Operating High Variable, Renewable Generation Power Systems

Lessons Learned from Ireland and Northern Ireland

16th September 2015

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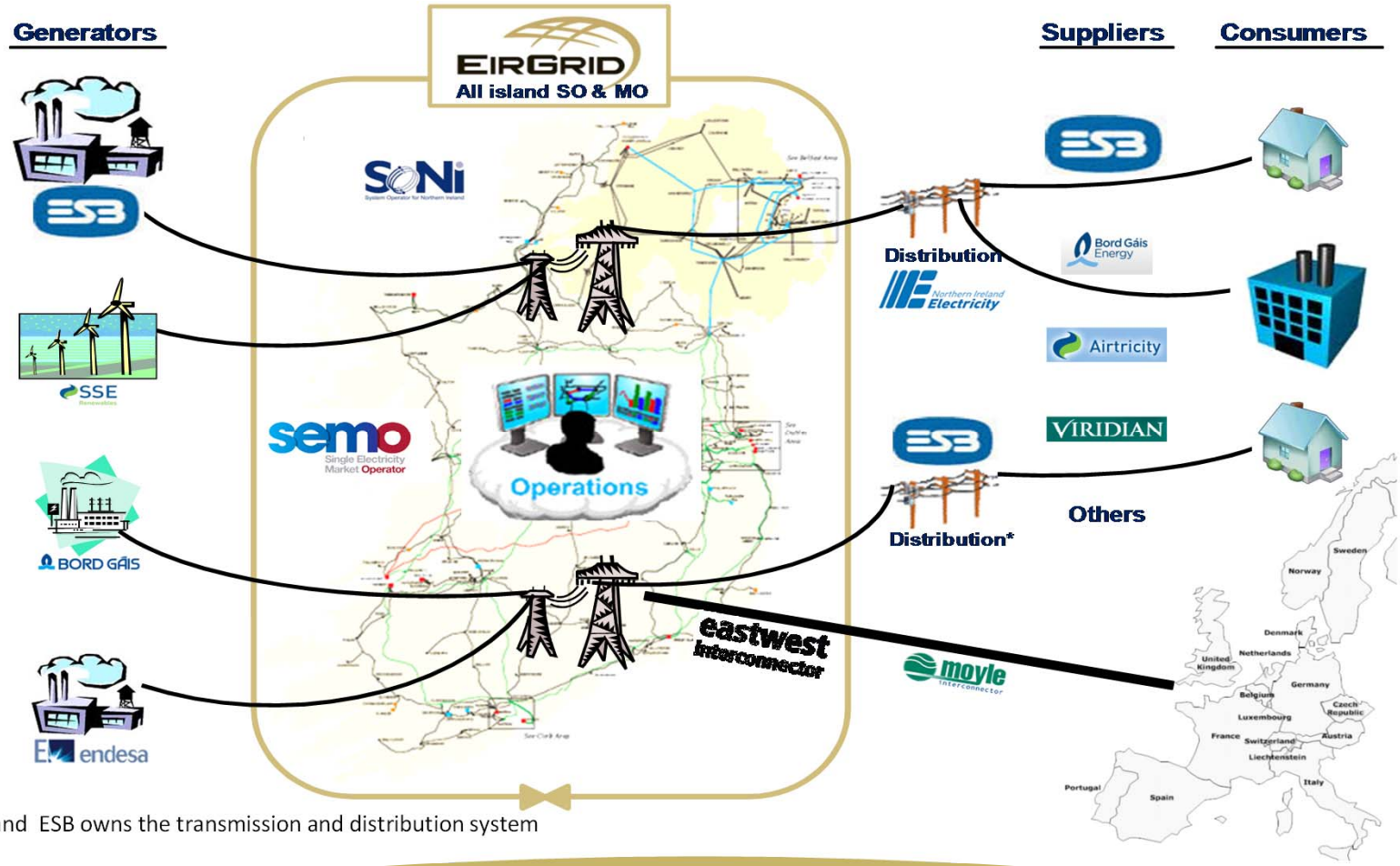
Overview

EirGrid's Role

EirGrid is the Transmission System Operator and Market Operator



* Note: In Ireland ESB owns the transmission and distribution system

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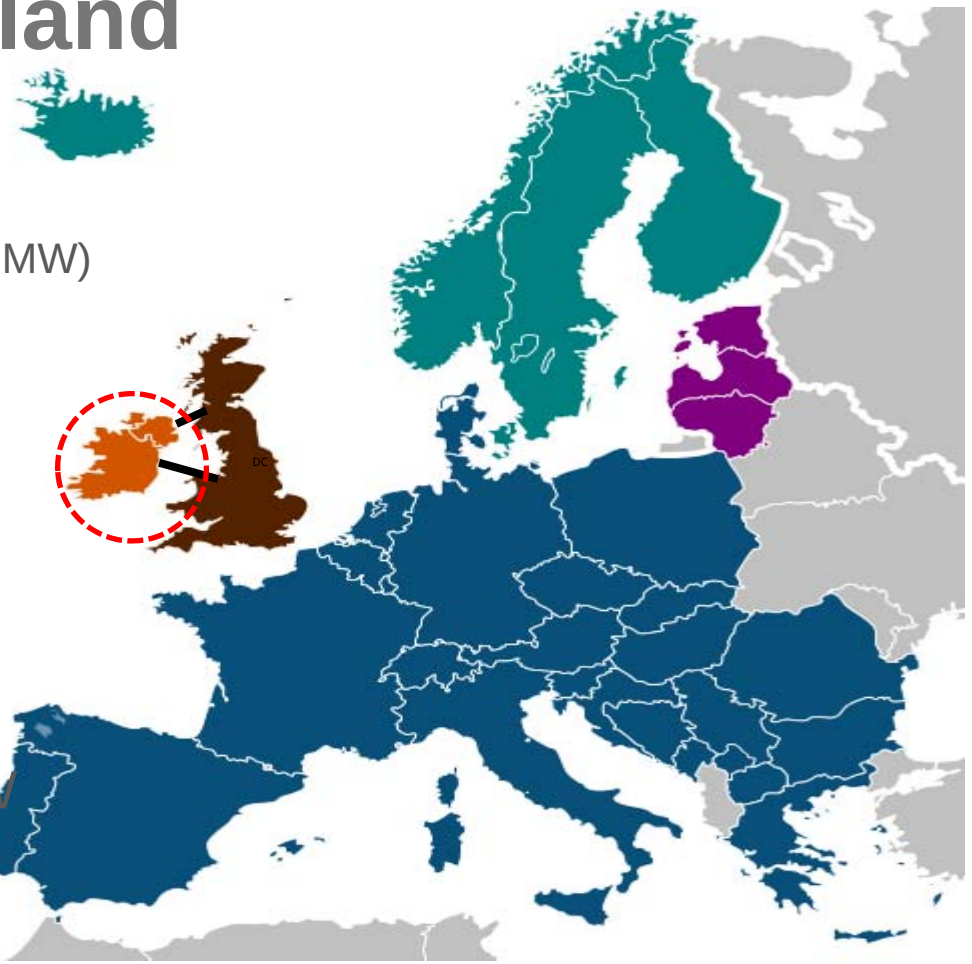
Power System of Ireland and Northern Ireland

- 9000 MW of conventional plant
  - Relatively large units (several > 400 MW)
- 2800 MW of Windfarms

- Peak Demand of ~6800 MW
- Valley Demand ~2300 MW
- Total annual demand ~36 TWh

- HVDC Interconnection: 1000 MW
  - NI & GB: Moyle (500 MW)
  - IE & GB: EWIC (500 MW)



