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EPRG WORKING PAPER NON-TECHNICAL SUMMARY

# Renewable Integration: The Role of Market Conditions

**EPRG Working Paper 2403**

**Cambridge Working Paper in Economics CWPE2421**

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The European Green Deal is the EU's long-term growth plan to make Europe climate neutral by 2050. This target is enshrined in the European Climate Law, as well as the legally binding commitment to reduce net greenhouse gas emissions by at least 55% by 2030, relative to 1990 levels. In May 2022, the Commission presented the REPowerEU Plan, in response to the hardships and global energy market disruption caused by the Russia-Ukraine war. The European Commission also adopted the European Gas Reduction Plan to reduce natural gas consumption for the winter. This plan included three pillars of action: fuel switching from gas to alternative energy sources such as RES, incentivizing energy consumption reduction, and reducing heat and cooling consumption temperature thresholds for district heating in the household sector.

These plans coincide with the desire to replace polluting generation technologies, i.e. coal or gas power, with RES. In many cases, grids capacity constrains the connection of new RES. This has attracted the attention of scholars to optimal grid investments to connect RES given the existing grid capacity. However, wind and photovoltaics generators are made of power electronics instead of rotating synchronous generators used in the replaced conventional generators. Power electronics have particular and limited operational behavior and operating higher rates of RES might affect the system stability and security. In these cases, system operators activate or curtail specific generation units to minimize the risk of blackouts. In Europe, these actions are managed through the redispatching processes, which were initially aimed to solve grid bottlenecks, but now they are mostly used for solving these non-grid issues.

In Spain, more than two-thirds of redispatching volumes in the day-ahead are used to solve voltage or power system stability needs. This presents a new scenario in highly decarbonized power systems where non-grid capacity issues become increasingly relevant and further technological developments in RES and storage are needed. This scenario highlights that the allocation of generation and consumption made in the electricity markets might be economically efficient, but are not always technically viable. In these cases, system operators must adjust market schedules with increasingly redispatching costly actions. With the greater connection of RES, this phenomenon is increasingly relevant.

This paper aims to analyze the costs and patterns related to the activation of conventional generators on the day-ahead market schedule with redispatching and identify how these could evolve with the implementation of programs now proposed in the European Gas Reduction Plan. All these programs affect the generation mix or change the hourly consumption profile, i.e., installation of RES, peak shaving, energy efficiency programs, and charging of electric vehicles (EVs). Activation of generators for operational security has relevant welfare implications: they represent an extra cost for consumers and produce $CO_2$ emissions. Moreover, the activated plants need an equivalent curtailment of other scheduled generators (RES) to maintain the system balance, which ends with another relevant inefficient allocation of resources.

This paper aims to answer two research questions: how does the electricity demand and renewables affect the redispatching volumes and costs?, and how could these redispatching volumes and costs develop in the future? The methodology consists of two stages. First, we empirically assess how the total electricity demand and the rate of RES in the mix have set the redispatching volumes and costs in the day-ahead (2019-2022). Second, using empirical estimates from the first stage we quantify how the volumes, costs and $CO_2$ emissions from redispatching processes could evolve in the future under different programs (scenarios), most of them related to the implementation of the European Gas Demand Reduction Plan. Precisely, this plan aimed to reduce gas consumption -reducing the electricity consumption and increasing the share of RES.

We find that each additional scheduled MWh in total demand reduces the cost of redispatching between 0.67€ and 2.63€. Moreover, each scheduled MWh of RES increases the redispatching costs between 1.63€/MWh and 6.24€/MWh in average. These costs include the activation of synchronous generators, and the curtailment of other generators keeps the system balanced. In our simulations, we find that the installation of new 10 GW of photovoltaics and wind increases the redispatching costs between 117 and 132 M€/year, respectively. Moreover, the installation of small generation behind the meter might become a regressive policy since all customers will bear the additional operational costs.

We offer several regulatory recommendations. System operators should devise efficient grid operation strategies to predict future network operation constraints. Moreover, grid planning analysis related to the location of RES should go beyond the forecast of future grid bottlenecks and consider its impacts on network operational constraints, which includes the assessment of future redispatching services when new grid is built. A massive development of generation behind the meter, namely self-consumption, might challenge the operation of the power system and create additional emissions and costs associated to these volumes. This might highlight that this policy might be regressive as the wealthier consumers can afford this investment in their homes, but the rest of customers should pay additional costs related to the operational needs. Finally, until the renewable or storage technologies evolve further, conventional generators (coal, combined cycle or nuclear) are needed for safe operation of systems with high rate of renewables, and countries need to assess when they disconnect them from the network.

The Spanish case anticipates similar scenarios in countries that are making efforts to decarbonize their mix. The magnitude of the challenge aggregated across the EU is much larger. Our main conclusion is that solving grid congestion is a necessary, but not sufficient condition for an efficient integration of RES. Further research is needed to analyse the remedial actions discussed also in real-time. A more detailed analysis of the activated units could provide useful locational information on potential network operational constraints.

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| Publication | April 2024 |
| Financial Support | Copenhagen School of Energy Infrastructure and the Chair of Energy Sustainability (IEB, University of Barcelona), FUNSEAM |