The Social Efficiency of Electricity Transition Policies Based on Renewables. Which Ways of Improvement?

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The need for carbon emissions reduction in economies has been introduced into the policy agendas in most of the developed world. It is increasingly common to consider climate and energy policies in joint packages targeting simultaneously CO2 reductions and explicit shares of renewable energies (RE) for a given horizon.[c]

Direct climate policy instruments (addressing CO2 emissions) provide "first-best" solutions regarding the long term coordination between gas turbines and non-emitting flexibility sources in order to limit the use of fossil fuels (Abrell, Rausch, and Streitberger 2019). In the EU, even if concerns with reducing CO2 emissions exist, in practice, very few reforms have succeeded in implementing direct climate policy instruments effectively. Only indirect technology-oriented instruments such as renewables obligations, energy efficiency mandates or coal phase-outs have been effectively put in place.

As a result, renewables development (formulated as targets on the share of electricity generation) has become an objective in itself and may take precedence over the objective of decarbonization, without questioning the economic rationality of this inversion of objectives and its environmental effectiveness. This could indeed lead to an unbounded development of renewables, which would result in a high opportunity cost, in particular in countries where the nuclear option is still open, but also to potential conflicts with the carbon mitigation goal. Large scale deployment of variable renewables (VRE) needs complementary production by fossil fuel plants and flexibility resources, including gas turbines, to maintain security of supply and to provide system stability.

This problem can only be addressed appropriately by using detailed models of the power system that can take into account the dynamic interactions between all the production units including large amounts of VREs, in real time, the provision of system services, hour by hour supply and demand balances, while in the long-run the modelling should comply with capacity adequacy requirements. We use a detailed model of the power system for a "greenfield" optimization in 2050, with the particularity of considering the nuclear option as open alongside the development of renewables and fossil-fueled power plants. The last are potentially used for back up purposes and for providing system flexibility if cost effective. We optimize capacity investment and system operation using different combinations of policy instruments, namely a RE obligation (similar to a Renewable mandate) and a CO2 cap per MWh (equivalent to imposing a screening carbon price). In this way, we seize the interplays between policy instruments and compute the minimum cost solutions for various combinations, and we rank the resulting solutions regarding their climate effectiveness and their social efficiency. Thus, we obtain first and second-best solutions regarding the CO2 savings and the costs overruns achieved with respect to the reference case (BAU).

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c The most recent examples are the National Energy and Climate Plans (NECP) requested by the European Commission to the Member States covering the period 2021-2030. Further information on the NECP is available at: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/governance-energy-union/national-energy-climate-plans

A detailed model of the power system helps to capture the complex interactions between policies targeting very high shares of RE technologies, CO2 reduction targets, and the possible recourse to new sources of new flexibility technologies enhancing system integration on one side, and captures their environmental effectiveness on the other side. Assuming technology costs for 2050 from official reports (i.e., low RE costs, high nuclear cost), only modest levels of VRE (around 11%) are developed in the system without subsidies in the optimal mix, whatever the emissions cap or the carbon price level. The flexibility sources increase the optimal shares of VRE from 11%¨to 18%. Different tests on the renewables shares required (supposed to be the main instrument to reduce the power system emissions) show trade-offs between increasing VRE shares, economic efficiency and environmental effectiveness of the respective policies, with some unexpected effects. For the severe norm of 50 g/kWh needed to maintain environmental performance, a policy targeting 80% renewables is 45% more costly than the BAU case, while the additional cost is only 13% if RE share is only forced up to 50%.

Tests including new flexibility sources (i.e. different storage techniques, demand - response) show that their optimal deployment logically reduce the overall cost and improve CO2 performance to a certain extent, but this does not hold true in every situation. Indeed, moving from an 50% to an 80% RE obligation leads to a total emission rebound, even with the development of flexibility resources. This effect results from the fact that from a certain penetration of RE the carbon policy becomes unbinding (e.g., a carbon market with oversupply of emission allowances), thus, the time arbitration capabilities of storage and demand response improve the economics of fossil equipment, as mid-merit suppliers, by providing them with higher load factors, which may bring on additional emissions. This effect can be countered by strengthening the carbon constraint when pushing to very high RE shares, but it leads to a non-linear increase in the overall cost at the same time. At the end it is possible to rank the different combinations of RE obligations and carbon caps.

Our findings are at the crossroads of different strands of the literature on VRE integration and on model-based climate policy assessments. We aim to make each strand converge into the evaluation of joint climate-energy packages. This includes papers on the economic values of VRE which decline as their capacities develop "out-of-the-market" (Hirth, 2015, Bruninx et al. 2016), those that identify the optimal share of VRE in an electricity mix (Hirth, 2015, 2016), those that compare the overall costs of the system for different penetration rates of VRE under carbon constraints (Hirth, 2015, Delarue, Van den Berg. 2016), and those assessing the economic value of storage and demand response to improve the economic integration of renewable energy sources (Zerahn et al, 2015; Hirth, Ueckerd, Edenhofer, 2016; Sisternes et al, 2016). These papers often do not consider one or more aspects of the problem: some reduce the range of low-carbon technologies (e.g. without a nuclear option), others ignore some sources of flexibility (such as demand response) or simplify the links with the carbon policy by adopting exogenously fixed CO2 prices. Here we consider a wider range of technology options on the supply-side, and focus on the interactions between policies targeting the large scale development of RE technologies, a carbon policy using CO2 caps, and the possible recourse to new resources of flexibility, in order to assess different energy-climate policies targeting the power sector, we propose a framework to rank them regarding their environmental and economic performance, and present the implications of our findings in view of the theoretical and energy policy literature (Abrell, Rausch, and Streitberger 2019; Newbery, Reiner, and Ritz 2019; Percebois and Pommeret 2019).

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