The '*Energiewende*' and the '*transition énergétique*' by 2030

Focus on the electricity sector. Co-dependent impacts of German and French choices on nuclear and coal in the context of renewable energy development.

STUDY – EXECUTIVE SUMMARY

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IMPRINT

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We thank them for their important contributions.

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Preface

Dear reader,

In line with the Paris Climate Agreement, France and Germany are aiming for a deep decarbonisation of their economies by 2050, which will require major sectoral changes. In the electricity sector, the two countries have different starting points, but their current long-term strategies contain many similar orientations: increasing energy production from renewable sources, improving energy efficiency, and increasing electrification of heat and transport.

The expected growth of energy production from wind turbines and solar photovoltaic, supported by the recent fall in the costs of these technologies, will lead to a profound transformation of the electricity systems in both countries. It is becoming necessary to adapt such systems to be able to integrate these variable energy sources. In this context, the question of the adjustment of today's dominant conventional power generation fleets, nuclear in France and coal in Germany, arises on both sides of the Rhine.

In 2030, the choices made by France and Germany will have an influence far beyond their borders on the electricity flows and the formation of electricity prices on the market. These choices will therefore have a major impact on the achievement of the energy-climate objectives in Europe, and on the realization of the Energy Union.

This study highlights the interdependence of national policy choices beyond borders. We hope that it will contribute towards facilitating a transparent and open dialogue between the actors of the two countries, encourage the development of a shared understanding of the energy transition, and help reach the necessary compromises for a deeper integration of the European energy system.

We hope you will enjoy reading this report!

Patrick Graichen, Director, Agora Energiewende
Michel Colombier, Scientific Director, IDDRI

Key findings:

1. **With the growth of renewable energy, France and Germany are facing common challenges regarding the restructuring of their conventional power plant fleet.** With a renewable electricity target of 40% in France and 65% in Germany by 2030, the two countries will significantly increase their production of wind and solar energy. Their conventional power plant fleet will have to be resized accordingly to avoid stranded costs.

2. **In France, the targeted development of renewable energy alongside the reinvestment in the nuclear fleet greater than 50 GW would pose a significant risk of stranded costs in the electricity sector.** A nuclear fleet exceeding 40 GW in 2030 would increase the national electricity export surplus and additionally postpone the achievement of the objective of reducing the share of nuclear power to 50% beyond 2030. The profitability of a nuclear fleet greater than 50 GW would not be assured in 2030, even when assuming a 60% increase in French export capacity, a doubling of interconnectors capacity in Europe and a CO2 price of 30 euros per ton of CO_2.

3. **In Germany, achieving climate targets requires a halving of coal-fired power generation and an increase in the national renewable electricity target to at least 60% of electricity consumption in 2030.** In this case, Germany's electricity trade balance with its neighbours is balanced. The new planned target of 65% renewable energy in electricity consumption by 2030 will ensure that Germany will not depend on undesired electricity imports while phasing-out coal.

4. **France and Germany should rapidly define their national strategies regarding their nuclear and coal fleets, closely consult each other on cross-border consequences and initiate joint actions for the implementation of the energy transition at bilateral, regional and European levels.** These joint actions could take the form of initiatives led by the two countries on the development of renewable energy, interconnectors or CO_2 pricing.

Executive summary

France and Germany face common challenges: the integration of renewable energy production, along with the resizing of their conventional power production fleet.

To fight against climate change, France and Germany have both engaged in major transformations of their energy systems. In the electricity sector, both countries have different starting points inherited from past decisions. In addition, the future role envisioned for nuclear energy differs: Germany has decided to phase out nuclear by 2022, whilst France has decided to reduce its share to 50% of electricity production to diversify its power supply.[1] However, beyond these differences, the French energy transition and the German Energiewende pursue several similar goals in the medium term: increasing renewable energy, improving energy efficiency and increasing the use of electricity in transports and buildings.

By 2030, France and Germany have set ambitious targets for the development of renewable electricity generation: 65% of electricity consumption in Germany and 40% of electricity production in France.[2] Until now, however, these technologies have developed at different rates in both countries. Germany has actively developed the production of solar photovoltaic and wind power since the early 2000s, whereas France, which has a large hydroelectric fleet, has developed these technologies much more gradually. Yet both countries are now aiming for similar growth rates in wind and solar photovoltaic production by 2030, facilitated by the recent fall in the production costs of these technologies.

1 Meeting these objectives was initially set for 2025. However, the new French government announced in Novembre 2017 that it intended to postpone meeting the target of 50% without specifying a new date.

2 In 2016, renewable energies accounted for 32% of electricity consumption in Germany (36% in 2017) and 17.8% of electricity production in France.

In Germany and many other countries, these technologies are now able to compete against conventional power generation technologies. Their development therefore is increasingly economically motivated. Despite a lower level of development in France, solar and wind energy costs are likely to reach parity with costs in Germany by 2030, given that sunlight and wind patterns are more favourable in France. Based on the latest tenders, average production costs of around €0.04/kWh for solar PV, below €0.05/kWh for onshore wind[3] and €0.06/kWh for offshore wind power now seem feasible for new production capacities in Europe. The variable nature of this type of production however poses a challenge to the electrical system, which requires an adaptation of its organization and the development of the appropriate level of flexibility.[4]

While both countries are developing detailed trajectories for the development of renewable energies,[5] there is still uncertainty regarding their strategies for their conventional production fleets, coal in Germany

3 This level may seem conservative when compared to the results of recent wind tenders in Germany, which were won by projects requiring an average remuneration level of €0.047/kWh for commissioning in 2022. Yet, the level of recent tenders does not necessarily reflect the actual cost of wind projects. Firstly, this price represents a minimum remuneration (which serves as a basis for calculating the monthly remuneration of projects), so that the projects can in principle be remunerated at higher levels over the total lifetime of the installation (by 2045). Furthermore, those projects relying on larger wind turbines face the risk of lower acceptance with the local population. Finally, some observers consider that these very low levels are a reflection of the strategic behaviour of certain actors to win bids.

4 See in particular the study Fraunhofer IWES (2015): *The European Power System in 2030: Flexibility Challenges and Integration Benefits. An Analysis on behalf of Agora Energiewende.*

5 In France, the 2016 Multiannual Energy Plan sets detailed renewable energy development targets for the technology sector for 2018 and 2023, and a new version planned for adoption in 2018 will specify the objective for 2023 and set new ones for 2028. The German renewable energy targets are set in the Renewable Energy Sources Act (EEG Act).

