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Energy turnaround: implications for energy supply and potential economic effects

DIW Berlin — Deutsches Institut
für Wirtschaftsforschung e. V.
Mohrenstraße 58, 10117 Berlin
T +49 30 897 89 -0
F +49 30 897 89 -200

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Press office
Renate Bogdanovic
Tel. +49-30-89789-249
Sabine Fiedler
Tel. +49-30-89789-252
presse @ diw.de

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The Moratorium on Nuclear Energy
No Power Shortages Expected

by Claudia Kemfert and Thure Traber

With the moratorium on nuclear energy, the German federal government passed a resolution to shut down seven nuclear power plants for a period of three months. According to the calculations of DIW Berlin (German Institute for Economic Research), sufficient electricity is being produced despite the nuclear plants' removal from the grid. Electricity prices are only likely to increase slightly. The moratorium therefore does not pose a threat to the security of supply. However, with coal and gas-fired plants compensating for much of the fall in nuclear energy generation, a significant rise in greenhouse gas emissions is to be expected. An immediate shut down of all nuclear power plants is currently not an option since the remaining power plants are not able to securely provide the energy levels needed to meet demand during peak loads.

Following the catastrophe that struck Japan in March 2011, the German federal government imposed a moratorium in order to examine and discuss the role of nuclear energy in Germany. The moratorium involved disconnecting seven nuclear power plants from the grid and the continuation of the shutdown of a further power plant (Krümmel) for reasons of safety and security. The purpose of the three-month moratorium is to facilitate the reevaluation and change of the general conditions that apply within the energy sector. The German federal government will only make a decision on whether the power plants, or particular power plants, can be reconnected after the Ethics Commission, which it set up for this purpose, has presented its results. But the tougher safety regulations and resulting retrofitting requirements may, also from the viewpoint of companies, render the running of these plants economically unfeasible. Furthermore, the shutting down of the remaining active nuclear power plants is also the subject of discussion.

Scenarios for the German electricity market

The decommissioning of nuclear power plants has a direct effect on the use of fossil fuels and, thus, on the emission of the greenhouse gas CO2. It also impacts the price of electricity. The electricity market model ESYMMETRY[1], developed at DIW Berlin (German Institute for Economic Research), facilitates the calculation of the expected effects of such a scenario. To do this, we use current data relating to power plants, fuel and emissions prices, demand for electricity, and expected energy generation from renewable energy sources.

The electricity market scenarios analyzed here only vary with respect to the use of nuclear energy for electricity generation. In the scenario "Business as Usual," cal-

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[1] Traber, T., Kemfert, C. (2011): Gone with the Wind? – Electricity Prices and Incentives to Invest into Thermal Power Plants under Increasing Wind Energy Supply. Energy Economics, Vol. 33 (2).

Table 1

Power plant capacity and firm capacity in 2011 according to varying nuclear energy scenarios
In gigawatts of electrical output (net)

	EnBW	Eon	RWE	Vattenfall	Rest	Total	Firm Capacity
Without nuclear power plants							
Wind	0.00	0.00	0.00	0.00	27.70	27.70	2.08
Solar	0.00	0.00	0.00	0.00	17.30	17.30	0.00
Pump storage	1.01	1.02	1.02	2.89	0.46	6.40	5.76
Run-of-river	0.43	1.51	0.64	0.00	0.89	3.47	1.39
Brown coal	0.87	0.87	9.46	7.45	0.53	19.18	17.65
Hard coal	3.17	8.48	4.78	1.19	7.46	25.09	21.57
CCGT	0.55	1.33	2.04	0.73	4.71	9.38	8.06
Gas ST	0.00	2.30	2.58	0.42	1.66	6.96	5.57
Gas GT	0.00	1.33	1.68	0.92	3.69	7.63	4.58
Oil ST	0.00	1.18	0.00	0.20	0.62	2.00	1.60
Oil GT 0	0.00	0.00	0.56	0.17	0.73	0.44	0.44
Other	0.00	0.00	0.00	0.00	12.80	12.80	8.32
Nuclear power							
"Business as Usual"	4.31	6.74	5.46	0.27	1.32	18.11	15.03
"Moratorium"	3.44	3.79	3.06	0.27	1.31	11.87	9.86
Total							
"Business as Usual"	10.34	24.76	27.67	14.64	79.32	156.74	92.04
"Moratorium"	9.46	21.81	25.27	14.64	79.31	150.50	86.87
"No nuclear power plants"	6.03	18.02	22.21	14.37	78.00	138.63	77.01

Source: Calculations of DIW Berlin

Despite the moratorium on nuclear energy, there is sufficient firm capacity to meet demand during peak loads.

culations are based on the energy produced by nuclear power plants in operation at the end of 2010 (Table 1). These include a total of 15 nuclear power plant blocks with 18.11 gigawatts net installed capacity (GW). The two nuclear power plants Brunsbüttel and Krümmel have not been connected to the grid since 2010 for operational reasons, and are therefore not taken into account in any of the scenarios. The scenario "Moratorium" assumes that the plants affected by the moratorium are to be permanently shut down.[2] The remaining technologies have a total production capacity of 138.25 GW, of which 30% are coal-fired power plants and almost 20% gas and oil-fired plants. The total production capacity in the scenario "Business as Usual" is 156.74 GW. And the total production capacity in the scenario "Moratorium", in which Krümmel, Brunsbüttel and a further six plants under moratorium are not in operation, is 150.5 GW. In the scenario "No nuclear power plants," additional analysis into the effects of a hypothetical total withdrawal from nuclear energy is conducted (Table 1).

Based on own calculations and on current data, the following prices are assumed for the individual energy sources (EUR/MWh):[3] hard coal 11.4; natural gas 24.1; heavy fuel oil 27.3; light fuel oil 30.0. The current European emissions trading price for emissions allowances is at around 16 euros per metric ton of CO2.[4] Taking into account the economic developments of the last few quarters, we expect the total demand for electricity in 2011 to equal that of 2008. In addition to this, the model assumes that the demand for electricity produced domestically will react to electricity price fluctuations on the stock market such that an electricity price increase of 1% will result in a fall in demand of around 0.6% (price elasticity of demand at – 0.6).[5]

All scenarios are based on the assumption that renewable energy sources will continue to be developed. In order

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[2] This study takes planned outages of power plants into account by corresponding seasonal availability limitations. Traber and Kemfert, at place cited.

[3] Bundesamt für Ausfuhrkontrolle (Germany's Federal Office of Economic and Export Control); EWI, IER, GWS (2010): "Energieszenarien der Bundesregierung" (Energy Scenarios of the Federal Government).

[4] European Energy Exchange, April 2011: www.eex.com/de/.

[5] This value is the result of a calibration of the model. Traber and Kemfert, loc. cit.

to simulate individual quarters, representative weeks are used. With respect to the dynamic expansion of the solar energy market, the model is based on the assumption that half of the additional output available in each quarter as a result of new power plants is exploited. Based on an output of 17.3 GW from solar energy plants at the beginning of the year and an annual expansion of 5 GW,[6] this would mean an additional effective output of 0.63 GW in the first quarter, of 1.88 GW in the second quarter, of 3.13 GW in the third quarter and of 4.38 GW in the fourth quarter. With regard to wind power, we assume that an annual production potential of 51.7 terawatt hours (TWh), pursuant to the scenario developed by the Federal Ministry of the Environment, is the case. In order to simulate this, the model reflects a typical pattern for hourly amounts of wind-generated energy.[7]

Increased CO_2 emissions as a result of the moratorium

The scenarios for the withdrawal from nuclear energy result in varying values as regards total supply, price responsive use of power plants (i.e. operation of coal and gas-fired power plants) and, consequently, CO2 emissions (Table 2). We find that an unlimited moratorium is expected to lead to an increase in energy production from coal and gas-fired plants in particular. According to the simulations, production in coal-fired plants will increase by 21.6 TWh or 20%, and generation in combined gas and steam turbine power plants (CCGT) will rise by almost 5 TWh or 13% compared tothe “Business as Usual” scenario. The remaining gas turbine (GT) or steam turbine (ST) power plants will increase output by 47% and 57% respectively. Due to a continued moratorium, around two-thirds of the 48.4 TWh decrease in energy produced by nuclear power plants will be compensated for by an increase in energy production at fossil fuel power plants amounting to 31.7 TWh in total. However, this increase will lead to an additional 25.8 million metric tons of CO2 emissions, a rise of approximately 9%. The scenario involving the immediate shut down of all nuclear power plants, which, due to the supply difficulties this would entail, is purely hypothetical, would lead to a marked increase in emissions (Table 2).

The immediate, total withdrawal would put security of energy supply at risk

The immediate, complete withdrawal from nuclear power would put the security of energy supply at risk due to the lack of firm capacity of remaining power plants to meet the demand. In the event of such a withdrawal, the German electricity network would not be able to provide the sufficient degree of supply security for expected peak loads of around 77 GW.[8] If the relative amount of electricity retained as a safety margin is 8.2%,[9] then 83 GW of firm capacity is required. If we compare this target figure with the firm capacity in the various scenarios, then we see that the scenario “No nuclear power plants,” with 76.8 GW, falls short of the firm capacity target by around 7.5%. The immediate shut down of all nuclear power plants is therefore not possible without putting the security of the electricity supply at risk. By contrast, in the scenario “Moratorium,” the availability of secure power even exceeds demand – by around 5%.

Table 2

Production at German power plants according to differing nuclear energy scenarios in 2011
In TWh

	Business as Usual 2010	Scenarios		Difference in percent compared with Business as Usual in 2010	
		Moratorium	No nuclear power plants	Moratorium	No nuclear power plants
Production					
Nuclear energy	140.9	92.4	0.0	–34	–100
Brown coal	144.7	146.5	147.3	1	2
Hard coal	108.2	129.8	157.8	20	46
Gas CCGT	36.9	41.8	55.6	13	51
Gas ST	3.0	4.7	10.1	57	234
Gas GT	3.3	4.9	11.2	47	237
Water	23.5	23.5	23.5	0	0
Wind	51.7	51.7	51.7	0	0
Solar	16.1	16.1	16.1	0	0
Other	66.1	66.2	66.3	0	0
Total	**594.5**	**577.8**	**539.7**	**–3**	**–9**
Emissions in million t CO_2	293.7	319.5	358.1	9	22

Source: Calculations of DIW Berlin.

