, "CCTS-Technologie ein Fehlschlag – Umdenken in der Energiewende notwendig," Wochenbericht des DIW Berlin, no. 6 (2012).

<sup>30</sup> European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the of Future of Carbon Capture and Storage in Europe COM (2013) 0180 final (Brussels: March 27, 2013).

<sup>31</sup> Characteristic of the parlous state of carbon capture is the Commission's description of the status of the pilot project in Belchatow (Poland), the largest lignite power plant in Europe, "The project received no funding as part of the NER300 program and has a significant financing gap. In addition, Poland has yet to implement the CCS Directive and to adopt legislation for the planning and construction of the CO<sub>2</sub> transport corridor. Against this background, the project initiators decided to begin ceasing the project in March 2013." p. 31.

<sup>32</sup> European Academies Science Advisory Council (EASAC), "Carbon capture and storage in Europe," EASAC policy report, no. 20 (Halle, Saale: 2013).

<sup>33</sup> The Crown Estate, Carbon Capture & Storage Association, DECC, UK Carbon Capture and Storage Cost Reduction Task Force, Final Report (2013). UK. Expected technological developments could hypothetically reduce this share to 30-45 percent over the next 20 years, but given the current situation this is purely speculative.

<sup>34</sup> The capital costs in this network-based, part of the CCTS technology chain represent 90 percent of the total costs. Depending on terrain, transport volumes, and distances, costs are in the range of four to 21 euros per megawatt-hour of electricity generated.

<sup>35</sup> However, negative learning rates are also plausible, analogous to nuclear energy, which would lead to cost increases. Already in 2009, researchers at Stanford University highlighted the risk that the positive learning effects expected for CCTS could in fact fail to materialize. R. Varun, D.G. Victor, M.C. Thurber, "Carbon Capture and Storage at Scale: Lessons from the Growth of Analogous Energy Technologies," Energy Policy 38 (2009): 4089-4098.



because current calculations for the sensitive thermodynamic and chemical processes of carbon capture are designed for continuous base load operation. Increasing the flexibility of CCTS power plants can only be achieved with significant cost increases.<sup>36</sup>

Against this background, the optimistic cost estimates for CCTS in the Energy Roadmap 2050 are certainly surprising: Although the estimated capital costs of 3,481 euros per kilowatt for CCTS coal-fired power plants in 2010 are in the plausible range, no transport costs were factored in and storage costs were set very low, even though considerable cost increases are expected here. A very high figure of 5.4 GW of generating capacity for CCTS was assumed for 2020. This figure supposes the successful implementation of all current proposals of the European Economic Program for Recovery. Moreover, the Energy Roadmap assumes significant learning rates beyond the year 2020. Given the presumed high growth rates, specific investment costs are expected to fall to 2,064 euros per kilowatt by the year 2020, which will generate additional capacity at CCTS power stations; this additional capacity will further reduce investment costs, so at the end of the observation period in 2050, the price per kilowatt in 2050 levels at 1,899 euros and installed CCTS power plant capacity exceeds 100 gigawatts.

### Costs of Power Generation from Renewables Systematically Overestimated

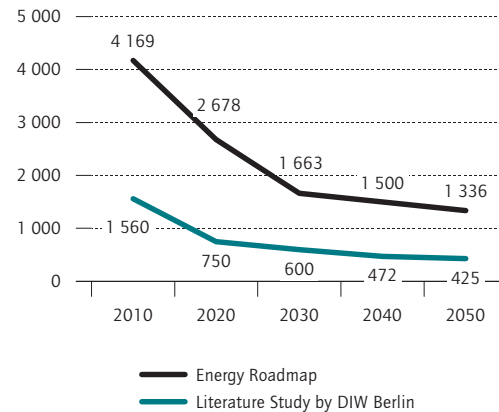
The production cost of power from renewable energy sources has plummeted in recent years. This development is not sufficiently taken into account in the model assumptions that underlie the EU Energy Roadmap. Unlike nuclear and coal power plants with CCTS, the cost of producing power from renewable energies has been systematically overestimated. Given the progressive global diffusion of renewable energy technologies, it is no surprise that there are economies of scale. Given ongoing technological innovation, especially in solar and wind power generation technologies, further decreases in specific production costs and significant learning potential can be expected for these technologies on the 2050 horizon.