2030 Scenarios for France and Germany — Figure ES1

CO_2 reference price of €30/t	High nuclear (63 GW), PPE RES	Medium nuclear (50 GW), PPE RES	Low nuclear (40 GW), PPE RES
Medium coal* (24,3 GW) RES ~ 50%	✓	✓ + CO_2 high price €50/t	✓
Low coal (18,6 GW) RES ~ 60%	✓	✓	✓
Low coal (18,6 GW) RES ~ 50%	✓		

* A scenario with a coal capacity exceeding 24,3 GW in 2030 in Germany is not considered, as it appears politically and economically improbable (for more details see Agora Energiewende (2016): *Eleven principles for a consensus on coal: Concept for a stepwise decarbonisation of the German power sector.*
Agora/Iddri (2018)

and nuclear in France. These strategies will nevertheless be decisive for achieving the climate and energy objectives of both countries and the European Union. They will also have economic consequences for electricity producers in all sectors and on the evolution of the international electricity trade.

Eight co-dependent scenarios for 2030 studied for France and Germany

To shed light on the debate, this study provides a detailed exploration of the consequences for the European electricity system resulting from eight different intersecting scenarios regarding the size of the conventional power fleets in France and Germany in 2030, modelled for 10 weather years (see Figure ES1). Each of these variants considers a set of realistic assumptions regarding the evolution of other parameters of the sector.

Electricity consumption is stabilizing in Europe as energy efficiency gains accelerate, counterbalancing the electrification of new uses. Renewable energies are growing in line with national objectives. New interconnectors and other flexibility solutions for the integration of renewable energies are developing at an ambitious but realistic pace.[6] The cost of CO_2 for the whole of Europe is €30/tCO_2 for electricity production, except for one scenario where a higher price of €50/tCO_2 is set.[7]

Less carbon intensive electricity mixes transformed by the increase in renewable generation in 2030

Renewable energies are progressing significantly in all scenarios considered, reaching 220 TWh/year in France,[8] 320 TWh/year in Germany in the 50 % renewable case and 355 TWh/year in the 60 % renewable case.[9] These levels enable Germany to exceed its current renewable energy target[10] and France to reach it when its nuclear fleet is reduced to 40 GW. Security of supply is guaranteed in all scenarios considered. Thus, in France, the criterion of security of supply as defined by the public authorities[11] is verified in all scenarios while no hours of shortage are recorded in Germany. In both countries, all mixes considered for 2030 emit less CO_2 than at present. The increase in variable renewable production leads to greater flexibility in the operation of

6 In all scenarios, interconnectors assumptions are based on the completion of half of the planned projects in the Ten Year European Network Development Plan 2016, which represents more than a doubling of capacity on the European scale, from 57 to 136 GW.

7 Energy prices are derived from projections of the International Energy Agency's "New Policy" scenario of the *World Energy Outlook* (2015).

8 Compared to 95 TWh in 2016.

9 Compared to 191 TWh in 2016.

10 Renewable energies thus cover 53% of gross electricity consumption in Germany in 2030 in the medium renewable case, and 59% of gross consumption in the high renewable case.

11 In France, the criterion of security of supply is fixed at 3 hours of Loss of Load Expectation per year.

power plants means, including nuclear, and is facilitated by the development of additional flexibility solutions for the electrical system.

The cost of renewable energy will continue decline, but the ability of renewables to cover their cost with market revenues will depend on the resizing of conventional power plant capacities and the CO_2 price

The cost of renewables has fallen sharply in recent years. Nevertheless, the current low market price of electricity, which could persist, limits its ability to cover its investment costs with electricity market revenues. This is one of the arguments that today justifies keeping support schemes for renewable producers, without which few investments in new capacity would happen. In 2030, the ability for power producers to cover their costs from the power market will therefore depend on the evolution of these costs, but also on the evolution of market prices. Our study shows that the evolution of these market prices will be closely linked to the choices made on the size of the conventional power plant fleet and the CO_2 price level.

In France, maintaining a nuclear generation capacity of 63 GW reduces the average annual remuneration of solar photovoltaic production to less than €15/MWh, well below the levels necessary to cover its cost. When the nuclear fleet is reduced to 40 GW or 50 GW with an increase of the CO_2 price to €50/tCO_2, the remuneration of ground-mounted solar PV goes above €45/MWh, a price level that would probably allow the costs of new projects to be covered by market revenues at this time horizon. In Germany, ground-mounted solar PV is also close to economic equilibrium in the majority of scenarios considered once the price of CO_2 reaches €30/t. According to our assumptions, PV production costs would reach €41/MWh and its remuneration would be between €38/MWh and €47/MWh, depending on the scenarios (for a CO_2 price of €30/t), or even €56/MWh in a scenario with a CO_2 price of €50/t. On the other hand, market prices could remain insufficient to cover the costs of wind power by 2030, in France and Germany alike, except if these costs decrease below €40/MWh, or if the CO_2 price rises to €50/t. An additional remuneration would therefore continue to be required for wind energy with a CO_2 price of €30/tCO_2.

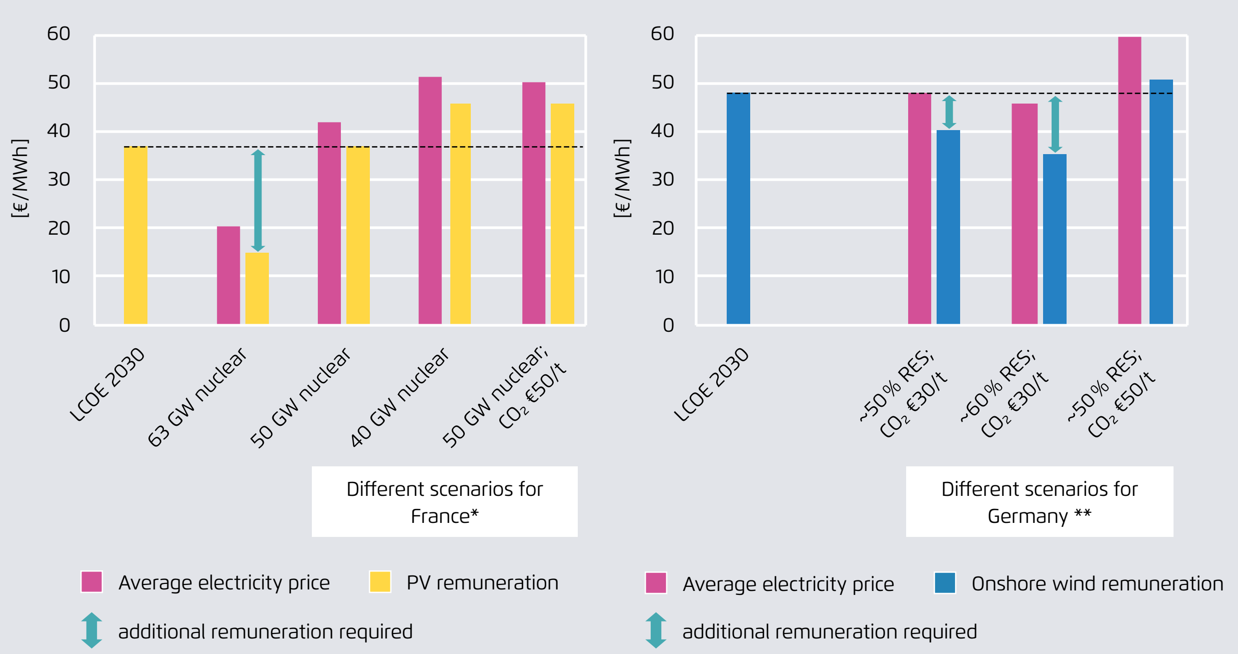
Maintaining high conventional production capacity therefore delays the moment when renewable producers can cover their costs with market revenues. This strong link between the remuneration of renewable energy producers and the composition of the power mix shows the importance of closely coordinating the strategies on conventional power with the rise of renewable energy. An uncoordinated transition would risk raising the cost of support mechanisms for renewable energy borne by final consumers.