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The moratorium on nuclear energy leads to a small decline in production and increases emissions.

The price of electricity will only increase slightly

Had the nuclear power plants not been shut down, the average expected stock exchange price for electricity in 2011 would be 6.14 cents per kWh (Table 3). Shutting

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[6] Traber, T., Kemfert, C., Diekmann, J. (2011): German Electricity Prices: Only Modest Increase Due to Renewable Energy, DIW Weekly Report 6/2011.

[7] Traber and Kemfert, loc. cit.

[8] ENTSOE (2009): System Adequacy Forecast, quoted in: Monitoring report of the Federal Ministry of Economics and Technology pursuant to Section 51 EnWG (German Energy Management Act) on security of supply in grid-based electricity provision.

[9] ENTSOE, ibid.

Table 3

Electricity prices according to different nuclear energy scenarios

In euro cents/kWh

	Business as Usual 2010	Scenarios		Difference in percent compared with Business as Usual in 2010	
		Moratorium	No nuclear power plants	Moratorium	No nuclear power plants
Stock exchange price	6.14	6.53	7.50	6.3	22.0
Sales, grid, billing	8.9	8.9	8.9	0.0	0.0
EEG/KWKG-apportionment[1]	2.6	2.5	2.3	–3.4	–12.6
Net electricity price	17.7	18.0	18.7	1.7	5.8
Taxes, charges	7.8	7.8	7.9	0.7	2.5
Household electricity price (total)	**25.5**	**25.8**	**26.7**	**1.4**	**4.8**

1 Apportionment (Umlage) according to the "Erneuerbare-Energien-Gesetz" (German Renewable Energy Sources Act) and the "Kraft-Wärme Kopplungsgesetz" (German Cogeneration Act).

Source: Calculations of DIW Berlin.

Despite considerable increases in the stock exchange price, households will only experience minimal electricity price increases

down the nuclear energy plants affected by the moratorium for all of 2011 would result in an average stock exchange price of 6.53 cents per kWh and thus in a 6% increase on the aforementioned 6.14 cents. This increase corresponds to approximately 1.5% of the current household electricity prices of around 26 cents per KWh, approximately a quarter of which is determined by the stock exchange price. In addition, the higher stock exchange prices would result in the renewable energy apportionment[10] falling by circa 0.1 cents.[11] On the other hand, the tax burden increases of around 0.7% would add to the total price increase for households of 1.4%.

Due to the almost balanced price increasing and price decreasing effects, the consumer price is expected to increase only slightly. The price increases for electricity on the stock exchange, strengthened by the increase in emission trading prices resulting from rising emission levels, tends to increase prices. The retrofitting requirements at power plants and the necessary grid expansion would also bring about price increases, with grid expansion being the less influential factor.[12] The growing stock exchange prices would bring about a decline in the electricity trading balance surpluses due to the increase in electricity imports. The decline in domestic production of around 17 TWh is therefore unlikely to result in a corresponding decline in domestic demand of the same size. Considering the fact that electricity from abroad is cheaper, the increase in imports will have a dampening effect on price increases. Also, higher electricity prices would cause the apportionment levied for the development of renewable energy sources to fall by about 0.1 cents. An immediate, total withdrawal from nuclear energy would cause an increase in the stock exchange price of up to 22%, or almost 1.4 cents per kWh. However, due to factors such as the lower EEG apportionment (levies as per the German Renewable Energy Sources Act), household electricity prices would only increase by a total of up to 5%.

Conclusion

The shutdown of the nuclear power plants affected by the moratorium will not switch off the lights in Germany . The existing power plant capacity is sufficient to compensate for these gaps. However, should further nuclear power plants be taken from the grid in the next years, measures that improve grid stability have to be taken. With a maximum expected increase of 1.4%, the effects of the moratorium on household electricity prices are minor. And this increase is predominantly the result of stock exchange price increases of around 0.4 cents per kWh (6%). Without the expansion and replacement of power plant capacity, firm capacity would reduce to 77 gigawatts in the event of a total withdrawal from nuclear energy, an capacity level unable to secure current power supply. Renewable energy sources can potentially close the gap, provided that development of the corresponding infrastructure and storage facilities is intensified.

Prof. Dr. Claudia Kemfert is Head of the Department Energy, Transportation, Environment at DIW Berlin | ckemfert@diw.de

Dr. Thure Traber is research associate at the Department for Energy, Transportation and Environment | ttraber@diw.de

JEL: Q40, Q48
Keywords: German nuclear moratorium, energy policy, impacts on electricity prices

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[10] The EEG apportionment was computed in accordance with the calculations in Traber, Kemfert, Diekmann (2011) at the place cited. Only the scenarios relating to stock exchange electricity prices were adjusted according to the values specified here. Compared with the 3.5 cent apportionment, which was determined in 2010 for 2011, there is a difference of approximately 1 cent per kWh. The resulting excess income can be used to reduce EEG apportionments in subsequent years.

[11] A possible increase in grid charges has not been taken into account.

[12] Investments of one billion euros would only cause the electricity price to rise by between 0.3 and 0.5 cents per kWh; cf. "Dena Netzstudie II: Deutsche Energieagentur dena-Netzstudie II" (Power grid study conducted by German energy agency Dena) – "Integration erneuerbarer Energien in die deutsche Stromversorgung im Zeitraum 2015–2020 mit Ausblick 2025, Berlin 2010". (Integration of renewable energy into the German electricity network in the period from 2015 to 2020 with a view to 2025, Berlin 2010.")

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

»The Lights Won't Go Out«

1. Prof. Kemfert, seven nuclear power stations were removed from the grid for a three-month moratorium. Will the lights go out in Germany if these power plants are never reconnected? No, the lights won't go out. The fact is that we produce more electricity in Germany than we consume and, even in the past, we have exported much more than we have imported. Naturally, the exports are now dwindling. The utilization of existing power plants is also increasing. Overall, while we still have overcapacities, these are shrinking appreciably.
2. What would be the repercussions of leaving these power stations shut down for the long term? Keeping these nuclear power stations shut down for the long term should mean minor increases in electricity prices. This would primarily be due to the trading prices rising. On the other hand, if the trading price climbs, then the share of costs for funding renewable energies will fall. These two effects would offset each other, so that the result would be an only minor increase in prices.
3. Would it be possible to withdraw from nuclear power immediately? No. That wouldn't work, because then we wouldn't have enough output to cover demand at all times. We have to bear in mind the issue of grid stability. A large portion of the nuclear power plants leaving the grid are in southern Germany. This shortage has to be compensated by other power plants, and these can't simply be constructed in one year. However, it would be possible to initiate the plans of the Red-Green Coalition, which stipulate that all nuclear power stations will be taken offline by the year 2021/22.
4. How strongly would electricity prices increase if all nuclear power plants are taken offline within the next ten years? We forecast that the trading price of electricity would rise by about 22%. That's only the trading price, though. This would again be partly offset by a reduction in the share of costs for funding renewable energy. In addition, let's not forget that the grids have to be expanded, which will also be a cost factor - though only a moderate one. The greater proportion of electricity generated using coal would increase the CO_2 price, though cheaper imports would increase in turn. Overall, households would only have to face a minor increase in the price of electricity, somewhere between 1.5% and, at most, 6%. When we consider the offsetting factors as well, you can see that the expected price increase is quite moderate.
5. What impact would the diverse withdrawal scenarios have on CO_2 emissions and the government's climate targets? This would now depend on how many of the old, inefficient coal-fired power plants we reactivated. Our own scenario predicts that more gas-fired power plants will be used in addition to the coal-fired plants. CO_2 emissions would increase by up to 9%, which is approximately 26 million metric tons.
6. Can we make up for the shortage of energy caused by gradually shutting down the nuclear power plants if we expand renewable energy more quickly? Over the next ten years, we'll be able to double the contribution of renewable energy from the current 17% to 35%. This is in line with the volumes of nuclear energy. The question is what other power stations are being used. They still account for 65% of our energy needs, and most of them are coal-fired. The best thing would be to reduce the volumes from coal and replace them with better gas-fired plants because the latter generate less CO_2 and can be better combined with renewable energy.

Interviewed by Erich Wittenberg

Economic Opportunities and Structural Effects of Sustainable Energy Supply

by Jürgen Blazejczak, Frauke G. Braun, Dietmar Edler and Wolf-Peter Schill

Renewable energy sources and increased energy efficiency are not only crucial for reducing greenhouse gas emissions and other negative impacts of conventional energy supply; they also hold enormous economic opportunity. Significant and dynamically growing sectors have emerged in the area of renewable energy over the last several years. In 2010, 26.6 billion euros were invested in Germany alone in renewable energy facilities. Altogether, renewable energy sources created 35.5 billion euros in demand for the German economy. Gross employment in the area of renewable energy is estimated at 367,400 persons for 2010.

Likewise, the net economic balance for the expansion of renewables is positive. Model calculations conducted by DIW Berlin show that the gross domestic product is by 2.9 percent higher in 2030 in the "Expansion Scenario" than following a "Null Scenario" with no expansion. Depending on the labor market conditions, the net employment effects appear to be weak to moderate, but in any case positive. These scenario calculations also illustrate that the impact of the expansion differs across sectors. Furthermore, the transition from the current energy supply regime to one where renewable energy sources contribute a large share and energy efficiency has been substantially increased will require a structural change in business and the working world that will have to be followed closely in the future.

