NEA
NUCLEAR ENERGY AGENCY

NEA Policy Brief

June 2020

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Nuclear power and the cost-effective decarbonisation of electricity systems

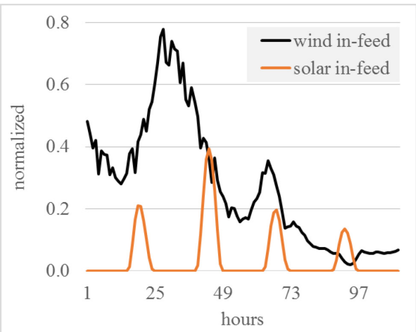
- Post-pandemic recovery plans to reconcile climate objectives with economic goals need to put system costs at the heart of energy policy.
- Moving to a carbon neutral electricity system without nuclear power would significantly increase system costs and threaten security of supply.
- Achieving cost-effective decarbonisation requires structural reform of the electricity market.

What's the problem?

The current Coronavirus (COVID-19) pandemic is a stark reminder of the critical role of electricity infrastructures in modern societies. The pledge by a number of governments to emphasise decarbonisation commitments as part of their economic recovery strategies will only further increase the importance of a reliable and resilient electricity supply. Meeting the 2015 Paris Agreement goals demands that the carbon intensity of the electric power sector is reduced to 50 gCO2/kWh by 2050, or one-eighth of the current levels in OECD countries. Decarbonising the energy sectors will require electrification of sectors such as transportation and an increase in the share of electricity in the overall energy mix. This will require a rapid and radical transformation of the power system with the deployment of low-carbon emitting technologies such as nuclear, hydroelectricity and variable renewable energy (VRE). It also means dramatically reducing the use of carbon-emitting technologies. Investing in low-carbon electricity technologies is therefore vital and requires a clear regulatory environment to enable these investments. These changes must be approached with a full understanding of the costs and impacts of various technologies in the electricity system as a whole.

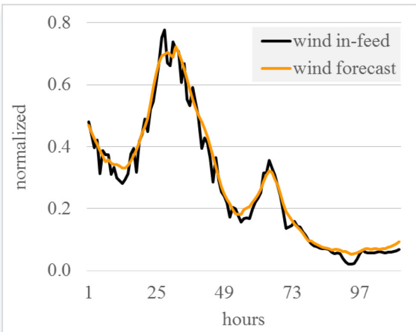
System costs are mainly due to characteristics intrinsic to variable generation

Profile and backup supply costs



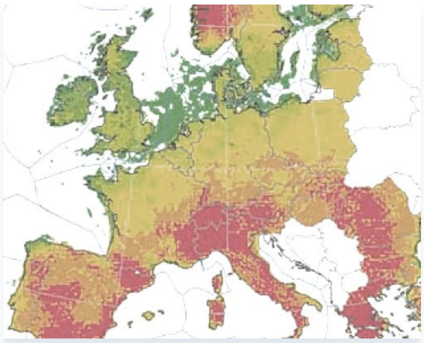
VREs are not always available

Balancing costs



VREs are difficult to predict

Transmission and distribution



VRE sites are distant from demand centres

Source: Hirth, 2015.

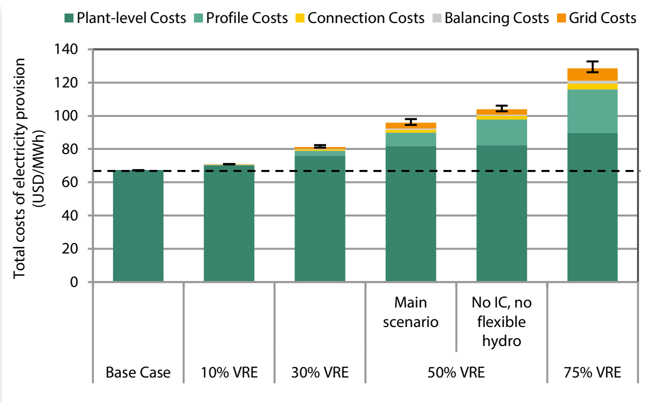
Why is this important?

A resilient electricity system that provides security of supply takes into account system effects (profile costs, balancing costs and transmission and distribution costs) which grow significantly as the share of VRE increases. Today, those costs are barely considered in energy transition plans – mainly because they are an intrinsic part of the grid operation and cannot be easily allocated to a specific renewable generation plant. However, they are tangible costs that will eventually have to be paid by the end-consumer or by the taxpayer.