The "cannibalization effect" of renewable energies is real but limited by the development of flexibility solutions

The correlation of weather-dependent renewable electricity contributes to the higher decrease of their remuneration compared to other production technologies, when their share in the electricity mix increases (the so-called cannibalization effect). This effect primarily concerns Germany, which targets higher levels of variable renewable energy. The development of additional flexibility solutions however, makes it possible to limit this effect. In the scenarios of this study, the reduction in the remuneration of renewable energies in 2030 compared to the average market prices in Germany remains at levels similar to those projected for the coming years by the grid operator (from -6% to -9% for PV, from -15% to -21% for onshore wind), because the increase in renewable energy capacity coincides with the development of additional interconnection capacities, demand response and storage capacity (pumped-storage and batteries) and new flexible consumption (electric

Electricity prices and remuneration in 2030 for PV production in France (left) and wind production in Germany (right)

Figure ES2



* The German scenario is fixed at the medium coal case (24,3 GW) and 50 % RES.
** The French scenario is fixed at the medium nuclear case (50 GW).
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vehicles, heat pumps). In France, a larger nuclear fleet reinforces the loss of revenue of renewable energy, the decrease being greater for solar photovoltaic production than for onshore and offshore wind power.

In France, maintaining a nuclear capacity of more than 40 GW would increase electricity exports. The profitability of a nuclear fleet over 50 GW would not be guaranteed.

France has a large nuclear fleet of 58 reactors (for a total of 63.1 GW), a large majority of which will have been in operation for 40 years by 2030. An extension of their operation beyond this term is one of the identified options for France and would require significant investment to be carried out. To diversify its electricity production mix, an objective of reducing the share of nuclear power to 50% in 2025 (compared to 72% in 2016) was approved in 2015 with the French law on energy transition and green growth. In November 2017 the current government announced that it would postpone its nuclear target without establishing a new deadline.

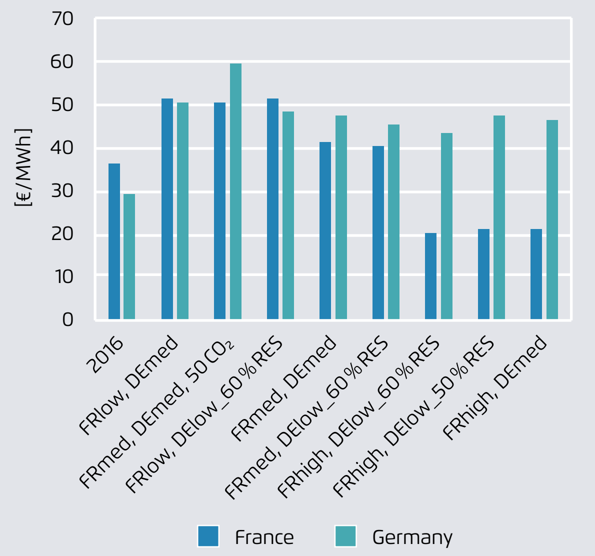
Our study shows that maintaining a nuclear fleet that exceeds 40 GW in 2030 would lead to an increase of the French electricity exports, but also postpone the achievement of the 50% nuclear target to beyond 2030.

Given the planned development of renewable energy in France and Europe, it is not clear whether there will always be sufficient demand to absorb both nuclear and renewable generation. Nuclear energy would therefore need to modulate its production more often, thus reducing its utilization. Although technically possible, this modulation would significantly increase the production costs of extended-life reactors.

In addition, a large nuclear fleet would contribute to the depreciation of electricity market prices and reduce the profitability of reinvesting in the nuclear reactors. In our scenarios, the average selling price of nuclear electricity would reach only €23/MWh in 2030 with a nuclear fleet of 63 GW. Resizing the fleet to 50 GW or 40 GW would raise these prices to €42/MWh and €52/MWh, respectively (see Figure ES3). These results depend on the level of CO_2 and fuel prices, as well as assumptions about electricity interconnectors. For example, the average remuneration of a 50 GW nuclear fleet is increased by €10/MWh if the CO_2 price rises from €30/t to €50/t.

If we make realistic assumptions about electricity consumption, interconnectors capacity and fuel prices, and if we assume that renewable energy are developped as planned, a comparison between the

Average electricity prices in France and Germany in 2016 and in all scenarios for 2030 — Figure ES3



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costs of production of extended nuclear reactors and the revenues from the sale of this electricity on the market shows that there is an optimal size for the nuclear fleet that can be estimated based on an economic criterion. Despite a 60% increase in French export capacity, a doubling of interconnectors capacity in Europe and a CO_2 price of €30/t, the profitability of reinvesting to extend the nuclear fleet to above 50 GW would not be ensured in our scenarios.

Nuclear power remuneration (€250 to €313kW/year depending on the CO_2 price) would barely cover the fixed cost of extending the reactors to 50 GW (see Figure ES4). In such a context, the decommissioning of up to 13 nuclear GW by 2030 could be carried out on a purely economic basis. A higher reinvestment cost for the extension of the lifetime of nuclear reactors would increase the amount of nuclear capacity that could be phased-out on an economic criterion.

The production cost of extended nuclear power plants is highly dependent on the reactor utilization rate. This cost is comparable to alternative wind and PV technology.

On the basis of data from the French Court of Auditors, the cost of extended nuclear power production would reach €42/MWh with an average utilization rate of about 80%. These costs would be increased to €49/MWh if there was a 50% increase in the reinvestment cost for nuclear lifetime extension (see Figure ES5)[12].

