Comparing the Cost of Low-Carbon Technologies: What is the Cheapest Option?

An analysis of new wind, solar, nuclear and CCS based on current support schemes in the UK and Germany

ANALYSIS

Agora Energiewende

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IMPRINT

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Preface

Dear reader,

Two decades of technological development have led to a strong reduction in the cost to produce power from wind and solar energy. The roughly 80 percent reduction in the feed-in tariff for solar power in Germany witnessed over the past five years demonstrates this fact. But how competitive are wind and solar power today in comparison to other low-carbon technologies? In view of Europe's ambition to achieve the cost-effective decarbonization of the power sector, we believe this question is highly relevant.

We have therefore asked Prognos AG to compare the current cost of different low-carbon technologies, based on current technology specific support schemes, and taking into full account the reliability of the power system.

The comparison of costs presented here is only a snapshot of the current situation. Policy choices and technological developments will influence future cost trends for all technologies. With this snapshot we hope to contribute to a fact-based debate on different policy options.

Yours,
Patrick Graichen
Executive Director of Agora Energiewende

Key findings at a glance

1. **New wind and solar can provide carbon-free power at up to 50 percent lower generation costs than new nuclear and Carbon Capture and Storage.** This is the result of a conservative comparison of current feed-in tariffs in Germany with the agreed strike price for new nuclear in the UK (Hinkley Point C) and current cost estimates for CCS, neglecting future technology cost reductions in any of the four technologies.

2. **A reliable power system based on wind, solar and gas backup is 20 percent cheaper than a system of new nuclear power plants combined with gas.** A meaningful comparison of the costs of different energy technologies should take into account the need for backup capacities and peak load plants. Such a comparison shows that while additional costs arise for backup gas capacity in a system based on wind and solar PV, these costs are small compared to the higher power generation cost of nuclear.

Content

1 Overview

→ Some EU Member States are considering the construction of new nuclear power plants, whereas others favour the expansion of renewable energy or Carbon Capture and Storage (CCS). All claim to bring down costs and enhance energy security.

→ Of the three low-carbon technologies under discussion – renewables, nuclear, and CCS – we find that currently the cheapest technologies are wind and solar photovoltaics (PV). Today's feed-in tariffs for wind and PV in Germany are up to 50 percent lower than those offered for new nuclear in the UK according to the Hinkley Point C agreement. This comparison does not consider future cost reductions.

→ For CCS, currently no real cost figures are available, since this technology is still in its demonstration phase, and the first commercial plants are not expected to be operational before 2020. The latest studies estimate CCS to cost about as much as new nuclear power or more.

→ Simple cost measures for individual technologies such as the levelized cost of electricity (LCOE) fail to consider the higher-priority requirement of power system stability. A comparison of renewables and nuclear power must take the needed backup capacity for renewable energy sources into account in order to arrive at more meaningful cost estimations for the power generation system. Moreover, nuclear power plants are never used to cover full demand but are always accompanied by flexible peak load plants. Therefore, a low-carbon system cost comparison needs to contrast a mix of wind, solar and gas with nuclear and gas.

→ Cost estimates for power generation systems show that even today and under conservative assumptions, a generation mix consisting of PV, onshore wind and gas is approximately 20 percent less expensive than a mix consisting of new nuclear power (based on the Hinkley Point C agreement) and gas. In the future, renewables are likely to become even more competitive in comparison to nuclear power due to technological advancements and associated cost reductions, even if nuclear can make up some ground through cost reductions.

2 Background and approach

Mandatory renewable energy targets have been set for EU Member States for the period until 2020. After 2020, however, things are less clear (EC 2014). Member States' preferences and perceptions on how to best pursue greenhouse gas emission reductions in the power sector vary considerably. Many emphasize the importance of renewable energy sources, whereas others see a significant role for new nuclear power stations or Carbon Capture and Storage (CCS). For example, the UK government recently concluded an agreement with a group of companies on the key conditions for a proposed investment contract for the Hinkley Point C nuclear station ("HPC agreement").[1] This planned project is supposed to start the process of replacing the existing fleet of nuclear power stations in the UK. Furthermore, the UK government issued funding contracts for the next phases of two CCS demonstration projects ("White Rose" and "Peterhead"). Final government funding decisions in this connection are expected in 2015 (UK Government 2013a, b).

Apart from questions related to externalities and the risks associated with different power generation technologies, the arguments revolve around cost and energy security. While wind and solar energy installation costs are becoming more and more competitive, the power from these technologies is variable in nature and cannot be easily compared to the firm capacity secured by dispatchable power plants. Simple cost measures for individual technologies such as the levelized cost of electricity (LCOE) do not take into account the fact that variable PV and wind depend on backup capacities, as they are not capable of supplying the market at any given time. Therefore, a meaningful comparison must take this needed backup capacity for renewable energy sources into account.

For CCS, no cost figures based on actual experience are available since there is currently no commercial power plant with CCS in operation (IEA 2013). Of the 12 CCS demonstration plants in Europe that the EU Commission envisaged in 2008, two projects in the UK are still being actively pursued: White Rose, a coal-CCS plant, and Peterhead, a gas-CCS plant. Both have won the latest tender of the UK government to receive funding for the next planning phase. In 2015, the UK government is expected to make its final decision on the financing of these projects. Both projects are supposed to contribute to the objective of achieving cost-competitive CCS technology in the 2020s (UK Government 2013b). The comparisons conducted in this analysis rely on the latest available CSS cost estimates from studies commissioned by the UK Department of Energy and Climate Change.

Against this background, the present analysis aims to conduct a fair comparison of low-carbon technologies for power generation. It seeks to answer two questions:

- → Which of the key low-carbon technologies – new wind, new solar PV, new nuclear and new CCS – produce electricity at the lowest cost?
- → What is the cheapest low-carbon technology mix when accounting for the variability of wind and PV by including the cost of adequate backup capacity?

