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System Costs of Electricity

- **Limiting the rise of global temperature to less than 2°C represents an enormous challenge for the whole electricity sector**
- **Decarbonising the electricity sector in a cost-effective manner while maintaining security of supply requires the rapid deployment of all available low-carbon technologies**
- **System costs are not properly recognised by current market structures and are currently borne by the overall electricity system in a manner that makes it difficult – if not impossible – to make well-informed decisions and investments**

Understanding the costs of electricity provision requires systems level thinking

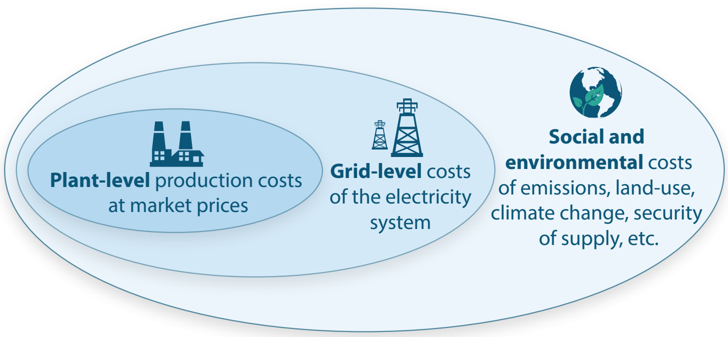
The first level of analysis is **plant-level costs** of generation, which include, among other costs, the costs of the concrete and steel used to build the plant, as well as the fuel and human resources to operate it. These plant-level costs are typically referred to as the levelised cost of electricity (LCOE), and they may include some costs that were previously considered as externalities – for example, if there is a price on carbon or a legislated requirement to internalise the end of life cycle costs into plant-level costs.

The next level of analysis takes into account **grid-level system costs**. These are the costs that generating units impose on the broader electricity system – including the costs of maintaining a high level of security of supply at all times as well as delivering electricity from generating plants to customers – in other words, in addition to production, they include connection, distribution, and transmission costs. Most importantly, grid-level costs include the costs associated with compensating for the variability and uncertainty in the supply from generating plants. This includes the costs of additional dispatchable capacity to account for the variability of certain renewables such as wind and solar PV and for maintaining spinning reserves that can be ramped up when the production of variable sources falls short of forecasts.

The final level of analysis addresses the full costs, including the **social and environmental costs** that different technologies impose on the well-being of people and communities, including negative externalities like atmospheric pollution, impacts on land-use and biodiversity, as well as, in certain cases, positive externalities such as impacts on employment and economic development, or spin-off benefits from technology innovation. These are the externalities that are not accounted for in plant-level costs or grid-level system costs.

The combination of plant-level costs, grid-level systems costs, and full social and environmental costs creates a framework that allows policymakers to compare the costs of different generating options – comparing apples to apples, not apples to oranges. To do so requires a systems level perspective.

Figure 1: **Understanding the system costs of electricity**



Source: Adapted from NEA (2012).

Total economic system costs, then, are defined as **plant-level generating costs** plus **grid-level system costs**. Taking this systems level perspective includes:

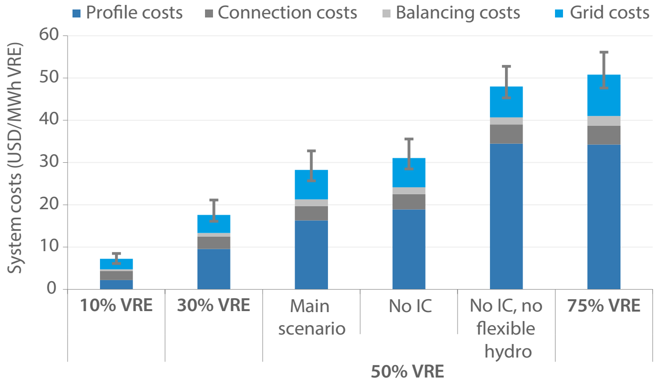
- **Profile and balancing costs** – the grid-level costs imposed by variability and uncertainty.
- **Connection, distribution, and transmission costs** – the costs of delivering electricity from distributed power generation to customers.