In all scenarios considered, the average loading factor of the nuclear fleet drops in 2030, by 79% (low

12 In the high variant scenario we consider that the cost of reinvestment in nuclear reactors is increased by 50% compared to estimates from the Court of Auditors. It aims to illustrate the technical and economic uncertainties surrounding the extension of nuclear reactors and the existence of differences in costs between nuclear reactors according to their age and ageing rate. For a more detailed discussion of the uncertainties about the extension of the French nuclear fleet, see (Rüdinger, A.; Colombier, M.; Berghmans, N.; Criqui, P.; Menanteau, P., 2017)

nuclear scenario) and down to 71% (high nuclear). At these levels, the average production cost of the extended fleet is between €42 and €55/MWh. The utilization of the "last installed GW"[13] decreases even more and reaches only 27% for 63 GW of nuclear, 64% for 50 GW and 77% for 40 GW. The 63rd extended GW would thus have a production cost in the order of €100 to €120/MWh, i.e. two to three times more than the wind or solar alternative.

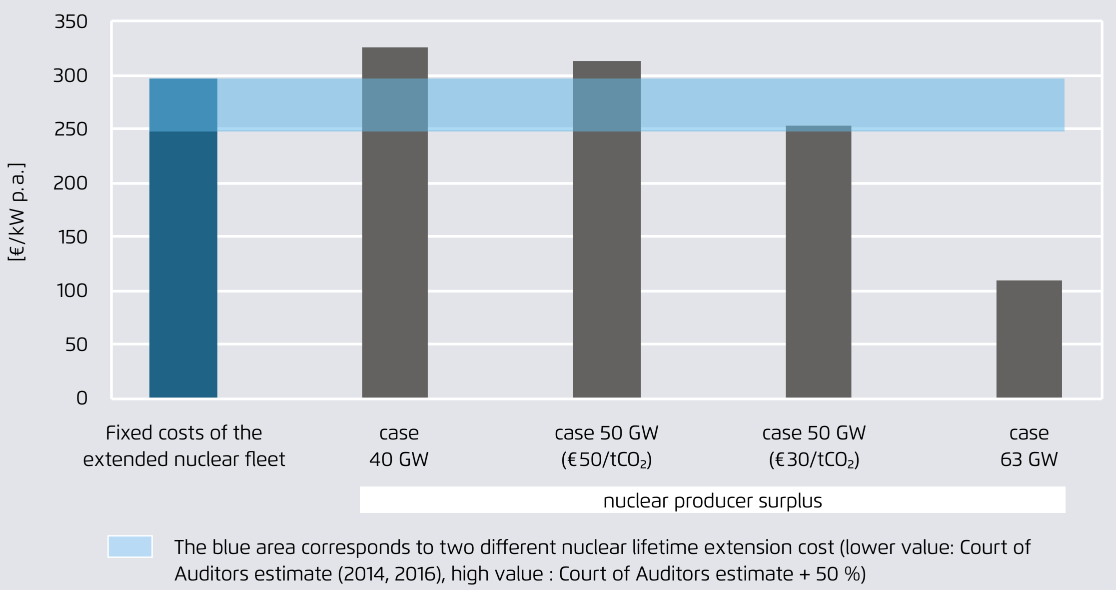
A comparison with renewable production costs, taking into account the difference in value of technologies for the electrical system,[14] shows that an extended nuclear reactor with an average annual utilization rate of less than 50% (4,820 hours per year) could be more expensive than a solar-based alternative over the entire period 2017-2030 (see Figure ES5). In 2030, a nuclear reactor with a load rate of less than 70% could be more expensive than ground-mounted solar plants. This shows that investing in renewable generation capacity to reach a 40% share is economically viable and can be compared to reinvestment in the nuclear fleet. At these levels of renewable production, the difference in average market remuneration between wind and solar PV production on one side, and nuclear power generation on the other, is below €10/MWh.

13 This load rate is calculated by comparing the annual nuclear genera-tion of nuclear capacities of, respectively, 63 GW and 62 GW, 50 and 49 GW and 40 and 39 GW to the annual full load production of 1 GW of nuclear power.

14 This approach takes into account the difference in market revenues between renewable generation and nuclear generation. This difference is sometimes attributed to renewables as one of the components of the "integration costs" (in addition to network and balancing costs); see in particular "The Integration Costs of Wind and Solar Power". Agora Energiewende (2015).

Fixed costs of nuclear power production compared to the nuclear producer surplus in different scenarios for 2030

Figure ES4



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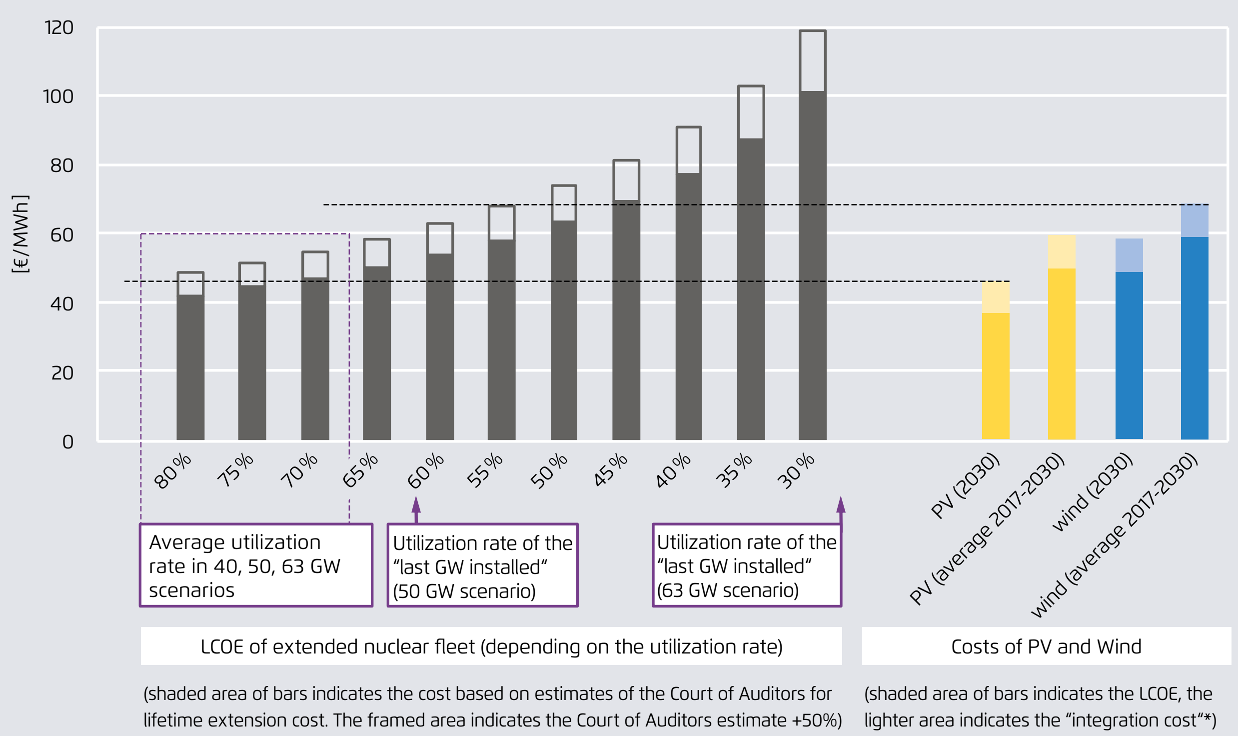
Nuclear generation costs (LCOE) according to the utilization rate of the reactors and compared with the production costs of renewable energy

Figure ES5



* The integration cost is defined here as the difference between the average market value of PV / wind for the electric system and the average market value of nuclear power.

