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SUPPORTING TECHNICAL PAPER:

CALCULATING GREENHOUSE GAS EMISSIONS ARISING FROM ELECTRICITY GENERATION IN THE NATIONAL ELECTRICITY MARKET

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Emissions are calculated on an annual basis as the sum of emissions arising from each thermal power station supplying the National Electricity Market (NEM). This is the procedure used by the Australian Electricity Market Operator to calculate, on a daily basis, its Carbon Dioxide Emissions Intensity Index (CDEII)[1]. AEMO calculates emissions from each power station as the product of electricity sent out from the station by the sent out emissions intensity of the station.

This study uses the AEMO sent out emissions intensity figures, in t CO_2-e/MWh sent out, for each power station (most of which are calculated from individual power station NGER reports). AEMO's list of power station emission intensities are summarised in an Excel file entitled *Available Generators*, accessible on the website. AEMO's calculation uses the metered sent out data for each power station, which AEMO gathers as a key input to its market settlement procedures. However, these data are commercially confidential and not publicly available. This study therefore uses AEMO's published data on power station output as generated, accessed through *NEM-Review*. The conversion from as generated to sent out uses AEMO's list of estimated power station auxiliary load factors. AEMO uses these values as an input to its annual National Transmission Development Plan process. Values for each individual power station were compiled for AEMO by ACIL Allen, and are available in a workbook entitled *Emission Intensity Values*[2].

This study uses a workbook model containing annual generation, sent out emissions factors and auxiliary load factors for each power station in the NEM. Past values for each year from 2011-12 to 2017-18 were inserted and used to calculate total emissions in each state (NEM region) and the NEM as a whole. The calculated values exactly matched AEMO's published CDEII values, thereby confirming that the model was correctly set up.

The starting point for estimating future emissions is operational load in each of the five NEM regions, as projected in AEMO's most recent (2017) *National Electricity Forecasting Report*[3]. Operational load is defined as the total quantity of electricity supplied to consumers through the

[1] http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Settlements-and-payments/Settlements/Carbon-Dioxide-Equivalent-Intensity-Index
[2] http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan/NTNDP-database
[3] http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Electricity-Forecasting-Report

NEM transmission grid, plus transmission losses. The modelling also includes AEMO's projections of electrical energy produced by rooftop solar installations in each NEM region.

Other key input assumptions are the capacity factors which new wind and grid scale solar generators are expected to achieve. These values are used to convert nameplate capacity of new wind and solar farms to annual sent out electrical energy. The values used are based on the actual performance of existing projects in each region, and are as shown in the following table.

NEM region	**Wind**	**Solar**
Queensland	33%	26%
New South Wales	33%	26%
Victoria	34%	24%
South Australia	32%	25%
Tasmania	38%	NA

Modelling was undertaken for three different levels of renewable generation capacity, exclusive of any capacity incentivised by the National Energy Guarantee policy, should it be implemented. The three cases are:

- Large Renewable Energy Target (LRET) only completed,
- LRET plus Victorian Renewable Energy Target (VRET), and
- LRET plus VRET plus Queensland Renewable Energy Target (QRET).

The legislated LRET target is for 33,000 GWh to be supplied nationally by new renewable generators in 2020. The Clean Energy Regulator (CER) stated in January this year that it expects that this target will be met by existing LRET generation plus new renewable generation currently under construction or firmly committed[4]. The complete list of wind and solar generation projects under construction or firmly committed in the NEM, as shown in the CER's most recent (May 2018) market supply data[5] has been incorporated into the model. The CER list identifies projects by the renewable generation technology used (wind or solar), the NEM region in which the project is located, and nameplate capacity. The total NEM generation capacity needed to meet the target has been calculated by adjusting for LRET generation located outside the NEM (mainly in Western Australia), the 850 GWh allowance within the target reserved for waste coal mine gas generation, supply from small LRET generators, such as landfill gas facilities, embedded within distribution networks, and renewable generation capacity contracted by the ACT government. This will be additional to LRET generation because the ACT government is cancelling (voluntarily surrendering in the terminology used by the LRET scheme) all renewable certificates earned by the generation it has contracted.

When these adjustments are made, the model estimates that the total new capacity listed by the CER exceeds the capacity needed to fulfil the LRET by at least 1,500 MW. It is assumed that most of

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4 http://www.cleanenergyregulator.gov.au/RET/Pages/News%20and%20updates/NewsItem.aspx?ListId=19b4efbb-6f5d-4637-94c4-121c1f96fcfe&ItemId=468

5 http://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/Large-scale-Renewable-Energy-Target-market-data/large-scale-renewable-energy-target-supply-data

this new capacity will come on line during 2018-19 and 2019-20, with a small quantity coming on line in 2020-21.

