100% renewables:
Feasible. But how costly?

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Is 100% renewables a sensible target? My hypothesis in a nutshell

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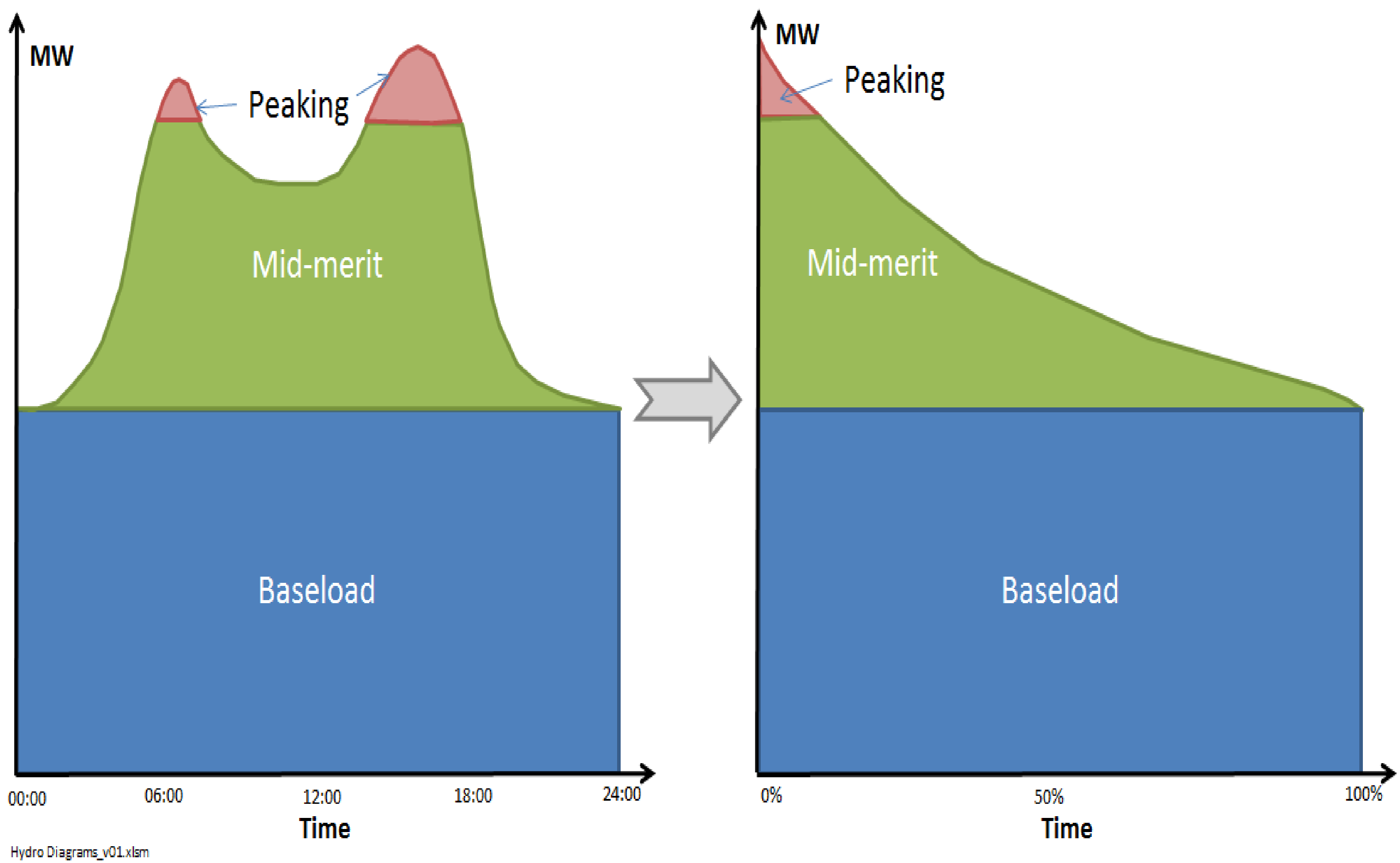
- For any given combination of fuel and CO_2 prices, demand shape, etc., the least-cost renewables penetration could be anywhere between 75% to 90%+ (higher for high CO_2 prices and/or futures with high EV penetration).

- Beyond this level, each extra % of renewables penetration will start to get exponentially more expensive as it results in more and more spill
  – particularly on a seasonal and dry-year/wet-year dimension which existing hydro storage and batteries are not able to address

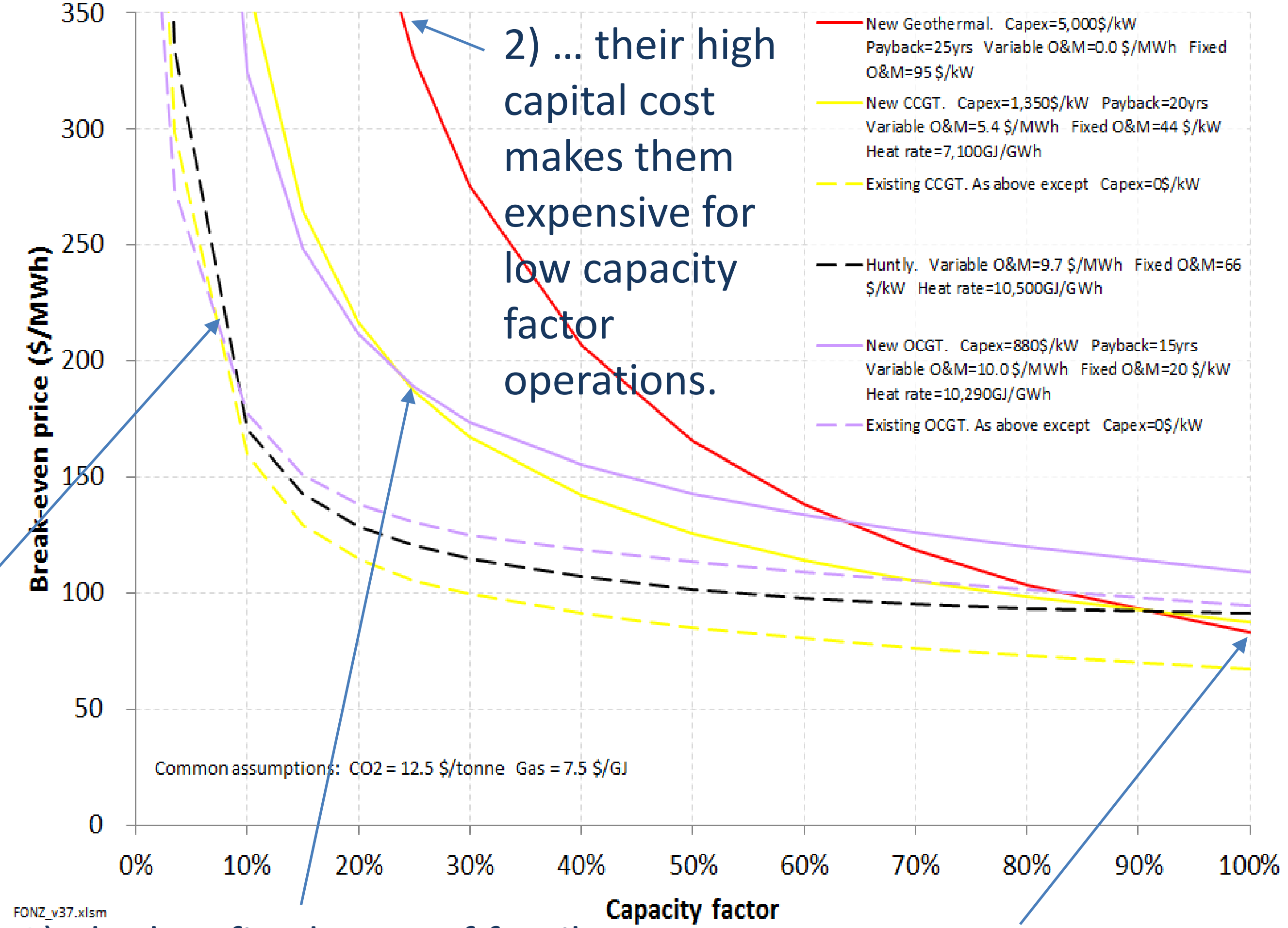
- Aiming for an unrealistic target risks poor policy decisions which, as well as being higher cost, may be counter-productive for tackling global warming
  – E.g. resistance to tariff reform because of perceived PV 'benefit', may frustrate uptake of EVs which are much better at de-carbonising our economy

Demand varies throughout the day and year

→ requirement for some generation to operate at low capacity factor



Low capacity factor operation is expensive to meet by high capital cost generation



1) Although new renewables may be cheapest new baseload option….

