openCEM

ARENA Open Source Grid Integration Model for the NEM

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Introduction—Motivation

A freely available, trusted, robust capacity expansion model with integration of renewables does not yet exist[a]

[a] This might have changed since the beginning of this project

Decision makers, regulators, operators and investors are grappling with complexity, uncertainly and rapid change – without adequate analytical tools

Modelling work to date has not examined, in detail, the lowest cost transition pathways for the NEM.

Existing modelling tools tend to be proprietary and are used to produce reports that have static assumptions and date quickly

Introduction—Project aims

To develop a NEM grid integration model which will:

- For the first time allow decision makers, and energy system planners, regulators and project developers to freely undertake scenario modelling.
- Analyse changes in regulation, technology, system operation and investment.
- Provide insights into pathways for the evolution of the NEM to a low-carbon power system.

openCEM—Overview

openCEM (Capacity Expansion Model) is a collection of utilities written in Python 3 to compute generator and storage capacity expansion decisions for the NEM (National Electricity Market). Loosely speaking, the suite consists of the following components

- A capacity expansion model
- A dispatch model
- A cost and input trace database
- Utility scripts for visualisation and reporting

openCEM—Capacity Expansion Model

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Transmission between NEM *regions* uses a pipeline model. Transmission is "copper plate" between zones within a region.

The capacity expansion problem in the CEMO suite is solved as an optimisation problem that can be summarised as:

> For a given dispatch period, satisfy the hourly electrical demand in each region with a combination of new and existing generation, transmission and storage capacity at the least total cost

This optimisation problem is constructed as a **linear program (LP)** for each dispatch period.[1] Capacity decisions from one period are carried forward to the next to assemble a transition of generation and storage capacity for the NEM.

[1] Dispatch periods are typically calendar years in 1 hour intervals

openCEM—Capacity Expansion Model

Technologies

openCEM models a range of conventional and renewable energy technologies:

- Black Coal (opt CCS)
- Brown Coal (opt CCS)
- Closed Cycle Gas Turbine (opt CCS)
- Open Cycle Gas Turbine
- Gas Thermal
- Reciprocating Engines
- Solar PV SAT
- Solar PV DAT
- Solar PV FFT
- Wind
- CST (6 hours of storage)
- PHES (6 hours)
- Batteries (2 hours)
- Biomass
- Hydro power

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It will be possible to override these costs in simulations.

The main decision variables in the capacity expansion model are new capacities in (MW):

- New Generator capacity `gen_cap[z,n]`
- New Storage capacity `stor_cap[z,s]`
- New Hybrid capacity `hyb_cap[z,h]`

and hourly dispatch for the total capacity (new + existing) in each category (in MW h)

- Generator dispatch `gen_disp[z,n,t]`
- Storage capacity `stor_disp[z,s,t]`
- Hybrid dispatch `hyb_disp[z,h,t]`

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Brown coal ramp up/down is rate constrained and hydropower is constrained to a total "budget" of MWh/yr

openCEM—Capacity Expansion Model

Additional constraints and options

Renewable energy targets can be set per region or for the entire NEM. They are declared for each simulated year.

Emission targets can also be set for the entire NEM for each year of the simulation.

Emissions can be penalised with a cost in $/kg of emissions. Each fuel using technology emits at its own rate and emission rate.

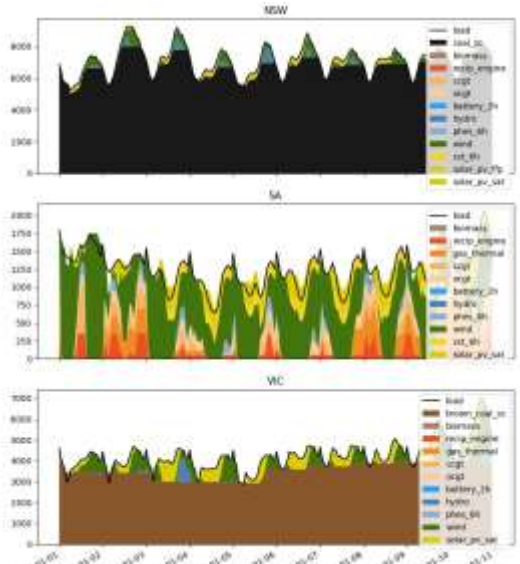
These will be offered in a (as simple as possible) configuration interface. If a user is proficient in Python and associated tools they can edit the model to their needs.