The German energy supply is currently primarily based on fossil energy sources. In the medium to long term, however, the aim is to switch to mainly renewable energy sources in all usage sectors (electricity, heat and fuel) and to abandon nuclear energy. Renewables lower the consumption of finite energy resources and reduce greenhouse gas emissions. The use of renewable energy sources available domestically also decreases the dependence on imported nuclear and fossil energy sources. Lastly, expanding the use of renewable energy sources is also hoped to have a positive economic impact by increasing value added in promising sectors of the future which is also supported by tapping new export markets.

Several studies have shown that a fundamental transformation of energy supply in Germany is technically possible. Particularly in the electricity sector, our demand could be mostly met by low-emission renewable energy sources by the middle of this century.[1]

The contribution of renewables to total final energy consumption has been rising steadily since 1998 (Figure 1). It came to 11 percent in the year 2010. After shrinking in 2008 and 2009, it rose to a 5.8 percent share of fuel consumption. For heat, the proportion grew from 3.6 percent in 1998 to 9.8 percent in 2010. The share of renewable energy sources in gross electricity consumption even leaped during this period from 4.7 percent to 16.8 percent.

The importance of renewable energy is to increase further in Germany. The government's 2010 "Energy Concept" foresees that the share in gross electricity consumption will rise to 35 percent by 2020, 50 percent by

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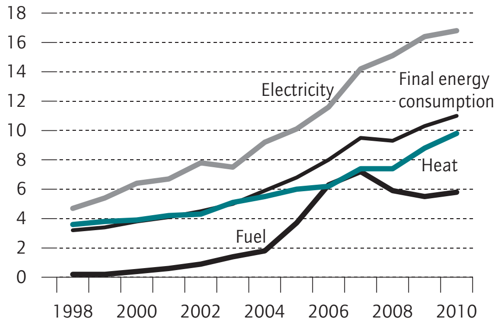
[1] The German Advisory Council on the Environment (SRU): Wege zur 100 Prozent erneuerbaren Stromversorgung. Sondergutachten. January 2011. (Executive summary also available in English: SRU: Pathways towards a 100% renewable electricity system. Special report. January 2011.). Greenpeace International, European Renewable Energy Council: Energy [R]evolution. A sustainable world energy outlook. 3rd Edition World Energy Scenario. 2010; Öko-Institut, Prognos: Modell Deutschland Klimaschutz bis 2050: Vom Ziel her denken, Studie im Auftrag des WWF. Basel, Berlin 2009.

Figure 1

Share of renewable energy sources in final energy consumption in Germany between 1998 and 2010



Electricity generated from renewable energy sources compared to total gross electricity consumption. Heat generated from renewable energy sources compared to total energy consumption for heat. Fuel created from renewable energy sources compared to total fuel consumption (figures through 2002 refer to fuel consumption for road traffic; from 2003 on they refer to total consumption for all engine fuels except aircraft fuel).
Sources: German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU): Erneuerbare Energien in Zahlen: Internet-Update ausgewählter Daten. Berlin, December 2010; and BMU: Erneuerbare Energien in 2010. Vorläufige Angaben, as of March 23, 2011. Berlin.

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The share of renewable energy sources in total final energy consumption is steadily rising.

2030 and 80 percent by 2050.[2] Its contribution to the sectors heat and fuels should nearly double by 2020 and then continue to rise.

Improving the framework for the further expanding renewable energy sources

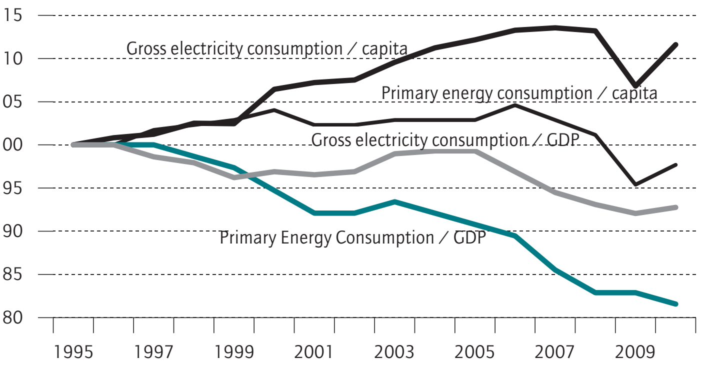
Several requirements need to be fulfilled to further adapt the energy system, especially in the electricity segment.[3] Funding through the Renewable Energy Sources Act (EEG), to be amended in 2011, will continue to be needed. Sufficient incentives for investment must be maintained so that the expansion of renewables does not slow to a halt. Deadweight effects should also be avoided wherever possible. Considering the growing share of fluctuating electricity generation, it is necessary to advance the support framework so that the feed-in better meets the needs.

The transmission and distribution systems need to be expanded to integrate renewables in a safer and more effective way.[4] Additional storage facilities will also be required and the necessary capacities will depend on integration measures such as load management. Furthermore, institutional and organizational provisions need to be taken that will also affect the design of the electricity market.[5]

The targeted, very high share of renewable energy will only be achieved if the energy efficiency (that is, the energy productivity) of the economy is significantly improved. Between 1995 and 2010, the (adjusted) primary energy consumption as measured relative to gross domestic product (GDP) fell annually by 1.3 percent on ave-

Figure 2

Primary energy consumption and gross electricity consumption in Germany from 1995 to 2010
1995 = 100



Primary energy consumption adjusted for temperature and inventory effects. Gross domestic product (GDP) in real terms.
Source: AG Energiebilanzen: Ausgewählte Effizienzindikatoren zur Energiebilanz Deutschland. Berlin, March 2011.

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Improving the efficiency of electricity consumption has been less successful than for primary energy consumption.

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[2] Federal Ministry of Economics and Technology (BMWi), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU): Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung. Berlin, September 28, 2010. (Also available in English: BMWi, BMU: Energy concept for an environmentally sound, reliable and affordable energy supply. Berlin, September 28, 2010.)

[3] Traber, T., Kemfert, C.: Nachhaltige Energieversorgung: Beim Brückenschlag das Ziel nicht aus den Augen verlieren. Wochenbericht DIW Berlin No. 23/2010.

[4] According to Dena's Grid Stuy II 3 600 kilometers will have to be added to Germany's transmission grid by the year 2020. German Energy Agency (Dena): Dena-Netzstudie II – Integration erneuerbarer Energien in die deutsche Stromversorgung im Zeitraum 2015-2020 mit Ausblick 2025. Berlin 2010. (For an executive summary of this study in English cf. Dena: Dena Grid Study II Integration of renewable energy sources into the German power supply system until 2020. Berlin 2010.)

[5] Cf. the next article in this issue of the DIW Economic Bulletin for more information on this point.

rage.[6] Gross electricity consumption in relation to GDP sank in the same period by only 0.5 percent, while electricity consumption per capita actually rose by 0.7 percent annually (Figure 2). If we are to switch electricity generation to mostly renewable energy sources by 2050, a substantial increase in energy efficiency will be needed in the future.

The expansion of renewable energy sources is already a driver of growth

The economic costs of the transformation of the energy supply, especially the use of funding for renewable energy and the costs of withdrawal from nuclear energy in the form of rising electricity prices has been subject of much debate as of late.[7] However, the picture is only complete if apart from costs also the economic opportunities are taken into consideration.

Using renewable energy sources helps to avoid a substantial part of the negative external effects of conventional energy supply.[8] Furthermore, expanding renewable energy offers significant opportunities for economic growth. This growth potential is especially large for the German economy, which already leads in renewable energy and efficiency technologies. In this regard, the associated need to restructure the economy represents a challenge to any forward-looking policy.

The increasing usage of renewable energy sources requires substantial investment. This has increased in Germany from 10.3 billion euros in 2005 to 26.6 billion euros in 2010 (Table 1).[9] Thus, the investment in renewable energy has grown by 158 percent in five years. Renewable energy facilities are therefore one of the fastest growing investment areas in the economy. Invest-

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[6] AG Energiebilanzen: Ausgewählte Effizienzindikatoren zur Energiebilanz Deutschland Daten für die Jahre von 1990 bis 2010. Berlin, March 2011.

[7] Traber, T., Kemfert, C., Diekmann, J.: Strompreise: Künftig nur noch geringe Erhöhung durch erneuerbare Energie. Wochenbericht DIW Berlin No. 6/2011. (English version published as: Traber, T., Kemfert, C., Diekmann, J.: German Electricity Prices: Only Modest Increase Due to Renewable Energy expected. Weekly Report of DIW Berlin No. 6/2011.) Also see prior article in this issue.

[8] Cf. Breitschopf, B., Diekmann, J.: Vermeidung externer Kosten durch Erneuerbare Energien – Methodischer Ansatz und Schätzung für 2009 (MEEEK). Study commissioned by BMU as part of its project "Einzel- und gesamtwirtschaftliche Analyse von Kosten- und Nutzenwirkungen des Ausbaus erneuerbarer Energien im deutschen Strom- und Wärmemarkt" – Arbeitspaket 3/2010.

[9] The figures for the economic development of renewable energy are based on studies conducted by DIW Berlin in collaboration with other institutions. Cf. GWS, DIW, DLR, ISI, ZSW: Kurz- und langfristige Auswirkungen des Ausbaus erneuerbarer Energien auf den deutschen Arbeitsmarkt. Research project commissioned by the BMU, Osnabrück, Berlin, Karlsruhe, Stuttgart 2011, and O'Sullivan, M., Edler, D., van Mark, K., Nieder, T., Lehr, U.: Bruttobeschäftigung durch erneuerbare Energien in Deutschland im Jahre 2010 – eine erste Abschätzung. Research project commissioned by the BMU, March 2011. A summary report is made available in English: O'Sullivan, M., Edler, D., van Mark, K., Nieder, T., Lehr, U.: Gross employment from renewable energy in Germany in 2010 – a first estimate. Berlin, 18 March, 2011.