2) … their high capital cost makes them expensive for low capacity factor operations.

3) The low fixed costs of fossil stations outweighs their high variable costs for low capacity factor operations…

4) … particularly for existing fossil stations with sunk capital

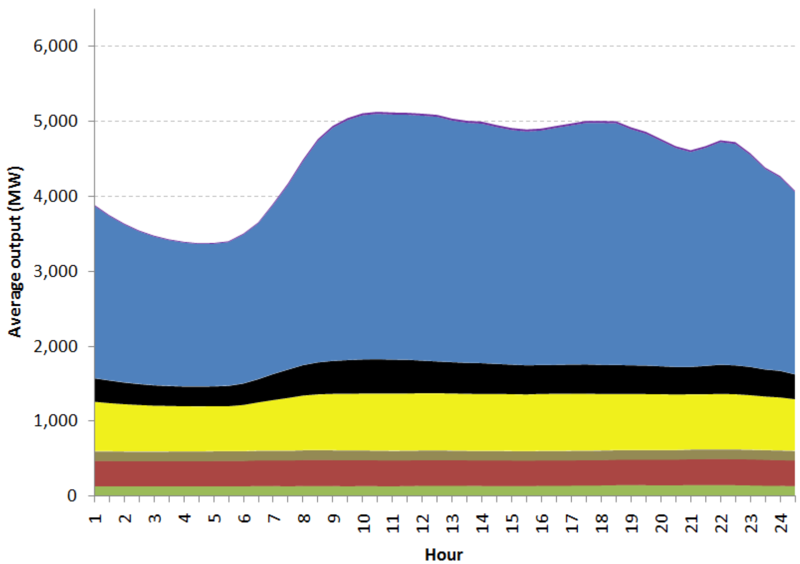
Variation in renewable flows can exacerbate the variations in demand

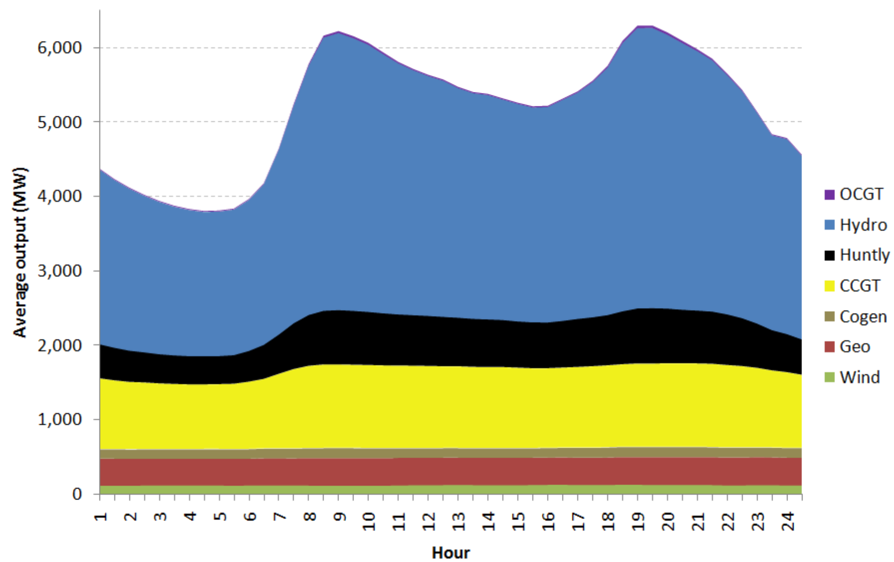
- For example:
  - Can be significant ***day-to-day*** variation of wind, sun, rain
  - Some renewable flows (e.g. South Island hydro inflows, sunshine) are anti-correlated with ***seasonal*** variation in demand
  - ***Year-on-year*** variations due to dry-year / wet-year phenomena

- Exaggerates the distribution of the 'residual demand'. i.e. (demand less wind, solar PV, and RoR hydro)
  - Makes an even more 'peaky' load duration curve → greater requirement for low capacity factor generation

Existing hydro storage helps manage this imbalance…

- On diurnal basis significant sculpting of water from periods of low demand to high demand
  - Increasingly also used to help balance wind variations
- Some schemes have seasonal storage → shift water from summer to winter