<sup>36</sup> E. Rubin and H. Zhai, "The cost of carbon capture and storage for natural gas combined cycle power plants," *Environmental Science & Technology* 2013 47(6) (2012): 3006–3014.

Figure 5

### Development of Specific Investment Costs for Photovoltaic Systems

In euros per kilowatt



Sources: European Commission (2011) and research by DIW Berlin.

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The cost of photovoltaics has been grossly overestimated by the Commission.

### Photovoltaics: Costs Continue to Fall

More recently, there have been significant cost reductions in the field of photovoltaics. There have been both increases in efficiency<sup>37</sup> and reductions in plant costs; this has led to significantly lower average costs for photovoltaic power. Given some excess capacity, particularly in the last two years, the price pressure on photovoltaic modules, which make up the largest proportion of total costs, has continued to rise. Due to the cost dynamics, it is particularly important to include the latest developments in scenario calculations.

Many studies point to annual cost reductions of 15 percent since 2008.<sup>38</sup> Unlike other technologies, learning rates in photovoltaics over the last few years have remained stable at 15 to 20 percent;<sup>39</sup> this means that the specific costs fall by 15 to 20 percent when installed capacity is doubled. It can be generally assumed that this

<sup>37</sup> L. Kazmerski, *Solar Energy Technologies Program - Multi-Year Technical Plan 2003-2007 and beyond* (Hamburg: National Renewable Energy Laboratory (NREL), 2013). Original from 2007, updated 2013.

<sup>38</sup> H. Wirth, *Aktuelle Fakten zur Photovoltaik in Deutschland* (Freiburg: Fraunhofer ISE, 2013). See also T. Gray, M. Huo, and K. Neuhoff, "Survey of Photovoltaic Industry and Policy in Germany and China," *DIW Discussion Paper*, no. 1132 (Berlin: 2011).

<sup>39</sup> Pahle et al. "Kosten des Ausbaus erneuerbarer Energien," (2012).

trend will continue for the foreseeable future.<sup>40</sup> It is anticipated that the installed capacity of solar photovoltaics all over the world will double again from the current 70 GW to about 150 GW by as early as 2015.<sup>41</sup>

The cost of photovoltaics is made up of module costs, inverter costs, installation, maintenance and area, also known as the "balance of system" (BOS). Module costs make up about 50 percent; but are following a downward trend given the rapidly falling specific module prices. While numerous studies in the mid-2000s still assumed specific investments at around 3,000 euros per kilowatt-peak, today less than 1,000 euros per kilowatt-peak for large-scale systems including installation costs is more realistic.

Figure 5 compares the estimate on specific investment costs contained in the Energy Roadmap with figures that appear to be more realistic today. There is a striking difference in both the initial level and the trend:

In 2020, a figure of 750 euro per kilowatt would be plausible,<sup>42</sup> whereas the Energy Roadmap assumes costs of 2,678 euro per kilowatt by 2020;

In terms of dynamics, the authors believe development with a slight decline in economies of scale is plausible. The assumption is that costs will fall by 20 percent between 2020 and 2030, by another 15 percent by 2030, and by ten percent between 2040 and 2050. Here, the Energy Roadmap appears very conservative in its estimate of the cost reductions in photovoltaics beyond the year 2030: although capital costs will decrease linearly from 2010 (about 4,000 euros per kilowatt) to 2030 (about 1,660 euros per kilowatt), they will only drop slightly by 2050.

Both the initial figures and the development of these cost estimates seem implausible from today's perspective. As a result, the costs of large photovoltaic systems today are already lower than the figures estimated in the Energy Roadmap for 2050.

## Onshore Wind Turbines Have Considerable Cost Reduction Potential

Like with photovoltaics, field of onshore wind turbines has seen significant production increases and cost reductions in recent years. Most scenarios still assume possible cost reductions in the future. Different studies identify learning rates ranging from five to 15 percent;<sup>43</sup> however, these will decline over time.<sup>44</sup> The decline of onshore wind turbine capital costs was as rapid as that of photovoltaic systems. While investors had to raise more than 2,000 euros per kilowatt in the early 2000s, specific investments have since fallen to about half that.