A 2019 NEA study assessed the total costs of achieving the low-carbon constraint of 50 gCO2 per kWh in the electric power sector of a representative OECD country. The study compares six different scenarios with different shares of fossil fuel, nuclear energy and renewable energies – in particular wind and solar photovoltaic (PV). The study found that achieving the same low carbon emissions with a larger contribution of nuclear generation makes the total cost of electricity for the end consumer or the taxpayer more affordable compared with a generation mix that relies on a large share of VRE. In fact, combining explicit targets for VRE technologies and a stringent limit on carbon emissions has important impacts on the composition of the generation mix and its cost. First, the total installed generation capacity needed to meet the same demand increases significantly as the penetration of VRE generation increases. This is due to the variability and the lower load factors and capacity credit of VRE, which results in the need to install additional generation capacity to supply electricity when renewables are not running. For example, for a system with a VRE penetration level of 50% the total installed capacity would need to double, and for a system with a 75% VRE penetration level the installed capacity would need to be more than three times the peak demand. In other words, as the penetration of VRE generation increases vast amounts of excess capacity – and therefore investment – is needed to meet the same demand. This results in significantly larger overall system costs, which would grow faster for countries without abundant hydro resources (such as Australia) or interconnections to neighbouring countries (such as Korea or Japan).

Achieving the same low-carbon emissions with a higher mix of nuclear generation makes the total cost for the end consumer or taxpayer much more affordable compared with a generation mix that relies on higher share of VRE.

Figure 1: **Total cost of electricity at different shares**

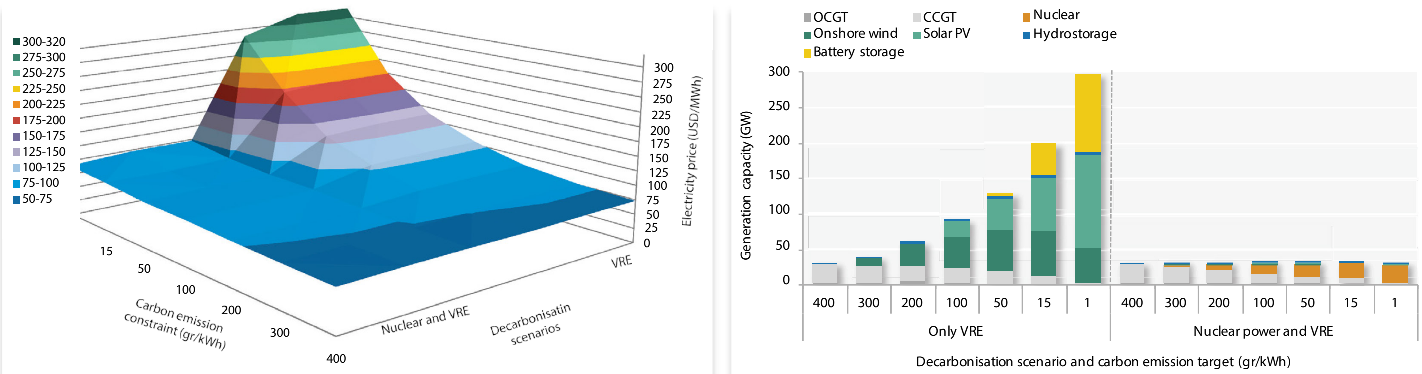


Source: NEA, 2019.

Beyond the objectives of the Paris Agreement, a number of OECD countries are today strengthening their climate commitments with new climate neutrality objectives by mid-century. This is in particular a key component of the European Commission's recent "Green Deal" proposal that is expected to drive the European post-COVID-19 economic recovery.

A recent MIT study analyses the range of possible decarbonisation scenarios in the United States as a function of different sets of available low-carbon power generation technologies and of different carbon emission targets: from 400 to 1 g CO2/kWh. This study highlights that when nuclear power is excluded from the list of available low-carbon technology solutions, the average cost of electricity increases as the carbon constraint becomes more stringent.

Figure 2: **Summary of electricity prices (left graph) and generation capacity (right graph) as a function of carbon intensity and share of nuclear and variable renewable energy (VRE)**



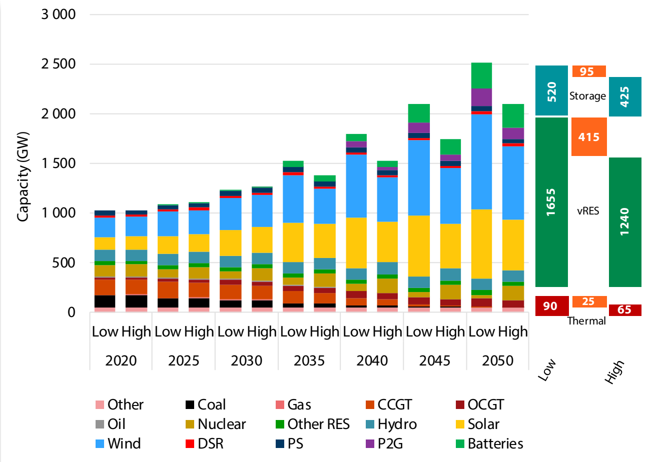
Source: Sepulveda, N.A., 2016.