Table 1

Economic key indicators for the development of renewable energy sources (RES) in Germany

	2005	2006	2007	2008	2009	2010[4]	Difference 2010/2005 In percent	
							Total	Annual
	In billion euros (current prices)							
Investment in Germany	**10.3**	**11.1**	**11.6**	**16.8**	**20.2**	**26.6**	**158**	**21**
Sales of complete facilities[1]	7.9	10.6	11.8	15.5	16.8	19.7	149	20
Export of components[2]	0.7	0.7	3.4	4.1	4.6	5.6	67	52
Demand for operation and maintenance[3]	2.5	2.6	3.9	4.3	4.7	5.2	110	16
Demand for biomass and biofuels[3]	2.6	3.6	5.6	6.1	5.6	4.9	94	14
Total demand impulse from RES	**13.7**	**17.6**	**24.8**	**30.1**	**31.7**	**35.5**	**160**	**21**
	In 1,000 persons							
Employment	**194**	**236**	**277**	**322**	**340**	**367**	**89**	**14**

1 From manufacturers based in Germany, including the export of complete facilities.
2 Change in calculation basis in 2007, thus change shown for period 2007 to 2010.
3 Increase in demand in Germany.
4 Preliminary figures.
Sources: DIW Berlin; DLR; GSW; ZSW.

The economic significance of renewable energy sources has risen strongly.

ment in photovoltaic installations, in particular, has expanded strongly. Due to this boom, they made up nearly three quarters of total investment in renewable energy in Germany in 2010, while facilities using wind energy and biomass only accounted for around one-tenth each (Figure 3).

Companies in Germany have profited considerably over the last several years from the investment in Germany, mainly driven by the EEG, and from the rising demand for renewable energy facilities worldwide. These companies are now established as a strongly growing economic sector. Sales (including the export of components) have steeply increased from 8.6 billion euros in 2005 to 25.3 billion euros in 2010, which puts this in line with the growth seen for investment in renewable energy overall. Accounting for 48 percent of all sector sales in 2010, photovoltaic manufacturers were in the lead, followed by manufacturers of wind energy installations with 32 percent and those of biomass heat and power plants with 11 percent.

Thanks to Germany's lead position in the expansion of renewable energy, and the favorable sales conditions this provided, Germany has developed into a lead market for this field of technology. National support schemes, international climate protection policies and the rising price of fossil energy sources play an important role in foreign demand. Though demand has been volatile in some countries, the volume of global investment in renewable energy has nearly quadrupled within a few short years. Worldwide, 150 billion US dollars were invested in this segment in 2009. The amount estimated for 2005 was only 40 billion US dollars.[10]

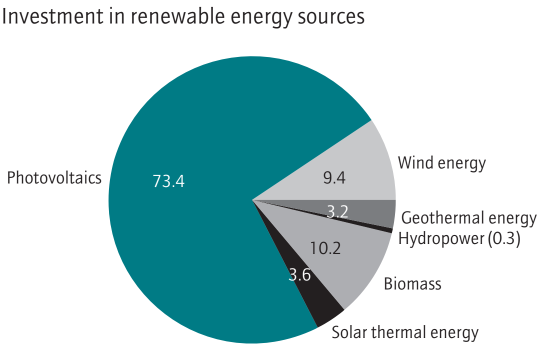
In Germany so far, it is the manufacturers of wind energy facilities and of specialized, high value-added system components that have succeeded in selling a noteworthy proportion of their production abroad. Companies specialized in equipment and in machinery and plant engineering that have managed to gain technological know-how in setting up production lines for facilities using renewable energy sources in Germany are increasingly achieving substantial sales on foreign markets.[11]

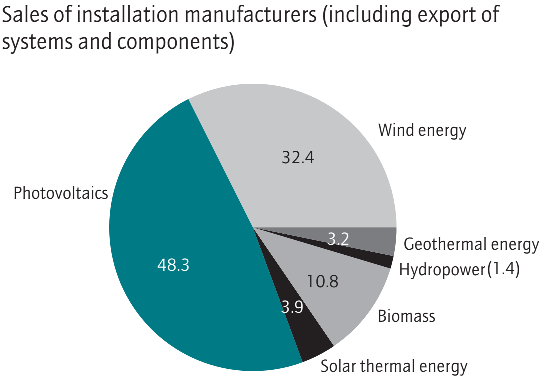
As the number of installations in Germany grows, operation and maintenance become more important, as well. While sales in this area were 2.5 billion euros in 2005, the volume of demand more than doubled by 2010 to 5.2 billion euros. The demand for biomass and biofuels has grown, too. The demand inducing production in Germany amounted to 2.6 billion euros in 2005 and rose to 4.9 billion euros in 2010. Altogether, the demand impulse associated with renewable energy sources accounts already for 35.5 billion euros for German industry.

The strong rise in total sales has also resulted in considerable employment in the area of renewable energy. In 2005 gross employment in the segment was 194,000 persons in Germany . It rose steadily over the following years. Thanks to the stable support conditions and robust foreign demand, the expansion also continued during the years of the global financial and economic crisis and had a stabilizing influence throughout this period.

Figure 3

Investment and manufacturer sales in the area of renewable energy sources in 2010
In percent





Source: O'Sullivan, M., Edler, D., van Mark, K., Nieder, T., Lehr, U.: Bruttobeschäftigung durch erneuerbare Energien in Deutschland im Jahre 2010 – eine erste Abschätzung. Research project commissioned by the German Federal Ministry of Environmental Protection, Natural Resources and Nuclear Safety (BMU), March 2011.

Photovoltaics dominated both sales and investment in 2010.

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[10] REN 21: Renewables 2010, Global Status Report. Paris 2010. In addition, 40 to 45 billion US dollars were invested in large hydropower projects. The countries with the greatest investment volumes were China and Germany.

[11] For the photovoltaics area, cf. Grau, T., Huo, M., Neuhoff, K.: Survey of photovoltaic industry and policy in Germany and China. CPI Report. Berlin, March 2011, 15–17.

It is estimated that 367,400 persons were employed in this segment in 2010 (including research and development). This translates into a growth of 89 percent compared to 2005 and an average annual growth rate of nearly 14 percent. In 2010, the majority of employment was in the production of biomass (33 percent)[12] and solar energy (33 percent), followed by wind energy (26 percent) (Figure 4).

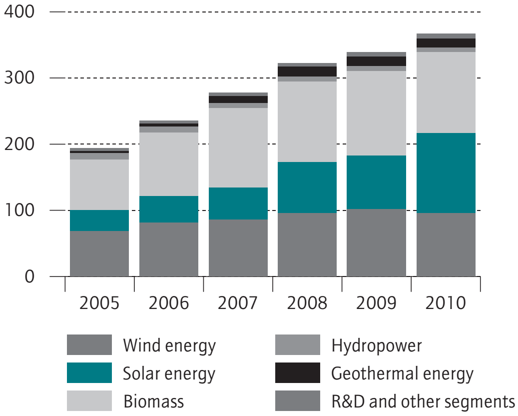
Economic effects in Germany also mostly positive in the future

As part of a study, DIW Berlin recently calculated the net economic balance of expanding renewable energy sources in Germany through 2030.[13] A new model (the Sectoral Energy-Economic Econometric Model or SEEEM) was developed for this purpose and applied for the first time. It enables the calculation of dynamic impacts on the economy at an aggregate level as well as the effects on individual sectors.

Figure 4

Gross employment from renewable energy sources in Germany from 2005 to 2010

In thousands



Sources: DIW Berlin; DLR; GSW; ZSW.

Gross employment in the area of renewable energy is estimated at 367,400 persons for 2010.

To determine the net economic balance, we compared an expansion scenario to a hypothetical null scenario, whereby renewable energy sources were not expanded after the year 2000. The expansion scenario is based on the BMU's reference scenario from 2009.[14] The expansion scenario contains positive stimuli such as additional investment, operating costs, displaced imported fossil energy carriers, and the export facilities and components. On the other hand, it also covers negative stimuli, such as displaced investment in the conventional energy business and additional costs (differential costs) (Figure 5).

The model calculations show that expanding renewable energy sources in Germany, together with the export of installations and components, will create higher economic growth. In the year 2030, GDP is by 2.9 percent higher in the expansion scenario than the respective GDP figure in the null scenario (Table 2). On the expenditure side, the greater GDP encompasses higher private capital investment (+6.7 percent in 2030) and higher real private consumption (+3.5 percent). Net employment increases only marginally in the base scenario.

According to the model findings, the expansion would overall not have any economic disadvantages, but rather slight, positive effects. The results of a sensitivity analysis confirm this. One scenario version assumes that the increased costs of renewable energy (compared to conventional energy supply) will set off a spiral of rising wages and prices that will limit the ability of the German economy to compete internationally. The growth-enhancing effect of expanding renewable energy is less pronounced in this case, but still positive. Another version "ACTIV" assumes that additional labor forces will be activated from unemployment. In this case, the number of additional employed persons rises significantly through 2030. In the scenario calculations, the effects on employment depend substantially on assumptions regarding the concrete conditions on the job market, but they are all positive.

The study examined the sectoral effects through 2030. It shows that (even if the input-output matrix representing the interindustry linkages is kept unchanged) the changing structure of final demand will also alter employment in the sectors. The positive net employment effect found in this scenario version "ACTIV" is diffe-

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[12] The high employment in the biomass sector is due to the fact that the supply of biomass and biofuels is assigned to this category.

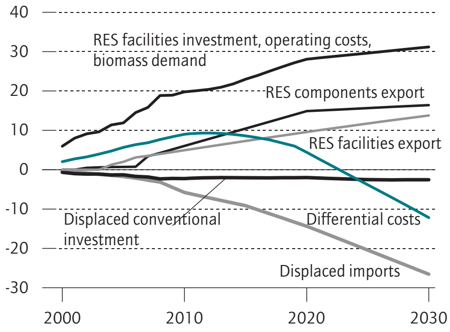
[13] This study was conducted as part of the project "Gesamtwirtschaftliche und sektorale Auswirkungen des Ausbaus erneuerbarer Energien". Research project funded by the BMU. The project findings are summarized in Blazejczak, J., Braun, F. G., Edler, D., Schill, W.-P.: Ausbau erneuerbarer Energien erhöht Wirtschaftsleistung in Deutschland. Wochenbericht DIW Berlin No. 50/2010.

