IMPACT OF A HIGH PENETRATION OF VARIABLE RES IN THE EUROPEAN POWER SYSTEM FOR 2050 – A TECHNICAL AND ECONOMIC ANALYSIS AS PART OF EU-SYSFLEX PROJECT

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Overview

This abstract presents a technical and economic analysis for the European power system with high shares of variable renewable energy sources (RES) for 2050. Results were obtained as part of EU-SysFlex, a EU-funded H2020 project from the Low Carbon Europe call. The goal of the EU-SysFlex project is to identify issues and solutions associated with integrating large-scale renewable energy into the European power system as well as provide practical assistance to power system operators across Europe. This should ultimately lead to identification of a long-term roadmap to facilitate the large-scale integration of renewable energy across Europe.

Methods

The European power system is modeled with a state-of-the-art unit commitment model which was also used for the study on integrating 60% Renewable Energy into the European System (Burtin and Silva, 2015). The strength of this work is that it simulates a wide perimeter comprised of twenty interconnected countries on multiple climate years to represent the uncertainties associated with demand and RES generation, while optimizing the european-wide generation of thermal, nuclear and hydro plants and reserves. The time step is hourly. For each plant, the outputs are dispatching production plans, associated costs data, reserve provided and direct emissions. For each zone, the marginal cost is calculated as well as the duration of unserved energy and curtailed RES energy.

The two main scenarios from EU-SysFlex are taken from the publicly available 2030 and 2050 EU-Reference scenarios (European commission, 2016). Interconnexion levels and generation cost assumptions are based on relevant public data, *i.e.* (OECD/IEA, 2018). The 2030 scenario developed for EU-SysFlex, called Energy Transition, has a share of 23% of variable RES (52% of RES in total demand) while the 2050 scenario, called Renewable Ambition, has a share of 34% (66% of RES in total demand). A sensitivity analysis is performed on variable RES shares for the 2050 scenario to investigate their impact in the European system (this constitutes three sensitivity scenarios for 2050). We economically adapt the power mix by adjusting combined cycle gas turbines (CCGT) and open cycle gas turbine (OCGT) power plants from the Renewable Ambition scenario to reach shares of 23%, 45% and 55% of variable RES, so that there is at most 3h of loss of load per country in Europe and adequate level of service is provided to consumers.

Results

<u>The power system is transformed by variable RES, with a particular impact for gas power plants in the mix</u>

Comparing the four adapted power mixes with variable RES shares for 2050 highlights the low capacity credits of variable RES and the fact that it tends to decrease with higher penetration levels (OECD/NEA, 2019). It shows that additional variable RES capacity replaces gas power plants capacity but not on a 1-to-1 ratio. On average, the ratio is about 1 GW of decommissioned gas plants for 6 GW of newly installed wind and solar capacity in the beginning but the replacement capacity for variable RES increases sharply as the share of RES in the power system increases.

When there is no wind or sun, gas plants supplement variable RES, especially at high shares of variable RES. The total running time for gas plants does not allow for a larger installed capacity of less carbon intensive CCGT to cover their costs despite a 90€/tCO2 carbon price for 2050. Peaking plants (OCGT) with lower investment costs but higher CO2 emissions make it possible to offer an adequate level of service to customers at a lower price. Therefore, the capacity of peaking plants is increasing with variable RES share (+45 GW between 23% and 55% variable RES share), as well as their load factors, while load factors for CCGTs are decreasing sharply.