To answer these questions, this paper

1. compares publicly stated remuneration levels for new PV, wind (in Germany) and nuclear power (in the UK),

2. contrasts the remuneration paid for renewable energy sources with the levelized cost of electricity from fossil-based power generation technologies with CCS, and

3. estimates system cost for different portfolios of power generation technologies, namely a mix with variable renewable energy sources and gas versus a mix with nuclear power and gas.

1 In what follows, the HPC agreement is also referred to as "new nuclear power".

The **comparison of remuneration levels** includes onshore wind, offshore wind, PV and new nuclear power. Remuneration levels for PV, onshore wind and offshore wind are drawn from the current German feed-in tariff, whereas levels for new nuclear power are taken from the contractual conditions of the HPC agreement. The two types of remuneration differ substantially. While the German feed-in tariff involves nominal payments that lose real value over time, remuneration for new nuclear power is indexed to inflation so that the real value of payments remains stable.

The **levelized cost of electricity (LCOE) for fossil-based power generation technologies** is drawn from the literature to supplement the remuneration levels described above. LCOE is a simple and widely used indicator of energy generation cost that calculates the unit electricity production cost of different technologies over their economic lifetime (OECD 2012). The LCOE depends on annual full-load hours and a given technology's capital and operating costs. Customarily, the LCOE of a given technology is covered by support scheme payments such as feed-in tariffs. In this way, remuneration levels can be seen as proxies for the LCOE. For the cost estimates provided in this paper it is therefore adequate to compare the remuneration levels for nuclear power and renewable energy with the LCOE of other power generation technologies. But since the LCOE for individual technologies provides only limited information, the scope of the analysis needs to be enlarged to encompass the power generation system.

Estimating the system cost of different generation portfolios answers the question whether an energy mix consisting of nuclear power and gas or, alternatively, of renewable energy sources and gas results in lower total cost. To obtain such estimates, we analyse a German load profile. Covering the fluctuating load requires the supply of sufficient energy (MWh) as well as sufficient power generation capacity (MW) at every point in time. The first option (with nuclear power and gas) features two dispatchable generation technologies, in which gas is needed for intermediate and peak loads. By contrast, the second option needs to address variable power generation from wind and PV. Since these plants cannot ensure sufficient power generation at every point in time, more backup capacity is needed to provide the same security of supply. Combined-cycle gas power plants are used for intermediate loads and open-cycle gas turbine plants for peak loads. Our analysis of system costs does not include an option with CCS because commercial experience with CCS in Europe will not exist before 2020.

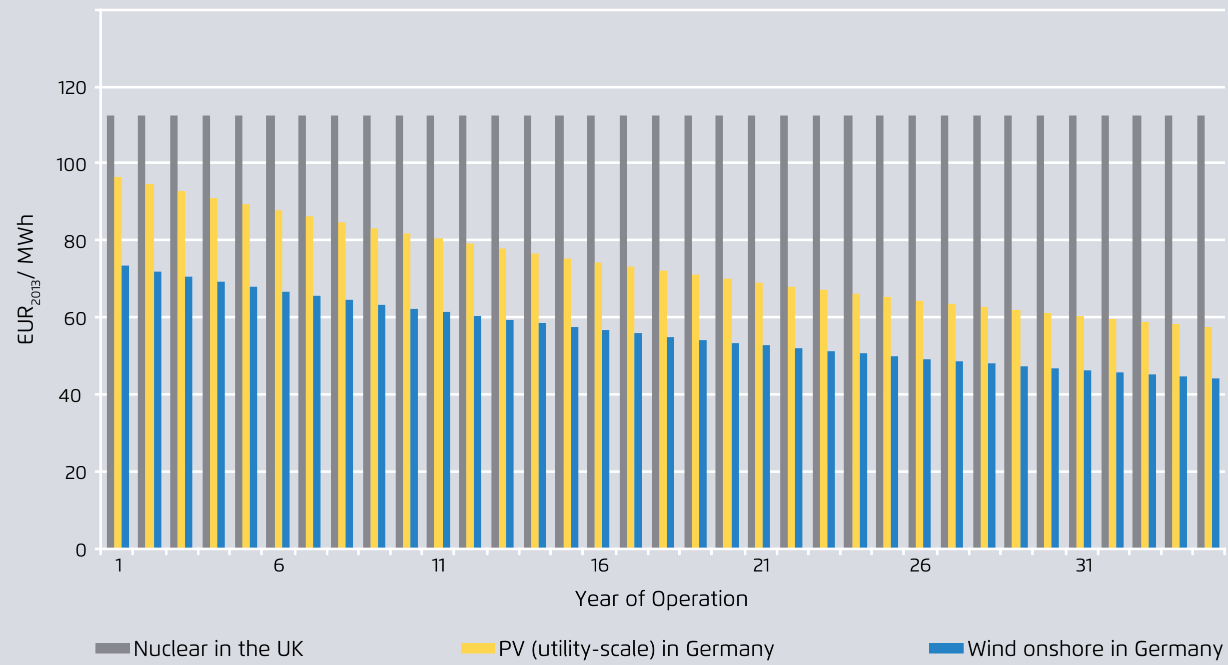
3 Comparing the cost of individual power generation technologies

This section presents two different kinds of cost figures. For new PV, wind and nuclear power, we draw on public figures for remuneration levels in Germany and the UK. For CCS, on the other hand, no such official figures exist. Since a commercial power plant with CCS has yet to go online (IEA 2013), the estimates from the UK presented here are likely to mark the lower bound of CCS costs that will be realized in the future.[2]

2 Since there is no commercial CCS experience in the UK, the CCS figures presented here represent "First of a kind" estimates for a commercial plant that assume experience has been gained from international and demonstration projects (DECC 2013).