[14] BMU (ed.): Langfristszenarien und Strategien für den Ausbau erneuerbarer Energien in Deutschland: Leitszenario. Berlin 2009. The BMU has published an updated reference scenario that contains higher investment in photovoltaics and higher differential costs. It suggests that both the negative and positive growth stimuli would be stronger than assumed herein.

Figure 5

Economic stimuli in the expansion scenario for the period from 2000 to 2030

Price base 2000, in billion euros



RES = Renewable energy sources
Less import of conventional fuels
Investment, operating costs, and export from domestic production
Differential costs = Additional costs of energy supply from renewable energy

Source: Calculations of DIW Berlin based on BMU 2009, loc. cit.

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Increasing economic stimuli from expansion of renewable energy sources.

Table 2

Effects from expanding renewable energy

Percentage of deviation between expansion scenario (base variation) and null scenario

	2010	2020	2030
Gross domestic product	1.7	2.6	2.9
Private consumption	1.0	2.3	3.5
Private investment in facilities	9.1	8.9	6.7
Exports	0.9	1.2	0.9
Imports	1.0	1.0	1.0
Productivity per worker	1.7	2.6	2.9
Employees	0.1	0.0	0.0

GDP and expenditure components in prices of 2000
investment in facilities ex housing construction.

Source: Calculations of DIW Berlin with SEEEM.

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Higher growth and consumption from expanding renewable energy sources.

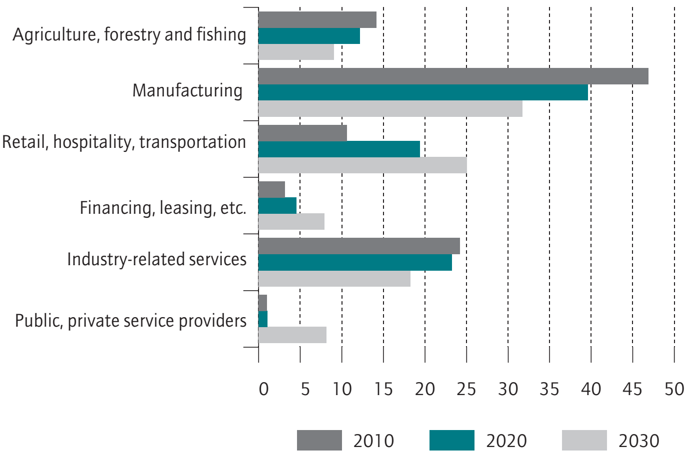
rently distributed from one sector to another.[15] Most are positive, but there are a few sectors where employment shrinks. Figure 6 shows the employment effects for the sectors aggregated into main groups. All of these main groups show positive net employment effects, though to different extents.

The structural change accompanying the expansion of renewables results in the greatest rise in employment in the manufacturing. Nearly 40 percent of the employment effect shows up here in 2020 and in 2030 it still accounts for 32 percent. This high proportion of the employment effect is due in part directly to the economic activities in the area of renewable energy (investment, operation and trade) and in part indirectly to interindustry linkages for intermediate goods and and aggregate second round effects. At 18 percent, industry-related services also account for a significant part of the net employment effect in 2030. Over the course of time, the share of employment effects in retail, hospitality and transportation grows: Starting at 19 percent in 2020, it rises to 25 percent in 2030. While the sectors that directly manufacture or operate renewable energy installations are

Figure 6

Breakdown of net employment effects by sector

In percent



Source: Calculations of DIW Berlin with SEEEM for scenario version reflecting the activation of additional workers.

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The weight of net employment effects in the manufacturing industries decreases over time.

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[15] These calculations are based on the variant scenario "ACTIV" ("Aktivierung zusätzlicher Arbeitskräfte"). The scenario assumes that the unemployed can be successfully activated and that employment will increase instead of labor productivity. The net employment effects amount to 98,000 persons in 2010, 166,000 in 2020 and 270,000 in 2030 (cf. Blazejczak, J. et al., as shown above).

clearly winners of the structural change in employment, many other sectors also profit indirectly.

Sustainable energy supply implies structural change in business and the working world

Transforming the energy supply to one with a high contribution of renewable energy sources and better energy efficiency will be accompanied by a considerable structural change in business and the working world.[16] This change will affect more than the energy industries and energy-intensive sectors; the entire economy will feel its impact. Additional resources have to be mobilized through innovation, especially when the availability of labor diminishes. A forward-looking analysis of this structural change can help avoid some of the frictions. In addition, social hardships and inequalities can be lessened, making the transformation economically and socially sustainable.

A considerable strain on the labor market is expected in the future. This is also shown in the scenario calculations of DIW Berlin regarding long-term economic trends. Even if the population develops relatively favorably,[17] significantly increasing employment rates or working times will be necessary if real GDP is to grow 1.5 percent annually on average. If per capita productivity were to grow at the same rate as the GDP and the number of employed were to remain unchanged, the employment ratio (referring to the population aged 15 to 65) would have to increase from 75.2 percent in 2010 to 81.5 percent in 2025.[18] If we assume a longer employment phase in the future and use the population aged 15 to 67 as our reference, the employment rate will still have to rise to 77.7 percent in 2025. These relationships have to be kept in mind when evaluating the structural change related to the shift in energy supply.

Even if the net employment impacts of expanding renewable energy sources are moderate, the extent of structural change in employment will be considerable. The significant gross employment impacts shown above are an indication of this. If the net employment impacts are small, then roughly in the same dimension of the gross employment impacts new jobs will be created as are eliminated. For indirect gross employment this implies only moderate changes of occupations and structural change.

The transformation of energy supply will weigh especially on real estate activities, utilities, manufactures of transport equipment, transportation and a few energy-intensive sectors such as iron and steel manufacture and the chemicals industry. Sectors that might benefit by opening up new areas of business at home and abroad are construction, building technologies, electrical engineering, manufactures of machinery and equipment, agriculture and forestry, and some service sectors such as research and development and financial services. Some divisions in utilities, transport equipment and chemicals will feel a strain, others, however, will find new sales opportunities. Due to cross-sector interdependencies – especially from deliveries of intermediates and cost pass-through – as well as macroeconomic feedbacks, the structural effects are broadly distributed across all sectors of the economy.

The required qualifications will also change. This can already be anticipated because the sector composition of employment is changing and the required qualifications vary from one sector to another. Furthermore, the necessary qualifications within the sectors principally affected will change. Due alone to the high degree of innovation found in new energy technologies, it can be supposed that the required qualifications will increase. Looking at the occupations of workers employed in the use of renewable energy in 2007, the breakdown was 41 percent specialized labor, 27 percent commercial, 19 percent academics and 8 percent technicians and master technicians.[19] Jobs for workers with little qualification will also arise in some sectors, but the proportion of low-skilled workers in the aforementioned study was only 5 percent. The need for low-skilled labor in the area of heat insulation could increase. In general, there will likely continue to be a surplus of labor without professional training or education in the future.[20]

In addition to changes in the qualification required, it will frequently be necessary to supplement classic vocational training with sector-specific training. The impor-

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[16] de Serres, A., Murtin, F., Nicoletti, G.: A Framework for Assessing Green Growth Policies. OECD Economics Department Working Papers No.774. Paris 2010.

[17] These scenario calculations assume the upper limit of the middle variant of the 12th coordinated population projection of the German Federal Statistical Office (Statistisches Bundesamt). Statistisches Bundesamt: Bevölkerung Deutschlands bis 2060. Ergebnisse der 12. Koordinierten Bevölkerungsvorausberechnung. Wiesbaden 2009. (English version: Federal Statistical Office: Germany's population by 2060. Results of the 12th coordinated population projection. Wiesbaden 2009).

[18] Between 1991 and 2000 and between 2000 and 2010, per capita productivity rose more slowly than the real GDP. Cf. Statistisches Bundesamt: Volkswirtschaftliche Gesamtrechnungen. Inlandsproduktberechnung. Lange Reihen ab 1970. 2010. Fachserie 18, Series 1.5. Wiesbaden 2011.

[19] Bühler, T., Klemisch, H., Ostenrath, K.: Ausbildung und Arbeit für Erneuerbare Energien. Statusbericht 2007. Bonn 2007. For more up-to-date figures, cf. Wissenschaftsladen 2010: Arbeitsmarktmonitoring Erneuerbare Energien 2010.

[20] Helmrich, R., Zika, G. (ed.): Beruf und Qualifikation in der Zukunft – BIBB-IAB-Modellrechnungen zu den Entwicklungen in den Berufsfeldern und Qualifikationen bis 2025. Bonn 2010.

tance of cross-sector qualifications will rise at the same rate as innovative, quickly growing areas of business.

Little research has been conducted on the effects on the quality of jobs. The extent to which this reflects the structural change of sectors has yet to be examined because the incidence of atypical forms of employment, job security and remuneration can vary strongly by sector.

A sustainable energy supply with a high proportion of renewable energy sources and a significant increase in energy efficiency will also create structural change within sectors that – as measured by changes of job – might be more significant than the structural change between sectors, but is difficult to assess. From the social point of view, intrasector structural change is viewed as less serious because it generally requires less time and less need for retraining to change jobs within a sector.

Dr. Jürgen Blazejczak is a professor at the Merseburg University of Applied Sciences and a research professor at DIW Berlin | juergen.blazejczak@hs-merseburg.de

Dr. Frauke G. Braun is a research assistant in the Department Energy, Transportation, Environment at DIW Berlin | fbraun@diw.de

Dr. Dietmar Edler is a research assistant in the Department Innovation, Industry, Services at DIW Berlin | dedler@diw.de

Wolf-Peter Schill is a research assistant in the Department Energy, Transportation, Environment at DIW Berlin | wschill@diw.de

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Opening the Electricity Market to Renewable Energy —Making Better Use of the Grid

by Karsten Neuhoff

Opening the electricity market to renewable energy sources would create flexibility for the further integration of renewable energy, leading to considerably lower costs and emissions. This requires the electricity markets to be reorganized in three ways.