Achieving German climate goals requires a halving of coal-fired generation by 2030 and raising the national renewable target to at least 60% of electricity consumption

In Germany, electricity production remains dominated by coal-fired power plants,[15] which accounted for 40% of the national electricity production in 2016. As a result of this still very carbon-intensive electricity mix, the CO_2 emissions of the German electricity sector reached 292 $MtCO_2$ in 2017 (472g CO_2/kWh produced), i.e. electricity production with nine times more emissions than France (53g CO_2/kWh produced).

The German climate objective implies a halving of the share of coal in the electricity sector by 2030 to limit emissions from electricity production to less than 160 $MtCO_2$ by 2030. The size of the power generation fleet, as well as the utilization rate of the plants, will have to be significantly reduced by this time horizon to reach the country's climatic objectives. An accelerated reduction of coal capacity in Germany would not necessarily affect coal producers, as rising electricity market prices could increase the profit margins of the maintained capacities, despite lower electricity generation.

15 Coal and lignite combined. In 2017, the total installed capacity was around 46 GW (21 GW lignite, 25 GW coal)

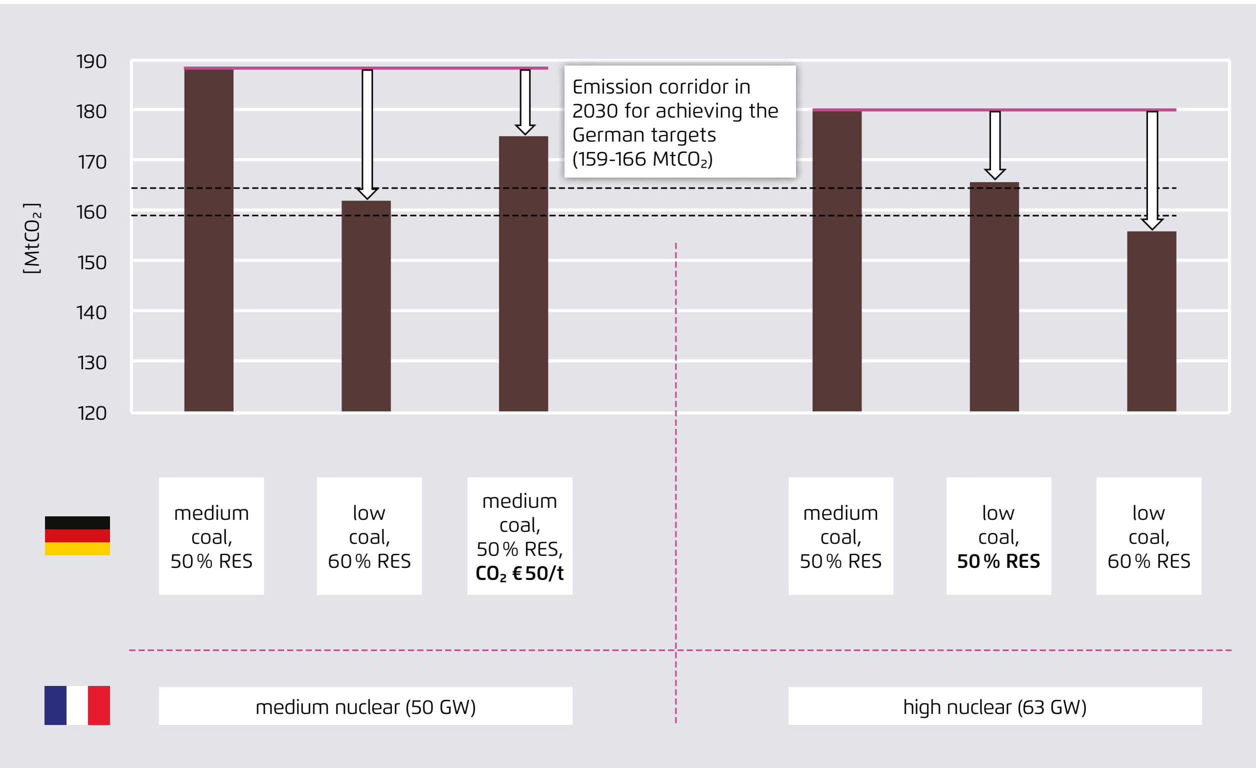
In accordance with several recent works,[16] this study shows that the decommissioning rate of coal plants at the end of their technical lifespan – estimated at 45 years[17] of operation – is insufficient to achieve the emission reduction objectives of the German electricity sector by 2030, despite an increase in the price of CO_2 to €30/t (see Figure ES6). A CO_2 price of €50/t at this time horizon would bring Germany closer to its climate goals, although would not be sufficient for it to reach them. An accelerated coal phase-out strategy is therefore necessary.

16 Agora Energiewende (2016): Eleven principles for a consensus on coal. Concept for a stepwise decarbonisation of the German power sector. UBA (2017). Kohleverstromung und Klimaschutz bis 2030. SRU (2017). Kohleausstieg jetzt einleiten. Greenpeace (2017). Klimaschutz durch Kohleausstieg.

17 Hypothesis made by German transmission system operators in NEP-B.

To compensate for the decline in coal production, Germany can either increase its development of renewables or increase its electricity imports. A coal phase-out coupled with an increase in the renewable target to 60% of electricity consumption would enable Germany to meet its climate objectives, while maintaining an electricity trade balance close to equilibrium. The new federal government's target of 65% renewable energy in electricity consumption is thus moving in the right direction. Without raising its renewable targets beyond 50%, Germany could reach the upper limit of its climate objective, but only if France maintains a nuclear fleet of 63 GW. This second option would widen the country's annual trade balance, making it a net importer of 41 TWh in 2030 or 8% of German domestic consumption.

German CO_2 emissions in 2030 under different scenarios for France and Germany — Figure ES6



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An accelerated coal phase-out would moderately increase the price of electricity for the German consumer compared to the reference case, especially if offset by increased renewable targets. Indeed, the stronger expansion in renewable energy planned by the new federal government will contribute to the dampening of prices on the electricity wholesale market whilst ensuring that Germany has a more favourable balance of trade in electricity. Nevertheless costs for German consumers will increase slightly (an additional €400m by 2030[18]), a modest increase compared to the costs borne by the German consumer for the financing of renewable energies through the EEG contribution which amounts to €23.8 billion for 2018. Increasing the development of renewable energy from 50% to 60% of consumption in 2030 would increase the EEG contribution of household and industry consumers by only €0.1 cts/kWh on average.