Remuneration of new nuclear power in the UK as well as large PV and onshore wind in Germany after accounting for inflation (in real $euros_{2013}$/MWh)

Figure 1



EEG 2012, UK Government 2013a, calculations by Prognos AG; Onshore wind remuneration in Germany is presented here in a simplified way by showing average payments. In reality, remuneration at the beginning differs from remuneration at the end.

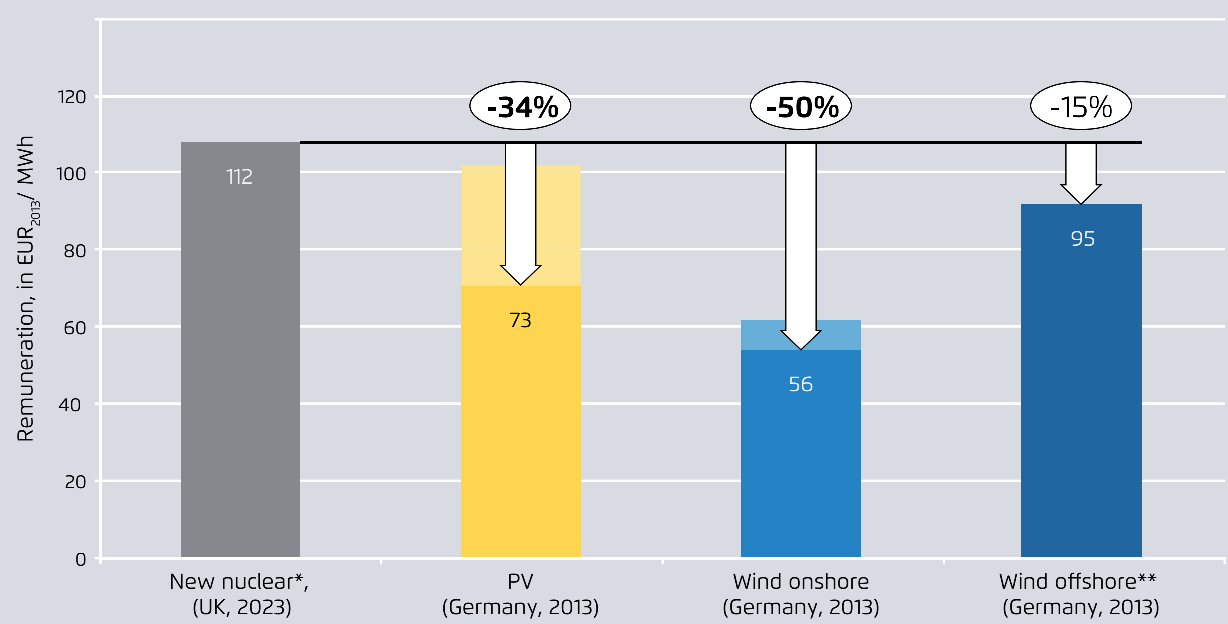
3.1 Remuneration levels for PV and wind in Germany and new nuclear power in the UK

Our comparison of remuneration levels for renewable energy sources and new nuclear power is based on the HPC agreement. According to this agreement, a new nuclear power station will be constructed in the UK and generate electricity from 2023 onward. Once the reactor goes online, the firms carrying out the construction will receive payments of 92.50 GBP_{2012}/MWh (about 112 $euros_{2013}$/MWh), indexed to inflation, for 35 years (UK Government 2013a; ECB 2014a)[3]. Those 35 years serve as the reference time horizon for the comparison below. Given the long-term character of these payments in the framework of a "contract for difference", they can be compared to the feed-in tariff payments for wind and solar energy in Germany, which span a time horizon of 20 years.

Figure 1 illustrates the constant value of payments for nuclear power in the UK during the reference time frame, assuming a fixed exchange rate of 0.85 GBP/euros. By contrast, the value of payments for PV and onshore wind in Germany diminishes continuously. Under current German law, a new wind or PV plant receives a fixed feed-in tariff for 20 years, without any adjustment for inflation. Therefore, over time, the value of payments decreases in real terms. The inflation rate is assumed to be 2 percent, which is consistent with the European Central Bank's target for maintaining price stability (ECB 2014b). To be compatible with the reference time horizon of 35 years, a new wind or PV installation is assumed to be built after the first 20 years. For the second installation, the same level of feed-in tariff is assumed as for the first installation,

3 The HPC agreement refers to 2012 prices. Taking into account inflation (as expressed in the consumer price index), 92.50 GBP_{2012}/MWh equals 94.8 GBP_{2013}/MWh (ONS 2014). Note that the remuneration for HPC may be reduced to 89.5 GBP_{2012}/MWh if the group of companies takes the final investment decision on another new nuclear power station at the Sizewell C site (UK Government 2013).

Comparison of average remuneration for new nuclear power in the UK, and PV and wind in Germany — Figure 2



DECC 2013; ECB 2014a; EEG 2012; Prognos AG 2013; UK Government 2013a; calculations by Prognos AG; * Hinkley Point C agreement ** Offshore wind 2013 without grid costs; in Germany, the regulatory approach excludes grid costs from being covered by the remuneration. Offshore grid costs are estimated to be between 25 and 35 EUR/MWh, depending on the distance to shore.

without any reductions in feed-in tariffs. This conservative assumption differs from current German law, which foresees a reduction of several per cent in nominal terms per year, depending on the capacity installed.

New nuclear power is remunerated with a constant payment of 112 euros$_{2013}$/MWh for 35 years. In contrast, large PV in Germany receives 96 euros$_{2013}$/MWh at the beginning, which declines to 57 euros$_{2013}$/MWh in the last year of operation. Similarly, onshore wind in Germany starts at 73 euros$_{2013}$/MWh and decreases to 44 euros$_{2013}$/MWh.

Overall, Figure 1 shows that PV and onshore wind remuneration in Germany is considerably lower than the remuneration paid for new nuclear power in the UK, even without taking into account further cost reductions for PV and wind that are likely to occur due to future technological learning effects.

