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Rooftop solar PV and the peak load problem in the NEM's Queensland region

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Over the period 2016-2021 Australia's National Electricity Market (NEM) experienced an investment supercycle comprising 24,000MW of renewables. One of the more intriguing aspects of the supercycle was a partial shift of investment decision-making from utility boardrooms to family kitchen tables – rooftop solar PV comprised 8,000MW of the 24,000MW total.

In NEM regions such as Queensland, rooftop solar has now reached ~40% of households, currently the highest take-up rate in the world. Yet at the household level there is a distinct mismatch between peak demand and solar PV output, which tends to suggest any peak load problem will be exacerbated. However, when the contribution of rooftop solar PV is abstracted to the power system level, these results reverse.

The purpose of this article is to examine the impact of rooftop solar PV on Queensland's power system, and examine whether the energy-only market design is capable of remaining tractable when rooftop solar and utility-scale renewables approach 50% market share.

The partial equilibrium framework of Boiteux (1949), Turvey (1964) and Berrie (1967) has historically been used to define the optimal plant mix to satisfy demand growth. In this article, their partial equilibrium framework is used to define conventional plant 'dis-investment' in the presence of rising renewables in an energy-only market setting.

Queensland's 4,430MW of installed rooftop solar capacity forms a non-trivial component of the aggregate supply function. Modelling reveals rooftop solar drives 1000MW ($1.35 billion) of utility-scale plant dis-investment in equilibrium, and perhaps surprisingly, 500MW of which is baseload plant. When the power system is then augmented with a utility-scale fleet of solar and wind such that VRE market share reaches 50%, the energy-only market remains tractable given the NEM's VoLL of $15,000 and a reliability constraint of not more than 0.002% unserved energy. The addition of VRE was welfare enhancing for any shadow CO2 price above $3.1/t.

There are important caveats to these findings. As VRE expanded through the modelling range, coal plant dis-investment was crucial to maintaining a tractable equilibrium. And any equilibrium is fragile – if divestment does not occur seamlessly, system average cost increased due to utilisation effects, and spot prices began to collapse due to merit order effects, with the net gap reaching $25/MWh in a c.$55/MWh power system. Importantly, the gap was not missing money, it was merely low prices due to structural oversupply.

Whether an energy-only market design is a suitable and enduring format for a renewable transition is an open question. The weight of energy economics literature is, on balance, in favour of alternate market designs comprising capacity payments, CfDs, or some other form of administrative coordination. These alternate designs entail centralised decisions where consumers or taxpayers bear an elevated risk of heightened cost by comparison to an energy-only market design. And the energy-only market design is thought to elevate consumer reliability risks and accompanying price shocks. The fact that there is no uniform solution tells us this is a complex area.

The energy-only market design contains many desirable features. Peak load pricing by way of a high VoLL provides a clear and unambiguous signal for performance at critical times. But the analysis makes clear frictionless dis-investment is important.

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