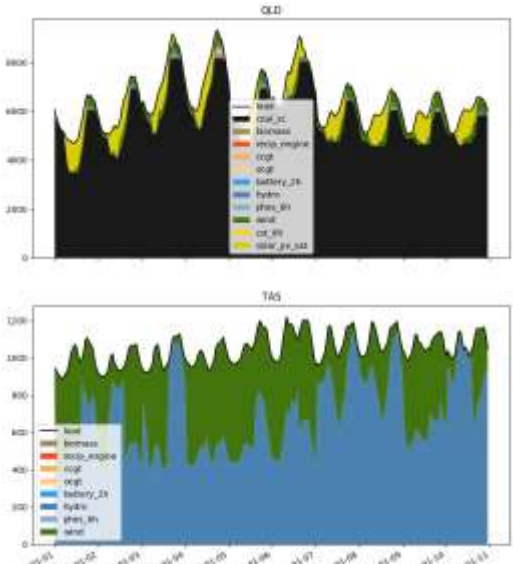
openCEM—Implementation

openCEM is implemented in Python 3, using Pyomo as the optimisation engine which provides the following functionality:

- High level language to implement the core optimisation problem
- Scripting facilities to integrate Pyomo models into larger multi year simulations and obtaining data from multiple sources
- Interface and handling of optimisation solvers, including commercial solvers and cloud based solutions
- Plotting of results, reporting of solution and exporting data into compatible formats, e.g. JSON

openCEM—Implementation





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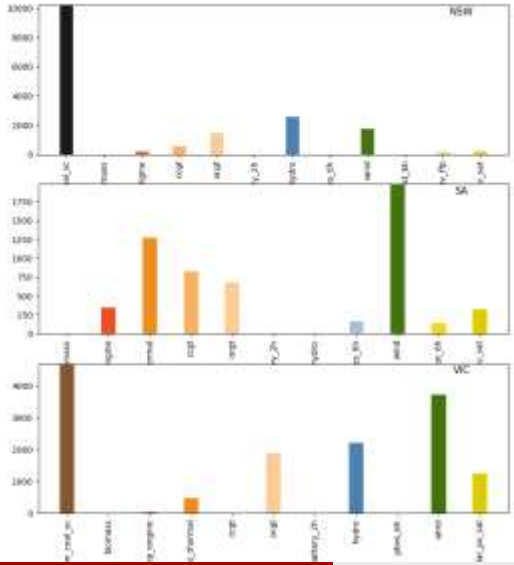

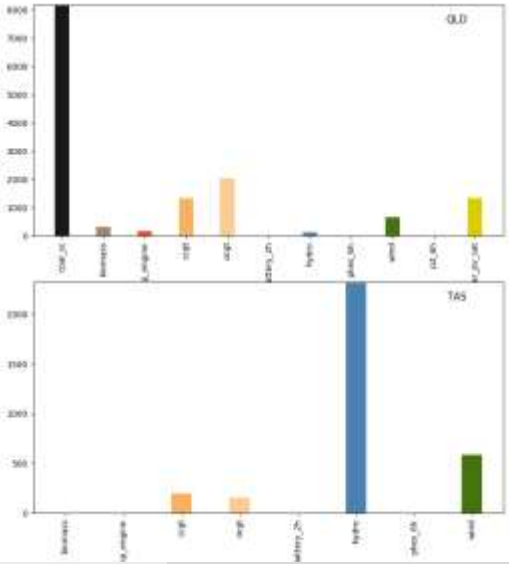

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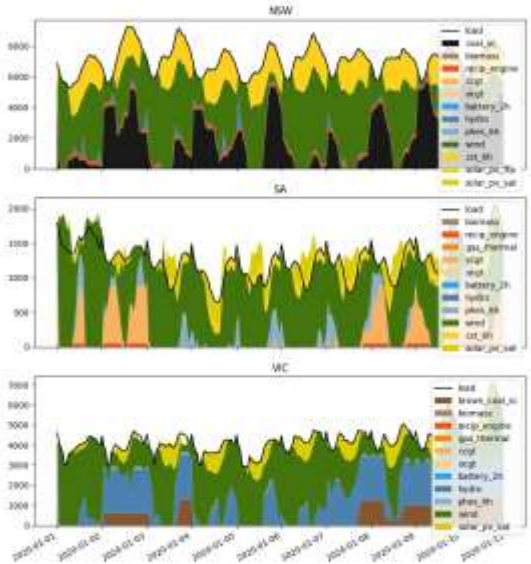