The development of remuneration over time can also be expressed as averages. Figure 2 depicts average remuneration in real euros$_{2013}$/MWh over 35 years for new nuclear power in the UK, and PV, onshore wind and offshore wind in Germany. Payment ranges reflect different plant sizes (in the case of PV) and resource potentials within Germany (onshore wind).

New nuclear power in the UK (as per the HPC agreement) will be remunerated with real 112 euros$_{2013}$/MWh. In contrast, remuneration for utility-scale PV in Germany is 73 euros$_{2013}$/MWh, and for wind at high-quality sites 56 euros$_{2013}$/MWh. Even the still very young technology of offshore wind, of which only 520 MW were installed in Germany as of January 2014, receives a remuneration of 95 euros$_{2013}$/MWh – that is, 15 percent below the remuneration for new nuclear power.

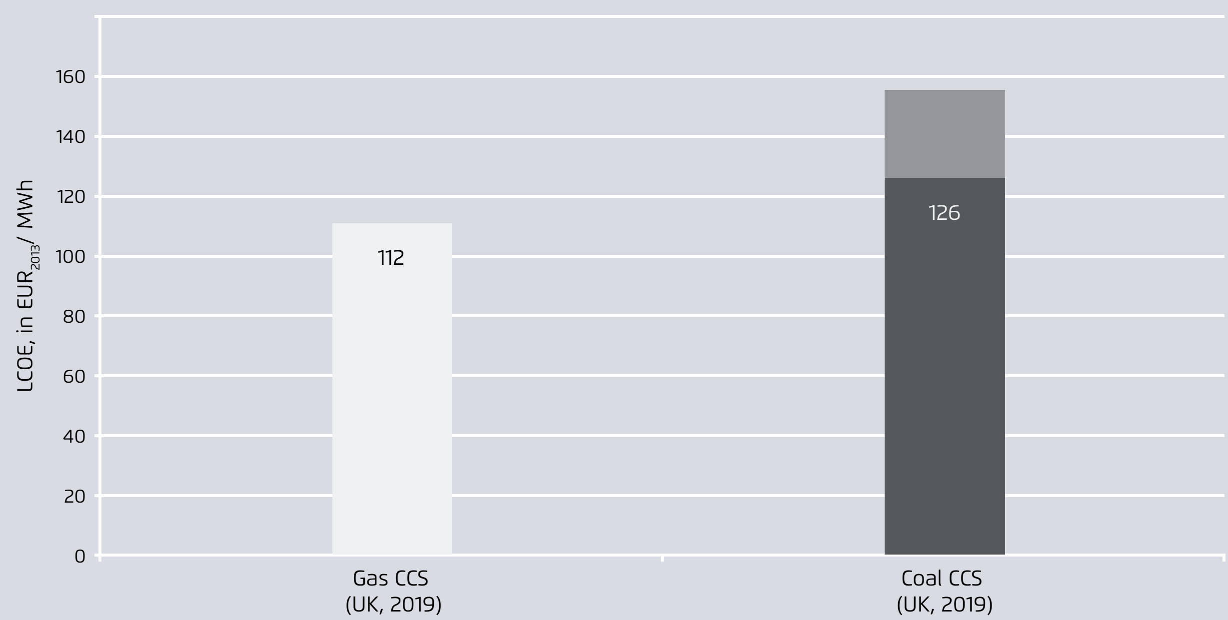
Overall, onshore wind at sites with a good resource potential and utility-scale PV cost substantially less than new nuclear power.

3.2 LCOE for different fossil-based power generation technologies with CCS

For new fossil-based technologies, no official remuneration payments by governments exist. Instead, different studies have estimated the costs of these technologies. Such individual cost are best expressed as the levelized cost of electricity (LCOE), and do not include any further cost components relevant to the entire energy system, such as grid costs or costs of providing sufficient backup capacity.

Figure 3 presents the LCOE estimates of the UK Department of Energy and Climate Change for 2019. The LCOE for gas power plants with CCS amount to 112 $euros_{2013}$/MWh. For power plants with coal CCS, the LCOE is estimated to reach 126 $euros_{2013}$/MWh (ASC with oxy combustion) or more (coal IGCC with CCS) (DECC 2013). Adding CCS to fossil-based plants will increase the cost of those power generation technologies.[4]

Comparison of levelized cost of electricity for gas and coal power plants with CCS — Figure 3



DECC 2013; ECB 2014a

4 Gas CCGT, for example, is 10–25 percent cheaper without CCS, as indicated in Table 2 in the appendix, depending on full-load hours and net efficiency.

