

Price Discovery under 100% Renewables

A discussion into potential issues and options for the New Zealand
Wholesale Electricity Market

6 August 2021

Introduction

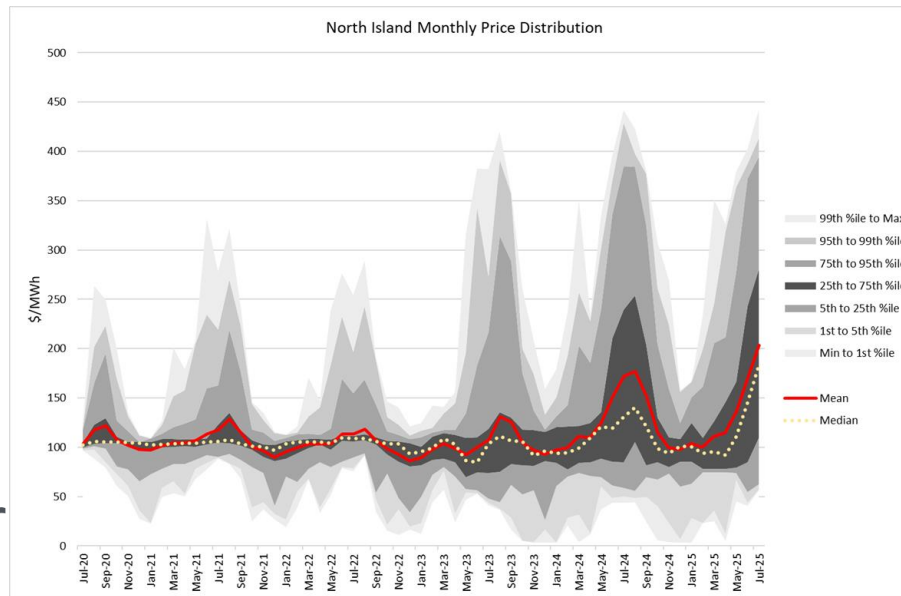
- Kevin Broad, Broad Solutions Limited
 - Auckland based consulting company specialising in Energy Market modelling and advice
 - Expert in energy market decision support tools, and NZ market dynamics
- Dr Paul Deane, Senior Research Scientist for Clean Energy Futures
 - Associated with Energy Exemplar
 - Experienced in researching and modelling renewables driven market change
- Steven Broad, Senior Principal Product Manager, Energy Exemplar
 - Responsible for growing and developing the PLEXOS energy market modelling platform
 - Deep knowledge of electricity market design, research into application of data science techniques for supporting energy market modelling and analysis

Agenda

- Background and Scene Setting
- Approaches taken in other jurisdictions with a focus on Ireland
- Deeper dive into market options drawing on US based developments
- Summary and recommendations
- General Discussion

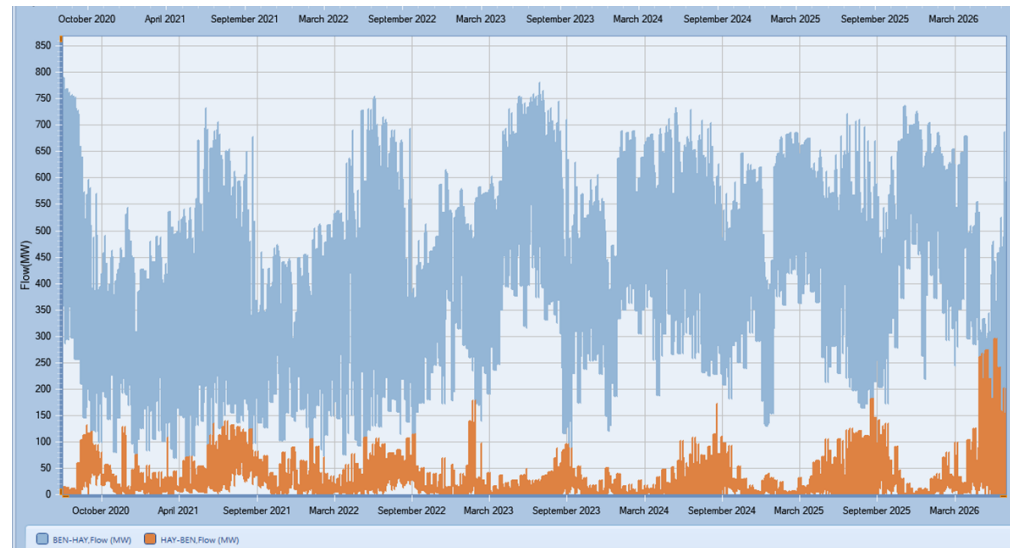
Our Understanding of the Challenge

- Potential loss of tangible price signals
- Volatile prices, with wide spreads. Generally low prices, with scarcity pricing at times
- However, potential for status quo type prices if hydrogen and/or biofuels are available and are of a scale suitable for thermal generation