Contrasting strategies in terms of international electricity trade for Europe's two largest electricity exporters

In Germany, the reduction of coal production capacity by 2030 would lead to a rebalancing of the current export balance in all scenarios considered (see Figure ES7). Germany would import and export significant volumes, varying according to the day and season, depending on the availability of renewable energy production. This balance of trade could be slightly export or import-orientated, depending on decisions in France on the future of its nuclear fleet. With the increase of the German government's renewable energy target, scenarios where the country is an exporter or close to having a neutral balance of trade in electricity are now more likely than those where the level of imports increase.

For France, the lifetime extension of a large part of the current nuclear fleet while developing renewable energies at the planned rate would amount to building a strategy for the mass export of electricity to its European neighbours. A nuclear capacity reduced to 40 GW would maintain the export balance of France at levels similar to those of today, i.e. around 50 TWh/year. Beyond this, the additional nuclear generation would almost completely result in increased exports, which would then reach 110 TWh/year when 50 GW of nuclear generation capacity is kept, and nearly 150 TWh/year if the nuclear capacity remains at the current level of 63 GW. A larger nuclear fleet would therefore have a significant impact beyond national borders. For example, average electricity prices in Germany would fall by around €5/MWh in "high nuclear" scenarios compared to "low nuclear" scenarios.

Phasing out coal, rescaling the nuclear fleet and increasing the CO_2 price for electricity production. These constitute three levers to articulate in order to achieve European climate objectives

The strategies that will be implemented by France and Germany for the development of their electricity mix, as well as the CO_2 price level for electricity generation will have a decisive impact on the European Union's CO_2 balance, and its ability to achieve its climate goals. Maintaining the current nuclear capacity in France would contribute to a reduction of the EU's CO_2 emissions, through a significant increase in French electricity exports. However, such a choice would be economically risky if it is not linked with the development of the interconnectors capacity and the requesite CO_2 price level in Europe. Potential stranded costs would be ultimately borne by the French citizen.

18 Additional cost to the German consumer of an accelerated coal phase out strategy combined with and an increase in renewable energy target to 60% in 2030, compared to a scenario of economic decommis-sioning of coal and 50% renewable energy.

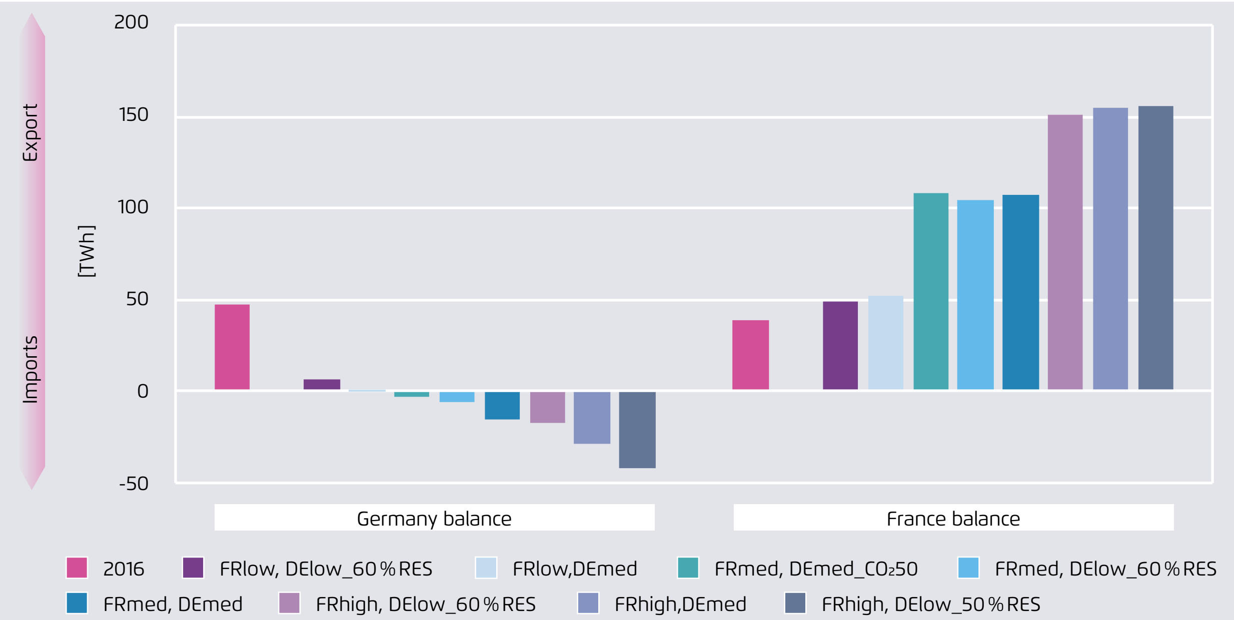
For its part, Germany could achieve its climate objectives by favouring a domestic option, that is to say by offsetting the reduction in its coal-fired electricity production by reinforcing its renewable objectives, or by the increased use of electricity imports. The current political situation in Germany clearly underlines a tendency towards higher renewable energy targets. The remuneration of German electricity producers, and in particular the refinancing of renewable energy projects, would nevertheless be affected if the choices made in France lead to a strong increase in the country's electricity exports.

A coordination tool at the European level is the price of CO_2. A concerted effort to increase the CO_2 price from €30 to €50/tCO_2 applied to electricity generation would have a significant impact in terms of reducing European emissions – a further decrease of 130 MtCO_2 in medium scenarios for France and Germany – and would enable a better remuneration of renewable and nuclear production in both countries. This measure would, however, have significant redistributive effects for the actors in the sector, and would require strong political compromises. These effects are asymmetrical between the players of the two countries, the French actors would benefit from a gain of € 1.2 billion when the German players would lose a total of € 602 million. These transfers of wealth between actors of both countries largely explains the different positions on both sides of the Rhine regarding the reinforcement of CO_2 prices.[19]

19 These redistributive effects may, however, be partially limited, as they generate additional revenue for states (estimated at €1.2 billion/year in Germany), which can be used to offset the losers of this measure at the national level. In France, the Regulated Access to Historical Nuclear Electricity (ARENH) mechanism limits the price of 100 TWh/year of nuclear generation sold to alternative electricity providers to €42/MWh. This regulated price, expected to last until 2025, could, if it is extended and if transferred to the final consumer, reduce the cost of a rise of the CO_2 price for the French consumer, while reducing the profit of the nuclear producer.

