Analytics of Agile and Resilient Manufacturing

Golbon Zakeri
Geoff Pritchard
Many researchers

EPOC, University of Auckland

March 12, 2018

A word about EPOC, EC, etc

- GZ is a director of EPOC and deputy director of the EC.
- Professor Basil Sharp is the Director of the EC.
- Basil is an economist with special research interest in econometrics.
- GZ does stochastic optimization and equilibrium modelling.
- GP answers all hard questions with special emphasis on probability and stats.
- The EC has significantly broader interests in the energy scene as a whole, EPOC is more focused.

A TIMES model for NZ

A brief description of TIMES would express that it is a:

- Technology explicit;
- Multi-regional;
- Partial equilibrium model; that assumes:
    - Price elastic demands; and
    - Competitive markets: with perfect foresight (resulting in Marginal value Pricing)

There is an intimate connection between perfect competition equilibrium and optimization that allows us to convert this problem to a linear program and solve it.

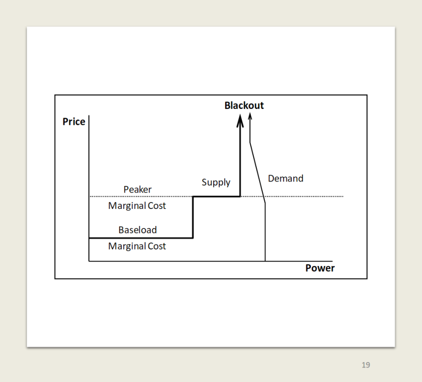
BEC postdoc Kiti Suomalainen

Why DR?

Because DR is at the bottom of every essential question of electricity markets, such as what is VOLL, how reliable the system should be etc.

Why not energy only?

- Market failure
  - Absence of demand side
- Practical realities
  - Price caps
  - Operator decisions
  - *Missing money*



The project

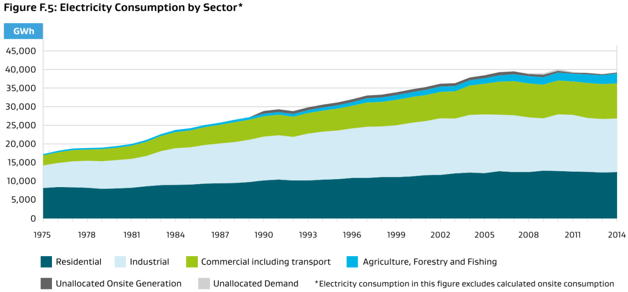
- Within "Science for Technological Challenge" portfolio of NSC. Thanks to MEUG and NZSteel for your support.
- Two PhD students working on DR: Mahbube Habibian and Kazem Abbaszadeh. Kazem is supported by our grant.

Mahbube

Kazem

The project, II

The project started as a proposal for agile and resilient manufacturing in NZ with particular emphasis on industrial demand response in the electricity market.



Tough Competition

- Most manufacturing companies in NZ (and in fact in the west) face seriously tough competitors.
- As an example, the number of active aluminium smelters in the US has reduced from 23 to 6 in the past 15 years.
- Low end product (e.g. metal) prices and high input prices (such as electricity) make the margins extremely lean.
- Need **agile and resilient manufacturing practices** to stay afloat.

Demand Response for Large Industrials

- It is important for participants in any market to receive and be able to respond to scarcity as signalled by price.
- A significant input into any manufacturing process (aluminium smelter, steel producer, pulp and paper mill etc) is electricity.
- Demand response is not only useful for the end user, but alleviates congestion in the network and reduces pressure on production from the least efficient (often most polluting) sources of electricity generation.
- Industrial use of electricity comprises 35% of consumption so it is a good sector to tackle.

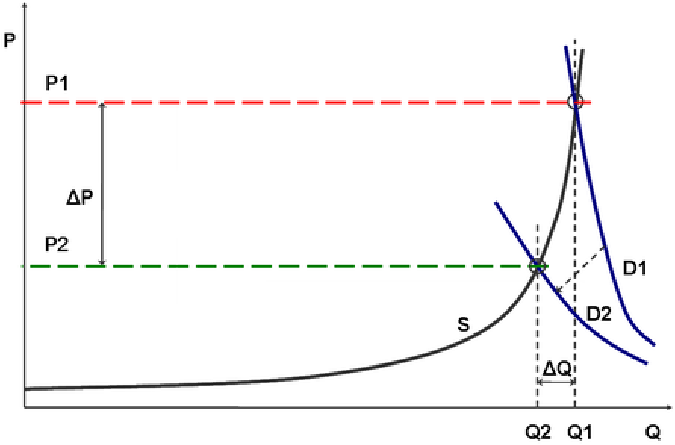
Problem breakdown

We want to plan an optimal production schedule for a large consumer of electricity.

1. First assess a single period.
2. Next string together many periods for a sensible time horizon.
3. Finally validate our plans through simulation to prove their worth.