3.3 Summary: Remuneration and LCOE for individual low-carbon technologies

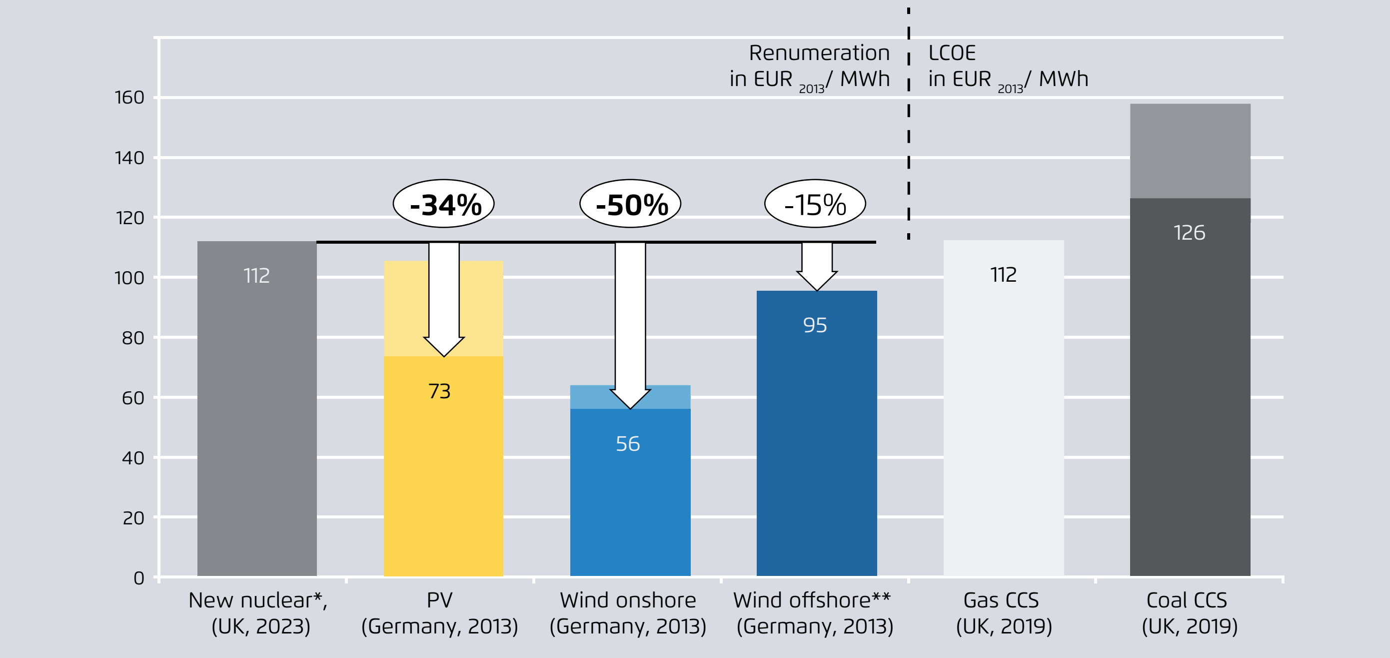
Figure 4 brings together the remuneration and LCOE figures from the two preceding sections. It shows average remuneration in $euros_{2013}$ per MWh over 35 years for new nuclear power in the UK; for PV, onshore wind, and offshore wind in Germany; as well as the LCOE of gas/coal CCS. When payment ranges are given, they reflect different plant sizes (in the case of PV), resource potentials within Germany (onshore wind) or specific CCS technologies (for coal CCS).[5]

New nuclear power in the UK will be remunerated with real 112 $euros_{2013}$/MWh, according to the HPC agreement. By contrast, remuneration for utility-scale PV in Germany is about 34 percent lower, and for wind at high-quality sites it is about 50 percent lower. Offshore wind receives 15 percent lower remuneration than new nuclear power. Gas CCS is estimated to cost about as much as new nuclear power, and coal CCS is estimated to cost 126 $euros_{2013}$/MWh or more.

Overall, onshore wind at sites with a good resource potential and utility-scale PV represent the low-carbon technologies with the lowest cost. Power from nuclear as well as gas and coal power plants with CCS represent the low-carbon technologies with the highest cost.

Comparison of average remuneration for new nuclear power, PV, wind and the levelized cost of electricity for gas/coal CCS

Figure 4



DECC 2013; ECB 2014a; EEG 2012; Prognos AG 2013; UK Government 2013a; calculations by Prognos AG; * Hinkley Point C agreement ** Offshore wind 2013 without grid costs; in Germany, the regulatory approach excludes grid costs from being covered by the remuneration. Offshore grid costs are estimated at between 25 and 35 euros/MWh, depending on the distance to shore.

5 Coal – IGCC with CCS and ASC with oxy combustion CCS. Note that the CCS figures refer to an underlying time horizon of 25 years (DECC 2013).

4 Analysis of power generation system costs

Simple cost comparisons of individual technologies, such as the ones presented above, fail to account for the larger requirements of the power generation system as a whole. For example, renewables need backup capacity to compensate for their inherent variability; and nuclear power plants need to be accompanied by flexible peak load plants to reach a capacity utilization that makes them economically viable. Therefore, comparing low-carbon system costs involves analyzing different generation technology portfolios.

4.1 Systems under consideration

To understand whether an energy mix with nuclear power and gas or with renewables and gas is less costly requires an assessment of the annual costs of two different energy systems. Such an assessment needs to include the cost of providing both sufficient energy (MWh) as well as sufficient power generation capacity (MW) at any given time.
Each system considered here is therefore designed to cover a real German load profile standardized to 1 GW, with 1 GW of average load, a minimum load of 0.6 GW and a peak load of 1.4 GW. The first system combines renewables (onshore wind, PV) and gas (combined-cycle gas turbine [CCGT] and open-cycle gas turbine [OCGT]). The second features nuclear power and gas (CCGT).

Both systems are designed in such a way that 50 percent of electricity is generated by renewables or, respectively, by nuclear power. The remaining 50 percent in each case is supplied by gas power plants. Since the same amount of electricity is produced from gas in both systems, the associated CO_2 emissions from electricity generation are approximately identical.[6] Consequently, changes in assumptions concerning the future cost of gas and CO_2 prices have the same impact on estimates for both systems. That is, the assessments are not sensitive to these price developments.

6 The uncertainties surrounding greenhouse gas emissions over the entire lifecycles of nuclear and renewable energy power generation are discussed in IPCC (2011).

The analysis here is limited to power generation cost and backup capacity. While the cost of grid expansion is not considered because it very much depends on the existing infrastructure in each particular case, its likely impact on the results is discussed in the final section of this paper.

Figure 5 shows samples for hourly energy production during one week for the two alternative energy systems. In both systems, gas power plants cover the residual load that is not covered by variable renewables or nuclear power. In the left panel, gas power plants balance the variation of residual load, whereas in the right panel, gas power plants compensate for the variation in power demand.

Our analysis is based on a historical load profile for Germany and the detailed modelling of power generation from onshore wind and PV performed by Fraunhofer IWES (Consentec et al. 2013)[7]. The system design ensures that hours of curtailment are scarce. Accordingly, this assessment does not consider storage technologies.