As these new generators enter the market they displace electrical energy supplied by existing thermal generators. The modelling does not attempt to simulate market bidding behaviour to determine which output is displaced. Such a simulation would be a complex task needing a large volume and variety of detailed data inputs, such as marginal fuel costs for each generator in each year, together with assumptions about the policy environment and how it might affect the commercial strategies and bidding behaviour of all market participants, many of which are unknown. Such a modelling approach is necessary to estimate what the effect of additional renewable capacity on wholesale prices might be (which is why such estimates are subject to high uncertainty). Simulation of economic behaviour it is not needed to calculate the purely physical effects on greenhouse gas emissions of supplying total demand for electrical energy by different combinations of generators.

The key assumption used to calculate these effects up to 2020-21 is that all of the generation displaced by new renewable generation will be that currently supplied by coal and gas fired generators. Coal generation supplied for 74% of total NEM generation in 2017-18. Since coal supplies most of the generation, it also provides most of the output reduction required to accommodate higher supply by renewable generators. Specifically, most of the supply displacement is assumed to occur at the older and mainly higher emission coal plants, such as Tarong and Gladstone in Queensland, Liddell in New South Wales, and Yallourn in Victoria.

Gas fuelled combined cycle and steam generation supplied a further 11%, and open cycle gas generation supplied 3% of NEM generation in 2017-18. It is assumed that open cycle generation will stay at the same level, because of its key roles in both meeting extreme demand peaks and, to some extent, off-setting variability in wind and solar generation. A modest decline in combined cycle generation is assumed to occur in both Victoria and Queensland, but not in New South Wales where its current level is very low. No change is assumed for the much higher share of gas generation in South Australia, because of its key role in ensuring supply security in a region with neither coal nor hydro generation. Finally, it is assumed that annual hydro generation in Victoria and Tasmania will remain at the same level as in 2017-18, while in New South Wales it will increase slightly, but still be lower than in either of the two previous years.

The level and mix of supply displacement is subject to the over-riding constraint that total supply in each year matches operational demand, with a small surplus included to allow for transmission losses on interconnector energy flows between regions. Interconnector flows themselves are constrained to remain at annual net levels no higher than the highest values observed during any of the past ten years.

After 2020-21, it is assumed that in the LRET case there will be no new investment in renewable generation, with the sole exception of the new wind and solar capacity which AGL has foreshadowed as part of its plan to replace Liddell power station when it is closed in 2022[6]. This is obviously an

[6] https://www.agl.com.au/about-agl/media-centre/asx-and-media-releases/2017/december/agl-announces-plans-for-liddell-power-station

unrealistically extreme scenario, given the likelihood that many larger commercial and industrial consumers will continue to pursue direct power purchase agreements with renewable generators even after the LRET reaches it ceiling level. This scenario, therefore, represents the absolute minimum level of emissions reduction likely to be observed in the absence of the NEG.

The second scenario, LRET plus VRET, adds additional wind and solar generation capacity in Victoria sufficient to achieve the state's two targets for renewable generation: 25% by 2020 and 40% by 2025. Both the 2020 and the 2025 targets include supply from rooftop solar installations, as well as grid-scale renewable generators, and both require all renewable generation to be physically located within Victoria. For the purpose of this modelling, the targets are defined as the ratio of energy sent out from renewable generators plus rooftop solar generation, to the sum of operational demand and rooftop solar generation. Defined in this way, the target is independent of the level of net interconnector flows, which can vary quite significantly from year to year.

The CER list of committed new renewable generation projects indicates that nearly half the new wind generation capacity and over a fifth of the new grid scale solar generation capacity will be built in Victoria. This means that the target 25% renewable generation share by 2020 will be comfortably exceeded, and additional investment between 2020 and 2025 will be at a substantially lower level than is currently being experienced in the state. It is assumed that further output will be displaced at Yallourn power station, so that from about 2024 onward it operates at capacity factors below 30%. In theory this might be achieved by closing the older two of the station's four units.

The third scenario, LRET plus VRET plus QRET sees significant investment in new wind and solar generation capacity in Queensland throughout the 2020s. In every year, however, new capacity commissioned remains little if any higher than the level likely to be seen in 2018-19. The volume of coal generation displaced is large enough to suggest that Queensland's two oldest coal fired power stations will be closed by 2030. The Queensland target, like Victoria's, includes rooftop solar as an important contributor. Consequently, in 2029-30, large renewable generators are modelled as supplying about 45% of grid generation.