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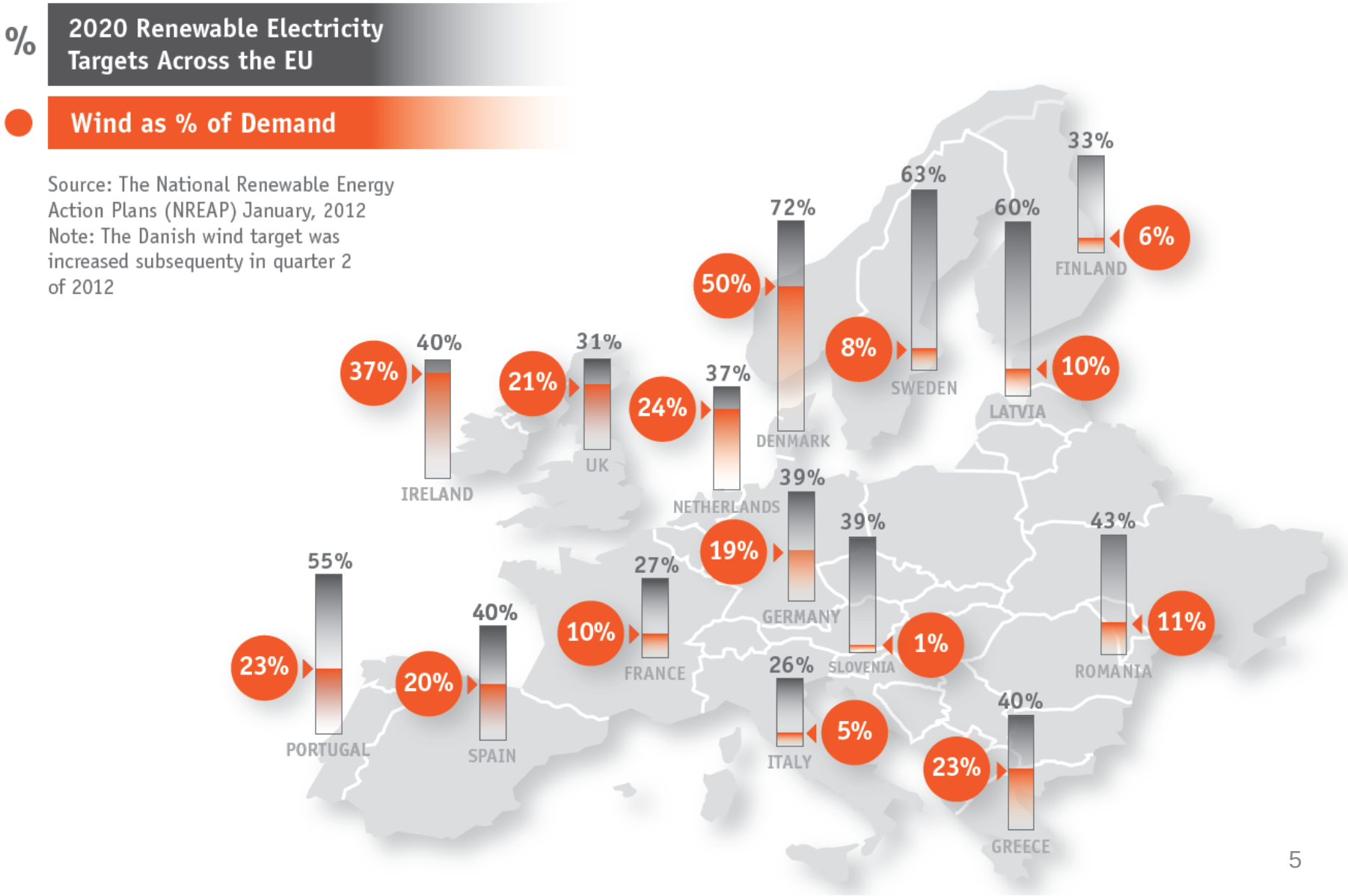
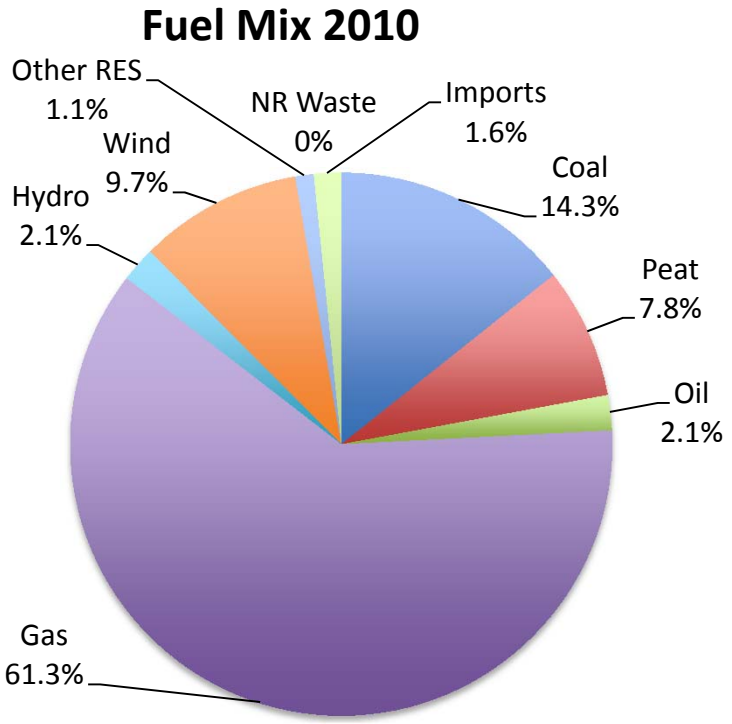
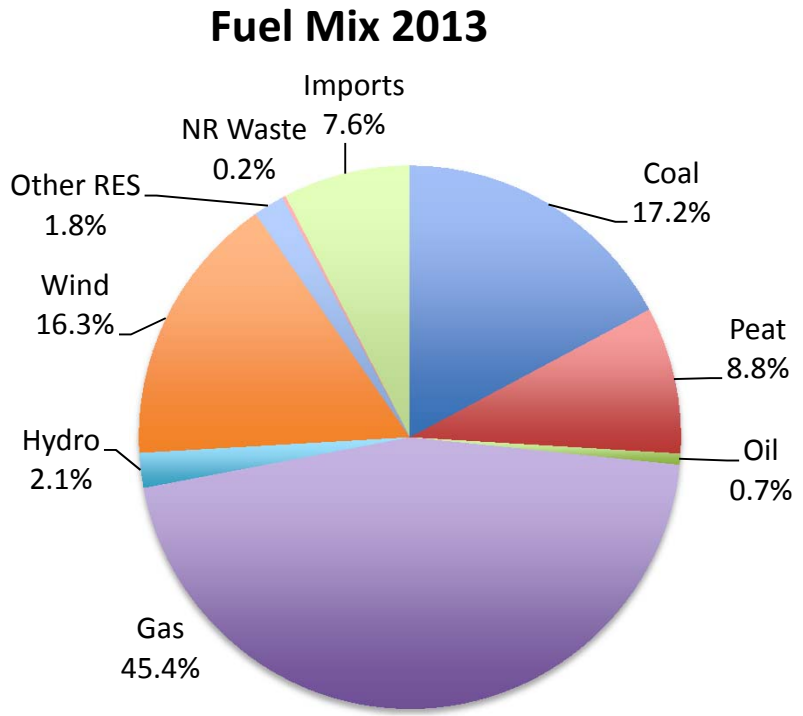
2020 RES-E Targets