Electricity trade balances of Germany and France (in TWh) in all 2030 scenarios, compared to 2016

Figure ES7



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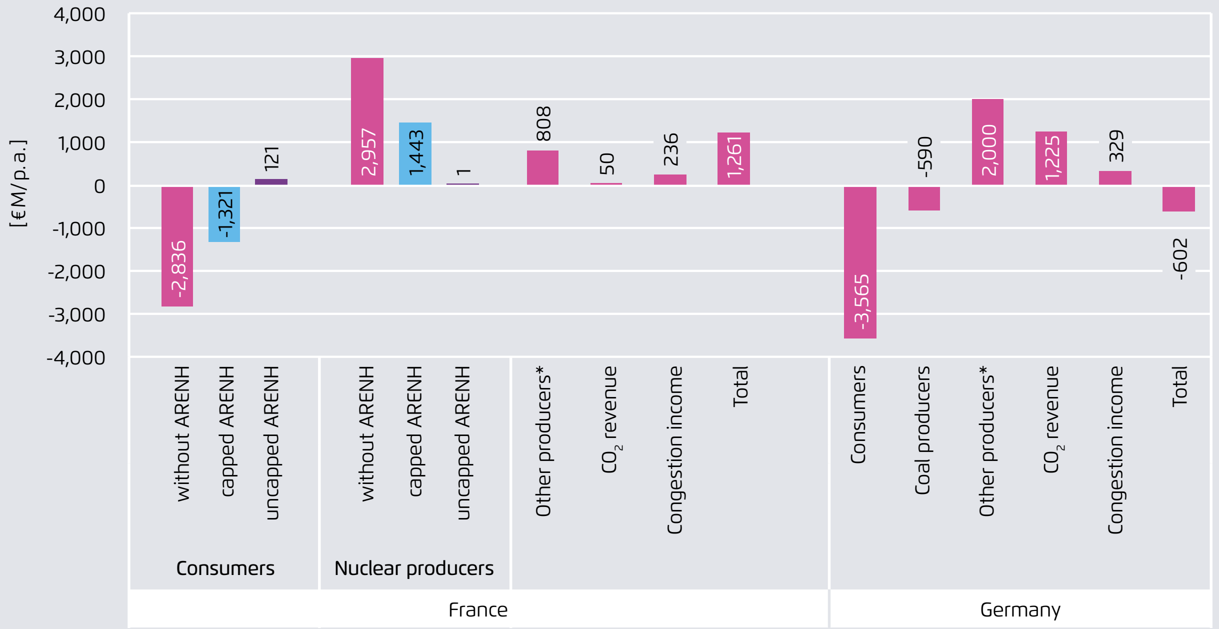
Redistributive impacts in France and Germany of an increase in CO_2 price for power production in the EU from € 30 to € 50 per tonne

Figure ES8



* Production technologies other than nuclear, coal-based (hard coal and lignite), solar and wind (onshore and offshore)
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Conclusion: define national transition strategies for power systems compatible with the achievement of the European Energy Union

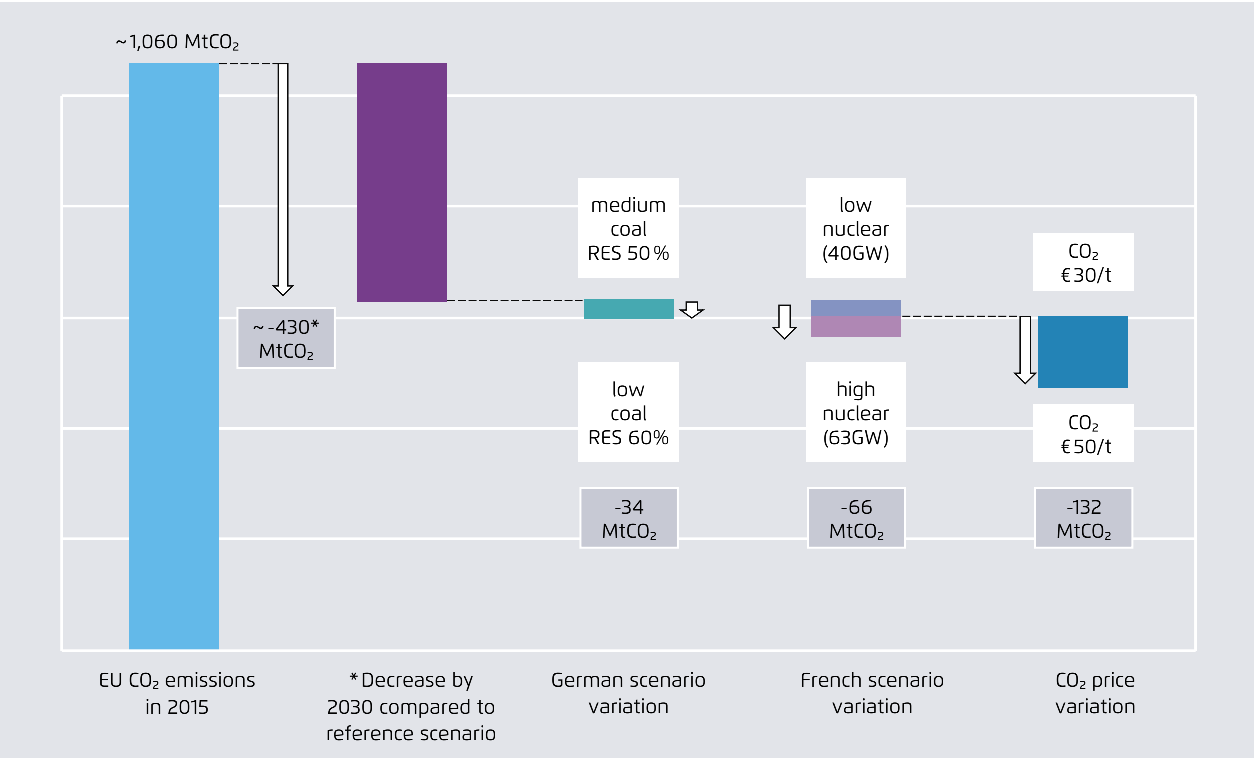
The transformations of the French and German electricity systems are part of a broader European framework aimed at reducing CO_2 emissions, developing renewable energies and energy efficiency, as well as strengthening the domestic energy market. In this context, the EU Member States will have to take into account the growing interdependence of their energy systems in order to develop their national strategies. In this respect, France and Germany play a pivotal role due to their position at the heart of the European electricity network. The choices made by these two countries regarding the evolution of their electricity systems will therefore have a strong influence on the achievement of Europe's energy and climate objectives.