…but the majority of seasonal flexibility is provided by fossil generation

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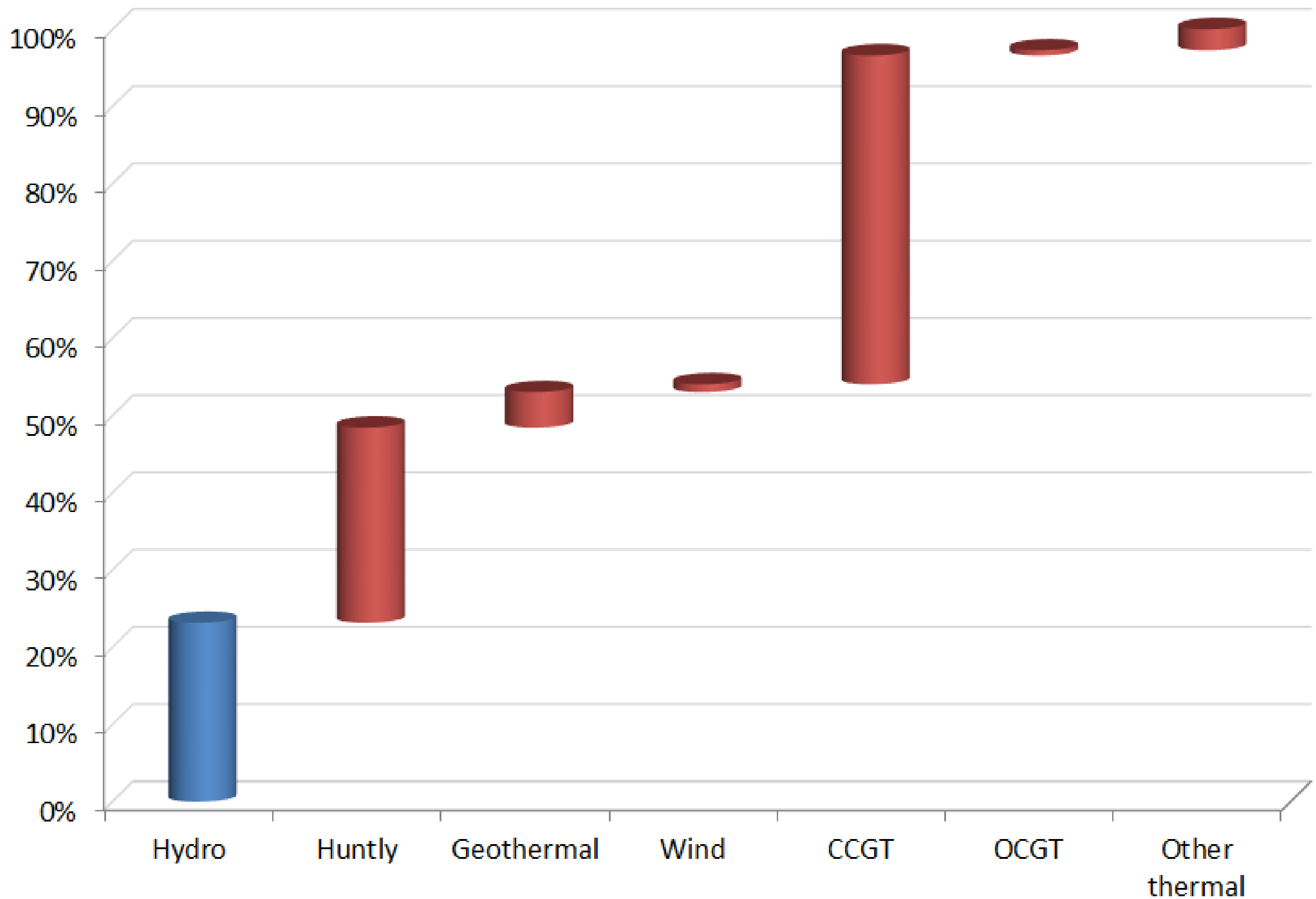
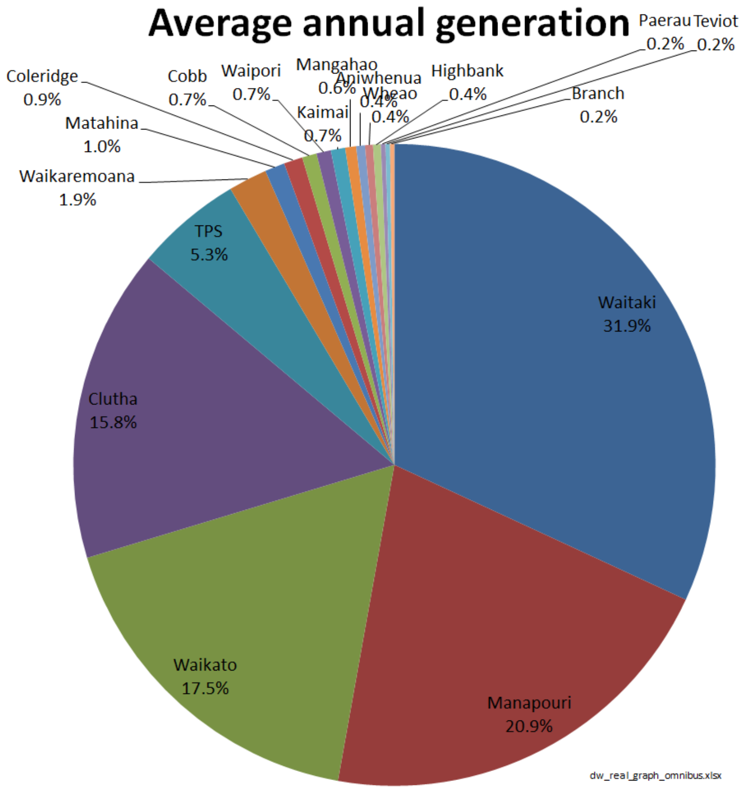
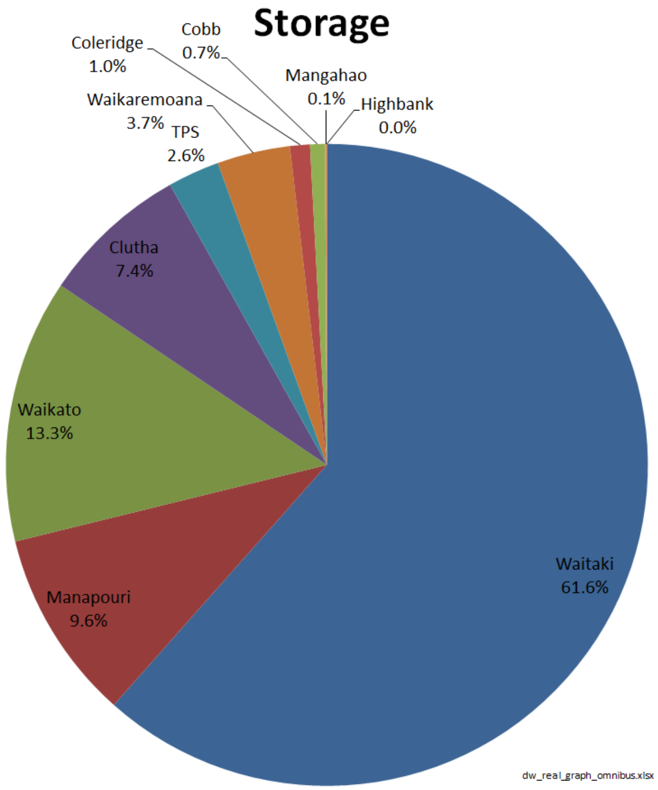
Average contribution to meeting quarterly changes in demand (2005 to 2009)