Ireland Fuel Statistics 2010 - 2013





Figures courtesy of Sustainable Energy Authority of Ireland

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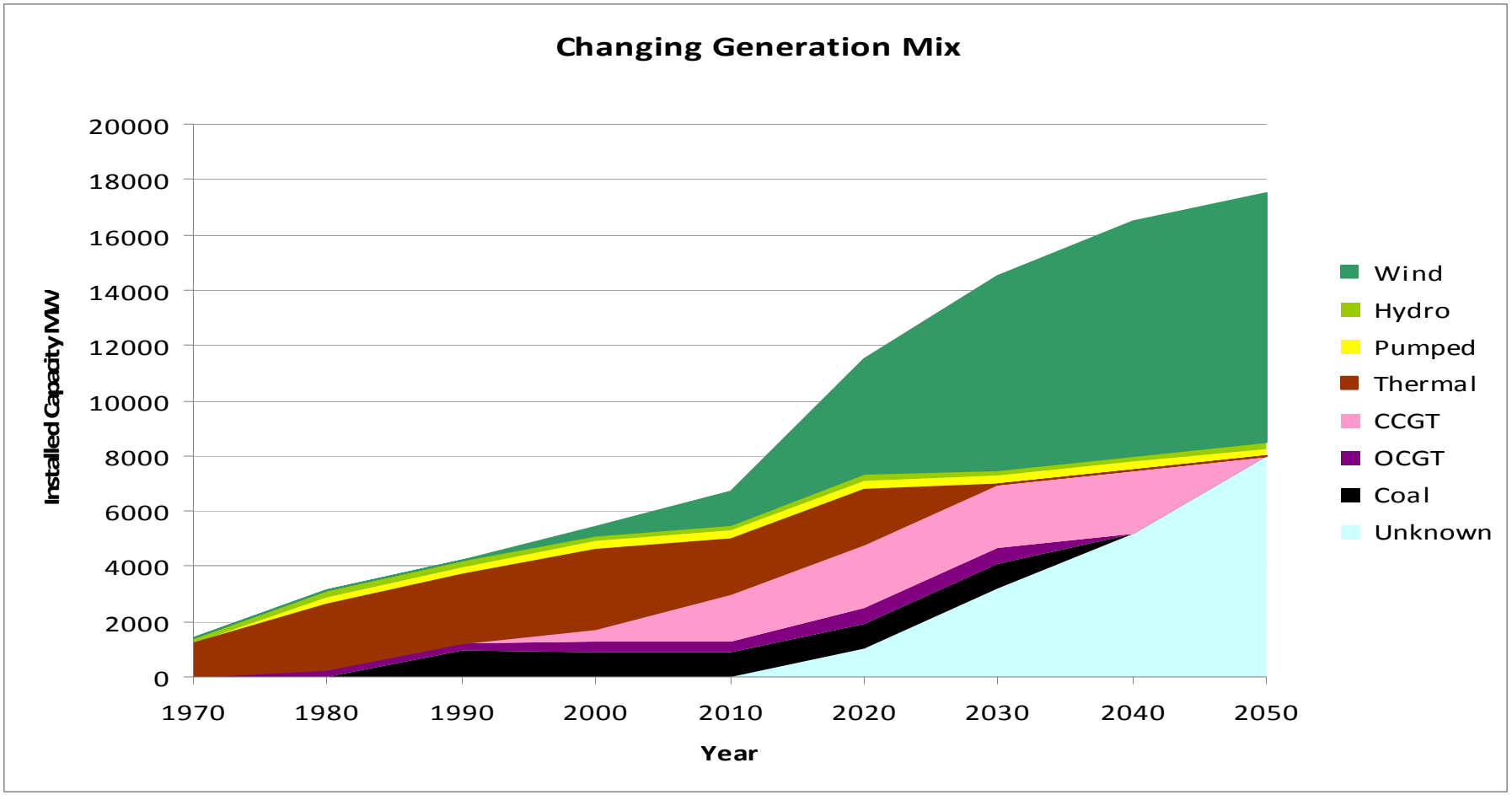
Changing Portfolio: Changing System Needs



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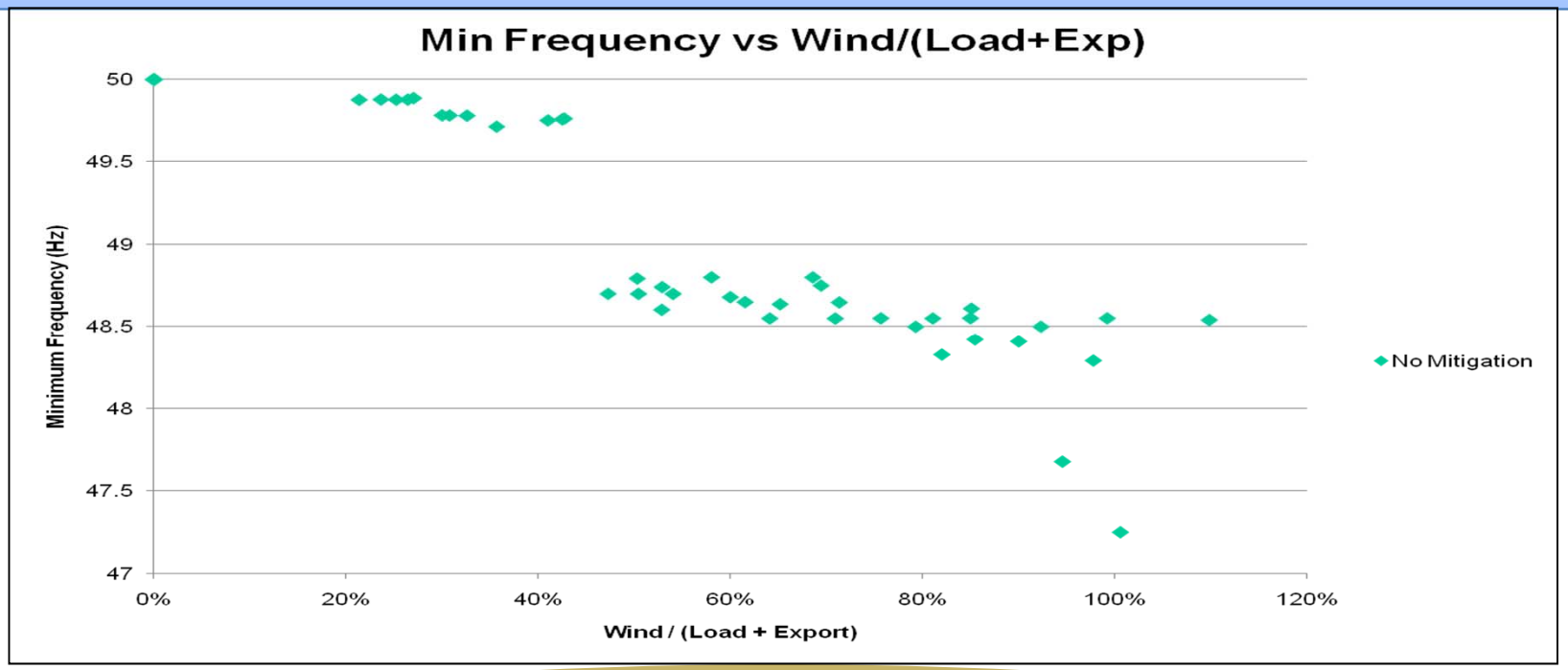
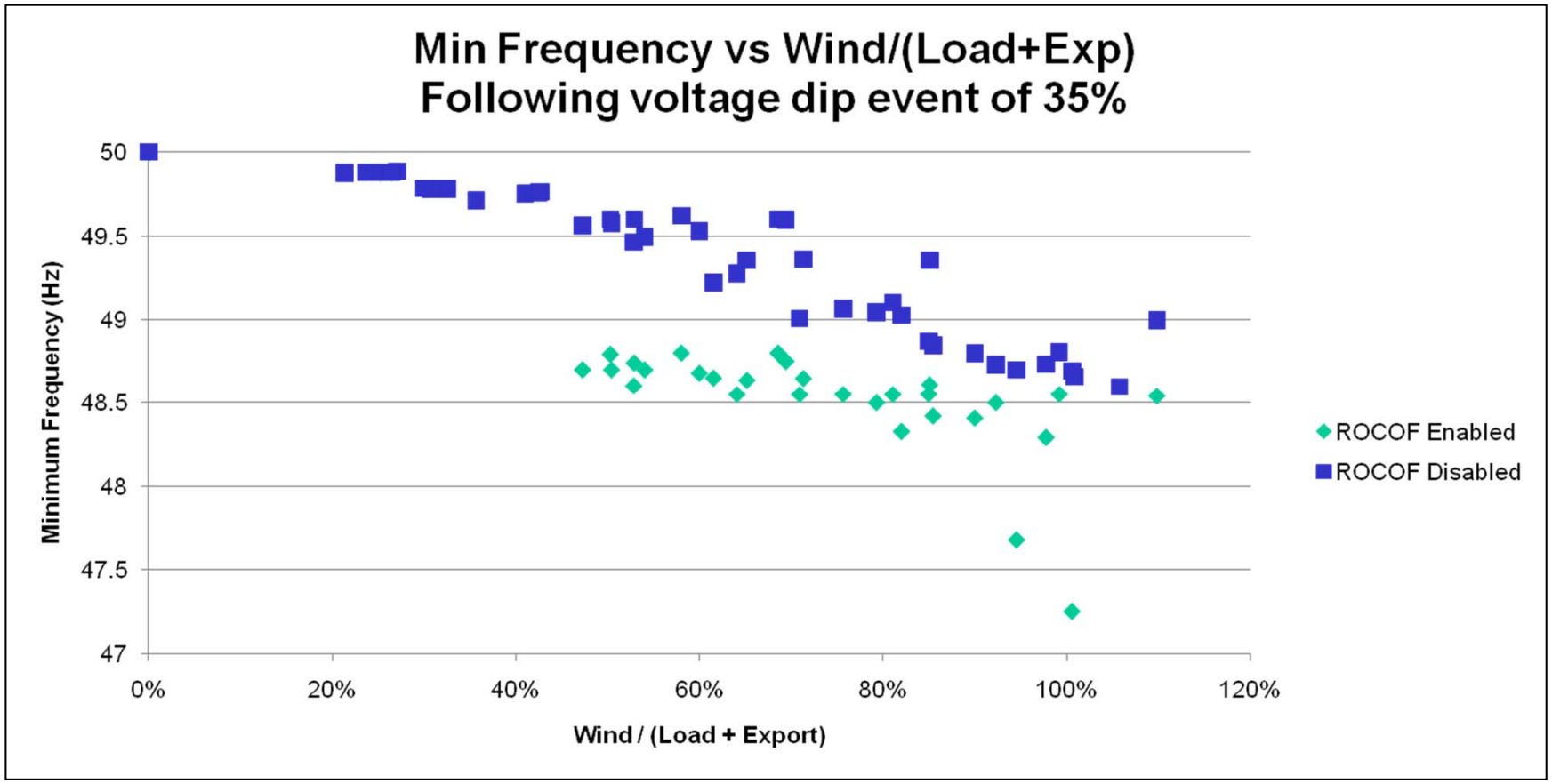
Facilitation of Renewables