Our Understanding of the Challenge

- Dispatchable demand may be one solution to help create more price points in the market
- Intermittency and forecast error of wind and in part solar are likely to lead to volatility and efficiency losses
- Ensuring appropriate/ideal generation and consumer investment will be difficult
- HVDC flows likely to continue to be constrained

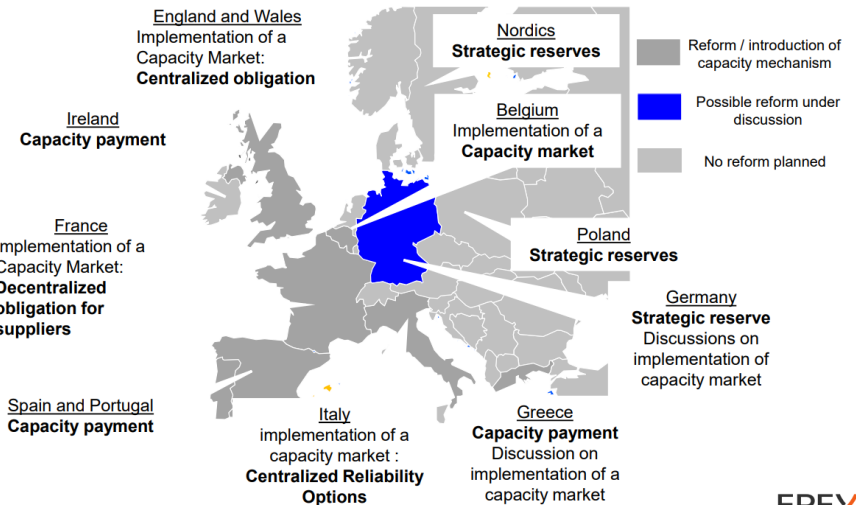


Our Understanding of the Challenge

- Our presentation today will draw on some relevant overseas developments that look to address similar issues as just mentioned
- We will discuss the approach with which other jurisdictions have developed and evaluated options
- Our overseas examples will initially start with Ireland and Europe and talk at quite a high level particularly around the market development approach taken. We will then talk to some developed US approaches that may have particular relevance to NZ
- Finally, we will bring this back to the NZ context and summarise our thinking

Approaches taken in other jurisdictions

- what does the literature tell us?



EPEXSPOT

- 1) Agreement that carbon pricing will not deliver the systems required for 100% RES-E
- 2) Strong agreement that today's markets must adapt
- 3) Much less information on small synchronous system with high levels of renewables