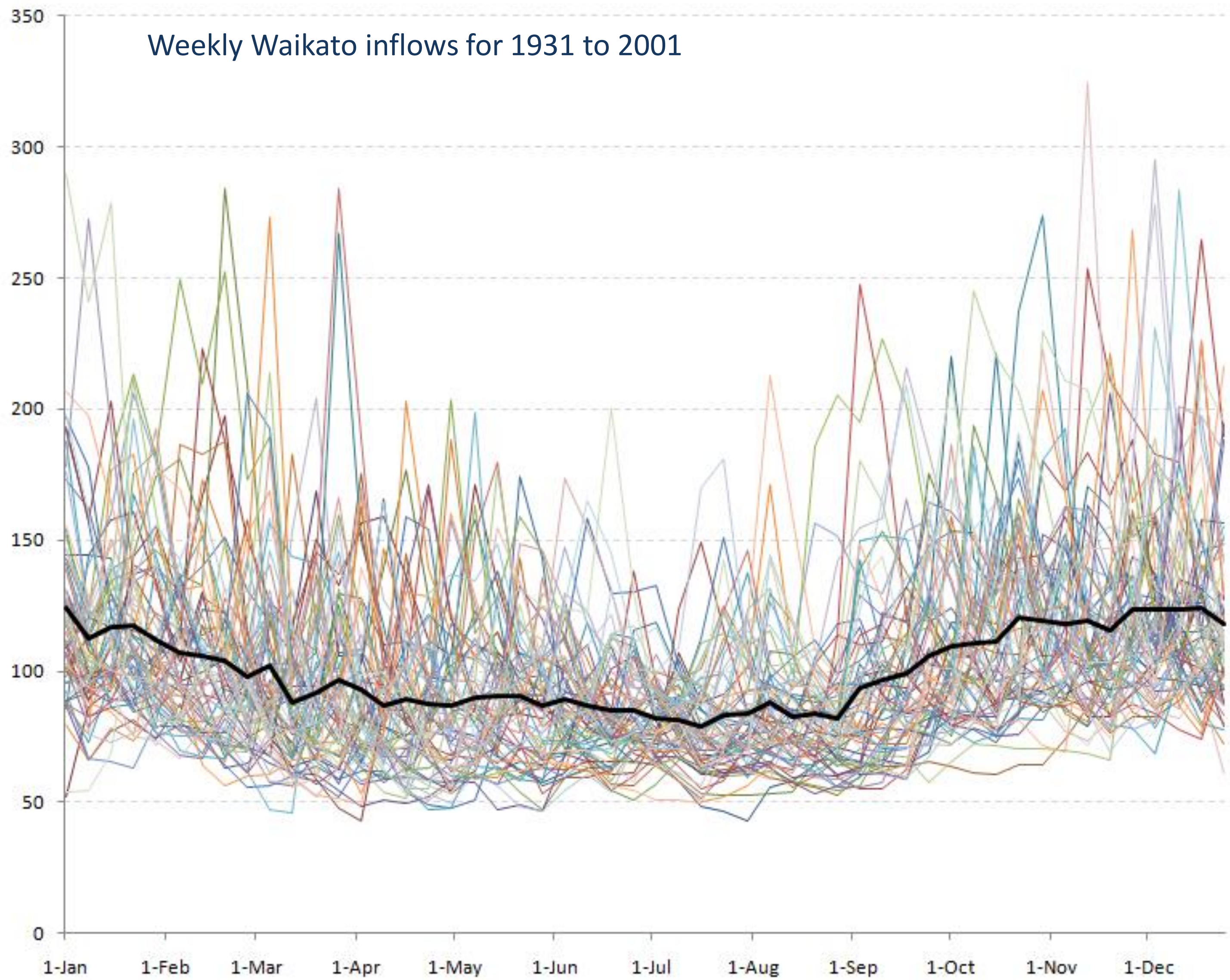
SchemeAnalysis_v02.xlsx

Only the Waitaki scheme has material seasonal storage…

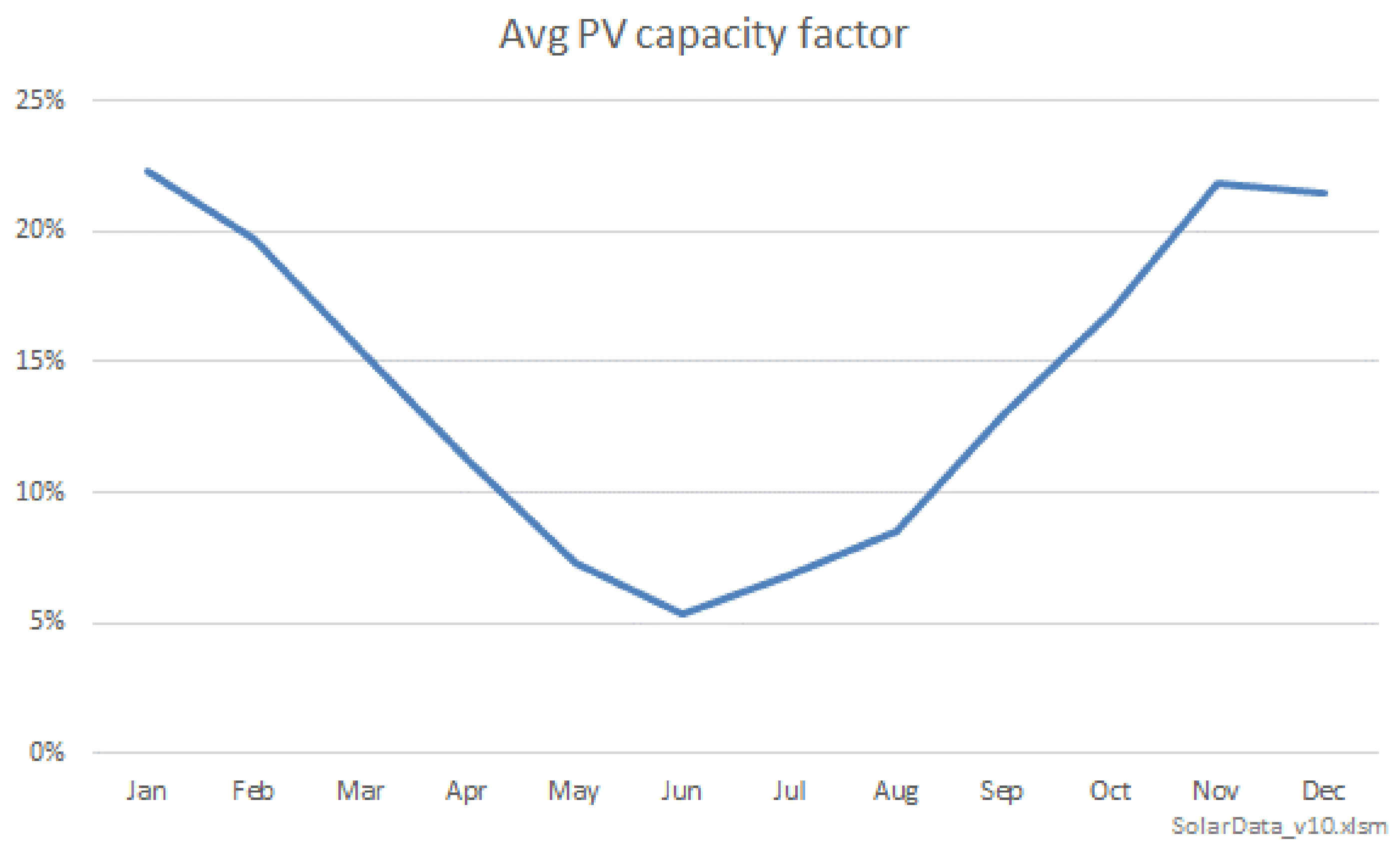




… and because its inflows are seasonally anti-correlated with demand, it is already strongly incentivised to seasonally time-shift



Solar PV is also anti-correlated with seasonal demand



- (As an aside, this seasonal PV shape means that some of the generation that PV will displace is <u>not</u> fossil, but new baseload renewables that would otherwise have been built to meet demand growth.)

And existing hydros appear limited in their ability to do any more time-shifting

- Hydro schemes operate within significant constraints on their ability to store water
  - Physical – the GWh size of storage (only Waitaki scheme has material seasonal storage), and the MW capacity of the schemes
  - RMA – particularly need to maintain minimum river flows and lake levels.
- Various data suggests they are already time-shifting as much as they can:
  - No evidence of materially shifting pattern of hydro generation on either a seasonal or diurnal basis over past 15 years, despite there being a growing demand for greater seasonal and diurnal generation
  - Modelling done by generators for MfE process considering possible changes to RMA regime suggested storage is operated to its limits
    - Actual changes from generators whose RMA consents have changed to increase minimum flows supports this
  - The presence of persistent significant price differentials between day/night and summer/winter.

And lack of multi-year-capable reservoirs, means hydro is unable to help manage dry-years

Probability of exceedence	Hydro generation (GWh)	Difference from mean (GWh)
99%	20,450	-3,900
95%	21,450	-2,900
90%	21,550	-2,800
85%	21,750	-2,600
80%	21,950	-2,400
65%	23,150	-1,200
50%	24,050	-300
35%	24,500	150
20%	26,100	1,750
15%	26,600	2,250
10%	27,300	2,950
5%	27,900	3,550
1%	29,750	5,400
Mean	***24,350***	***0***

Hydro_Data_v01.xlsm

- If had sufficient renewables to cover a 1-in-10 dry year event → spilling 2,500 GWh in a mean year, and 5,500 GWh in a 1-in-10 wet year