A discrepancy between the estimates in the Energy Roadmap and those in other analyses is also prevalent in the investment costs for onshore wind: while most studies predict cost reductions, in the Energy Roadmap, the specific investment costs for onshore wind remain almost constant for the next four decades (1,106 euros per kilowatt in 2010 to 1,074 euros per kilowatt in 2050).

Furthermore, recent experience with different types of wind turbines has shown that it is possible to decrease the average production costs of wind power when using optimized turbine designs, even when specific investment costs remaining constant. By adapting the design of the generator, rotor length, and mast height to locally prevailing wind conditions, significant gains in yield can be achieved. A lower specific capacity installation can lead to lower specific power generation costs.<sup>45</sup> A smaller design also results in lower grid connection costs, since the required cable size decreases. Greater turbine utilization leads to a reduction in system costs.<sup>46</sup> However, the Renewable Energy Sources Act has not yet taken this advantage of wind power into consideration by reducing connection costs.

## Conclusions and Recommendations for Energy Policy

The European Commission's Green Paper 2030 gives a valuable impetus to the discussion on the future structure of the power generation system in Europe. However, there is currently no transparent, quantitative scenario analysis which allows a forward-looking assessment

<sup>40</sup> W.Buchholz, J. Frank, H-D. Karl, J. Pfeiffer, K. Pittel, U. Triebswetter, J. Habermann, W. Mauch, and Thomas Staudacher, "Die Zukunft der Energiemärkte: Ökonomische Analyse und Bewertung von Potenzialen und Handlungsmöglichkeiten," ifo research reports 57, ifo Institute, 2012 This study also assumes a rapid cost reduction which will largely expire after 2030.

<sup>41</sup> K. Bloche-Daub, J. Witt, M. Kaltschmitt and S. Jaczik, "Erneuerbare Energien. Stand 2012 weltweit," BWK Das Energie Fachmagazin 65, no. 6 (2013): 6-17.

<sup>42</sup> J. Meiß, "Prospective Energy Generation Costs – Topic 1: Solar," Workshop on Prospective Generation Costs, (DIW Berlin, March 8, 2013).

<sup>43</sup> Pahle et al. "Kosten des Ausbaus erneuerbarer Energien," (2012).

<sup>44</sup> Offshore wind farms will not be discussed here due to more uncertain cost estimates.

<sup>45</sup> J.P. Molly, "Auslegung von Windturbinen und Speichern: Eine Frage der Systemoptimierung," DEWI Magazin, no. 40 (February 2012): 23-29.

<sup>46</sup> Agora Energiewende, Optimierte Windenergieanlagen bieten Vorteile für das Stromsystem (2013).

of robust development paths. An analysis by DIW Berlin of the technological developments and cost structures shows that the European Commission's data basis does not take into account important recent developments and is to some extent, based on unrealistic assumptions. This data needs to be updated, made more transparent, and publically available. The costs of renewables are overestimated by the Commission; in contrast the costs and technical challenges, in particular, of nuclear power and the CCTS technology are systematically underestimated. This could lead to erroneous conclusions, as the future role of renewable energy sources is underestimated. The current cost estimates indicate that a stronger focus on renewable energy would be favorable.

Given the lower variable costs of production, renewable energy sources have a long-term strategic competitive advantage over conventional fossil power generation technologies which tend to have higher and rising fuel costs and are associated with CO<sub>2</sub> emissions. Although renewables still have higher investment costs than some conventional power generation technologies, in recent years, a significant decline in costs has been observed. Moreover, not only private electricity generation costs but the full costs, including social and environmental risk costs, should be taken into account when assessing thermal power generation. Given the high cost and high risk, the assumption that CCTS and nuclear power can play a leading role in the future energy mix of the European Union seems implausible.

It is a matter of urgency that the European Commission, in cooperation with the member countries, develops realistic scenarios based on updated cost assumptions, which can be used to derive energy policy targets and measures to be implemented at European and national level. Besides challenging emission reduction targets, Europe should set ambitious, binding targets on expanding the use of renewable energy sources and improving energy efficiency, for the period after 2020.

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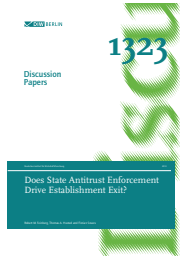
JEL: Q40, Q42, Q47

Keywords: Electricity generation, costs; learning, renewables

First published as »Europäische Stromerzeugung nach 2020: Beitrag erneuerbarer Energien nicht unterschätzen«, in: DIW Wochenbericht No. 29/2013.