Energy
Exemplar
Academic Literature



BROAD SOLUTIONS

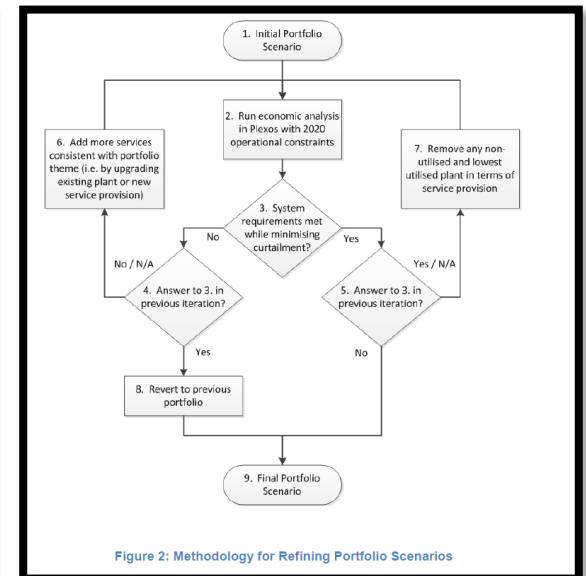
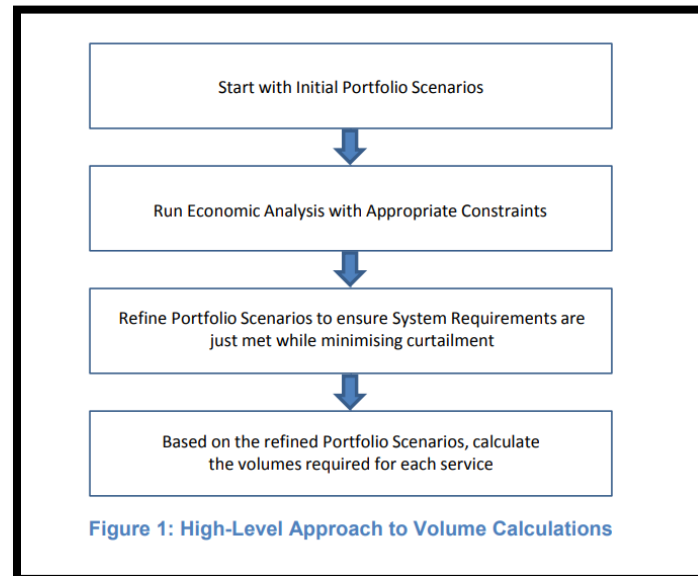
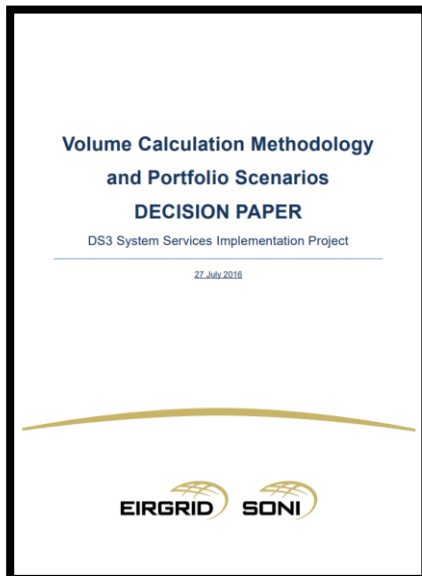
innovation • practicality • excellence

Overview of Challenges in Ireland and Relevance to New Zealand

EirGrid's (TSO) DS3 Program



To reach Policy goals for Renewable Electricity (%) Penetration it was found that **new System Services** were required to operate the system securely while facilitating increased levels of non-synchronous generation



System is moving from cost-based nature to a value-based alternative that rewards flexible and reliable capacity with the ability to evolve with market conditions of the future.

14 New System services were procured from market participants

Table 2

Summary of DS3 system services products.

Sources: Section A: DS3 System Services Technical Definitions Decision Paper, SEM-13-098. Dublin [65]. Section B: DS3 System Services Tariffs and Scalars, Dublin [66].

Section A					Section B
Service Name	Abbreviation	Unit of Payment	New or Existing	Short Description	Tariff Rates (€)
Synchronous Inertial Response	SIR	MWs ² h	New	(Stored kinetic energy) * (SIR Factor - 15)	0.0050
Fast Frequency Response	FFR	MWh	New	MW delivered between 2 and 10 s	2.16
Primary Operating Reserve	POR	MWh	Existing	MW delivered between 5 and 15 s	3.24
Secondary Operating Reserve	SOR	MWh	Existing	MW delivered between 15 and 90 s	1.96
Tertiary Operating Reserve 1	TOR1	MWh	Existing	MW delivered between 90 s and 5 min	1.55
Tertiary Operating Reserve 2	TOR2	MWh	Existing	MW delivered between 5 min and 20 min	1.24
Replacement Reserve (De-Synchronised)	RRD	MWh	Existing	MW delivered between 20 min and 1 h	0.56
Replacement Reserve (Synchronised)	RRS	MWh	Existing	MW delivered between 20 min and 1 h	0.25
Ramping Margin 1 Hour	RM1	MWh	New	The increased MW output that can be delivered with a good degree of certainty for the given time horizon.	0.12
Ramping Margin 3 Hour	RM3	MWh	New		0.18
Ramping Margin 8 Hour	RM8	MWh	New		0.16
Fast Post-Fault Active Power Recovery	FPFAPR	MWh	New	Active power > 90% within 250 ms of voltage > 90%	0.15
Steady-state Reactive Power	SRP	MVarh	Existing	MVar capability * (% of capacity that capability is provided)	0.23
Dynamic Reactive Response	DRR	MWh	New	MVar capability during large (> 30%) voltage dips	0.04

New metrics as well as system specific design features were needed.

