# The PRISM model

Simulating the future

of the New Zealand electricity sector

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## Aims

- Produce some self-consistent snapshots of the NZ electricity sector, representing possible scenarios during 2006-2025.
- Where possible, assign probabilities to these.
- Evaluate the outcomes (prices, return on capital, etc.)

For definiteness, consider for each year:

- Winter (July) and summer (January).
- Peak (TP 35-39) and off-peak (TP 3-10).

Since we are looking at a point in time, seasonal energy balance is not considered.

## Factors to consider

- Demand growth?
- Special loads: Comalco, Auckland electric rail, wood processing, irrigation and dairy farming, etc.?
- Natural gas supply? Imported gas (LNG)?
- Future generation development (hydro, geothermal, wind, coal, etc.)?
- Prices and costs - fuels, exchange rate?
- Transmission grid upgrades?

All of these are subject to *uncertainty*.

– so we need a stochastic model.

## Simulation

Simulate a future year/season/time of day by making random choices for uncertain parameters:

- General demand
  – lognormally distributed growth factor.
- Size and existence of new power stations and major loads.
  – probabilistic (assets may be present or not).
- Gas availability
  – scenarios, PJ/year available for thermal power generation.
- Fuel prices, exchange rate, carbon tax.
  – lognormal factors; the more distant future is less certain.
  – reduce gas-fired generation available in the event of gas shortage.
- Rainfall (for hydro inflows)
  – dry, normal, or wet.
- Wind
  – possibly at multiple sites.

Repeat to build up a sample of possible futures.

## Offering behaviour

How is the generation offered in?

Realistic answer:

- In reality, generation companies can ask any prices they like.
- This leads to a complex dynamic game.

Simple answer:

- Payment for power produced or consumed is at the *nodal* price (not asking price).
- Theoretically, this suggests generators should ask for the marginal cost of production (fuel cost).
- In practice, this is a good model only when the generator is small (a price-taker) or has zero fuel cost (run-of-river hydro, geothermal, cogeneration, wind).

Prism's approach:

- Allows fuel-cost offering

  *or*

  historical offering scenarios (large hydros)

  *or*

  a user-defined offer.
- Does not attempt to model gaming directly.

## Dispatch model

Simulate the operation of SPD.

Given:

- A network
- Generation offers
- Loads;

Solve for:

- Dispatch of power stations
- Prices
- Flows on lines.

PRISM uses PERM, an 18-node dispatch model implemented in AMPL/CPLEX.

Reserve markets are not represented.

## Antithetic sampling

- In a Prism-type simulation, we are evaluating

$$f(u_1, \ldots, u_n)$$

where $u_i$ are i.i.d. uniform$[0, 1]$ random variates.

- Include

$$f(u_1, \ldots, u_n) \qquad \text{and} \qquad f(1 - u_1, \ldots, 1 - u_n)$$

in the sample, instead of

$$f(u_1, \ldots, u_n) \qquad \text{and} \qquad f(u'_1, \ldots, u'_n)$$

where $u_i$, $u'_i$ are independent. This evens out the extremes.

- **Example**: In Prism, rainfall can be

| state | dry | normal | wet |
|---|---|---|---|
| prob | 0.25 | 0.5 | 0.25 |

- Antithetic sampling ensures that the sample contains equal numbers of “dry year” and “wet year” scenarios.

## Common random numbers

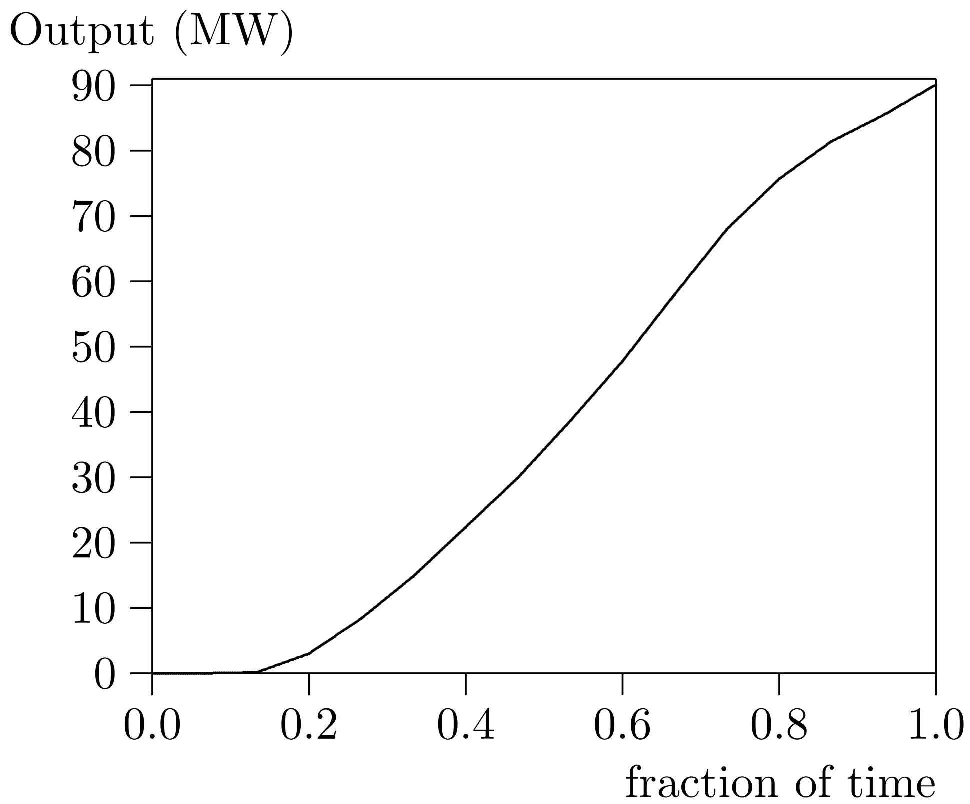
- Prism is typically used to investigate
  - Several alternative cases (e.g. with/without Comalco aluminum smelter);
  - over several years (e.g. $2006, \ldots, 2025$);
  - with four samples per year (summer/winter, peak/offpeak).
- We don't want results for the various runs to differ due to sampling error alone.
- Use the same underlying random variates $u_1, \ldots u_n$ in all runs.
- To achieve this: reset the random number generator seed between runs.
- Need to keep the random-number sequence aligned (e.g. if one run has an extra power station).
- A multi-stream RNG implementation makes this easier.

**Wind power - sampling correlated variates**

- Output from a wind farm is random.
- Prism generates the output from a single wind farm as

$$g(u)$$

where $u$ is a uniform$[0, 1]$ random variate, and $g$ is an "output duration curve" function (empirical quantile function) fitted from historical data.




Output duration curve for Te Apiti, 31/10/04 – 9/6/05

**Wind power - sampling correlated variates**

- Outputs from different wind farms are correlated.
- For wind farms $i, j$, Prism generates variates $u_i$, $u_j$:

$$\begin{array}{ll} u_i = u_j = u, & \text{with probability } c_{ij} \\ u_i, u_j \text{ independently}, & \text{otherwise.} \end{array}$$

  Note $c_{ij}$ =corr$(u_i, u_j)$.
- Set $c_{ij} = e^{-c|w_i - w_j|}$, where $w_i$, $w_j$ are positions on a line (the latitude of the wind farm is used as a proxy for this).