These high system costs reflect the limitations in the ability of electricity grids to manage high shares of variable capacity — limitations that are not expected to be solved in the foreseeable future. However, grids that benefit from appropriate shares of nuclear capacity operating in concert with renewables provide for a far more efficient system with less excess capacity and much lower overall cost of electricity.

While the relative share of nuclear and renewables in such low-carbon electricity mixes will certainly be system specific, a key finding of both the MIT and NEA studies is that from an economic perspective system costs will tend to rapidly increase when the share of VRE generation increases above 30%.

These results can be observed at the European level where, despite the high level of integration of the electricity grid, scenarios in which 2050 carbon neutrality objectives are achieved primarily through the promotion of VRE result in significant challenges in terms of electricity security. As highlighted in a recent FTI-FORATOM study, meeting the European Union's long-term energy and climate objectives with a low share of nuclear in the energy mix (such as 36 GW of installed capacity) will significantly increase the power system's reliance on large scale, yet immature, storage technologies with uncertain costs. In contrast, in a high nuclear scenario (150 GW of nuclear capacity), the nuclear load-following capability supports the integration of VRE, and therefore reduces the need for additional storage capacity and the associated investments.

Figure 3: **Low and High nuclear scenario capacity outlook to 2050**



Source: FTI-FORATOM, 2018.

What should policy makers do?

The 2019 NEA study found that decarbonising the electricity sector in a cost-effective manner while maintaining high levels of electricity security requires five complementary policy measures. These structural reforms should be prioritised to support cost-effective investments in the power system as part of the post-COVID-19 recovery:

1. Recognise and allocate the system costs to the technologies that cause them: For countries to make the most economic decisions regarding their future electricity supply, they must achieve a full understanding of the costs of each option. Exposure to electricity prices would internalise profile costs, and remunerate each unit of electricity generated at its true value for the system.
2. Implement carbon pricing, as the most efficient approach for decarbonising the electricity supply: For countries pursuing policies to reduce carbon emissions, this approach would increase the cost of high-carbon generation technologies, reduce greenhouse gases and enhance the competitiveness of low-carbon technologies such as nuclear and VRE.
3. Encourage new investment in all low-carbon technologies by providing stability for investors: In creating sustainable low-carbon electricity systems, all low-carbon technologies will need to play a part. However, their high capital intensity requires specific financing solutions as they will not be deployed solely on the basis of marginal cost pricing in competitive markets. Policy makers have to strike the appropriate balance between out-of market support and exposure to wholesale market prices for low-carbon technologies with high fixed costs such as nuclear and VRE.
4. Enable adequate levels of capacity and flexibility, as well as transmission and distribution infrastructure: Generation is at the heart of any electricity system, but the electricity system requires frameworks for the provision of capacity, flexibility, system services and adequate physical infrastructures for transmission, distribution and interconnections. The variability of VREs and new technological developments make these complementary services increasingly important. It is also important to recognise the positive contribution to system stability and inertia of large centralised units such as nuclear power plants or hydroelectric dams and to value them appropriately.
5. Develop truly competitive short-term markets for the cost efficient dispatch of resources: Marginal cost pricing based on short-term variable costs is an appropriate mechanism to ensure the optimal utilisation of existing resources. It is however, not sufficient to incentivise required investment in low-carbon generation technologies and grid infrastructure. Mechanisms such as capacity remuneration could recognise the value of dispatchability. In OECD countries, the deployment of large amounts of VREs has been successful partly because it was done over an amortised, relatively robust and over-dimensioned electricity system. Even in these conditions, the wholesale price of electricity is not sufficient to cover the cost of producing electricity. And clearly, current markets do not have price signals that may incentivize the investment in the renewal of this ageing electricity system infrastructure.

Further reading

FTI Consulting (2018), *Pathways to 2050: The Role of Nuclear in a Low-Carbon Europe*, www.fticonsulting.com/fti-intelligence/energy/research/eu-power-gas-markets/pathways-2050-role-nuclear-low-carbon-europe (Accessed 9 June 2020).

Hirth, L. (2015), "The Optimal Share of Variable Renewables: How the Variability of Wind and Solar Power affects their Welfare-optimal Deployment", presentation at Paris-Dauphine University, 8 July 2015, www.ceem-dauphine.org/assets/dropbox/Lion_Hirth-2015-07-08_Optimal_share_of_Variable_Renewables_Paris.pdf (Accessed 9 June 2020).

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NEA (2019), *The Costs of Decarbonisation: System Costs with High Shares of Nuclear and Renewables*, OECD Publishing, Paris.

Sepulveda, N.A. (2016), *Decarbonization of Power Systems: Analyzing Different technological Pathways*, Master Degree Thesis, Massachusetts Institute of Technology (MIT).