RAMPING MARGIN REQUIREMENTS

Ramping margin is a minimum level of ramping capability available from online or offline generation and demand units. Ramping margin is essential to manage the power system with increasing variability and uncertainty associated with increasing amounts of variable generation.

The ramping margin requirement is calculated on an on-going basis as follows:

$$RMR_{t(R)} = LSI_{(t+R)} + LFE_{(t+R)} + \max(RR_{(t+R)}, Uncert_{t(R)}) + Tie_{uncert} - IC_{Cap}(t+R)$$

Where

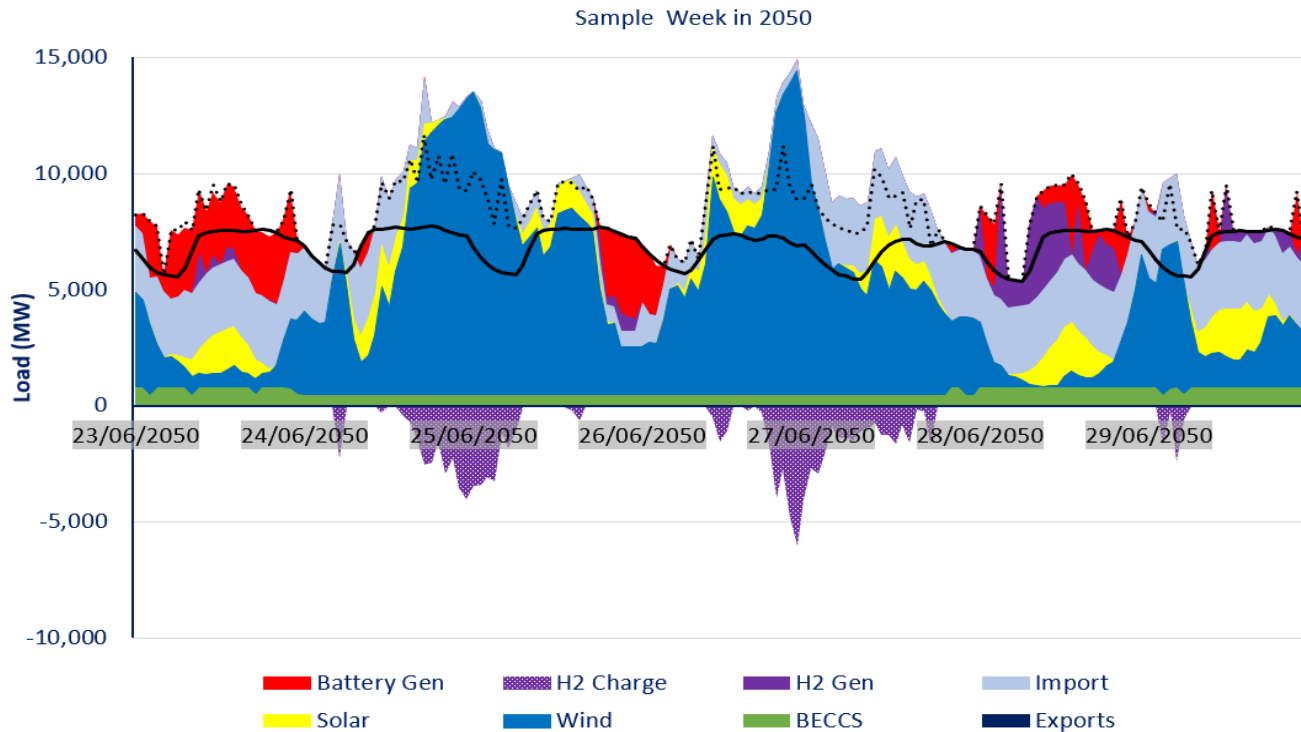
- t is the scheduling interval
- R is the ramping margin category interval, (RM1 (t+1), RM3 (t+3), RM8 (t+8))
- $RMR_{t(R)}$ is the Ramping Margin Requirement for interval “t” for ramping margin category interval “R”
- $LSI_{(t+R)}$ is the Largest Single Infeed in scheduling interval “t+R”
- $LFE_{(t+R)}$ is the Load Forecast Error in scheduling interval “t+R”
- $RR_{(t+R)}$ is the Replacement Reserve in scheduling interval “t+R”
- $Uncert$ is the variable generation uncertainty forecasted for each reserve category “R” in scheduling interval “t”
- Tie_{uncert} - Tie Line uncertainty flow, default value for each reserve category “R”
- $IC_{Cap}(t+R)$ is the interconnector capability in scheduling interval “t+R”