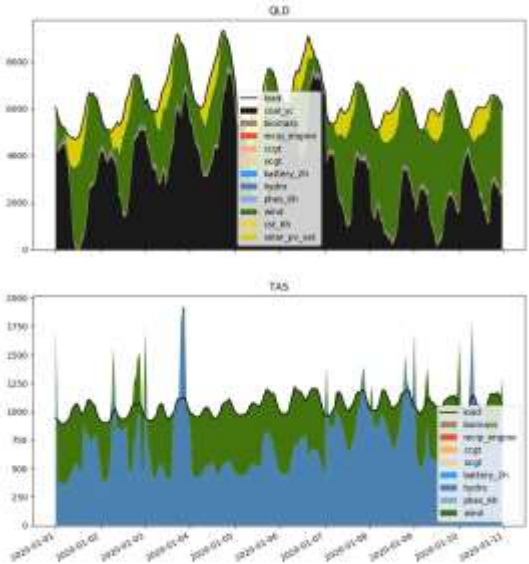

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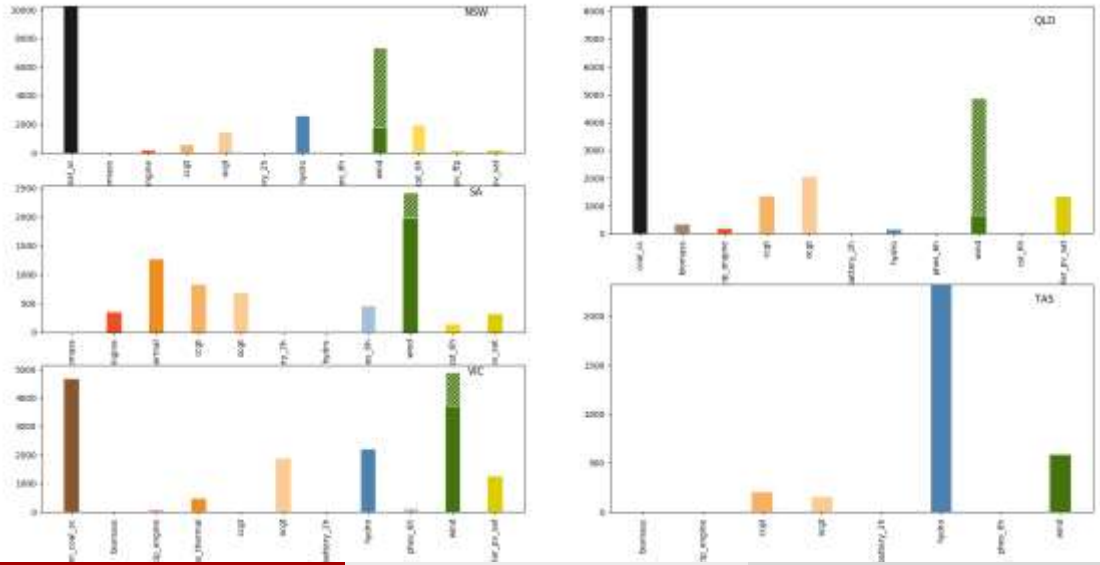

