Implications of the *National Energy and Climate Plans* for the Single Electricity Market of the island of Ireland[1]

EPRG Working Paper 2020

Cambridge Working Paper in Economics 2072

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The European Green Deal sets out a roadmap to climate neutrality in 2050. Member States, including Ireland, or more relevantly, the Single Electricity Market of the island of Ireland (SEM), have to set out the decarbonisation path to be followed by the electricity sector. Regulation EU/2018/1999 requires each Member State (MS) to establish a 10-year integrated *National Energy and Climate Plan* (NECP). These NECPs require increased renewables, overwhelmingly solar PV and wind in most MSs, and the phase-out of coal.

In the SEM the technology of choice is wind. The falling cost of solar PV is beginning to compensate for the poor solar resource. Wind and solar are variable and need controllable flexible back-up, which for more than very short-term demand and supply shifting, will have to come from fossil generation. This note asks what the ambitious renewables targets are likely to imply for storage, interconnection and curtailment, assuming adequate back-up power in the SEM. It is a back-of-the-envelope and hence rough estimate of the trade-offs, and cannot pretend to be a serious study, of the kind that others have undertaken for the UK and the SEM. It illustrates how to grasp the main determinants of the relative costs of different strategies to deal with a high penetration of variable renewable electricity (VRE), bearing in mind interconnection opportunities but recognising that other interconnected countries also face a massive increase in VRE under their own NECPs.

[1] The author is an independent member of the Single Electricity Market Committee of the island of Ireland but this paper is written as an independent academic and only draws on published sources. It does not reflect the views of the SEM Committee.

The N-1 security standard requires that there is a primary reserve equal to the single largest relevant infeed of 465 MW. There are additional constraints set by the allowable Simultaneous Non-Synchronous Penetration (SNSP) of supply from VRE (the SEM 2020 target is 75%). Starting from 2018 (a normal wind year) the hourly VRE and load in the SEM and neighbours, the simulated hourly load and VRE for 2026 is calculated from the NECPs (55% VRE for the SEM), and from that the potentially surplus VRE (VRE-Load) is calculated. The amount of VRE that will have to be spilled (curtailed) is magnified by the N-1 and SNSP constraints that require a minimum level of flexible generation, but can be reduced if it is possible to export or store some or all of the surplus. Exporting in this model is only possible if the integrated markets to which the SEM is connected (GB, to FR, BE, NL, to ES and DE) and only up to the export capacity (900 MW, rising to 1,600 MW if the Celtic Link to France is ready by 2026).

On the optimistic assumption that the SEM can raise SNSP to 85%, and using just existing interconnection and planned battery storage, the average amount of potential wind spilled is 8.1%, the proportion of the year in which at least some wind is spilled in considerably larger at nearly 25%. If the aim is that the average wind actually used is 55% of total domestic demand, then the potential wind would have to be 63% of average demand, with 12.5% of potential wind curtailed. The marginal curtailment of adding an extra 1% more capacity (and hence 1% more wind in each hour) is 38%, more than four times larger than the average curtailment of just 8%.

If it is not possible to increase SNSP from 75% to 85%, 13.3% of potential wind will be spilled, or 1,338 MWh per year. On the other hand, an extra 100 MW of battery electric storage reduces spilled wind by 18.47 GWh/yr or 185 MWh/MWyr battery capacity. For comparison, if a battery cycles from 20% to 100% state of charge daily it would manage 7,000 MWh/MWyr, so the reduced curtailment is less than 3% of the battery's potential capacity. If the 700 MW Celtic link is operational in 2026 then more wind can be exported instead of being curtailed. At the high SNSP of 85%, spilled wind falls to 7% (and to 12.4% at SNSP of 75%). Having more interconnection reduces both the average wind spilled and the marginal spillage (from 38% to 26%).

The paper also provides rough estimates of the potential storage available from electric vehicles, domestic heat with storage heaters, and electric water heating, but to realise these gains will require considerable metering and tariff development.

Conclusions and policy recommendations

Ambitious plans to reduce carbon emissions from electricity through increased VRE increase the likelihood of curtailment, as the ratio of peak to average power can be 3:1 for wind, and 6:1 for solar PV. It is tempting to think that surplus VRE can either be exported or stored, and this paper provides a rough estimate of what can be expected from these options. Interconnection indubitably reduces curtailment, as does storage, although increasing SNSP (which in turn benefits from increased interconnection and storage) has a larger effect. The direct impact of interconnection and storage alone would not seem to justify their cost, although would clearly improve their economics, provided their main justification (arbitrage and ancillary services) is (almost) adequate.

This note has employed very simple spreadsheet modelling and as such is easy to replicate and update, but is no substitute for a proper unit dispatch coupled set of system models, of which there are many. By spelling out each link in the determination of VRE curtailment is offers more (or quicker) insight into the determinants of curtailment than more complex black-box optimisation/simulation models.

The main policy conclusion is that the design of support systems for renewable electricity needs to ensure that at the margin extra wind is valued at the efficient price to ensure efficient trade and storage decisions (both spot and for long-term investment decisions). Providing subsidies to fix prices for VRE output equally in each hour will distort these signals, and instead support should be to effective installed capacity, not output. The first priority is to set an adequate carbon price floor (as in GB), to ensure efficient competition with remaining fossil generation. The simplest way to provide efficient subsidies is to auction the premium to be paid per MWh of the first 20,000 of full operating hours (i.e. 20,000 MWh/MW capacity). This ensures that the marginal value of an extra MWh is the spot or balancing price while providing an assured and bankable capacity subsidy. This would also reduce forced curtailments as VRE producers will only supply if the relevant price (spot, balancing or ancillary service) is higher than short-run avoidable cost.

In addition, it is increasingly recognised that optimising the choice of turbine technology for local wind conditions can be important, and possibly more important for reducing system-wide variability that geographic dispersion. Efficient decentralised choices require efficient signals (locational prices may be too cumbersome while last-in first-out curtailment may be cruder but simpler).

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Publication	July 2020
Financial Support	