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Present state of the power system in Spain and the optimal development of a future variable renewable energy (VRES) mix

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As the percentage of electricity from variable renewable energies, (wind and solar) gets above some 30-40% of the mix, the problems of integrating the VRES supply into the distribution grid rise significantly. In fact, the characteristic intermittency of renewable sources necessarily demands for its effective integration some combination of efficient and flexible backup plants, large energy storage systems, smart grids, etc. and, consequently, the costs of electricity could be notably increased.

This article analyses the present situation of the power mix making use of the latest data available from the Spanish distribution grid regulator (Red Eléctrica Española). The study is carried out in a two-tier analysis: Firstly we perform a descriptive analysis of the latest trends comparing the generation of the last years. Secondly, based mainly on the European directions on the future limitations of CO2 emissions, we make an analysis of the deployment of the optimal mix of VRES that would minimize the both the need of backup from conventional sources, as well as surpluses. A reduction in fossil fuel generation, as recommended by the European Union (EU) and several international treaties, is also considered. As far as we know, this kind of studies, based on linear programming for establishing the optimal power generation mixes for VRES at a country level, are unusual and yet to come. However, they can provide key figures to policymakers for the establishment of desirable investments for renewable energies in the nearly future.

Evidently, the main difficulty of the above study is caused by the large unpredictability of wind and solar resources and for this reason we base our optimization technique on the hourly data series (8760 hours in one year) provided by REE. It is also interesting to point out that in finding the optimal mix for VRES, we have considered two components for solar: photovoltaics (PV) and concentrating solar power (CSP). Practically, none of the European scenarios take into account these two solar components since it is known that for latitudes higher than the one of Spain, the conversion efficiency of CSP diminishes very rapidly.

In this work we have studied three possible scenarios. In the first one we suppose the hypothetical case of the total demand being mostly supplied by variable renewable energies. In this case, it is assumed that all the electricity demand is covered by wind and solar energies (PV and CSP). To do so in the solution of the problem we apply the stringent condition that the resulting mix should be optimal, that is, that the 8760 hourly periods in the year of backup and surplus are simultaneously minimized. The solution of the problem gives, as expected that the increase in VRES needed is too large to be implemented before 2030. In addition the amounts of surplus and backup are also unmanageable without an efficient storage and lack of demand-side response technologies.

In the second case we suppose that the hydraulic and nuclear generation are maintain ned at their present levels. Therefore, the VRES should cover only the reduced demand, that is, the difference between the total demand minus the sum of the hydraulic and nuclear components for each of the hours of the year. Under this situation, the solution of the optimization problem yields that the present wind, solar-PV and solar-CSP generations would have to be increased by 97%, 20%, and 528%, respectively. In this case, we have also calculated the aggregated yearly backup needed and the surplus obtaining 14.2 and 5.7 TWh, respectively. It is also evident that without storage the surplus electricity would be lost.

In the third scenario we study the more realistic case that Spain will follow the targets assigned by the EU for the reduction of emissions in 2030 as well as the increase of the corresponding renewable energies. This

implies a drastic reduction in the future coal-generated electricity reaching 15.2 TWh by 2030 (about 30% of its present amount). We call this case, the European Union-2030 Scenario. After performing the corresponding operations for the optimization problem, as in the previous case, we find that the current wind, PV and CSP generations would have to be augmented by 64%, 27%, and 332%, respectively. In addition, the yearly backup and surplus have been drastically reduced to 2.9 and 3.3 TWh, respectively. We would like to remark that it might appear surprising the large percentages resulting for CSP which can be explained by its low present participation in the actual generation mix and above all by its possibility of evening and overnight storing of energy during several hours after sunset.

It is important to remark that the needed backup will be mainly supplied by natural gas plants, which are less contaminating and have a faster response than coal plants. Finally, in this communication, we also discuss other strategies that will have to be implemented if we want to handle large amounts of VRES. These are storage, demand-side management, distributed generation, and smart grids, since they contribute to the improvement of the so-called flexibility of the systems for power generation. With respect to the management of the surplus, evidently storage could in theory accumulate the corresponding energy for later use, thus partially substituting the backup systems. However, a massive use of storage still has to wait due to the high cost of batteries and the need of a practical seasonal storage (summer-to-winter in the case of solar) yet to be developed.

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