GEMstone

GEMstone (Generation Expansion Model in a STOchastic and Noisy Environment) is a suite of stochastic programming capacity expansion models of the New Zealand electricity system. These are loosely based on the GEM mixed-integer programming model developed by Bishop and Bull (2008).

GEM is a deterministic multistage optimization model with binary investment decisions. The technologies in the New Zealand electricity system are represented with a high degree of fidelity. The model's forecasts of optimal investments diverge somewhat from what is observed. There are at least two reasons for this. First investments are made over long time horizons, and so uncertainty and risk plays a role in determining what investments are chosen. GEMstone is an attempt to represent the effect of this uncertainty on system optimal decisions. (The other reason is a divergence between firm optimization and system optimization when markets for risk are imperfectly competitive or incomplete. This is addressed by the CRAGE model.)

GEMstone has several versions. **GEMstone2** is a two-stage stochastic convex programming problem with continuous variables solved using GAMS/Conopt. The first stage in GEMstone2 involves a capacity investment decision by a social planner that is made to minimize the system investment cost plus the annual expected operating cost of the system to meet demand in various scenarios. Current scenarios consist of 13 inflow scenarios (corresponding to years 2005- 2017), two independent wind scenarios, and two reliability scenarios.

GEMstoneT is a multistage stochastic integer programming problem. This is a more sophisticated version than the two-stage model, and uses the Dantzig-Wolfe decomposition methodology of Singh et al (2009) to solve a multistage stochastic integer programming problem. A version of GEMstoneT to deal with wind capacity expansion was developed by Athena Wu (2016). Here "STOchastic" in "STONE" describes the uncertainty over long time scales, and "Noisy" the intermittency of wind that requires investments in ramping plant. GEMstoneT has also been applied (under a different name) in Latin America by Flores-Quiroz et al (2016).

References:

Bishop, P. and Bull, B. The future of electricity generation in New Zealand. In 13th annual conference of the New Zealand Agricultural and Resource Economics Society, Nelson, New Zealand, 2008. (see http://www.epoc.org.nz/workshops/ww2007/EPOC-Bishop.pdf)

Flores-Quiroz, A. , Palma-Behnke, R., Zakeri, G., Moreno, R. A column generation approach for solving generation expansion planning problems with high renewable energy penetration, *Electric Power Systems Research*, 136, 2016, 232-241.

Girardeau, P., Philpott, A.B. and Coussirou, J. GEMSTONE: a stochastic GEM, EPOC WinterWorkshop, 2011, (downloadable from www.epoc.org.nz).

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, 2018.

Singh, K., Philpott, A.B. and Wood, K., Dantzig-Wolfe decomposition for solving multi-stage stochastic capacity planning problems, *Operations Research*, 57, 1271-1286, 2009.

Wu, A., Philpott, A. and Zakeri, G., Investment and generation optimization in electricity systems with intermittent supply. *Energy Systems*, 1-21, 2016.