Batteries appear unlikely to help seasonal or year-to-year mis-matches

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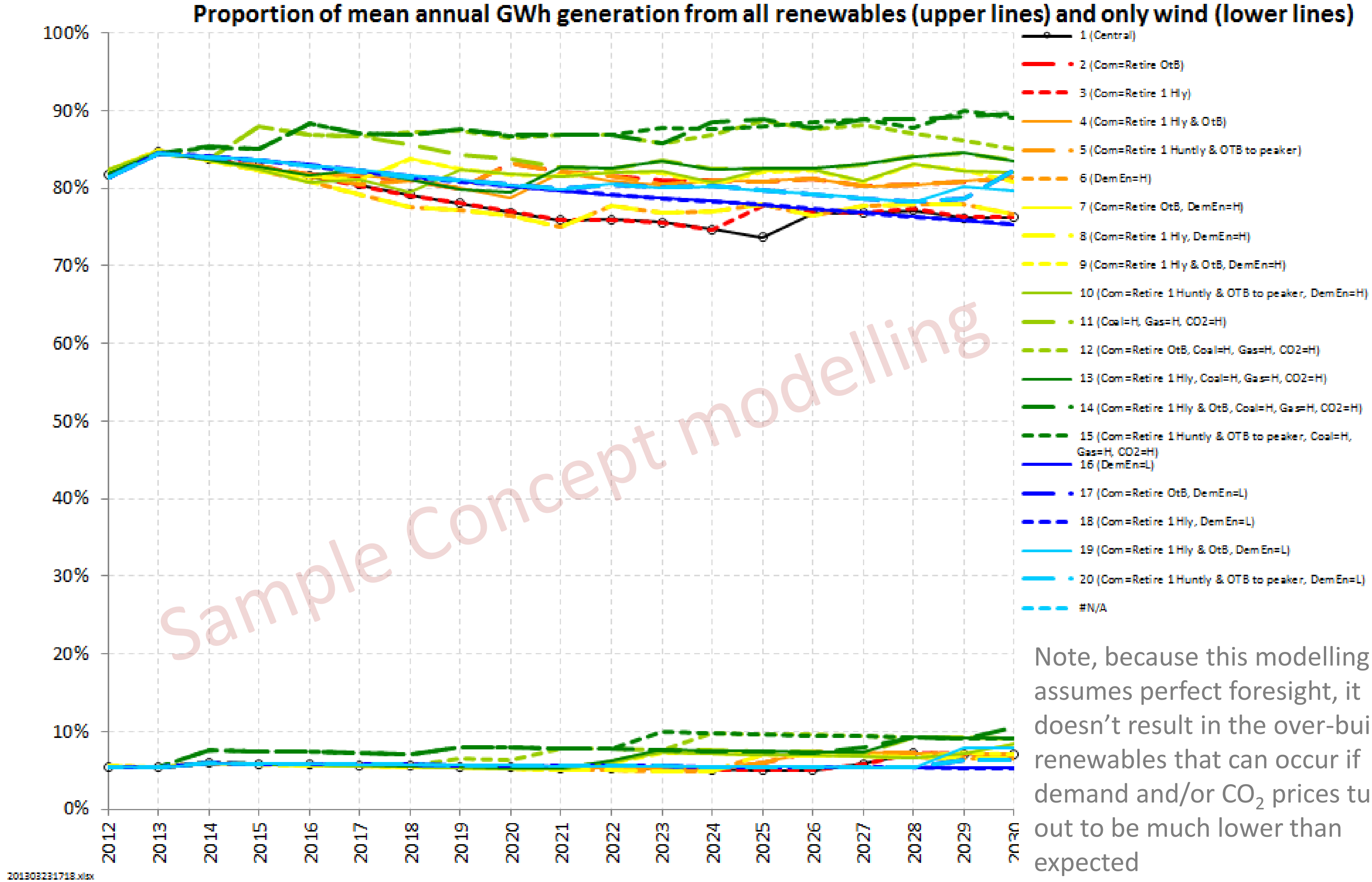
- In the context of achieving 100% renewables, the value of 1 kWh of battery storage is how many kWh of fossil generation is avoided

- They may be economic for managing ***diurnal*** mis-matches:
  - Storing 1 kWh of surplus renewable generation every night to use during the day will result in 365 kWh of avoided fossil generation each year
  - However, the day-to-day variability of renewable flows, coupled with existing hydro storage capability, will reduce the number of days in which such storage can occur

- Unlikely to be economic for managing ***seasonal*** mis-matches:
  - 1 kWh of surplus summer renewable gen. stored for use in the winter will only result in 1 kWh of avoided fossil generation each year.

- And for storing energy during a 1-in-10-year wet year which can be used in a 1-in-10-year dry year, the economics look even more 'challenging'

The most cost-effective proportion of renewables will depend on fuel and CO_2 prices, the peakiness of demand growth, etc.



Note, because this modelling assumes perfect foresight, it doesn't result in the over-build in renewables that can occur if demand and/or CO_2 prices turn out to be much lower than expected

In summary, let's aim high, but aiming for 100% could be counter-productive

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- The seasonal and dry-year / wet-year dimension of the mis-match between demand and renewable flows creates an upper limit on the proportion of demand which can cost-effectively be met by renewables
  - Likely of order of 90%+ for high CO_2 prices and/or futures with high EV penetration).

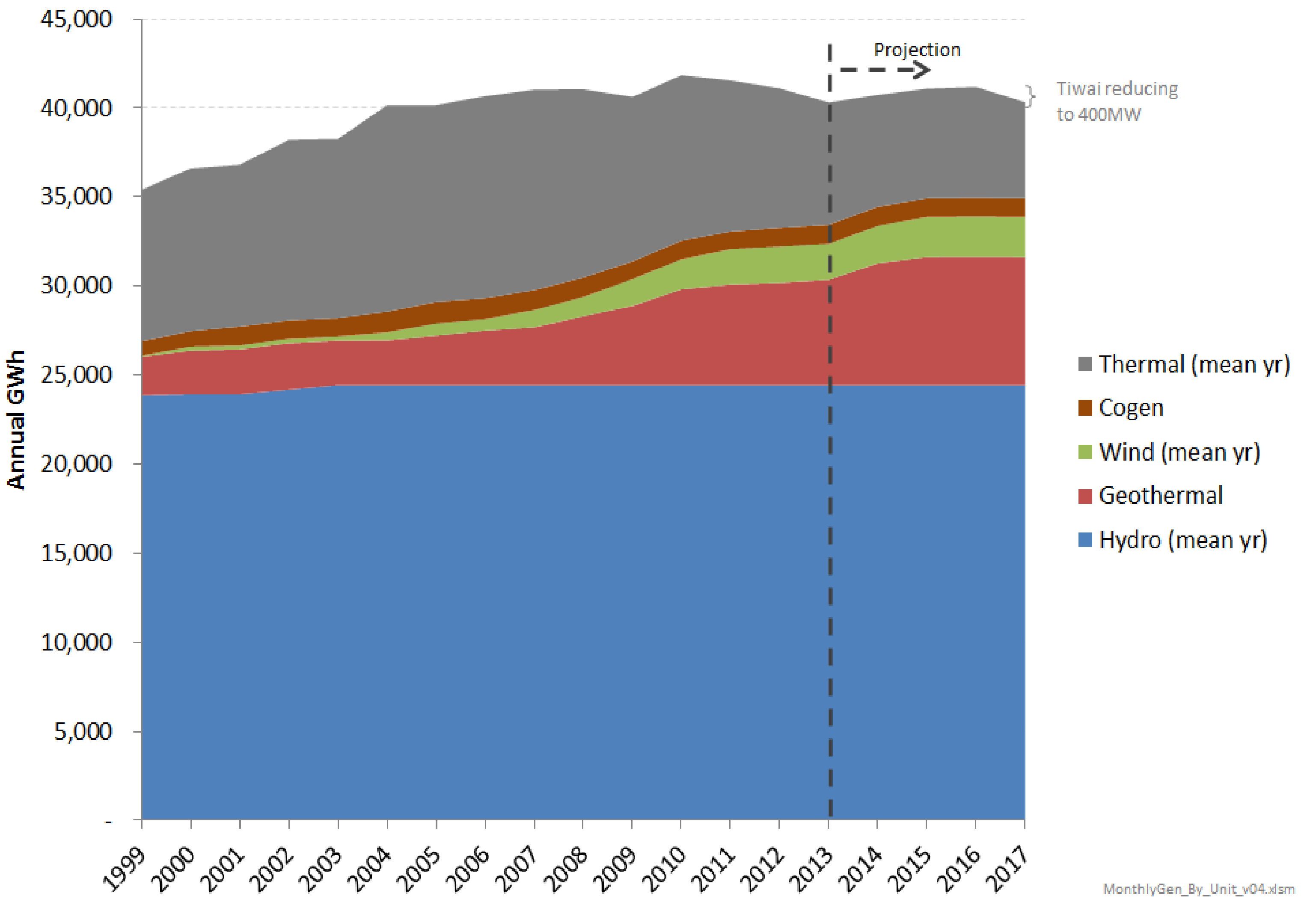
- Beyond this level, each extra % of renewables penetration will start to get exponentially more expensive as it results in more and more spill

- Aiming for an unrealistic target risks poor policy decisions which, as well as being higher cost, may be counter-productive for tackling global warming
  - E.g. resistance to tariff reform because of perceived PV 'benefit', may frustrate uptake of EVs and DSM which are much better at de-carbonising our economy