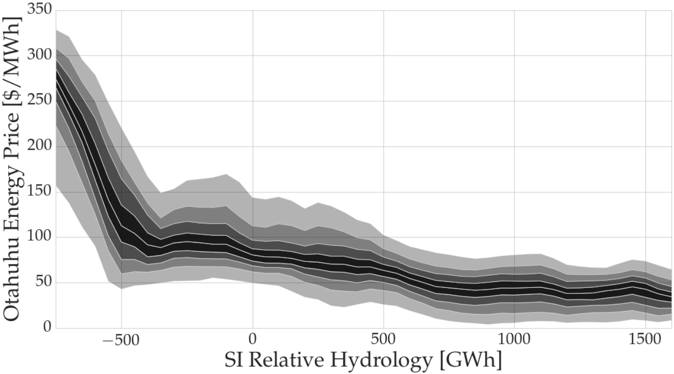
Single period, I

What is the effect of consumption on price of electricity.

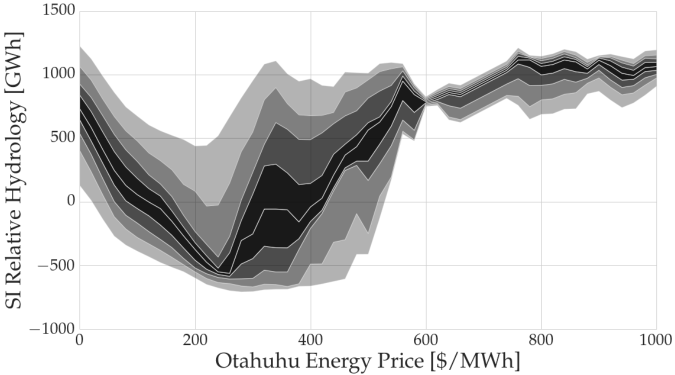


Single period, II

... but there is also reserves! Figure below shows lake level vs electricity prices (Jan 2008 to March 2014), from Cleland 2015.



Examining a larger range

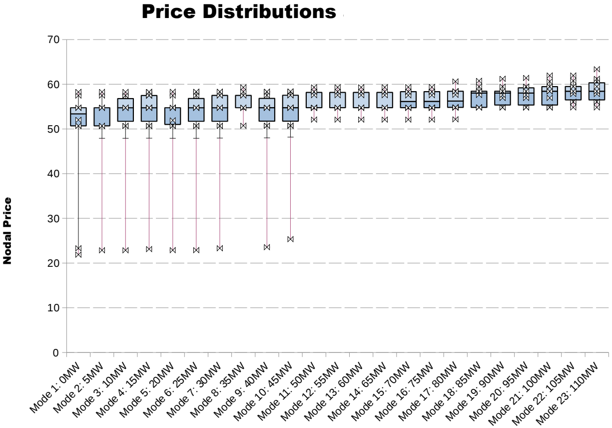


What is the data saying?

Why are the very high prices associated to periods of hydro plentifulness?

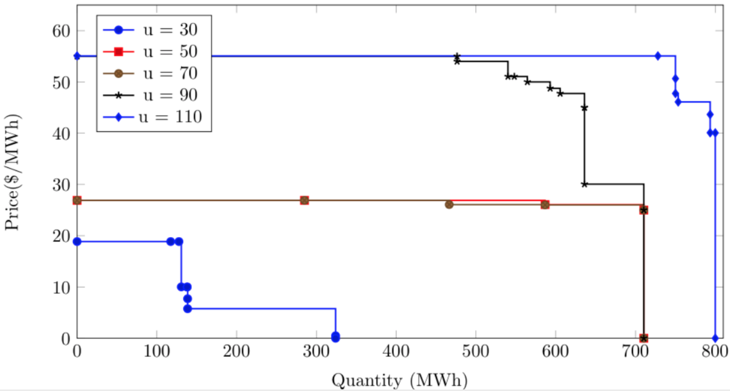
The answer lies in the co-optimization of energy and reserve in NZ. As large consumers of electricity can often offer reserves we need to take this into account.

Optimization using vSPD



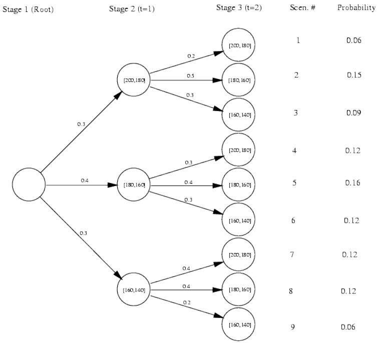
Dispatchable demand curve

The above is good but limited to pinning down a specific demand value. We want a dispatchable demand curve and one reserve stack. This is found by solving stochastic bi-level programs.