Shared Experiences of Challenges in Ireland for higher level of Renewables beyond 2030

Renewable Policy is based on Averages but Power System must be Resilience to extremes

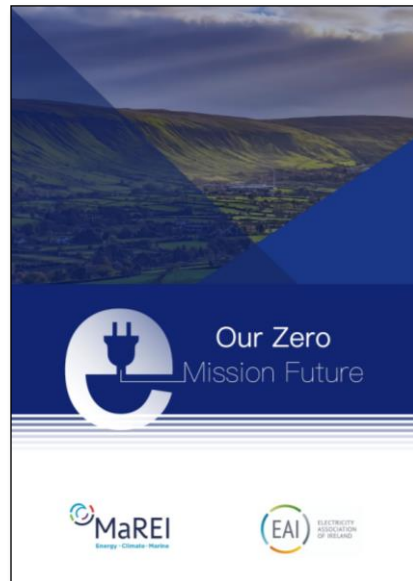
We looked at what the system needs to look like in 2030 to be resilient and now we are understanding what the market should look like to deliver this. Note there was price formation in the future system

After simulation 250,000 hours of weather data we found that a small number of days tend to shape the future landscape



Role of Demand Side is becoming more important, but we need to understand what it can deliver

- The **FlexTech Technology Integration initiative** aims to breakdown key barriers across a wide range of technical, operational, commercial, regulatory, and market challenges in order to facilitate the integration of renewable energy
- Data Centres | Moving from synthetic PPA, to 24*7 renewables and participating in DSM



Options for future market design (exploratory)

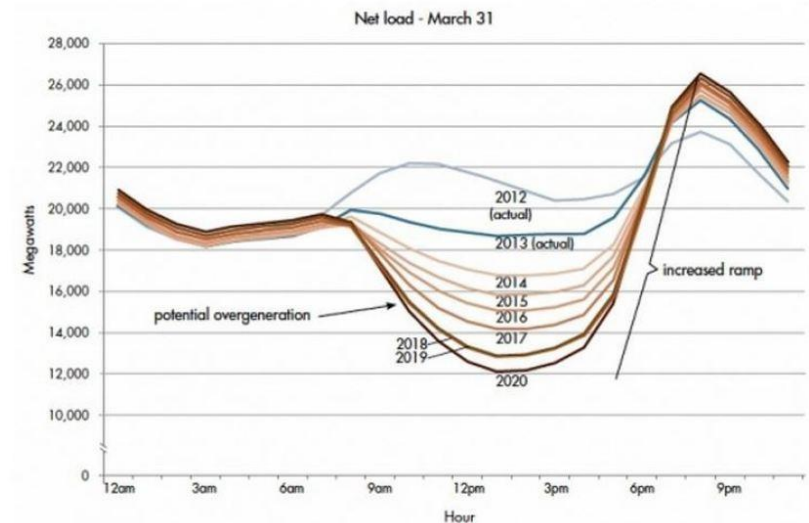
Design Feature	Benefit	Challenged
Higher frequency of market dispatch,	Facilitates variable nature of RES-E. Reduces requirement for out-of-market settlement	Implementation costs, Increased market power
Explicit compensation for flexibility	Addresses price cannibalisation, Provides price signal	Not Tested
RES subsidisation from an energy to a capacity basis	Removes price cannibalisation	Requires policy shift
Capacity requirement on the basis of improved risk criteria	Increase of scheduling robustness	Untested. Increased role of TSO
Fixed or service type retail contracts	Simplified Design. Certainty for customers	Distributional issues

US Challenges and Options under Investigation

- High renewables regions
 - Pacific Northwest
 - Ontario
 - Quebec/Newfoundland and Labrador
- High goal renewables regions
 - Many states, CAISO, NYISO, ISO-NE, individual states in PJM, MISO
- Situationally high renewables
 - SPP/MISO Wind, ERCOT Wind and Solar
 - Periods of time in which 70%+ of online energy coming from intermittent renewables

Situation 1: Duck Curve

- Phenomena of potential interest to NZ
 - Intermittent renewables creates net load shape
 - Net load Peak shifting
 - Inflexibility of balancing resources
- Potential mitigations
 - Robust Demand bidding – opportunity costs from industry
 - New sources of flexible demand: EV, Energy storage, Demand response
 - 2 stage market arbitrage values flexibility between forecast and actual
- Unmitigated impacts
 - Negative pricing – driven by tax incentives to renewables
 - Curtailment (or export) of renewable energy leading to missed opportunity to decarbonize other sectors