To be clear: while all technologies impose some system costs, variable, intermittent, and uncertain sources of power generation impose far greater grid-level system costs, which is why it is so important to take a systems level perspective when comparing the costs of variable renewables with nuclear, baseload hydro, and fossil generation.

Total costs rise as the share of variable renewables increases and imposes greater stability and flexibility costs on the grid.

The breakdown of system costs as the share of variable renewables grows from 10% to 75% of the mix. Profile costs (to compensate for variability and intermittency) are the dominant driver of increasing total costs as the share of variable renewables grows.

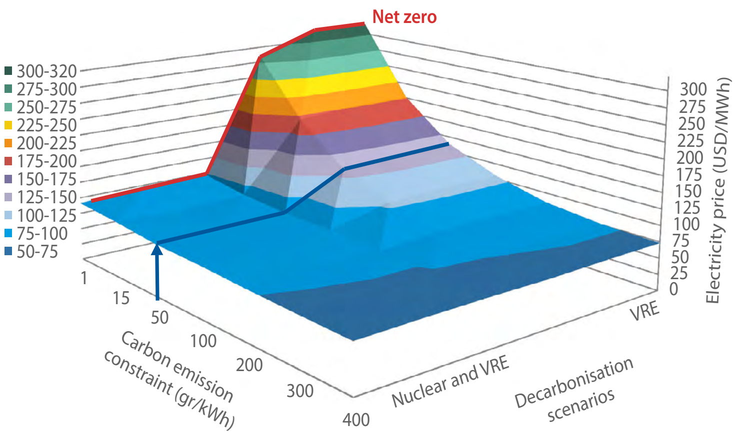
Figure 2: **System costs for different mixes of electricity (with a carbon constraint of 50 grams per kWh)**



Source: NEA (2019).

Figure 3 shows the effects on total costs as carbon emissions are increasingly constrained. The blue line shows how total costs grow as shares of variable renewables grow in a system with a carbon constraint of 50 grams per kWh. The red line shows what happens to total costs when carbon constraints reach net-zero emissions. The relationship between the share of variable renewables and systems costs, driven by profile costs to compensate for variability, is even more pronounced when carbon constraints become more stringent.

Figure 3: **Total costs for different mixes of electricity (driving to net-zero emissions)**



Source: Based on Sepulveda (2016) in NEA (forthcoming).

The policy implications of these systems costs findings are significant. It may be possible to reduce emissions to meet 2030 targets by increasing the share of variable renewables in the mix. However, the costs of reaching net zero with high shares of variable renewables are probably prohibitive. This is, in part, because initially as variable renewables are introduced, they can be backed up with a low cost option, which in the absence of a serious carbon constraint is likely to be natural gas. But eventually, in a carbon constrained world, the options for backing up variable renewables become increasingly expensive. Dispatchable hydropower and nuclear energy are the only economic options while batteries remain prohibitively expensive for anything other than very short-term storage.

What should policymakers do?

Total costs always increase as shares of variable renewables increase and carbon emissions become more constrained. However, the precise calculation of total costs for different shares of variable renewables depends on country-specific characteristics, such as the availability of hydropower. In other words, the overall shape of the three-dimensional graph in Figure 3 is the same everywhere – it always peaks at net-zero for high shares of variable renewables; however, the height of the peak differs based on specific endowments and conditions.

The Nuclear Energy Agency stands ready to provide country-specific system costs analyses.

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Further reading

NEA (forthcoming), *Meeting Climate Change Targets: Projecting the Potential Role of Nuclear Energy*, OECD Publishing, Paris.

NEA (2020), *Unlocking Reductions in the Construction Costs of Nuclear A Practical Guide for Stakeholders*, OECD Publishing, Paris, www.oecd-nea.org/jcms/pl_30653/unlocking-reductions-in-the-construction-costs-of-nuclear.

NEA (2019), *The Cost of Decarbonisation: System Costs with High Shares of Nuclear and Renewables*, OECD Publishing, Paris, www.oecd-nea.org/ndd/pubs/2019/7299-system-costs.pdf.

NEA (2012), *Nuclear Energy and Renewables: System Effects in Low-carbon Electricity Systems*, OECD Publishing, Paris, www.oecd-nea.org/jcms/pl_14754.