Key Finding 1: Frequency Control and Impact of ROCOF Relays

The management of frequency following the loss of the largest unit will become progressively more difficult at high penetration of wind. In addition the use of ROCOF relays, currently employed on all distribution connected windfarms, further threatens frequency stability.



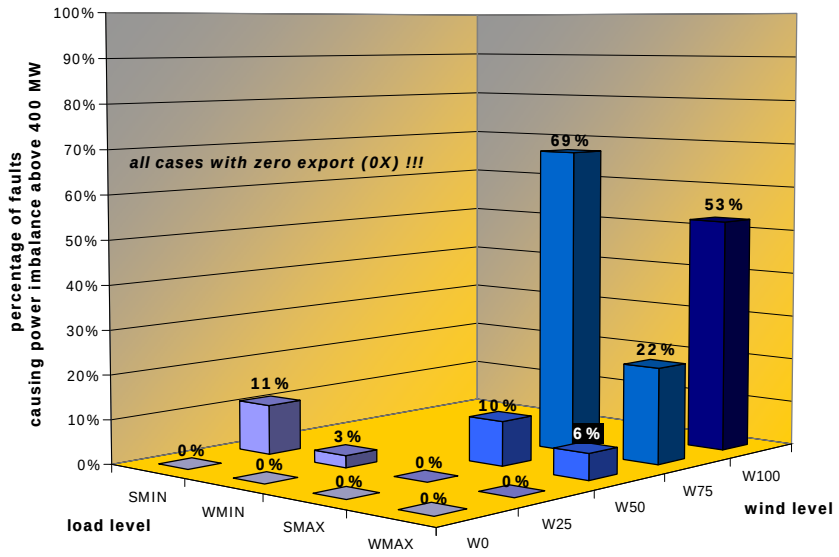
Key Finding 1: Frequency Control Mitigation Measures: Impact on Disabling RoCoF



Key Finding 2: Single Largest Contingency may change

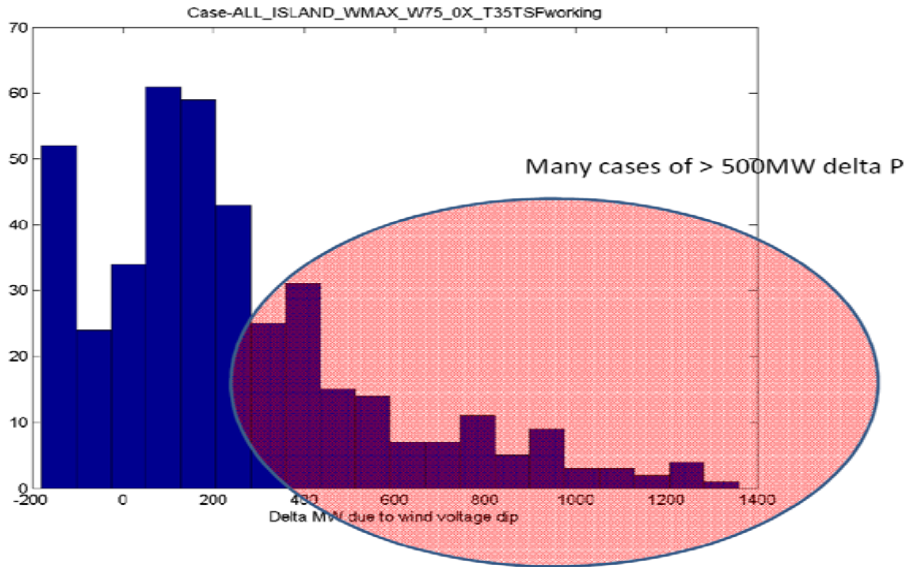
With large amounts of wind power, a transmission fault of 100ms has the potential to result in a MW reduction greater than that of the largest single in-feed, potentially resulting in serious frequency events.

Faults with wind reductions > 400MW



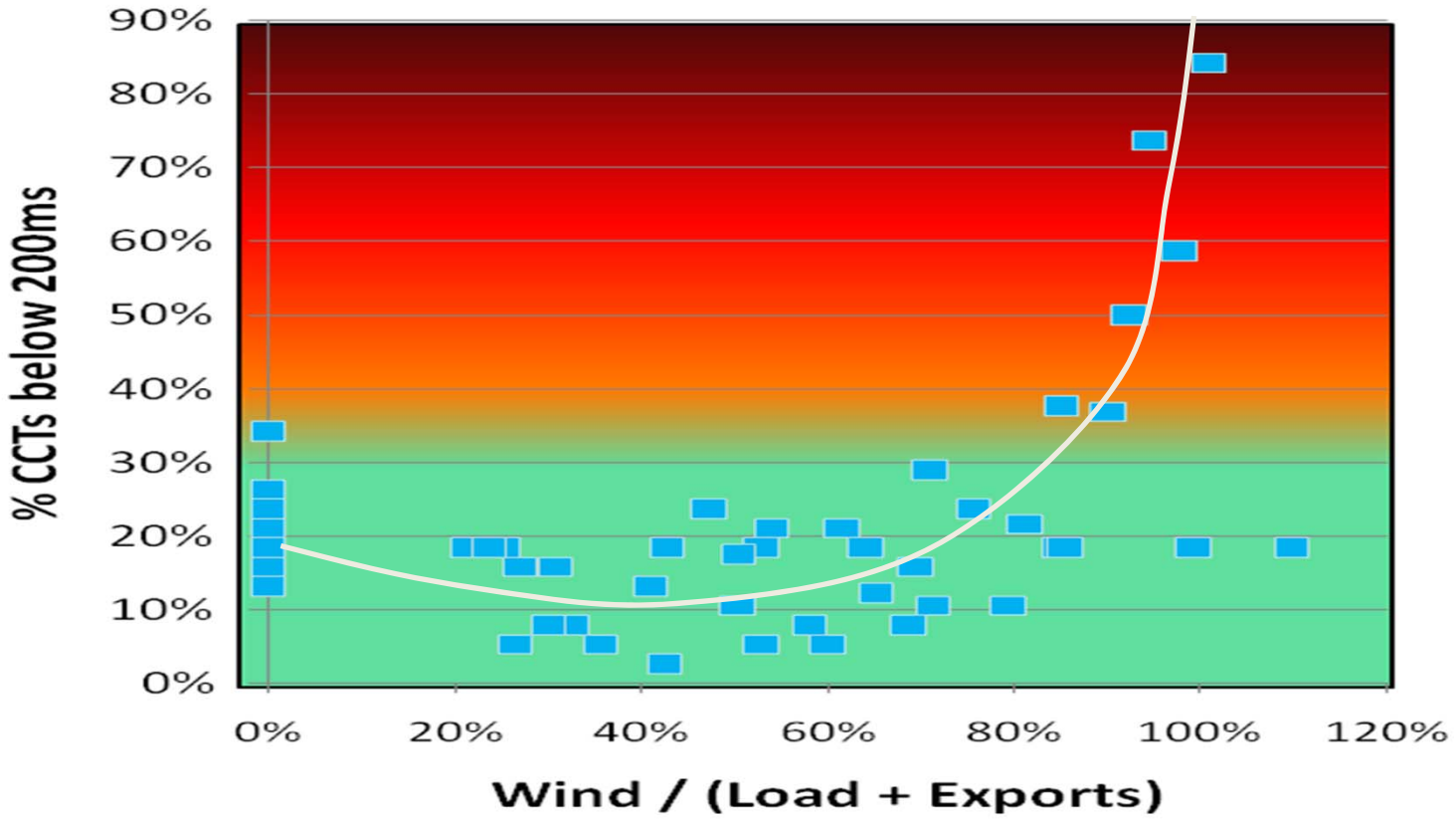
Winter Maximum, 75% Wind

- Post fault wind MW reductions



Key Finding 3: Dynamic Stability Issues

Moderate amounts of wind power increase dynamic stability, but at high levels of wind power penetration, dynamic stability deteriorates significantly



Key Finding 4: Voltage and Reactive Power Control

The management of both steady state and dynamic reactive control becomes difficult with the addition of significant amounts of wind.