Situation 2: Dry year

- Phenomena of potential interest to NZ
 - Failure of Resource Adequacy
 - Reduced system flexibility
 - Reduced energy storage
 - Correlated increased demand due to heat waves?
- Potential Mitigations
 - Renewable thermal gen (renewable fuels/hydrogen)
 - More seasonal storage (hydro/BESS/hydrogen)
 - More intermittent renewables
 - More flexible demand (downstream economy generates price signal)
 - Capacity or resource adequacy market to provide stable LT incentives (wet and dry years)
- Pricing Impacts
 - Renewable thermal fuels are expensive leading to higher prices
 - Increasing demand for reserve products to cover intermittent resources



From NWPP Resource Adequacy Symposium

What are the most important considerations in an resource adequacy program?



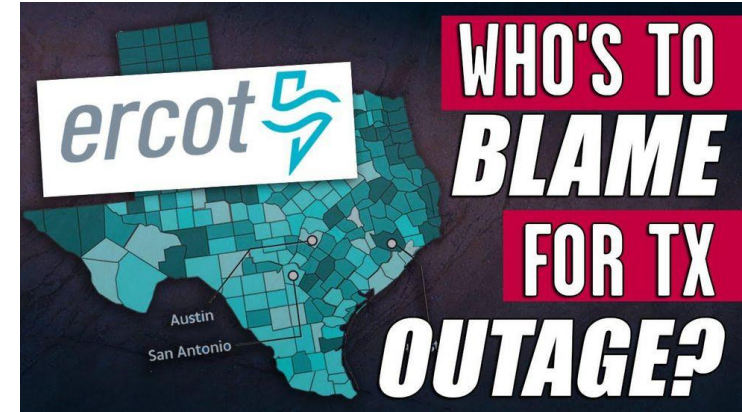
Situation 3: Intermittent oversupply

- Phenomena of potential interest to NZ
 - Average capacity factor for wind ~35-50%, solar <20%
 - Some periods > 90%, others 0%
 - Decommit other (renewable thermal?) resources
 - Frequency response, inertia, and dependability
 - Transmission outages have significant impacts
- Potential Mitigations
 - Robust demand side bidding
 - “Virtual” inertia, Inertia market product
 - More robust AS pricing/demand
 - DA/RT markets; Virtuals/Swaps
- Pricing impacts
 - Highly localized extreme prices (spatial and temporal)
 - Difficult to predict magnitude of market opportunity



Situation 4: Extreme Weather Phenomena

- Phenomena of potential interest to NZ
 - Frequency of extreme weather events is increasing
 - Severity of extreme weather events is increasing
 - Correlated planning challenges
- Potential mitigations
 - Pay for performance capacity market
 - Resource adequacy market product
 - Reserve product demand requirements
 - More robust demand bidding
 - Deeper demand response
- Pricing impacts
 - ORDC highlights the need for flexible demand and technologies that can hedge weather events
 - Capacity markets improve the durability of LT incentives through periods of abundance
 - Response to extreme weather reliability challenges is more straightforward when demand has the incentive to play a more active role



Situation 5: Prosumerism / IoT

- Phenomena of potential interest to NZ
 - Consumer and Industrial acquisition of supply
 - Distributed and concentrated in load centers
 - Often focused on solving retail problems rather than grid problems
 - A source of flexible demand at the device level
- Potential mitigations
 - Allow for aggregation of supply
 - Allow for aggregation of responsive demand
 - Allow for market participation for aggregated resources (FERC 2222)
- Pricing impacts
 - Potentially adds robust demand curve
 - Adds opportunity for consumer opportunity cost (personal vs. System use of supply) to present a price signal



Situation 6: Brazil

- Phenomena of potential interest to NZ
 - Hydro heavy
 - Intermittent renewables replacing thermal
 - Uncertainty of weather conditions drives pricing
- Potential mitigations
 - Market is sensitive to a stochastically forecast forward market
- Pricing impacts
 - Value-based instead of cost-based pricing paradigm