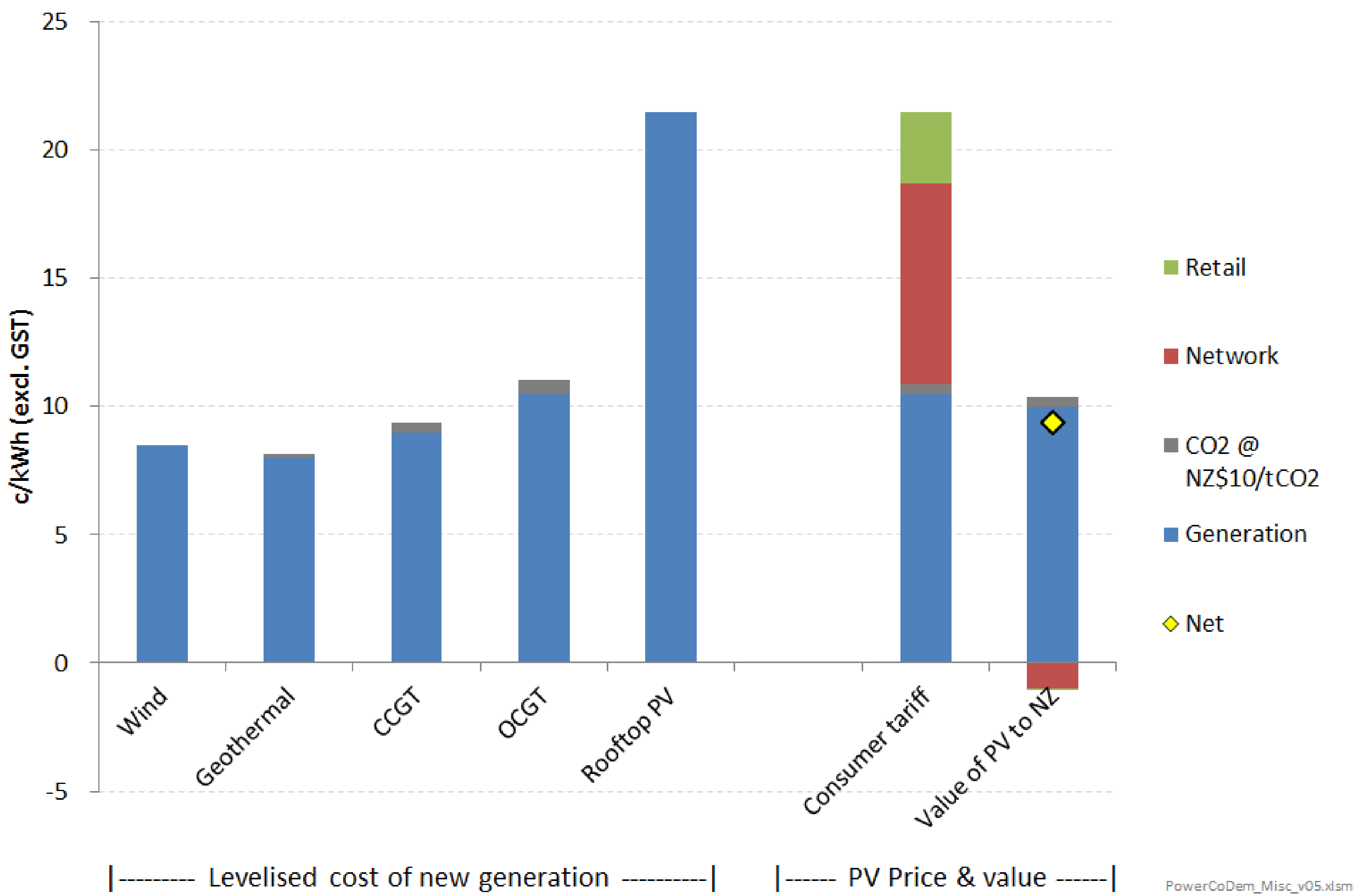
- And let's have a sensible CO_2 price as a key means of achieving this!

Back-up slides

Recent displacement of fossil generation is more due to an over-build of renewables than symptoms of a trend to 100% renewables

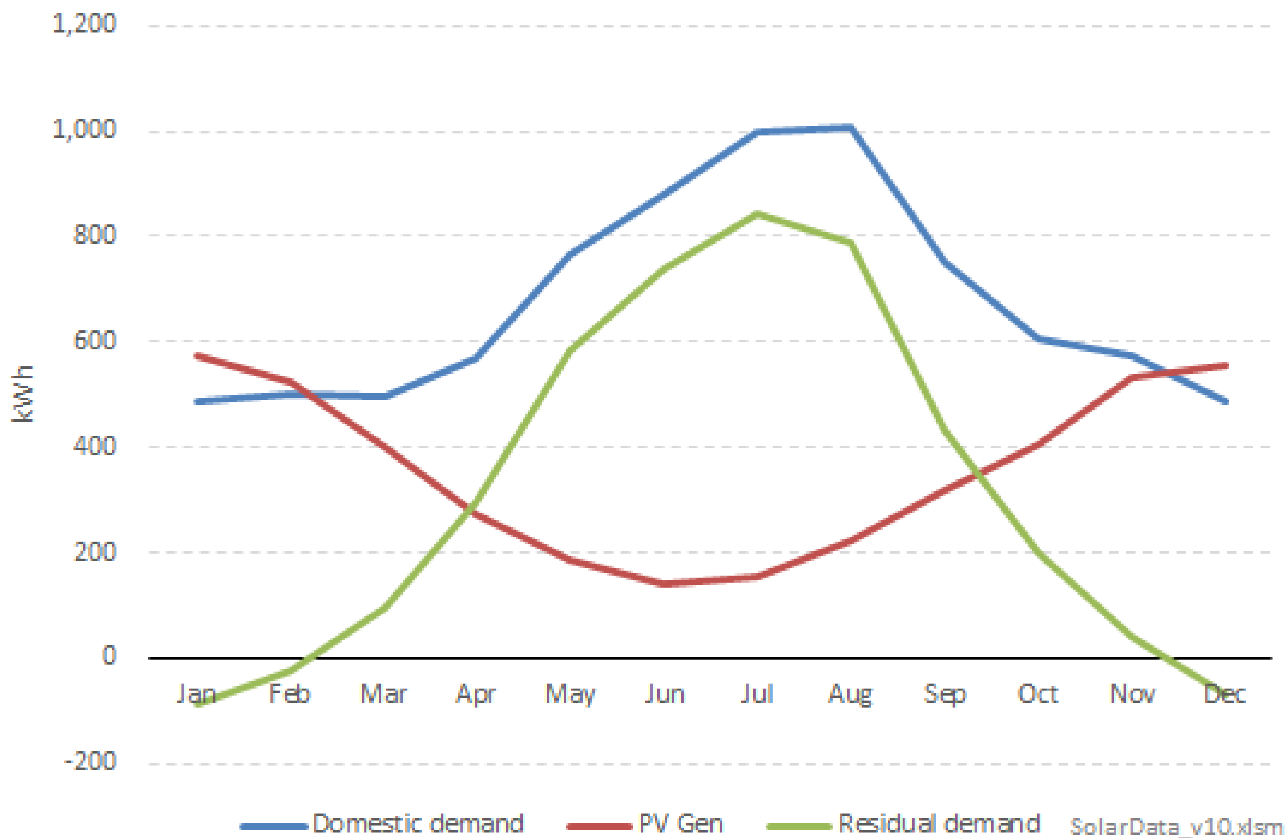


Wind and geothermal are likely to be more cost-effective means of meeting NZ's electricity needs than PV