- Requirement for significant reactive support in base case
- Modelling showed over compensated system can lead to voltage collapse at high per unit voltages
- Dynamic Response from all generators necessary to manage stability issues

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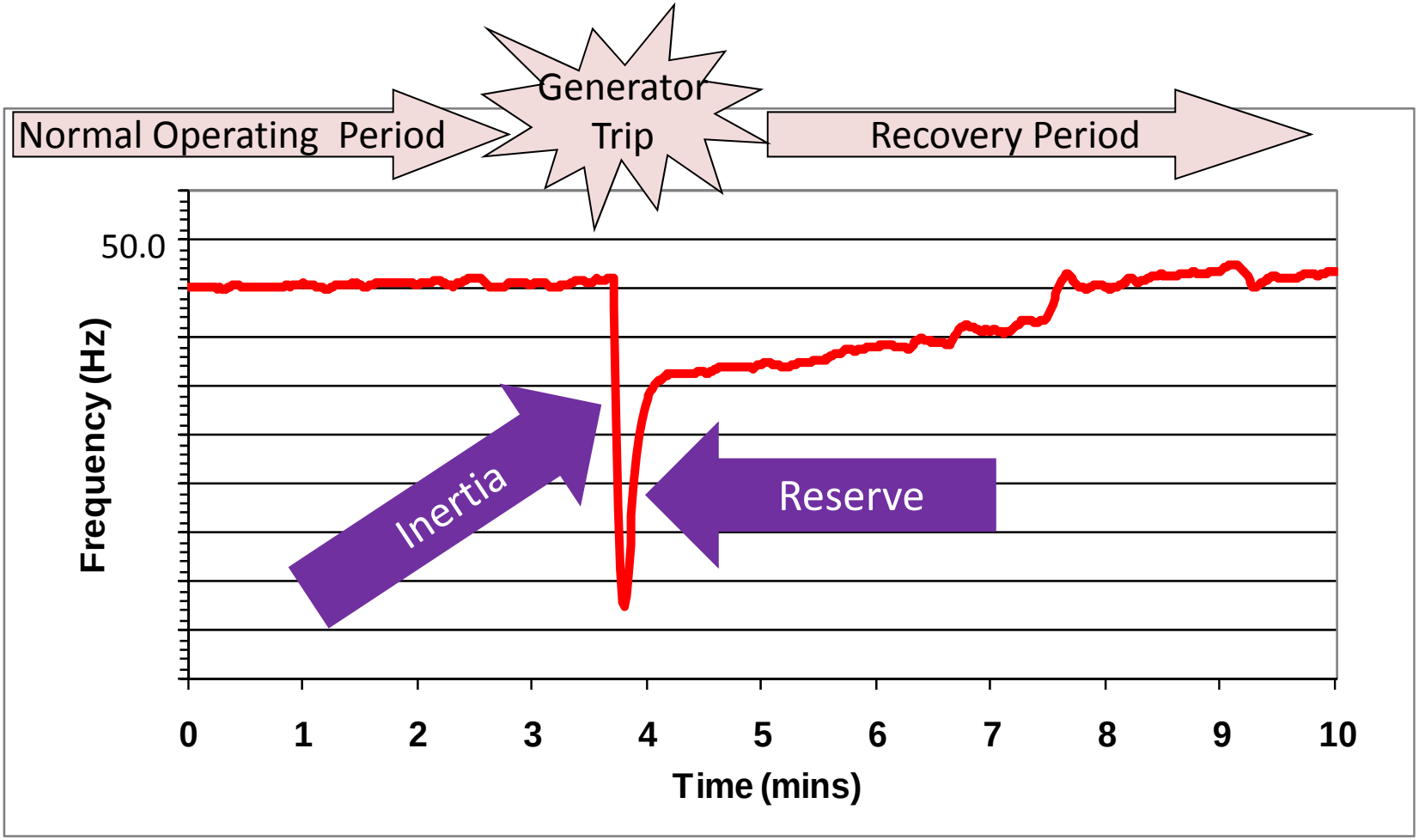
Example of Incident



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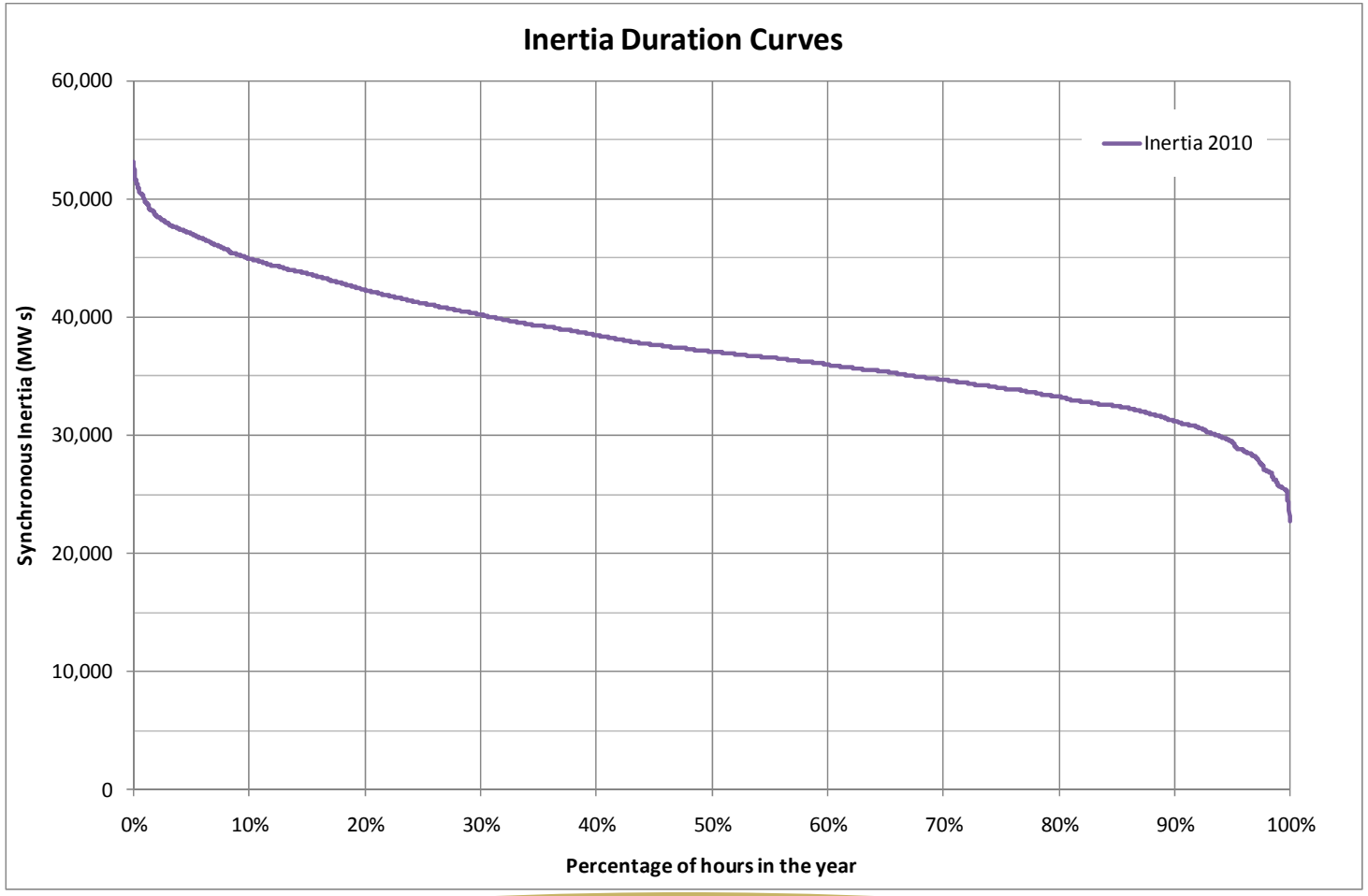
Frequency Response: Inertia