Firstly, most trading, and therefore production decision-making, is completed at least one day prior to electricity production. But it must be possible to make adjustments on shorter timescales, in order to effectively utilize wind forecasts, which are only relatively accurate a few hours ahead of production.

Secondly, demand for operating reserve to stabilize the grid varies with the uncertainty of forecasts for wind and other generation. Most power plants can offer operating reserve, but only together with electricity. At present, however, operating reserve is traded separately from electricity, often in long-term contracts. And thirdly, network operators generally compensate market participants for grid constraints. But with around 200 GWs of new wind and solar capacity being built by 2020, grid expansion must be combined with transparent, market-based congestion management.

The introduction of an independent system operator offering an integrated platform for short-term power trading using a pricing system that internalises network constraints (»nodal pricing«) could meet these conditions, allowing further openings of the power market for renewable electrical energy. Experience in the US and simulations for Europe show that international transmission capacity is up to 30% better utilized, congestion management alone yielding annual savings of 1 - 2 billion euros.

The deregulated electricity market was designed with conventional power generation in mind, but the requirements are changing with the rise of renewable energy.

Wind and solar energy production is dependent on weather conditions, which cannot be accurately predicted. It must thus be possible to coordinate with other power plants‘ production on short notice, i.e. up to only a few hours prior to delivery. The shorter time horizon is accompanied by a spatial challenge stemming from the fact that wind and solar power plants are connected to a network already being used by conventional power plants. Transmission capacity must now be flexibly allocated and expanded where production is concentrated.

In planning for the evolution of the electricity market, both the temporal and the spatial dimensions must be simultaneously taken into account. European national action plans for renewable energy envisage 200 GW of additional wind and solar capacity by the year 2020. It is not economically, environmentally or politically viable to expand networks to such an extent that transmission constraints never occur. Instead, what is important is to efficiently expand the grid while simultaneously implementing effective congestion management.

Integration of renewable energy poses new challenges

Energy production using coal, nuclear fuel and gas can be planned over the long term. Most output is traded no later than at the auction on the day before production; which has proven an appropriate practice in the past. The situation is different with wind power, however, as weather and wind forecasts are rather imprecise. Taking Spain as an example, Figure 1 shows that forecasts are considerably more accurate up to four hours ahead of real time. While forecasting has generally improved, inaccuracies cannot be eliminated, even in Germany[1].

Wind turbine operators and their representatives thus would like to trade power a few hours prior to production, but the previous day's central electricity auction is already over.

If wind forecasts indicate lower wind power generation versus the day-ahead forecasts, conventional power plants need to increase their own production accordingly. This considered, there are three reasons why in today's market the most suitable, cost-effective power plants are not always used.

- *Fragmentation*: In most cases, production only has to be adjusted for a few hours at a time to meet demand. Power plants need to be able to start up or increase production in exactly that period. But in the bilateral intraday market, plants with the right location and availability are relatively hard to find.
- *Participation*: Not all conventional power plants able to supply surplus electricity have a trading department that is open 24 hours a day.
- *Transparency*: Electricity prices in short-term bilateral trading are difficult for small suppliers and competition regulators to monitor, as prices in bilateral trading include a variety of costs not limited to fuel costs, but also a margin covering fixed costs and costs for power plant start-up and adjustments.

Reduction of power plant overcapacity and rising demand for flexible production are increasing the opportunities and incentives for participants to exercise market power. In the bilateral intraday market, it is however difficult to verify whether a power plant has offered all options for producing on short notice or adjusting production while offering a 'fair' price for the output.

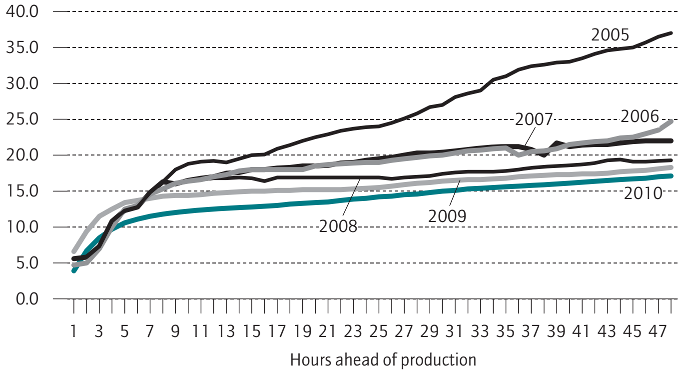
In the past, most renewable electricity in Germany has been produced in accordance with the German Renewable Energy Sources Act (EEG), and thus was marketed by transmission network operators –until 2008 all expected wind output was sold in the day-ahead power exchange, and since 2009 in short-term intraday trading as well. This has increased liquidity in intraday trading[2].

The next step proposed for the EEG by the German government is to offer renewable electricity producers the option to receive a variable market premium instead of fixed compensation when they market their own power[3]. This premium charge is to be passed on to the consumer, and gives plant operators a business incentive to effectively market their electricity. However, the optional premium model does not solve the fundamental problems with short-term trading (fragmentation, participation and transparency) or grid problems: they are only partially alleviated.

Figure 1

Average wind forecast error for Spain

In percent



Source: Based on data from Red Eléctrica de España, SA, error calculation for 2009/2010 adjusted, thus no direct comparability.

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Just a few hours ahead of production, the wind forecasting error rate falls below 10%.

The key role of the independent system operator

Platform for short-term energy trading

In most deregulated electricity markets in the US, an independent system operator (ISO) has been introduced who conducts the central auction on the day prior to electricity delivery. Specific power plant characteristics may also be stated (such as plant start-up duration and cost, minimum and maximum electricity production and adjustment period).

The auction outcome corresponds initially with previous-day electricity European exchange trading. However, the ISO retains the supply parameters for the remaining hours until delivery. The auction outcome is upda-

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[1] Dena Grid Study II – Integration of renewable energy into the German electricity network in the period from 2015-2020 with a view to 2025), Berlin 2010.

[2] Weber, C. (2010): Adequate intraday market design to enable the integration of wind energy into the European power systems. Energy Policy no. 7, 3155–3163.

[3] German government (2011): Report on Renewable Energy Sources Act, Federal Government draft, Version 03.05.2011.

ted to reflect any short-term changes in production and demand. All supply offers can still be included (participation) and specific power plant characteristics taken into account (fragmentation). Transparency is created by separately listing the cost components of offers and the operational requirements, and the ISO conducts the auction according to a clearly defined algorithm. Market participants benefit from this approach, as they are paid for all adjustments versus the previous day‘s auction outcome, while electricity consumers benefit from the algorithm‘s day-ahead and intraday optimization across the entire power system that lowers costs[4].

Combined trading of energy and operating reserve

Separate marketplaces were introduced in Germany upon deregulation of the electricity sector. Electricity supply firms buy electricity from power plants to meet their own customers‘ demand, and transmission network operators pay power plants for providing operating reserve (Box 1). This reserve power is utilized to balance out real-time fluctuations in production and demand.

In the past, power plants have sold energy and operating reserve separately and to different groups of buyers. This worked as long as it was possible to plan and coordinate coal, gas and nuclear energy production over the long term. If it is known which power plants are producing what amount of electricity, it is clear who is able to provide operating reserve. A wind farm can only do this when the wind is blowing. Therefore, it cannot sell operating reserve over a long-term period.

With electricity production from wind and sun increasing, conventional power plants must adjust their production to the supply situation on a more short-term basis, making the power system less predictable. Providing operating reserve thus becomes more complicated. If, on the other hand, electricity and operating reserve can be traded together on a short-term basis, all technologies can play a role in providing system services, thus reducing costs and emissions[5].

Optimal provision of operational reserve

The volume of operational reserve required is not fixed but depends on the current state of the system. For example when wind speeds are high, the probability that local wind speeds exceed the limit of wind turbines and they are shut down increases. Operating reserve can only be efficiently provided when the amount is determined on short notice based on information about the status of all power stations[6].

Box 1

Operating reserve

Operating reserve is utilized to ensure that electric power supply always precisely matches electricity demand. It is used to balance out the effects of short-term power plant failures, fluctuations in demand and load or wind forecasting inaccuracies. There are three types of operating reserve, reflecting the technical capabilities of traditional technologies:

- Primary operating reserve is available within 30 seconds for a period of 15 minutes. It can be produced by all major thermal power plants by exploiting the inertia in a steam cycle and temporarily heightened steam production.
- Secondary operating reserve is available within five minutes, for a minimum period of 60 minutes. It is provided by starting up rapid output generation plant such as pumped storage power stations and gas turbines, or by increasing the output of power plants already running at below capacity.
- Tertiary operating reserve is available within 15 minutes. The longer warning time allows including different types of power plants and power buyers, usually by notifying industrial firms by telephone.

Many renewable energy sources and demand side response can provide operating reserve both rapidly and over an extended period of time. However, they have to restrict their supply of operating reserve to categories/rules defined for conventional power plants. This reduces the amount they are able to supply to the power system, and for which they are paid (if not covered by the EEG).

Additionally, bids by transmission network operators for primary and secondary operating reserve apply for a whole month. This prevents wind energy from participating, as it will not be able to provide operating reserve when there is no wind.

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[4] Muesgens, F., Neuhoff, K. (2002): Modelling Dynamic Constraints in Electricity Markets and the Costs of Uncertain Wind Output, EPRG Working Paper Series 0514; TradeWind (2009): Integrating Wind. Project report for the trade-wind study coordinated by the European Wind Energy Association 2009.

[5] Smeers, Y. (2008): Study on the general design of electricity market mechanisms close to real time. Study for the Commission for Electricity and Gas Regulation (CREG).

[6] EWIS (2010): European Wind Integration Study – Towards a successful integration of wind power into European Electricity Grids. ENTSO-E Premises, March 2010.