Discussion Papers Nr. 1323/2013

Robert M. Feinberg, Thomas A. Husted, Florian Szücs



## Does State Antitrust Enforcement Drive Establishment Exit?

Previous work has shown that state-level antitrust enforcement activity may have impacts on entry and relocation behavior by U.S. firms. Significant state-level antitrust activity may be an indicator of a perceived adverse business environment and it is found to deter establishment entry, particularly for larger firms in the retail and wholesale sectors. An obvious question is whether establishment exit is affected in a symmetric way, or whether sunk costs of market entry may lead to a smaller impact in terms of the exit decisions. We first combine US Census establishment exit panel data with data for 1998-2006 on US state-level antitrust activity and other measures of state-level business activities that may affect establishment exit. We also consider establishment exit across different broad industry types -- manufacturing, retail and wholesale -- and several firm size categories. Local business cycle factors seem to be the primary driver of exit, though there is some evidence of political and antitrust determinants as well. In another approach, we examine firmlevel exit decisions and the extent to which these respond to state antitrust enforcement, with some indication of antitrust enforcement effects here as well, especially in the wholesale and retail sectors.

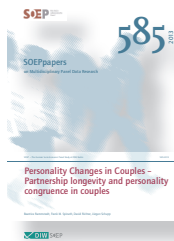
JEL-Classification: K21, L41, L60, L81

Keywords: antitrust enforcement, state level, firm exit

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SOEPpapers Nr. 585/2013

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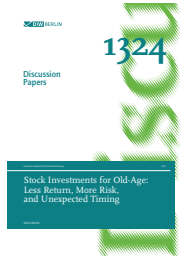


## Personality Changes in Couples: Partnership Longevity and Personality Congruence in Couples

Evidence of assortative mating according to personality was reported in a previous SOEP-based study (Rammstedt & Schupp, 2008). Based on population representative data of almost 7,000 couples, high levels of congruence between spouses were found, which increased with marriage duration. Almost 5,000 of these couples were tracked over a five-year period with personality assessed at the beginning and end of this time, which allowed us to investigate the relationship between personality congruence and marriage duration longitudinally. Using this data, we investigated (a) whether personality congruence is predictive for partnership longevity and whether congruence therefore differs between subsequently stable and instable couples, (b) if stable couples become more congruent, and (c) if separated couples become less congruent with regard to their personality over time. The results provide initial evidence of personality congruence as a predictor for partnership longevity: the more congruent couples are in the personality domain of Openness, the more stable their partnership. In addition, we found no indications of an increase in personality congruence over time within the stable couples; within the separated couples, however, a strong decrease in congruence was detectable.

Keywords: Assortative mating, Big Five, personality, congruence, personality change, partnership

Discussion Papers Nr. 1324/2013  
Dirk Ulbricht



## Stock Investments for Old-Age: Less Return, More Risk, and Unexpected Timing

Returns merely based on one purchasing price of an asset are uninformative for people regularly contributing to their old-age provision. Here, each purchase has an influence on the outcome. Still, they are commonly used in finance literature, giving an overly optimistic view of expected long-term stock market returns and risks. Moreover, around business cycle turning points when volatility is high, these differences are accentuated so that the timing of market entries and exits differ substantially. This article compares risk and returns for regular and lump-sum investors for all possible intervals of investments in the Dow Jones Industrial Average ranging from one to 480 months from January 1934 to April 2013. Moreover, the optimal timing for the two types of investors in the run-up to business cycle turning points are contrasted. Lump-sum returns for forty year-horizons overstate regular contributors yields by 1.4 percentage points implying a forty percent higher terminal value. The Sharpe ratio of lump-sum investments is about 260 percent higher than for regular contributors, and the risk of negative returns disappears for horizons that are six years shorter. Increasing contributions deteriorate risk and returns. While lump-sum investors have eight months more time to switch to riskless assets before a contraction, regular contributors may return five months earlier to the stock market than lump-sum investors.

JEL-Classification: G11, G10, E44

Keywords: Retirement Accounts, Risk and Return, Business Cycle, Investment Management, Dollar-Cost Averaging  
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