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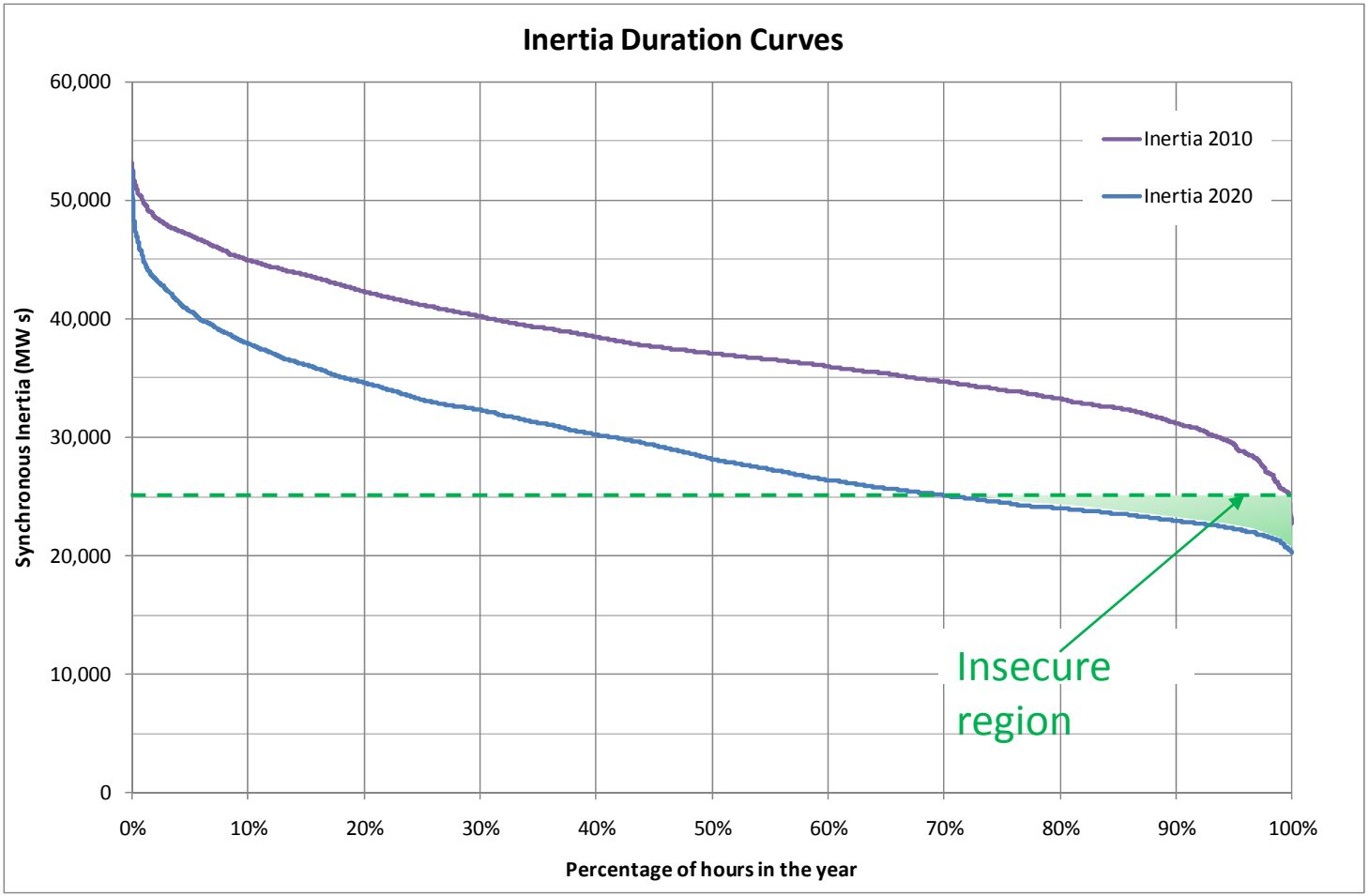
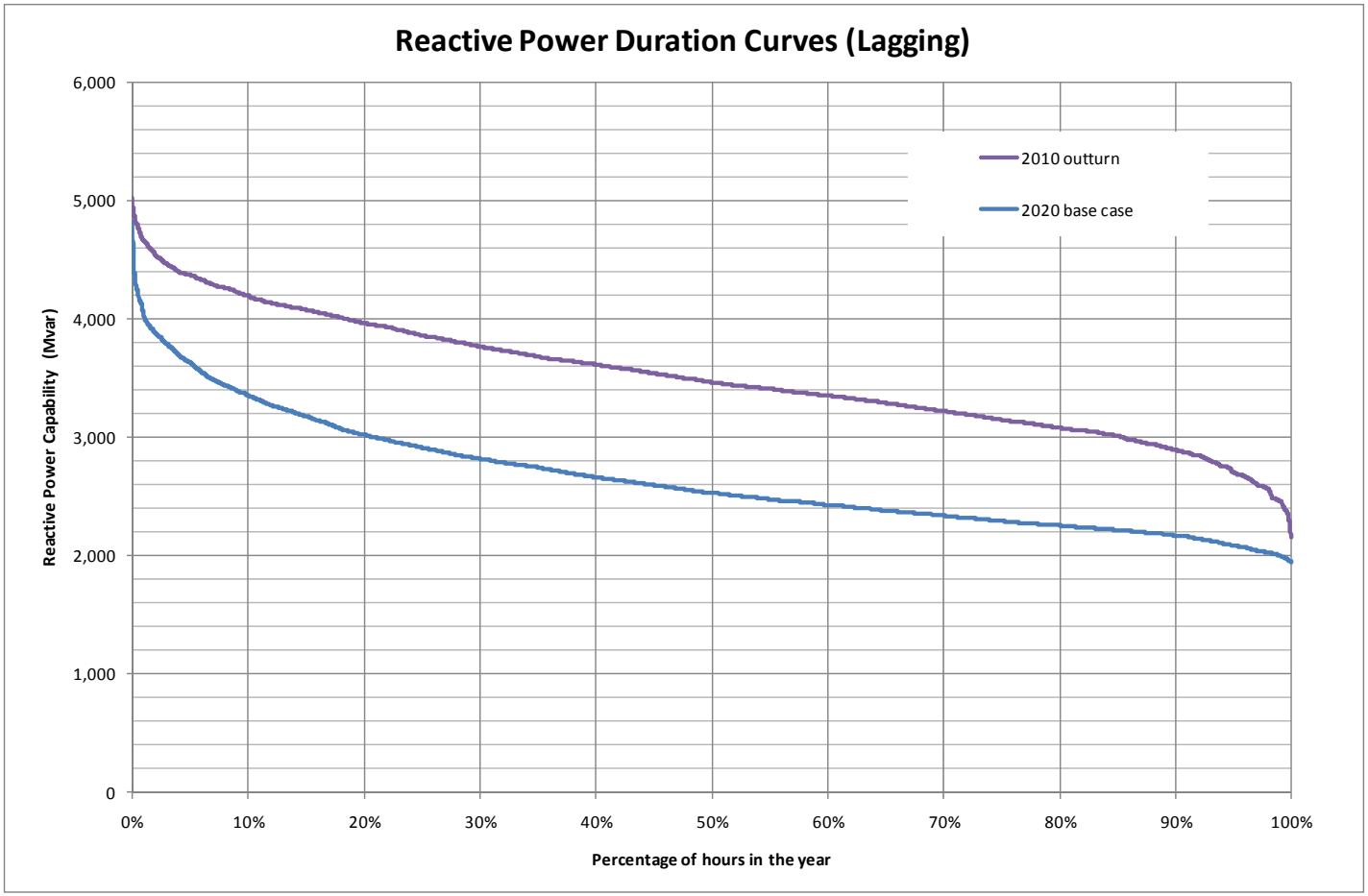
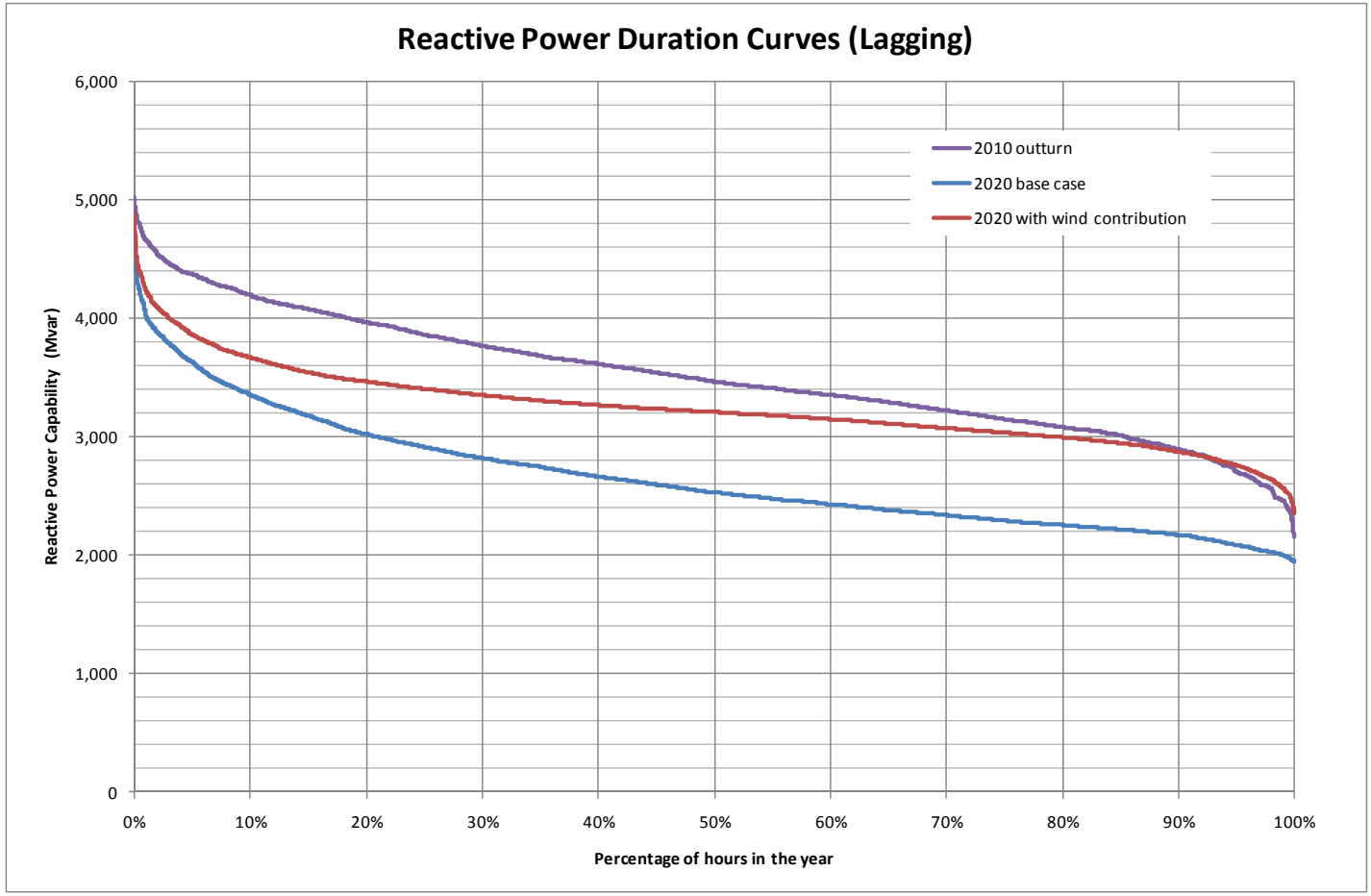
Frequency Response: Inertia