Transmission network operators, however, only have limited information on the status, the operational schedule of power plants and on neighbouring networks. Accordingly, it is difficult for them to optimize their provision of operating reserve.

Defining new categories of operating reserve

The ability to market new energy and system services is essential in opening the market to new technologies. Wind turbines, battery storage and demand management have completely different reaction times and operating periods compared to »traditional« types of operating reserve. However, they still have to serve the rigid auction formats matching traditional categories.

The integrated auction mechanism for energy and operating reserve used by ISOs allows the flexible formulation of specific technical options. In turn, this allows new technologies to be contracted and remunerated according to technological ability, boosting the incentives for innovation and investment.

Enhancing competition in trade

ISOs play a clearly defined role in providing a platform for day-ahead and intraday energy trading, but are not involved in longer-term energy trading. This allows for competition among trading platforms to host trades of longer-term energy products.

To implement market coupling between countries, one power exchange from each country is linked to the international clearing mechanism. This power exchange thus becomes the preferred place for short-term trading. The price on the power exchange is usually taken as a reference value for trading of derivatives, thus creating an incentive to also trade derivatives on the same platform and reducing competition with other trading platforms.

European markets too inflexible in the short term

The discussion up to now has shown some of the challenges in integrating renewable energy that have resulted from the current market design. An ISO may lend flexibility to a platform for short-term trade in energy and operating reserve. This becomes apparent by comparing selected countries according to the following criteria:

- Efficient use of power plants: Would this optimize production across power plants towards an efficient provision of energy and system services?
- Demand adjustment in operating reserve: Would operating reserve energy storage be adjusted for system requirement?
- Power plant flexibility: Can power plants trade energy in flexibly defined blocks of several hours (fragmentation)? The past saw predefined blocks of hours formed for trading in day and base load. Wind power does not follow these rigid structures.
- International market integration: Can energy and operating reserve be sourced from other countries on short-notice, and is the market compatible with congestion management?
- Transparency: Is there enough transparency for effective market supervision? This is especially important in short-term markets as they are predestined for exercising market domination for three reasons: First, the number of market participants is small - often only a few power plants offer the necessary flexibility and are in a suitable operating mode at appropriate locations. Second, production in hydro-electric power and conventional power plants changes with the production from wind and solar power. This will reduce the share of power output that already is committed based on long-term contracts, and increases the importance of short-term trading. Without coverage of output by long-term contracts, the most important mechanism in reducing incentives to exercise market power breaks. Third, the cost structures of the power stations bids are difficult to determine as they can reflect stand-by, start-up, and adjustment costs and can include the scarcity value.

A functional market that fulfils these criteria ensures fair power prices for final customers and reduces the costs of integrating wind and solar power, while promoting market opportunities for small suppliers that cannot optimize within the portfolios provided by power plants.

Qualitative evaluation in Figure 2 shows that the current electricity market does not provide the flexibility required for effectively integrating renewable energy. Fulfilling individual criteria is not enough – an integrated solution is required. The market model with an ISO, as introduced in most of the liberalized US markets, fulfils these new requirements. The comparison assumes that the ISO – as is the case in US examples – provides the platform for the short-term energy market.

Three factors explain the good results that this model shows. First, the ISO carries unequivocal responsibility for the system. Second, an independent system operator has all of the major information on the system and holds the responsibility for implementing efficient and safe system operation. The ISO uses a uniform auction

Figure 2

Market comparison for operating reserve and short-term energy trading

	Dispatch adjusted during day	Balancing requirements during day	Flexible use of conventional power stations	International integration of markets	Effective monitoring of market power
UK system	◔	◔	◔		◔
German system	◐		◔	◔	◔
Nordpool	◐	◐	◔	◐	◔
Spanish system	●	◐	●		◐
ISO with nodal pricing	●	●	●	◕	●

Source: Borggrefe, F., Neuhoff, K. (2011): Balancing and Intraday Market Design: Options for Wind Integration, www.climatepolicyinitiative.org.

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The European markets do not do justice to requirements with regard to integrating renewable energy.

platform that takes every bid from market players to find an ideal market solution across the system. Third, the clearing algorithm in the auction platform represents the technical reality of the electricity system. Most US regions with liberalized electricity markets have since switched to this market model combining an ISO with nodal pricing after its introduction in the integrated electricity markets of Pennsylvania, New Jersey and Maryland (PJM) in 1998.

Network congestion gaining relevance in the electricity market

Up to now, electricity has been traded on a nationwide wholesale basis at a uniform electricity price in Germany. This uniform price zone may turn out to be a serious challenge to the energy revolution. Producers and traders may freely choose where to supply electricity to the grid and where to draw electricity from the grid. This leads to situations where the planned electricity transmission is greater than the transmission capacity of the grid. Intervention is required from the network operator in order to ensure network stability. The operator pays the power plants contributing to the grid overload to reduce electricity production and conversely, pays power plants in other regions to replace the electricity (known as redispatching).

There are historical reasons for the congestion management we have today. European electricity markets were liberalized at the end of the twentieth century, when the electricity companies were vertically integrated. Simple, clear rules were necessary to give competition and new market entrants a chance. As it was difficult for third parties to verify calculations of costs and commercial available transmission capacity of vertically integrated electricity companies, regulators created uniform price zones and rules for international electricity transfers. Constraints within countries were not explicitly represented in the market design. Instead, the dominant companies were required to resolve constraints within their own supply areas. These companies owned almost all of the power plants that both contributed to constraints and were necessary to resolve them, and were thus in a good position to carry out the task.

Unbundling of electricity generation, transmission and distribution has reduced the ability of network operators to resolve constraints by adjusting production in their own power plants. Also more players – including renewable energy – contribute to grid constraints, and have to be included in congestion management. This requires transparent congestion management to solve conflicts between technologies (e.g. feed-in priority according to the German Renewable Energy Sources Act), as well as a credible basis for decisions on extending the network. However, the most important aspect is effective usage of grid capacity for increased inclusion of renewable energy and a secure European electricity supply.

Faced with increasing congestion on the network, costs to resolve transmission constraints and mitigate any risks to grid stability rise with uncoordinated congestion management[7]. Producers and traders can report their schedules to the network operators up to a quarter of an hour before real time. This gives the network operator a very limited time window to recognize and remedy any possible constraints. To make matters worse, the number of power plants located at suitable grid nodes and are in a position to react within the necessary timeframe is limited. For this reason, transmission system operators retain the right to refuse short-term changes in schedule[8]. However, this poses a challenge for short-term bilateral energy trade if agreed energy transfers can subsequently not be executed.

However, the alternative of subjecting the transmission system operator to the obligation to carry out all transactions is equally unsatisfactory. As soon as congestion is expected, even small producers in regions of an

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[7] Improved coordination would not have prevented the reasons for previous blackouts, but would probably have prevented their broad spread (USA and Italy 2003, UCTE 2006. Bialek , J. W. (2007): Why has it happened again? Comparison between the 2006 UCTE blackout and the blackouts of 2003. IEEE PowerTech Conference, Lausanne.

[8] Tennet (2011): Bilanzkreisvertrag zwischen TenneT TSO GmbH und BKV (Area supply regulation contract between Tenne T TSO GmbH and BKV), www.tennettso.de, May 4 2011.

export constrained area within a price zone would profit from first selling additional production, and then being paid by the transmission system operator for reducing production. In the autumn of 1998, this caused a failure on the British gas market[9], and was one of the most important factors in the failure of the Californian electricity market in the years 2000/2001. Both cases were triggered by increases in congestion levels.

Increasing constraints in Germany

In the past few years, increased electricity production from wind turbines has increased demands on the German grid. The situation began with a relatively well-developed national grid. The German grid had long since been up to the demands put to it, and the network operators contributed to improved grid capacity utilization with overhead cable monitoring. The years 2009 and 2010 saw two particular events which reduced electricity transmission from northern to southern Germany.

Reduced precipitation led to a reduction of hydro-electric power in Norway, with power imported also from Northern Germany to make up the difference. In addition, two nuclear power plants in northern Germany were out of action for servicing. Even if it is unclear what impact accelerated departure from nuclear energy will have on electricity transmission in Germany, one thing remains certain – investment in wind power in northern Germany will take a disproportionate share of future investment. In general, transmission constraints in Germany will likely undergo a sharp increase. This calls for extension to the grid while introducing appropriate congestion management to use the existing capacity efficiently.

Uniform wholesale price untenable in Germany

An argument that is often raised is that extending the grid to a sufficient extent will be enough to retain the uniform price zone. However, other transmission networks are not placed under such expectations. Capacity on rail, road and in the air usually falls short of demand at peak times. Flight prices, railway contingency ticketing and longer periods spent in traffic congestion often encourage travellers to alter their route or time of travel. In contrast, in the current power market design electricity producers are rewarded for congestion occurring on the network as the transmission system operators – and therefore also the end customer – subsequently pay the producer for adjusting production to resolve these constraints.

Introducing market based congestion management

Initial experience with market-based congestion management on the international electricity markets has been positive in Europe. First, auctions were introduced for transmission capacity between individual countries. Only those that purchase transmission capacity can register for electricity trades between countries. Separate auctions for transmission rights and energy have not yielded an efficient market result – even after years of operation. Therefore electricity markets have been increasingly coupled directly to one another – market players submit their bids for electricity production at their national electricity exchanges. A common algorithm determines the market price in individual countries, and uses the transmission capacity available between the countries to balance out price differences as far as possible. Common optimization across several price zones is referred to as market coupling.

Norway and Sweden often experience transmission constraints between hydro-electric plants in the north and demand in the south. Several price zones have been introduced within the countries for this reason. However, defining price zones within a country proved difficult, even with the simple structure of the Scandinavian supply network[10].

In technical terms, the price zones should be formed in such a way that transmission constraints occur between the zones, where they are solved by market means, rather than by redispatching within a zone. However, the congested lines can change after grid extensions, or with the connection of new power plants or added demand. In each instance new price zones would have to be defined. This is unsettling for investors and dealers, as they have no way of telling whether their trading partner will remain within the same price zone or not. Possible changes in price zones also make it difficult for an ISO (in this case, Nord Pool), to conclude long-term transmission agreements with market players between price zones. This is a challenge to long-term contracting and thus also for investment in generation capacity.