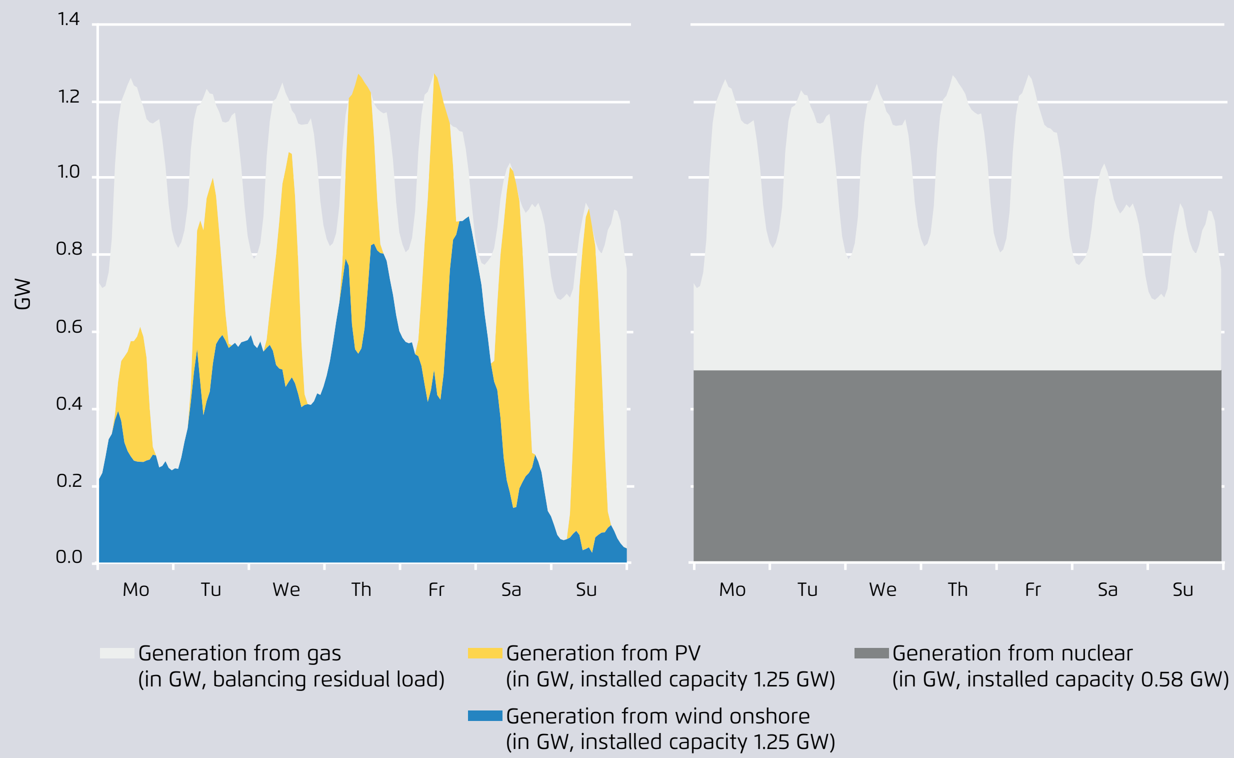
4.2 Installed capacity and annual power generation

The two systems under consideration use different power plants to securely cover electricity demand. The first system consists of installed capacities for onshore wind and PV of 1.25 GW each. With an average of 2,497 full load hours for wind and 1,016 for PV, total electricity production from renewables equals 4,391 GWh, of which 69 GWh needs to be curtailed (see below). In the second system, the installed capacity for nuclear is supposed to be 0.5 GW, which is slightly below the minimum load of the reference year. Due to regular maintenance, the nuclear plant only operates 7,500 hours per year. As a consequence, the actually installed capacity

7 8760 hours a year based on the weather year 2011. Further detailed modelling assumptions and figures can be found here: http://www.agora-energiewende.de/themen/optimierung/detailansicht/article/das-stromsystem-in-deutschland-2033-richtet-sich-nach-wind-und-sonne/

Sample comparison of hourly energy production during one week in the system with renewables and gas (left) versus the system with nuclear power and gas (right)

Figure 5



Own illustration, Fraunhofer IWES

must exceed 0.5 GW, and amounts to 0.584 GW. This leads to 4,380 GWh of nuclear power generated per year.

To balance the residual load, both energy systems use gas power. The gas capacity required for balancing is calculated from the maximum hourly residual load in both systems. As shown in Figure 6 (left panel) the derived installed gas capacity is 1.48 GW in the renewable energy system – enough to cover the entire peak load – and 0.9 GW in the nuclear system.