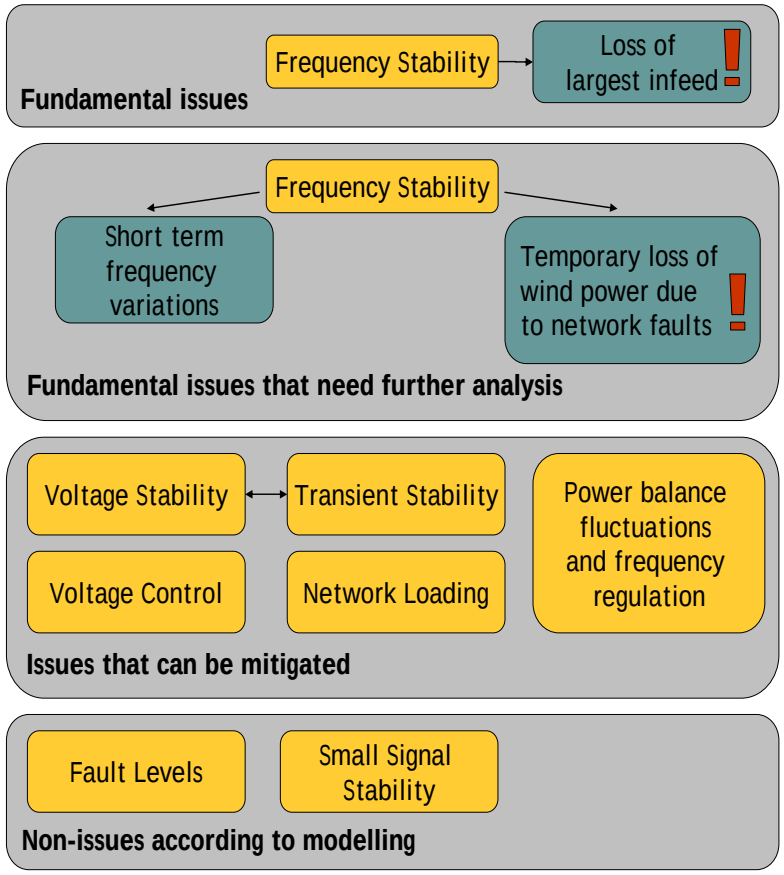
Reactive Power – Synchronised



Reactive Power – Synchronised



Facilitation of Renewables



- RoCoF capability and protection
- Conventional Generator Reserve performance
- Windfarms controllability and reactive power capability
- New operating procedures including embedded windfarms

DS3 Programme

Background – Operations and DS3

Detailed Technical Analysis

2008 - All Island Grid Study
2010 - Facilitation of Renewables
2011 - Ensuring a Secure Sustainable System

Delivering a Secure Sustainable System

- 2011 – Programme established
- Meeting the RES Policy Objectives efficiently while maintaining system security
- Holistically considering technical, commercial and regulatory needs of the system
- Engaging with all industry stakeholders