Market Mechanisms and the Incentives they create

Two Stage Energy Market

ST Forecast Error Resolution

Flexibility

Transparency to Volatile conditions

Resource Adequacy/ Capacity Market

LT Incentives to stabilize investments

Incentives to build/upgrade

Reserve Markets

Inertia market creates price signal

Increased demand to account for intermittency creates more robust price signals

ORDC

System wide price signals for insufficiency of reserves and energy

Flexible demand should want to avoid exposure to ORDC price curve

Market Mechanisms and the Incentives they create (Part 2)

Robust Demand Market

Price driven by value provided instead of cost

Opportunity for demand to hedge itself

Locational Marginal Pricing

Economic Transmission Expansion

Co-locate supply and demand

Distributed Aggregation

Smaller scale investment

Opportunity for load/gen to participate in market

Making use of IoT

General Themes

- Importance of a “value based” approach rather than “cost based”
 - Recognising the value of stability and flexibility
 - Incentivising investment in load shifting and firming renewable uncertainty
 - Opportunity to develop a range of ancillary services products
- Further development of futures market and/or capacity market (with pay on performance criteria)
 - Incentivising dry-year investment and provisioning
- Addition of hedging products to address future pricing issues:
 - Solar shape, super peak, virtual storage (Renewable Energy Hub, Australia)
- Addressing uncertainty and rewarding flexibility e.g., through a day-ahead market and balancing market

General Themes

- Start the journey as soon as possible
 - The earlier changes can be made the sooner a consistent long term price signal can be developed, and investment and behaviour steered to the long-term state
- Evaluate options the thorough scenario analysis
 - Use modelling to investigate and evaluate a wide range of market options
 - Scenarios should also cover a range of potential technologies both for generation and demand
- Develop industry partnerships to help in the evaluation and development approach
 - Engage with generation and energy storage investors to test viability of options and ensure rewards will incentivise the right responses
 - Investigate dispatchable demand opportunities now and for the future

Dispatchable Demand

- Potential for demand side participation in the spot market to help provide a richer spread of prices
- If mechanisms to encourage this can be developed now, then during the upcoming electrification drive, large C&I participants may be encouraged to consider process control, energy storage and load shifting options (geographical and time)
- Aggregation of small commercial and even residential load, EV's, battery storage through smart portal and applications can also help create participation
- New forms of demand such as data centres may provide pressure and drive the need for greater reliability but may also provide opportunities for flexibility

Potential for Spot Prices to be Preserved

- Hydrogen and biofuels may support a carbon neutral continuation of thermal generation
- Timing is an issue here as existing thermal plants are planned to retire and gas infrastructure may start to be taken out of service
- Hydrogen may provide for flexible use of surplus renewable generation for production, and possible underground storage or conversion to Ammonia for future use (e.g., dry year firming)
- Potential for export may put pressure and risk on domestic usage

Importance of Modelling

- Scenarios can be explored that are cover market change and applications not yet in existence or even contemplated
- The generation and demand landscape is also likely to change dramatically
- Modelling approaches need to be flexible and configurable
- PLEXOS has been used extensively in a range of markets for evaluating new market structures and assessing potential participant responses to these
 - ERCOT Ancillary Services, IESO Market Renewal, CAISO LMP, Chilean CEN DA, PJM EAS/MOPR, MISO Gas Electric coordination, NREL SEAMS Interconnection, CAISO EIM, Ireland ISEM

Importance of Modelling

- Metrics need to be developed against which modelling results and options can be scored:
 - Total System Cost
 - Reliability LOLP or EENS
 - Societal Benefit = Consumer Surplus + Producer Surplus
 - Adjusted Production Cost
 - Average system and marginal CO2 abatement cost
 - Insufficient ramp resource expectation (IRRE)
 - Price of Electricity (impact on households bills)
 - Market Competitiveness Indices (RSI, etc.)

Summary

- Value realisation for batteries and load shifting
- Getting things in place early enough so companies undergoing electrification, refurbishment, new investment are considering the value of load shifting capability and being dispatchable demand participants
- Exploring how aggregation can be encouraged - a platform they can easily trade on and products suited to this
- A market system that encourages renewables and wind in particular to address forecast error and intermittent generation through hedging and investment (battery storage, throttle capability, portfolio). Conversely rewards investment in flexible generation and load shifting that mitigates this.
- A longer term hydro risk insurance scheme - or a capacity market that pays for performance.
- A solution that allows for multiple future pathways including:
 - Thermals persisting fuelled by Hydrogen and/or biofuels
 - New forms of load-shifting (potentially geographical)
 - New scenarios not yet contemplated