Defining price zones in Europe‘s continental electricity network is even more difficult. Figure 3 shows how tightly meshed the transmission network is. The simulation represents electricity production in a randomized

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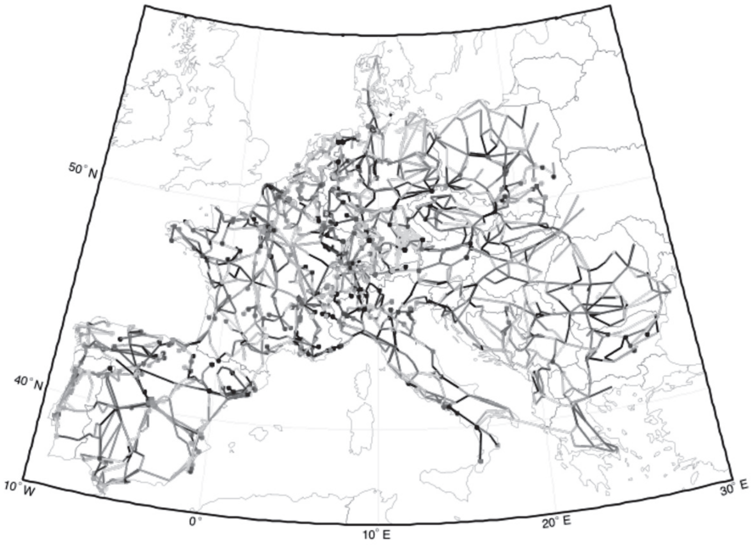
[9] McDaniel, T., Neuhoff, K. (2003): Auctions to gas transmission access: The British experience. In: M. C. 50W Janssen (Publ.): Auctions and Beauty Contests: A policy perspective. Cambridge.

[10] Bjorndal, M., Jörnsten, J. (2007): Benefits from Coordinating Congestion Management – the Nordic Power Market. Energy Policy, 35 (3), 1978–1991.

Figure 3

Line loads – simulation for Europe with 12.5% wind power



Dark lines = heavy load, light lines = less load.

Source: Neuhoff K, and J. Barquin, J. Bialek, R. Boyd, C. Dent, F. Echavarren, T. Grau, C. von Hirschhausen, B. Hobbs, F. Kunz, C. Nabe, G. Papaefthymiou, C. Weber, H. Weigt (2011): Renewable Electric Energy Integration: Quantifying the Value of Design of Markets for International Transmission Capacity, CPI Report. www.climatepolicyinitiative.org.

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wind situation assuming extended wind power. The darker lines represent heavier line load. Effective congestion management would prevent overload on individual lines. Many of the constraints have turned out to be within, and not between EU countries[11]. This speaks in favour of introducing price zones within national borders as well.

However, constraints do not only move with new investments, but also with changes in wind or demand situation, as the Scandinavian experience shows. National price zones need to be divided into smaller price zones, but defining them in such a way as to keep them stable is a difficult task. This matches the US experience after liberalizing the integrated electricity markets in Pennsylvania, New Jersey and Maryland (PJM). First, congestion management was only introduced for transmission lines that had often been subject to constraints. However, ever-increasing numbers of lines had to be included since the electricity transmission flow and therefore constraints often changed[12]. This resulted in excessive complexity in trading and operation. For this reason, the market system was transferred to a system of nodal prices as shown in Box 2.

Box 2

Keyword: nodal prices

Nodal prices are used for market-based congestion management. They may be regarded as an extension of market coupling. In today's market coupling systems, electricity auctions take place the day before for each price zone – such as the EEX in Germany and the APX in the Netherlands. The transmission system operators inform the exchanges taking part in the common auction program as to how much transmission capacity will be available between the price zones. The auction mechanism automatically plans for this in order to transfer electricity from price zones with low prices to price zones with higher prices. This leads to a convergence in price, often resulting in a single uniform price.

The more transmission constraints exist in the system, the smaller the price zones become for a uniform price to be applied to. Nodal pricing involves defining an individual price for each network node, typically connection points to the high-voltage network. If there are no constraints, neighbouring prices will still converge.

Usually, an independent system operator (ISO) will be ordered to implement the nodal prices. The ISO may take thermal, voltage and other technical network limitations into account in the auction mechanism. This makes effective and safe network utilization possible. In addition to the financially binding auction price from the previous day, the ISO also conducts several auctions during the course of the current day. This allows optimization across the whole system if forecasts for production and demand should change.

The ISO, usually a not-for-profit body, acts according to clearly defined algorithms and procedures, and can therefore act in the interest of the community without commercial involvement. The ISO only offers a platform for short-term trading, and publishes reference prices. Any longer-term trading will only take place bilaterally or at auctions.

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[11] EWIS (2010): European Wind Integration Study – Towards a successful integration of wind power into European Electricity Grids. ENTSO-E Premises, March 2010.

[12] Hogan, W. (2000): Flowgate Rights and Wrongs. Harvard University.

Nodal pricing is a market-based system of congestion management[13]. Up to now, electricity was only traded in one price zone under market coupling. Transmission system operators inform the electricity exchanges on the amount of transmission capacity available between national price zones. The common auction mechanism in the exchanges uses this information to plan transfers from low-price price zones to high-price price zones, thus also adjusting prices at the same time. Given sufficient free transmission capacity, this will result in a uniform electricity price. The more transmission constraints exist in the system, the smaller the price zones become that a uniform price can be applied to according to the Norwegian model. Nodal pricing involves always defining an individual price for each network node for this reason. If there are no binding constraints, prices in neighbouring nodes will converge.

In the European RE-Shaping Project, several European research organizations have simulated the European electricity system in order to quantify the effect of nodal pricing on the European market. First, the project involved modelling the electricity market with further development of zonal pricing, and the result was compared against a nodal pricing situation. Improvement in network utilization enables an increase of up to 30% in power to be transmitted between different regions. This matches the experience reported in the US on introducing nodal pricing[14]. The simulation results also show that effective network utilization would save annual fuel costs and emission rights by one to two billion euros[15].

Financial transmission rights key to introducing market-based congestion management

Clear definition and allocation of ownership rights are important for economic efficiency. Difficulties arise where ownership rights have been awarded more than once. This will be the case as long as market players are able to lay claim to customary rights to transmission rights unlimited by time or scope. One pragmatic solution could be for financial transmission contracts to be offered instead (Box 3).

Box 3

Keyword: financial transmission rights

Financial transmission rights remunerate the owner for price differences between two zones or nodes in the network. This allows longer-term electricity trading, such as where Power Plant at Node A sells electricity to a customer at Node B at a set price for one year. The power plant would sell electricity from Node A to buy it for the customer from Node B on a daily basis in the auction. The possible price difference – therefore the risk – would be secured by payments from the financial transmission rights.

If the sales price at Node A should fall short of the production costs of the power plant on a certain day, the power plant operator would be given the option of not producing any electricity. This would mean additional profit at the level of difference between the price at Node A and the power generation costs saved. Nodal pricing thus creates an incentive for flexible electricity production while financial transmission rights additionally secure long-term agreements and investments.

Introducing financial transmission rights was a central factor in the success of congestion management on the liberalized US electricity markets; physical transmission rights and other claims on the network were converted into financial transmission rights. This created legal security and acceptance. Financial transmission rights exist for time periods of up to thirty years in the US which protects investments against possible changes in network structure or utilization. A liquid market for financial transmission rights at periods of several years has established itself, which completes the picture in energy trading.

A pragmatic solution using nodal pricing was also found for household electricity supplies in most states. The whole state determines and applies a unified electricity price for households.

Karsten Neuhoff, PhD, is a Director of Research at DIW Berlin and heads the Climate Policy Initiative (CPI) Berlin office | kneuhoff@diw.de

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Discussion Papers

1133

Tilman Brück • Guo Xu

Who Gives Aid to Whom and When? –
Aid Accelerations, Shocks and Policies

Berlin, June 2011

Discussion Papers 1133 / 2011
Tilman Brück, Guo Xu

Who Gives Aid to Whom and When?: Aid Accelerations, Shocks and Policies

We address the pitfalls of averaging by exploiting the longitudinal variation in aid to identify sudden and sharp increases in aid flows. Focusing on specific events, we test if aid accelerations correspond to policies and shocks in the recipient country. For a large sample of 145 recipient countries and 33 donors from 1960- 2007, we find that positive regime changes and wars are significant predictors of aid accelerations. Disaggregating aid flows by donors, we find indicative evidence for competing allocation rules, particularly among European donors. We argue that drivers of aid accelerations differ from drivers of average aid flows - a distinction that can reconcile some of the ambiguous empirical results in the aid literature.

JEL-Classification: O1, F35, F50
Keywords: ODA, Growth Accelerations, Policies

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1132

Thilo Grau • Molin Huo • Karsten Neuhoff

Survey of Photovoltaic Industry
and Policy in Germany and China

Berlin, June 2011

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Thilo Grau, Molin Huo, Karsten Neuhoff

Survey of Photovoltaic Industry and Policy in Germany and China

As building-integrated photovoltaic (PV) solutions can meet around one-third of electricity demand in Germany and China, both countries are interested in exploring this potential. PV technologies have demonstrated significant price reductions, but large-scale global application of PV requires further technology improvements and cost reductions along the value chain. We analyze policies in Germany and China, including deployment support, investment support for manufacturing plants and R&D support measures, and we survey the industrial actors they can encourage to pursue innovation. While deployment support has been successful, investment support for manufacturing in these nations has not been sufficiently tied to innovation incentives, and R&D support has been comparatively weak. The paper concludes with a discussion of the opportunities for global policy coordination.

JEL-Classification: O31, Q42, Q48
Keywords: Photovoltaics, Technology Policy, Innovation, Investment Support