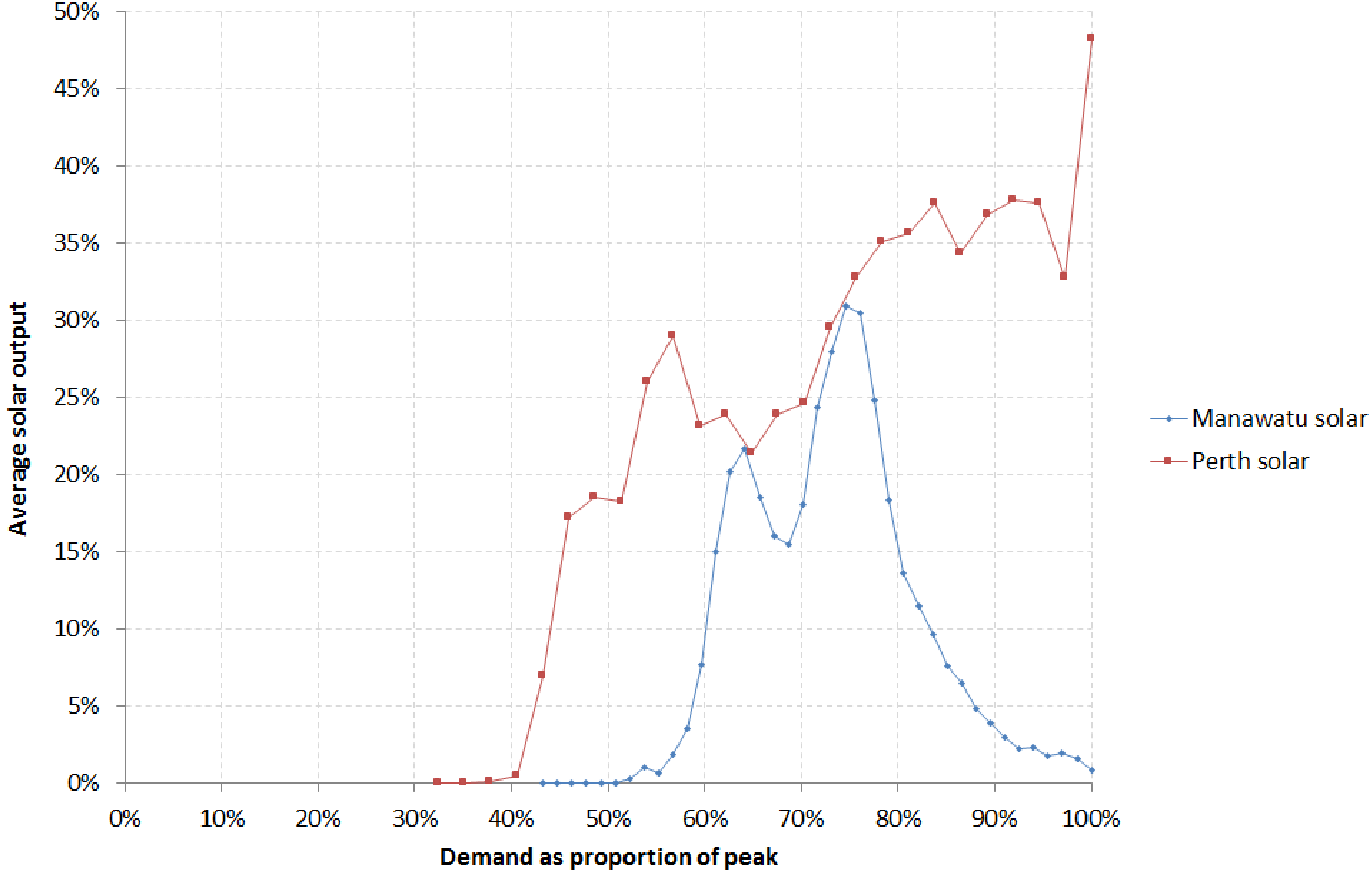


PV generation will have some impact on demand for the network – but potentially no impact on peak grid requirement

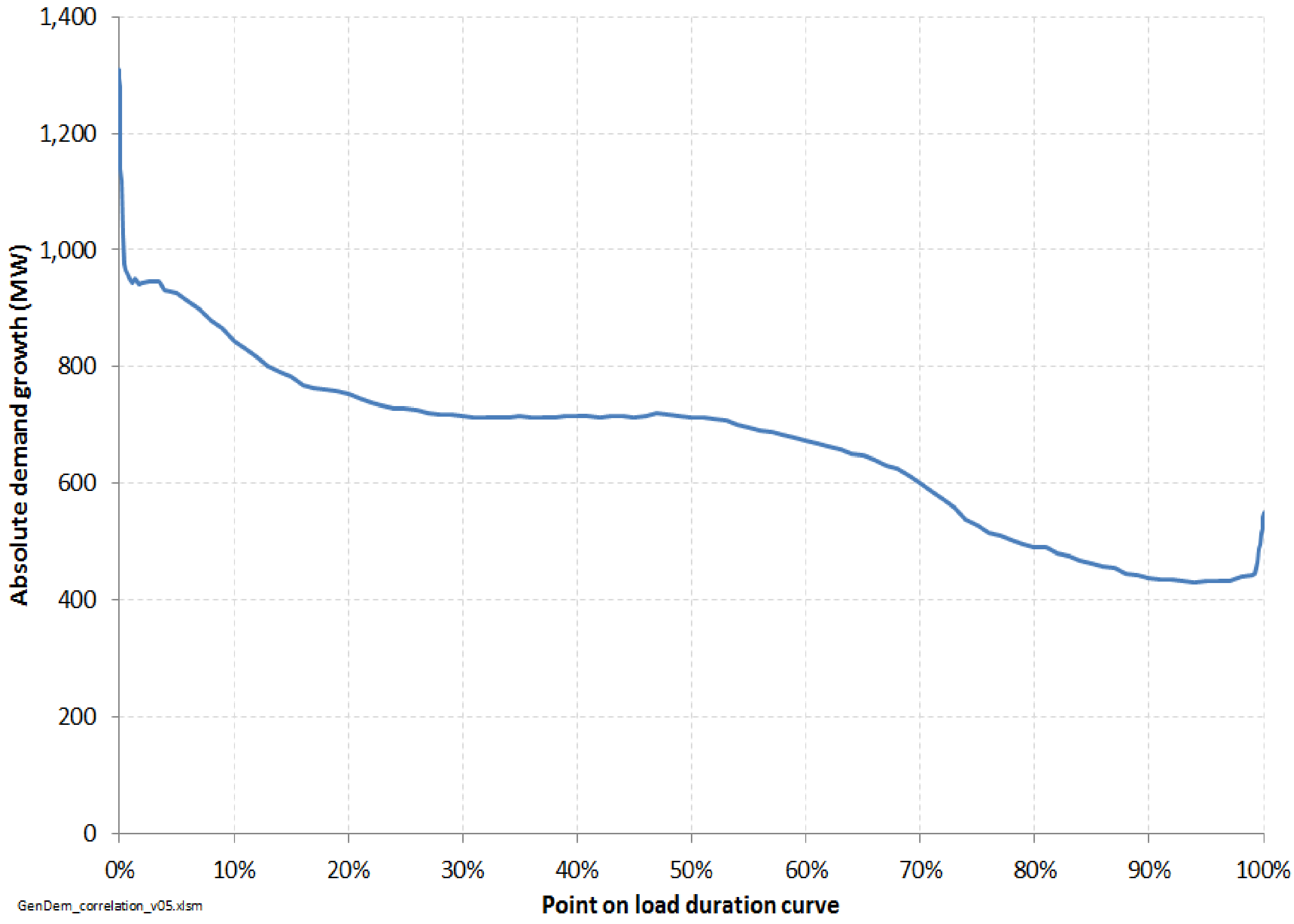
- Significant exaggeration of seasonal pattern of demand
- However, there may be no impact on peak demand requirements because virtually no PV generation during winter peak
  - Note batteries are a different story