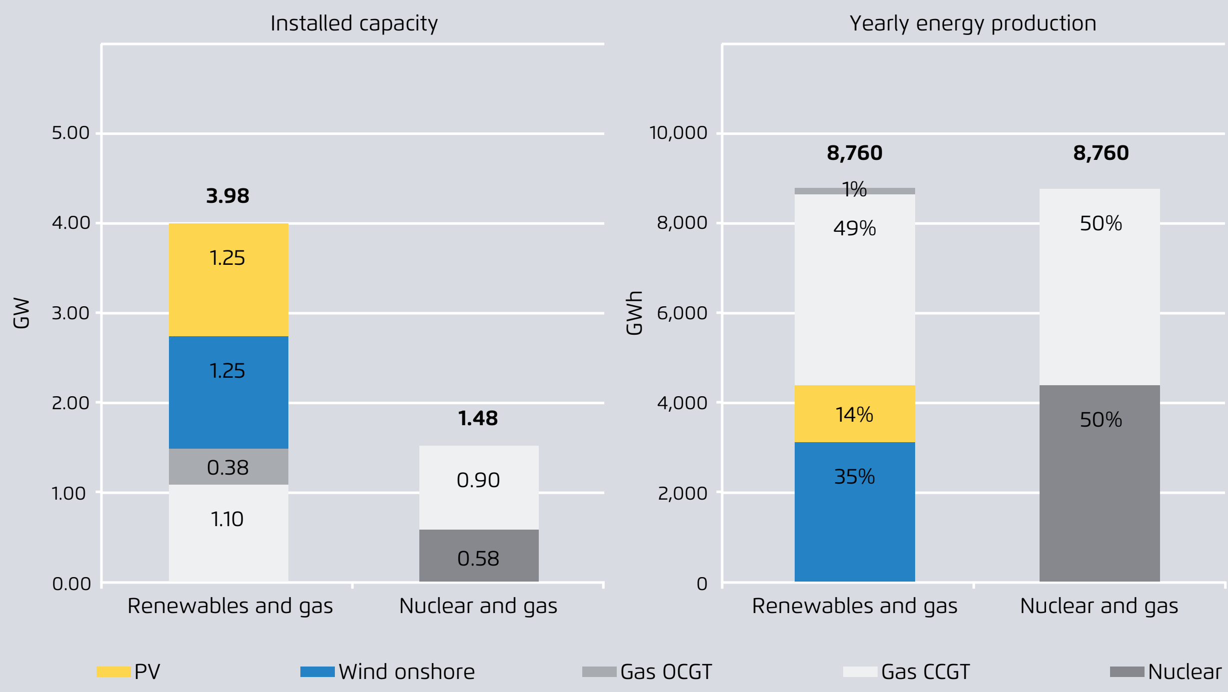
The total installed capacity of the renewable and gas energy system amounts to 3.98 GW. The total capacity installed in the nuclear and gas system amounts to 1.48 GW. Both energy systems have the same level of dispatchable generation capacity (1.48 GW) in order to ensure a balance between the generation and consumption of electrical energy at any given time. Overall, the installed capacity of the renewable and gas energy system is more than 2.5 times higher than the nuclear and gas energy system.

Figure 6 (right panel) compares the annual energy production of the two systems. Both systems produce a total of 8,760 GWh per year, of which 50 percent is provided by gas power plants.

In the renewables and gas system, wind accounts for about 35 percent of annual energy production, while PV accounts for about 14 percent. Approximately 49 percent of power is produced by gas CCGT, and 1 percent by OCGT.[8] The utilization of OCGT is only 289 hours a year. The total amount of variable power that exceeds the load and needs to be curtailed is 69 GWh – that is, 0.8 percent of total genera-

8 Wind 35.2 percent, PV 14.1 percent, gas CCGT 49.4 percent, gas OCGT 1.3 percent.

Comparison between installed capacity (in GW) and yearly energy production (in GWh) — Figure 6



EEG 2012; Prognos AG 2013; UK Government 2013a; calculations by Prognos AG.

tion. The nuclear and gas energy system obtains 50 percent of annual energy production from nuclear, and 50 percent from gas CCGT.

When added together, wind and PV energy production in the first system is equal to nuclear energy production in the second system. The energy production from gas is the same in both energy systems.

4.3 Annual power generation system costs

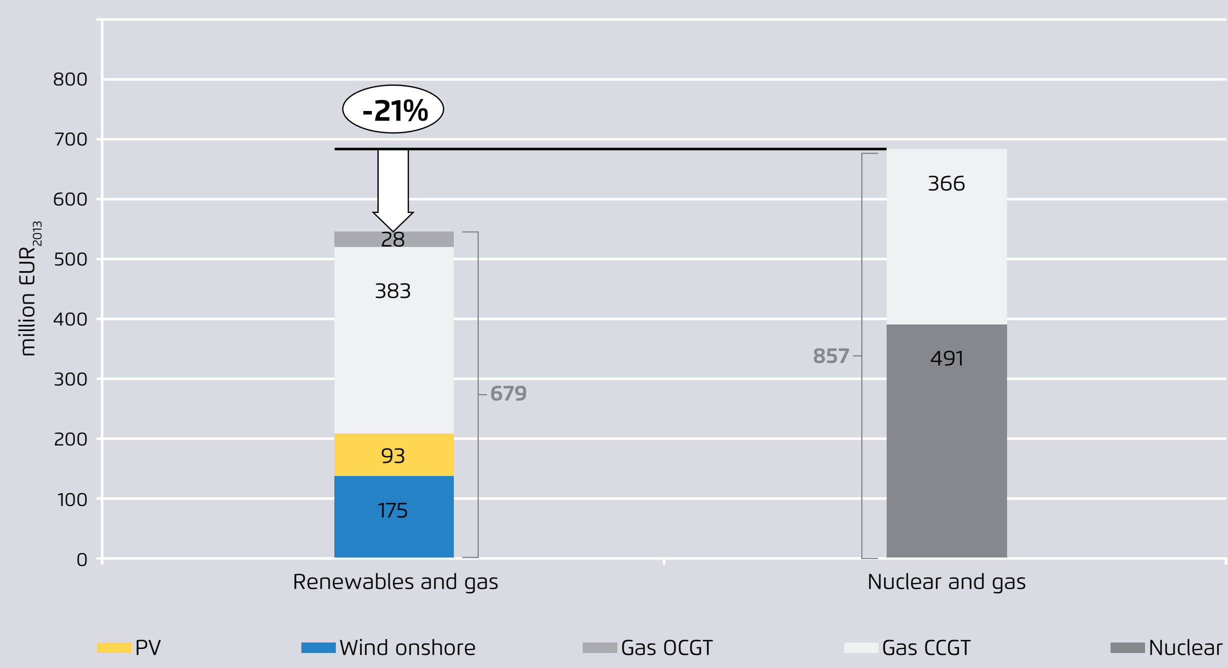
The final step in our analysis involves estimating the annual system costs for both systems, including the costs for energy production and security of supply. Costs are calculated based on the remuneration levels depicted in Figure 4. For CCGT and OCGT, LCOE figures[9] are adjusted for the full-load hours used in each system (see appendix).

