INCLUDING THE COST OF BALANCING VARIABLE RENEWABLES IN LEVELISED COST OF ELECTRICITY

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Overview

Calcualtions of the levelized cost of electricity (LCOE) are used as a method for making quick comparisons between technologies to understand where they rank in cost competitiveness of electricity supply. LCOE is an imperfect measure for many reasons. It often excludes costs that are out of the ordinary or outside of the project gates such as grid connection, transmission augmentation, waste and rehabilitation. It may also fail to take into account the different risks faced by projects, often applying a single discount rate across all projects. High emission electricity generation technologies face a greater risk of adverse economic outcomes from the implementation of future climate policies. As a result they may have to pay a premium to access finance relative to low emission technologies.

The specific concern of this paper is in relation to balancing costs of variable renewables. The standard LCOE calculations for variable renewable technologies does not take into account the cost of the additional balancing technologies required to ensure reliable and stable electricity supply. Every technology requires some level of support from other technologies. Electricity systems are reliable and stable due to their use of a combination of technologies, rather than a single technology. However, variable renewables increase this challenge for the system because their generation is governed by the weather.

Graham (2018) conducted a review of alternative methods for calculating the balancing costs of variable renewables. Methods for addressing this question are becoming more common as renewables increase their share in electricity systems and various stakeholders are seeking to understand the whole of system costs of renewable electricity generation. While lacking the transparency of simpler methods, system modelling methods are the most accurate at estimating balancing costs. Simpler methods often fail to optimise the capacity and operation of balancing technologies, leading to over- or under-estimation of costs.

Methods

It is a significant challenge to select the right model to estimate variable renewable balancing costs as the more commonly applied modelling frameworks are not well-suited. Applied electricity system models tend to be focussed on projecting the least cost amount of new capacity over a given investment horizon or optimally dispatching (operating) a known stock of electricity generation plant to meet demand in a single instant (e.g simulating the 5 minute dispatch market that exists in Australia). In more recent years, a third type of model has emerged which represents a hybrid of these two which we will call an intermediate horizon model (IHM). IHMs decrease the investment horizon to as short as one year to free up model space to include sequential intertemporal optimisation over all hours of the year (or half-hours in our implementation). In contrast, dispatch models are myopic in that they do not optimise plant operation based on future considerations. However, some dispatch models may include responses to information from day-ahead markets or other forecast information.

The motivation for working with IHMs is two fold. The first is that long horizon investment models are typically structured as annual models but with a limited number of aggregate time slices to represent the main features of demand such as seasons, weekend-weekday differences and peak, shoulder and off-peak periods of the day. This use of time slices is not sufficient to adequately capture the impacts and optimal capacity building of variable renewables. For example, a typical outcome is that wind generation is under-valued relative to solar photovoltaics because both appear to have a similar amout of variability. However, at a more detailed temporal scale wind resources are more diverse and therefore more valuable than they appear when represented through aggregate time slices.

The second and related reasons for using IHMs is that long horizon investment models and dispatch models are both poor at estimating optimal storage operation. Storage charge and discharge decisions are inherently a sequential intertemporal short time duration question which suits neither model framwork. If operation of storage technologies is not optimal, then this places some doubt over whether models are optimising the capacity of storage. That is, they could be over or underestimating the amount of storage needed. Graham (2018) found several methods in the literature simply assumed an amount of storage without any reference to whether it was the right amount required by the system. The Australian Energy Market Operator has been using an IHM called DLT in its Integrated System Plan process (AEMO, 2019) together with a long horizon investment model and a dispatch model.

It is important to note that, by shortening the investment horizon, on its own, an IHM will not make optimised long term investment decisions. An IHM will not be aware of future end of life asset retirements, changes in policy or other factors like changes in fuel prices and technology costs. As such, there is a risk that technology choices will not be optimal. However, the full costs of any generation and transmission investments are captured by annualising capital costs.

Results

We conclude IHMs are the best solution for calculating the costs of including balancing technologies to support variable renewables. They are the only modelling framework that optimises storage technology operation. The fine temporal scale of IHMs also means that the diversity of variable renewables is adequately captured. This is particularly important because previous analysis has indicated that adding more diverse renewables is one of the lower cost ways of balancing variable renewables (Campey et al., 2017).

The Dispatch and Investment Evaluation Tool with Endogenous Renewables (DIETER) is an open source IHM (Zerrahn and Schill, 2015). As an efficienct approach to model development, we have adapted DIETER since it already contains many of the desirable structural features. There were three main adaptations. The first is the inclusion of 5 state demand regions (consistent with NEM demand nodes) and 16 generation and transmission zones and their correspondence to each regional node. Secondly, all technology cost, resource and performance data for generation, transmission and renewable resources was included from Australian sources. Thirdly, we added an additional constraint that the system must maintain a minimum amount of inertia for stability purposes which can be provided by existing non-inverter based plant or deployment of synchronous condensers. We have renamed our adapted model Spatial Temporal Analysis of Balancing Levelised-cost of Energy (STABLE).

STABLE does not produce a single estimate for the costs of balancing variable renewables. It estimates a range for a given future year, demand region and renewable energy share. A large number of scenarios need to be run to have confidence that we have been able to calculate the full potential range of cost outcomes. The parameters we vary for any given estimate are historical weather years (with matched half-hourly demand and variable renewable production), random outages and retirement rates of existing plant.

Results so far indicate that there are no additional costs of balancing renewables below renewable energy shares of 40 to 50% (depending on the demand region). Existing plant provide the required flexibility and inertia. However, above 50%, balancing costs increase non-linearly but remain modest relative to other alternative generation sources This reflects that the underlying costs of renewable generation (i.e. without balancing costs) is still falling over time while balancing costs increase.

Conclusions

Many electricity stakeholders would like to understand more about the additional costs of balancing variable renewables. System modelling approaches have been found to be the most accurate methods but the most common types of electricity system models are not suitable. IHMs, which have become more common, are the best candidate approach. We have constructed a model called STABLE (adapted from the open source DIETER model) which has provided some results for variable renewables balancing costs in the NEM in Australia.

References

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