This study shows that in France reinvestments for the lifetime extension of a nuclear capacity greater than 50 GW could not be profitable, even if we assume that there is a significant strengthening of interconnector capacities and the CO_2 price reaches €30/t. The definition of the strategy on the nuclear fleet should fully integrate this dimension and cross-border impacts should be studied in detail. In Germany, a coal phase-out would reduce the country's export surplus and increase the level of electricity imports (see Figures ES7 and ES10). Furthermore, in the context of strengthened interconnections in the European electricity system, the cross-border effects resulting from national decisions will increase. The energy policy choices made by Germany's neighbours will thus have a more significant effect on the remuneration of German electricity producers. This will also be the case for the country's CO_2 emissions. With regards to France, a more rapid expansion of renewables in Europe would limit French nuclear exports and increase the risks of stranded assets in its electricity system.

Reconciling the French and German approaches would be facilitated by a swift decision on the national strategies for nuclear power in France and coal in Germany. These two countries should consult each other closely when defining these strategies, particularly regarding their cross-border impacts, as called for by the proposal for a new energy-climate governance presented by the European Commission in November 2016. In-depth forecasts on this subject can serve as a basis for transparent and open dialogue on national electricity strategies on both sides of the Rhine.

Once these strategies have been better defined, France and Germany could, on this basis, initiate new joint actions to implement the energy transition at bilateral, regional and European levels. These joint actions could take the form of closer cooperation on the development of renewable capacities and inter-connectors, or of a political initiative to reinforce the CO_2 price for electricity production. France and Germany could then play a decisive role in shaping necessary political compromises to enable the energy transition to become a reality throughout Europe, thus helping to put this transition at the heart of a revival of the project of European integration.

Decrease of CO_2 emissions in Europe between 2015 and 2030 in different scenarios — Figure ES9



* The decrease by 2030 is an estimate, in particular, it approximates the level of emissions derived from electricity production from cogeneration in the different European countries.

ECF (2017), Eurostat, TYNDP (2016), Artelys Crystal Super Grid model results.

Daily balance of crossborder electricity trade in Germany and France in the scenario "low coal 60% RES" for Germany and "high nuclear" for France

Figure ES10

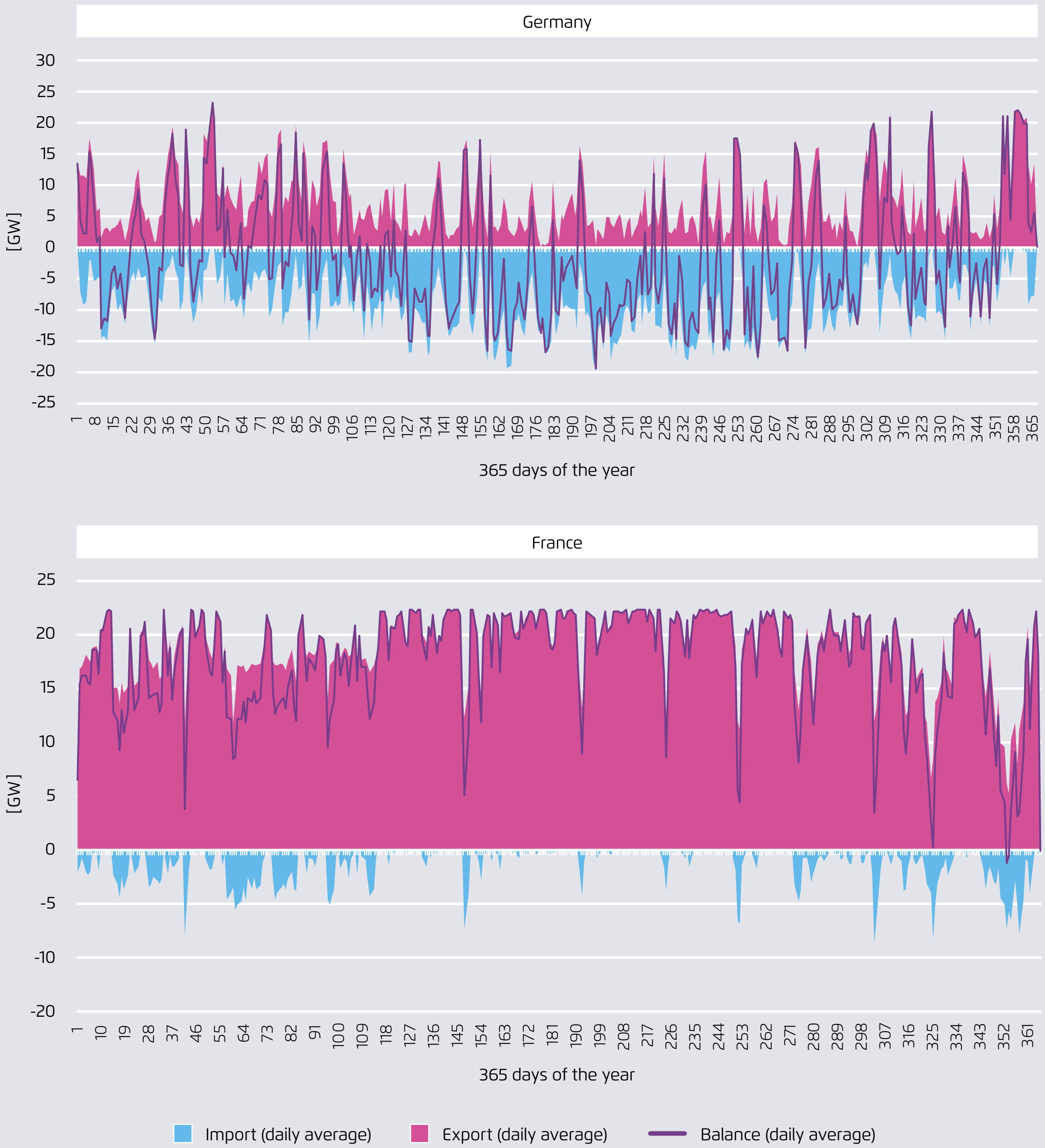


Illustration by the authors. This figure shows the daily balances of electricity trading in the two countries in the case of high nuclear power (63 GW) in France and coal phase-out, coupled with an increase in renewable energies to 60% in Germany. German trade (top) alternates throughout the year between exports and imports, while French trade is almost always oriented towards exports.

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About Agora Energiewende and IDDRI

Agora Energiewende develops evidence-based and politically viable strategies for ensuring the success of the clean energy transition in Germany, Europe and the rest of the world. As a think tank and policy laboratory we aim to share knowledge with stakeholders in the worlds of politics, business and academia while enabling a productive exchange of ideas. Our scientifically rigorous research highlights practical policy solutions while eschewing an ideological agenda. As a non-profit foundation primarily financed through philanthropic donations, we are not beholden to narrow corporate or political interests, but rather to our commitment to confronting climate change.

The Institute for Sustainable Development and International Relations (IDDRI) is an independent research institute dedicated to fostering the transition to sustainable development and prosperity for all. IDDRI identifies the necessary conditions for the integration of sustainable development into public policies and proposes tools for their implementation.

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