As shown in Figure 7, in the renewable and gas energy system, onshore wind (175 million euros$_{2013}$) and PV (93 million euros$_{2013}$) represent about 40 percent of total annual system costs, while they account for almost 50 percent of annual electricity production, as illustrated in Figure 6. This includes feed-in payments for the curtailed amount of renewable energy (69 GWh), consistent with current German law. Together with gas CCGT (383 million euros$_{2013}$) and OCGT (28 million euros$_{2013}$) the renewable and gas energy system produces costs of 679 million euros$_{2013}$ per year.

Annual system costs for nuclear power and gas are estimated at 491 million euros$_{2013}$ for nuclear power and 366

9 Based on Prognos AG (2013).

Comparison of annual system costs | Figure 7



ECB 2014a; EEG 2012; Prognos AG 2013; UK Government 2013a; calculations by Prognos AG.

million $euros_{2013}$ for combined cycle gas turbine (CCGT), and thus total 857 million $euros_{2013}$ annually.

A closer look at the cost of power generated by gas power plants highlights the additional costs for backup capacity in a system that relies heavily on renewables. The cost to produce the same amount of power from gas is 45 million $euros_{2013}$ higher than in the system with nuclear power. This cost difference reflects the need for additional secure power generation capacity from gas. However, the 50 percent of low-carbon power production is considerably cheaper with renewables than with nuclear. Producing this low-carbon power is 223 million $euros_{2013}$ cheaper in the system that relies on renewables – thus more than compensating for the additional 45 million $euros_{2013}$ in costs incurred for additional gas capacity required as backup.

Overall, based on today's cost for renewables, the energy system with renewables and gas is about 20 percent less expensive than the nuclear energy system.

5 Discussion and conclusion

Our analysis has shown that a power system based on variable PV, onshore wind and dispatchable gas backup is associated with significantly lower costs than a system based on nuclear power and gas.

The two systems we have considered are roughly similar in the carbon intensity of generation, as a similar amount of gas is used for power generation. The cost estimates presented here leave out grid costs, potential additional system costs (e.g. voltage and frequency control) as well as possible cost differences related to how gas power plants are operated (e.g. higher ramping rates). In light of existing research on how such cost components impact the total cost of power systems (IEA 2014), we assume that if these costs were included, our findings would not change fundamentally. Moreover, we have left out any consideration of the externalities and risks associated with the power generation technologies used in each system. Similarly, the analysis does not address additional necessary infrastructure, for example, the availability of gas grids.

Clearly, contrasting PV and onshore wind in different European regions would require a comparison of different resource potentials and corresponding differences in LCOE. For example, while PV potential in the UK is mostly below the average potential for Germany, the opposite is true for wind. Moreover, LCOE may vary depending on local differences in the cost components of power generation technologies, such as the cost of financing. Still, this analysis provides a good indication of the current competitiveness of PV and onshore wind vis-à-vis nuclear power, which should be valid for many other European regions.

A system with high shares of generation from coal or gas CCS was not included in our analysis of power generation system costs. Yet the preceding comparison of LCOE clearly shows that this technology costs about as much as new nuclear power or is even less competitive in comparison to PV and onshore wind.

In the future, PV and wind are expected to produce electricity at even lower cost, given the further cost reductions that are expected to result from technological advancements. Such cost reductions have not been factored into this analysis, which makes our estimates of the cost advantage of a system that relies on renewables rather conservative. Similarly, we have not included potential cost reductions for new nuclear power plants, which, however, seem to be less imminent, given historical trends in nuclear power costs. Ten years from now – when the Hinkley Point C nuclear power station is supposed to to go online, according to the HPC agreement – renewables will very likely be even more competitive in comparison to new nuclear power than they are today.

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7 Appendix: Assumptions and LCOE for gas CCGT and OCGT

Price assumptions for gas and CO_2 — Table 1

Brennstoff	**2013**	**2018**	**2023**	**2028**	**2033**	**2038**	**2043**	**2048**
Gas price, in $euros_{2013}$/MWh	26.5	26.2	29.1	32.0	34.2	37.4	41.1	44.0
CO_2 price, in $euros_{2013}$/Tonne	5.0	14.8	23.0	28.6	34.0	39.6	45.0	49.4

Prognos AG 2013

Assumptions and LCOE for gas CCGT — Table 2

Overnight construction costs, in $euros_{2013}$/kW	1,000
Annual fixed O&M, in $euros_{2013}$/MW	20,000
Net efficiency, in percent	58.0%
Variable O&M, in $euros_{2013}$/MWh	1.0
Specific CO_2 factor primary fuel, in g/kWh	202
WACC in percent, real	7.5%
LCOE with 3,933 full-load hours, in the system with renewables, in $euros_{2013}$/MWh	88.6
LCOE with 5,009 full-load hours, in the system with nuclear power, in $euros_{2013}$/MWh	83.6

Prognos AG 2013, adjusted for the full-load hours in the two systems considered here. Note that LCOE may also vary by regions or countries, depending on specific financing conditions (DECC 2013).

7 Appendix: Assumptions and LCOE for gas CCGT and OCGT

Assumptions and LCOE for gas OCGT	Table 3
Overnight construction costs, in $euros_{2013}$/kW	450
Annual fixed O&M, in $euros_{2013}$/MW	9,000
Net efficiency, in percent	38.0%
Variable O&M, in $euros_{2013}$/MWh	1.0
Specific CO_2 factor primary fuel, in g/kWh	202
WACC in percent, real	7.5%
LCOE with 289 full-load hours, in the system with renewables, in $euros_{2013}$/MWh	252.6

Prognos AG 2013, adjusted for the full-load hours in the system considered here. Note that LCOE may also vary by regions or countries, depending on specific financing conditions (DECC 2013).

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