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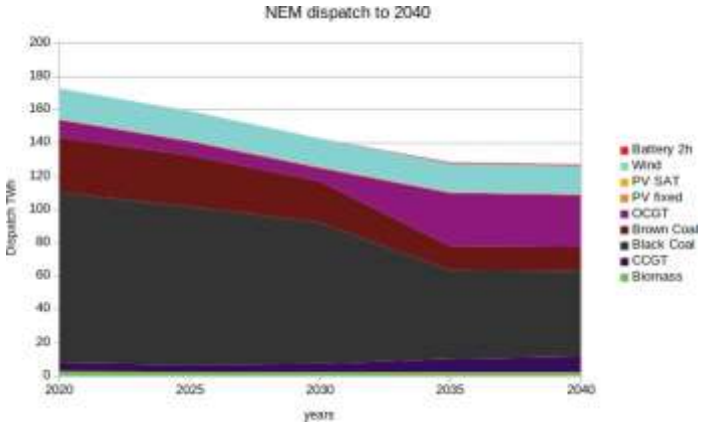
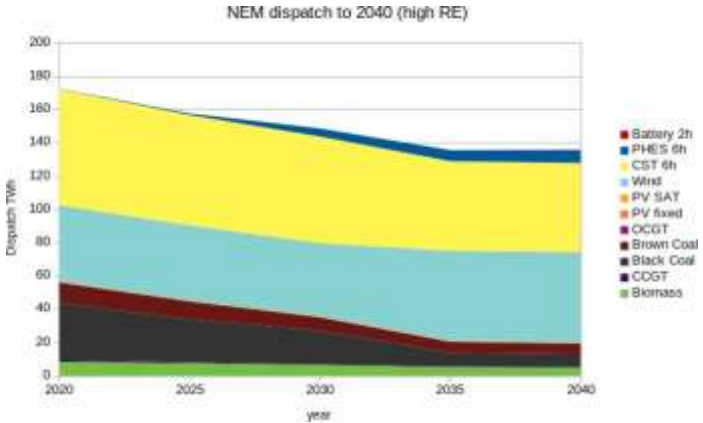


Multi-period simulation with no policy incentives

openCEM—Implementation



Multi-period simulation with aggressive RE incentives

Future work—Release

openCEM will be released to the public with an open source license at https://github.com/CEMOsuite/openCEM

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A companion website with visualisations of precalculated scenarios will be available at each release

Future work—Visualisations

openCEM includes a collaboration with creative technologist ThoughtWorks who are developing a highly interactive tool to visualise results for a range of precalculated scenarios.

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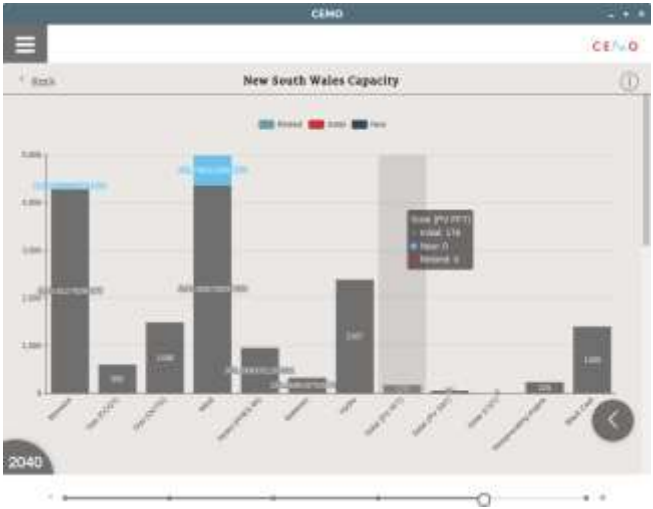

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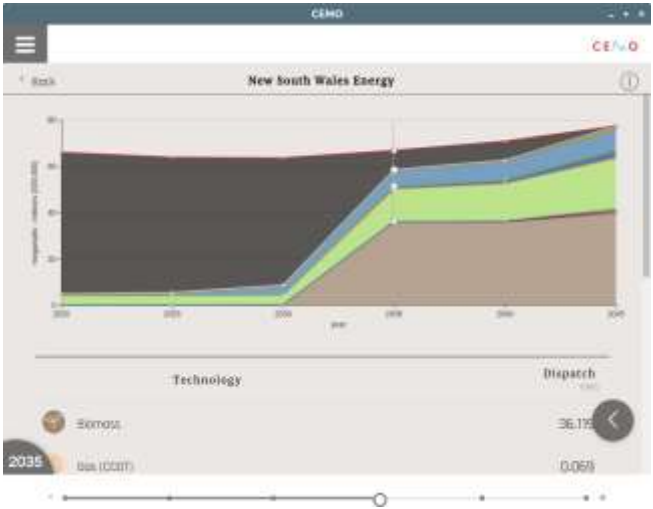

Future work—Next development steps

Validation against comparable tools and publicly available data

Transmission investment decisions

Calculation of a range of pre-calculated scenarios for companion website

End—Thank you

Thank you for your attention