PVs make no contribution to NZ peak

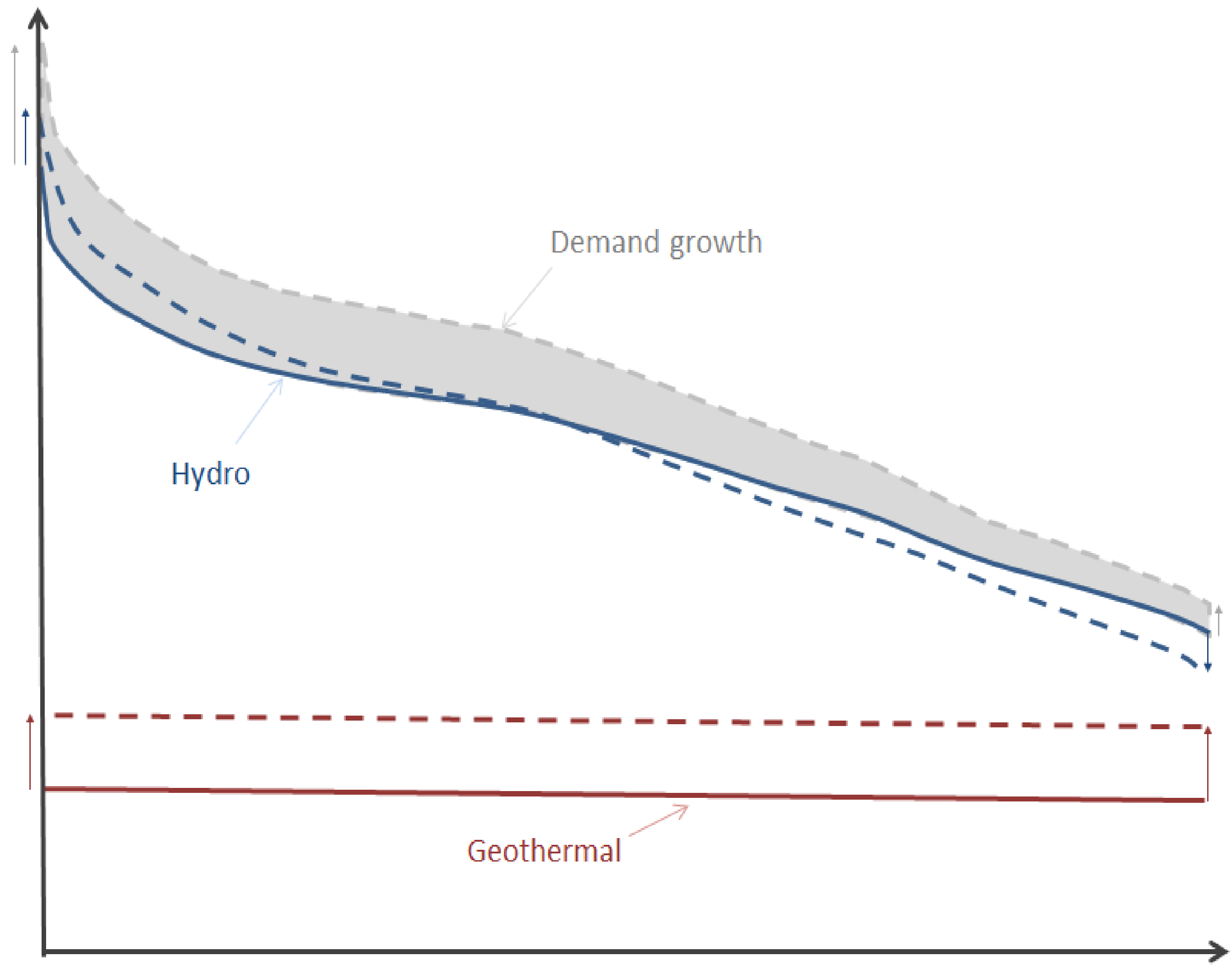


Demand growth from 1998 to 2011 was peaky



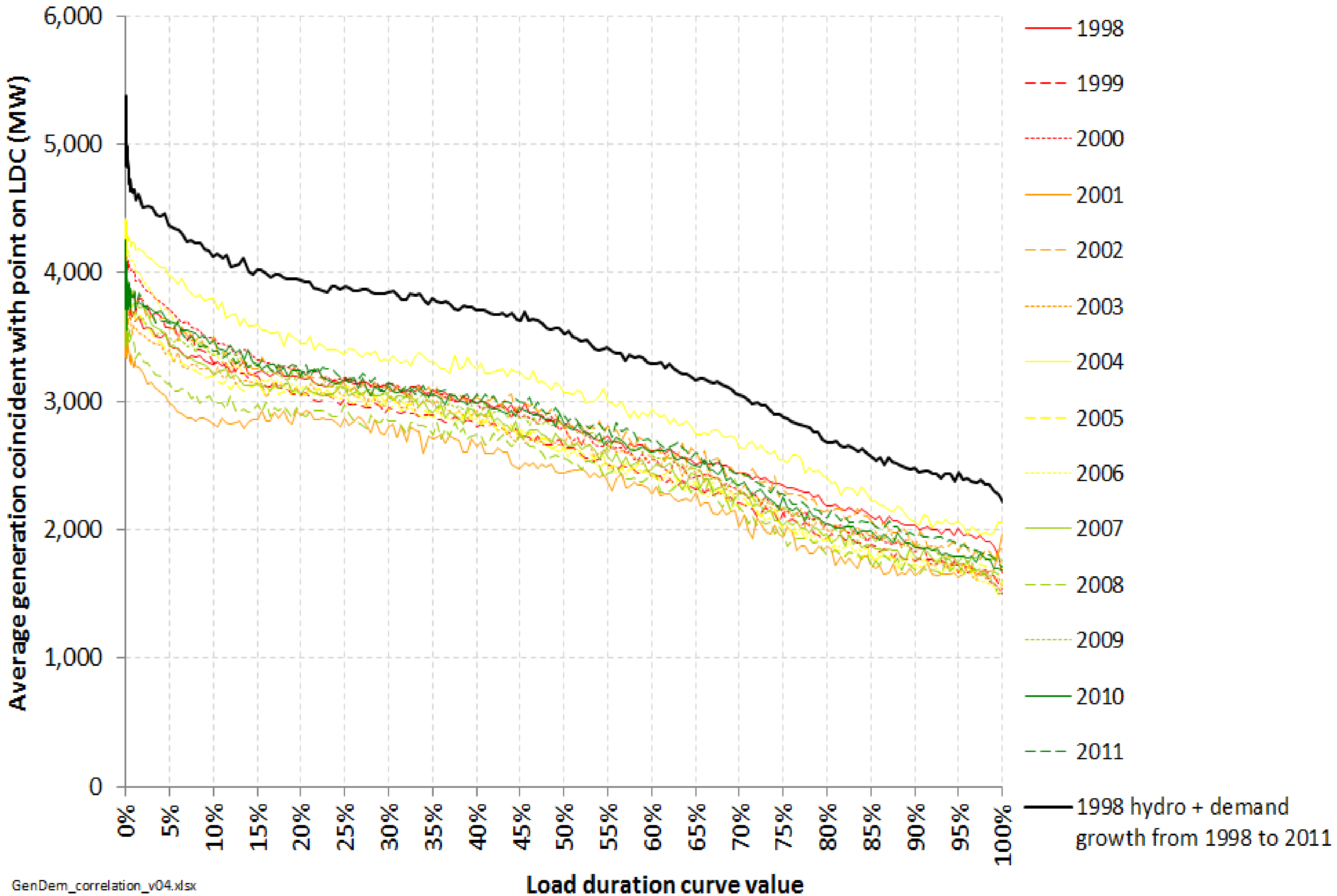
GenDem_correlation_v05.xlsm

In theory, this provided an opportunity for hydro generation to be further sculpted away from low to high demand periods



DUog_Miscellaneous_v03.xlsx

However, the storage and release decisions of hydro generators have remained relatively stable



- This suggests there are constraints on the ability of hydro generators to ‘balance out’ any altered hydro generation impacts from their fellow hydro generators

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