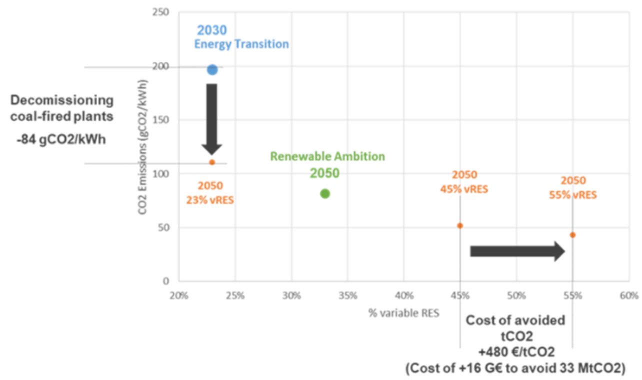
When there is a lot of wind and sun, variable RES generation can exceed demand even with storage through pumping stations because installed capacity can be very large : the installed variable RES capacity is scaled up to reach the target percentage using the annual capacity factor which can be fairly low. Occurrence of these episodes increases sharply with the share of variable RES in the power system. The number of hours of curtailment increases as a consequence, despite favorable interconnections assumptions to pool RES production and customer demand at a European level: as an example, 10% of the variable RES production is curtailed at a share of 55% variable RES.

Market revenues for variable RES do not cover costs at high shares of variable RES

Comparing cost structure (fixed -O&M and investments costs- and variable costs -i.e. mostly fuel and CO2 costs-) associated with the four sensitivity scenarios for 2050 shows a shift towards being overwhelmingly dominated by fixed costs as the variable RES share increases. The fixed costs represent 60% of the costs for a 23% variable RES share while it represents upwards of 90% for a 55% variable RES share. Furthermore, additional necessary network reinforcement, interconnections, or smart technologies deployment costs were not assessed but would reinforce the fixed costs share. One of the main implications of a power system mainly composed by capital-intensive technologies and high share of fixed cost is its exposure to risk issues. This raises the question of the appropriate market design to address the shift of system cost structure, so as to properly share the risks and promote necessary investments. Currently, the main source of revenues comes from the energy market reputated to be very risky in particular during energy transition.

The annual average marginal cost across the European power system is indeed dropping as the variable RES share increases, in particular around the solar hours. This can be explained in part by the fact that the share of hours with zero marginal cost increases sharply with the share of variable RES. This will translate into deterioted revenues for all generation plants in an energy-only market environement (no subsidies), that must bear at the same time a higher uncertainty and risk level. Wind and solar are the most affected by the decrease of marginal costs, and the market revenues do not allow them to cover their costs when the share is higher than 34% of variable RES. The value earned by solar on the energy market is divided by five between a scenario with 23% variable RES and one with 55% variable RES at the European level, whereas the marginal cost is only halved. The cannibalization effect is greatest for solar because its production is concentrated only on a few hours during the day where the drop in marginal costs is highest, as also pointed out by previous work (Hirth, 2013) (Burtin and Silva, 2015). The cannibalization effect also implies that if the policy target level of vRES is higher than economic optimal share, subsidies will be needed to ensure necessary variable RES investments.

The reduction of direct CO2 emissions by adding variable RES is tapering off when the power system is already low carbon



The figure aside shows the direct CO2 emissions in Europe from the EU-Sysflex sensitivity scenarios. The first difference is the share of variable RES but additional first order drivers are at play. The CO2 price increases from 27€/tCO2 in 2030 Energy Transition to 90€/tCO2 in 2050 Renewable Ambition. The higher CO2 price combined with a longer time horizon allows for less carbon intensive plants in Europe, with a reduction of 40% of direct emissions. As the share of variable RES increases the reduction of CO2 emissions tapers off partly because of a higher capacity in peaking plants. Computing the total cost difference between a power systems at 45% or 55% share of variable RES, the cost of an avoided ton CO2 is 480 € which emphasizes the message from the IEA on deep decarbonisation (OECD/IEA, 2019). There is no single or simple solution to reach deep decabonization. The most efficient way to lower CO2 emissions is to pool carbon-free technologies together in different sectors.

Conclusions

The sudy conducted for EU-SysFlex highlights some of the technical challenges of operating a system with high shares of variable RES, as well as the economic implications. The goal is to give the data necessary to anticipate new flexibility solutions or market designs, and reach a low carbon Europe with a resilient power system. Variable RES do lower the carbon footprint of the power system when combined with decommissioning of carbon intensive plants. However, to reach deep decabonization, the most efficient way is to pool carbon-free technologies together in different sectors as advocated by the latest WEO.

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