



# CRAGE

CRAGE (Competitive Risk Averse Generation Expansion) is a Walrasian partial equilibrium model of the New Zealand electricity system based on the Auckland PhD thesis of Corey Kok. The model represents the five major generators, electricity retailers, and industrial loads as risk-averse investors who compete as price takers. The transmission operator is modelled as a risk-neutral price taker. The output of CRAGE is a set of capacity choices for each technology for each generating firm, and operating decisions in varying load blocks in a number of different scenarios that model wind, solar and hydro inflow uncertainty.

Risk aversion in CRAGE is modelled using coherent risk measures. These have nice properties for optimization and equilibrium. The simplest example of a coherent risk measure is mathematical expectation, which is risk neutral. In this case, CRAGE reproduces a system optimal capacity plan (as computed by GEMstone). For risk-averse risk measures, the solution for CRAGE matches a risk-averse system solution only under special circumstances.

CRAGE was developed by researchers at the Electric Power Optimization Centre at the University of Auckland in collaboration with Professor Michael Ferris from the University of Wisconsin/Madison. It is coded in GAMS and solves using PATH.

The mathematics underlying CRAGE is described in more depth in the papers by Kok et al (2018), and Ferris and Philpott (2018), These can be downloaded from [www.epoc.org.nz/publications](http://www.epoc.org.nz/publications).

## References:

Kok, C., Philpott A.B. and Zakeri, G. Value of electricity transmission expansion when market agents are risk averse, downloadable from [www.epoc.org.nz](http://www.epoc.org.nz), 2018.

Ferris, M.C. and Philpott, A.B., Dynamic risked equilibrium, downloadable from [www.epoc.org.nz](http://www.epoc.org.nz), 2018.

Ferris, M.C. and Philpott, A.B., Risked investment in renewable generation, downloadable from [www.epoc.org.nz](http://www.epoc.org.nz), 2018.