Multi-period optimization

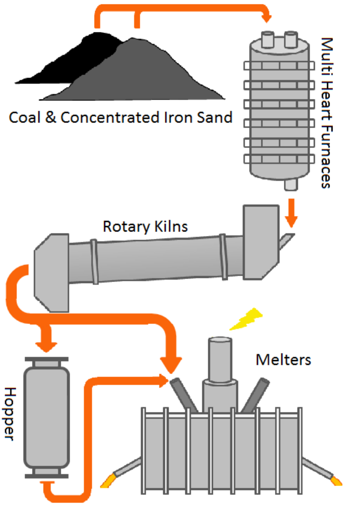
Compute a policy prescribing how to act optimally in the face of uncertainty.



Ingredients for SDP

- States of the system (varies by major user).
- Electricity price modelling.
  - Top down: As a whole, withut counting on our influence over the price, what does the process look like?
  - Bottom up: Have detailed information of what may go into vSPD (OS distribution, demand etc) and see how our actions influence the market.

State of the system: Iron making



Iron making II

- If the electricity prices are high, kilns' output can be stored in the hopper instead of being processed in the melters.
- Storing RPCC in the hopper leads to changes in chemical properties of the RPCC in different levels of the hopper known as the "segregation effect".
- These changes amount to low levels of carbon content in the RPCC as material is retrieved from the bottom of the hopper and high carbon content as we retrieve the last of the stored material.
- Lower carbon implies the "slag" gets too close to the wall of the melter, but the high carbon content makes the feed too close to the electrodes and tends to "choke" the process.

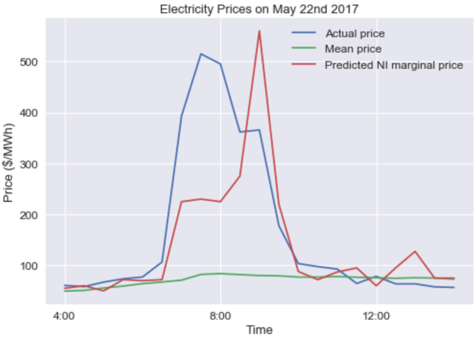
Top down electricity price modelling

- Hydro storage.
- Seasonality.
- Temperature.
- Peak/off peak/weekday/weekend/holiday, etc.

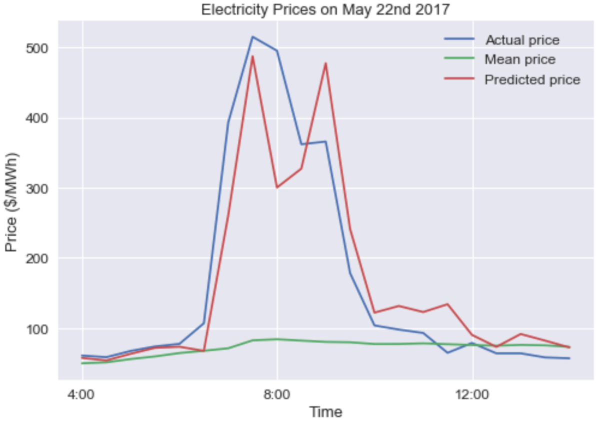
Then extract either a point forecast (Alan Ansell via machine learning) or a distribution (James Tipping, STEPS, Kazem, also Alan A.).

Machine learning of electricity prices, I

This gives a reasonable estimate of the nodal price.

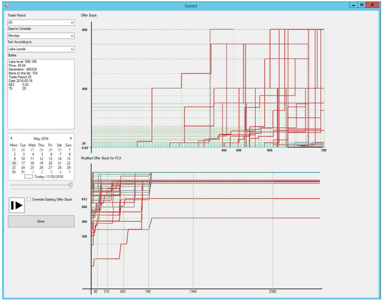


Machine learning of electricity prices, II

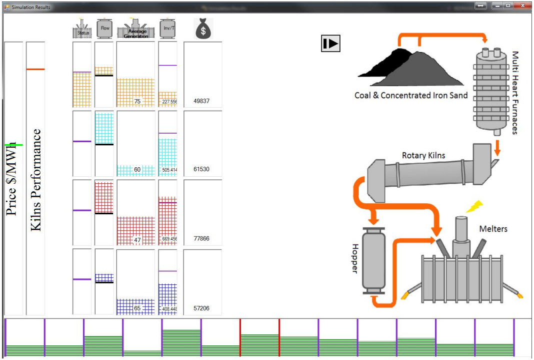


Constructing a distribution on offer stacks

Transform the offer stacks so that they are multi-dimensional objects in one parameter; e.g. quantities offered at or below 100 different price thresholds. Use PCA to cpture variation and ultimately construct a distribution.



Validation through simulation



Other projects spawned

- Pricing electricity using piecewise linear offer stacks to "reduce volatility". Part iv project for William Zhi.
- Modelling the inner processes of the hopper and the melter. Recently approached Nicola Payne from NZ Steel to work with Piaras Kelly and colleagues for a fluid dynamics/mechanical engineering model of these.

Chewing the fat

As this is work in progress any comments or questions are most welcomed.