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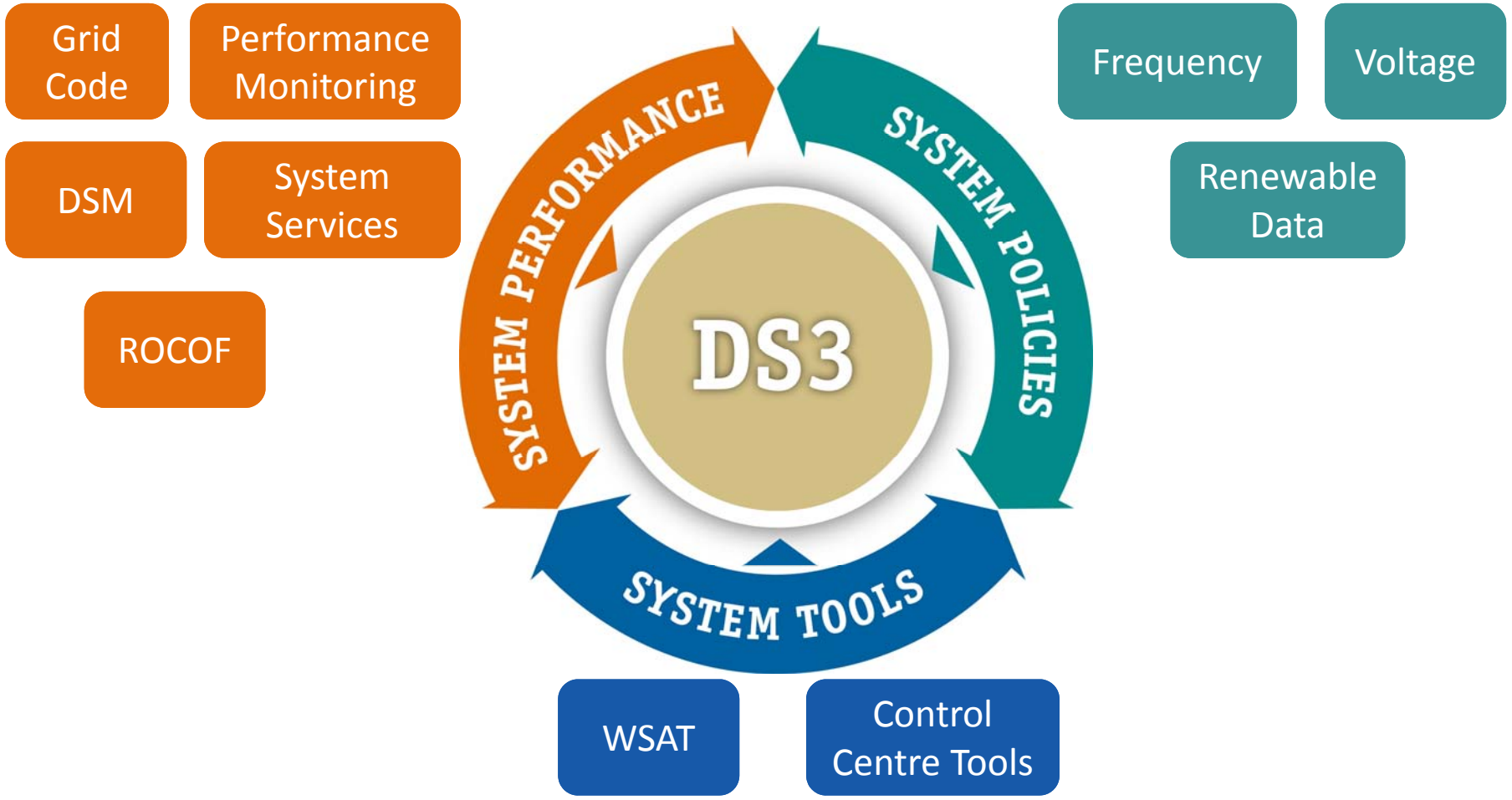
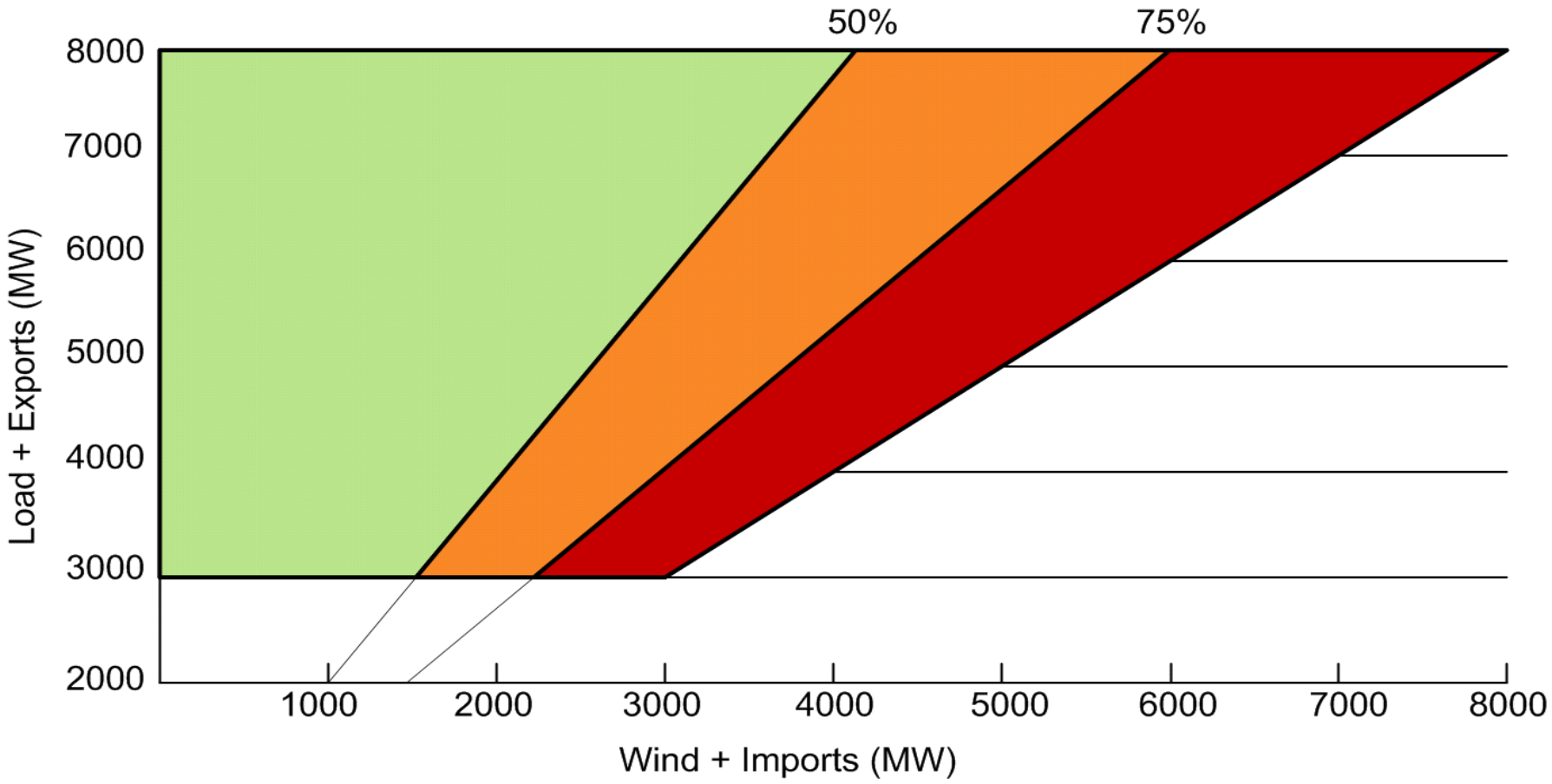
DS3 – Shaping the System of the Future



Real-Time Operational Limits and Impact on RES-E



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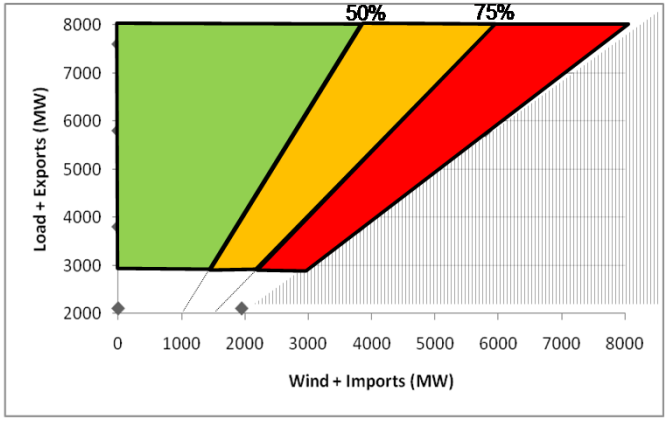
Challenges and Responses

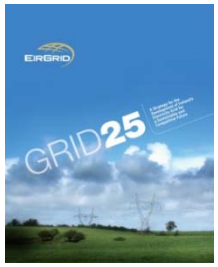
Facilitating up to 75% Renewables in real-time requires change

Challenges

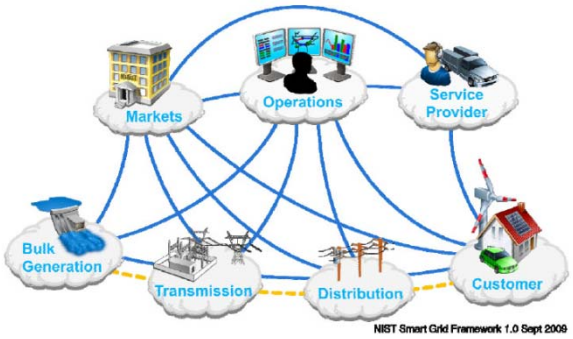
- System Stability
- Resource Variability
- Uncertainty
- New connections
- Changed power flows



① Infrastructure: Network and Interconnectors



② Operational:DS3 and Smart Grids



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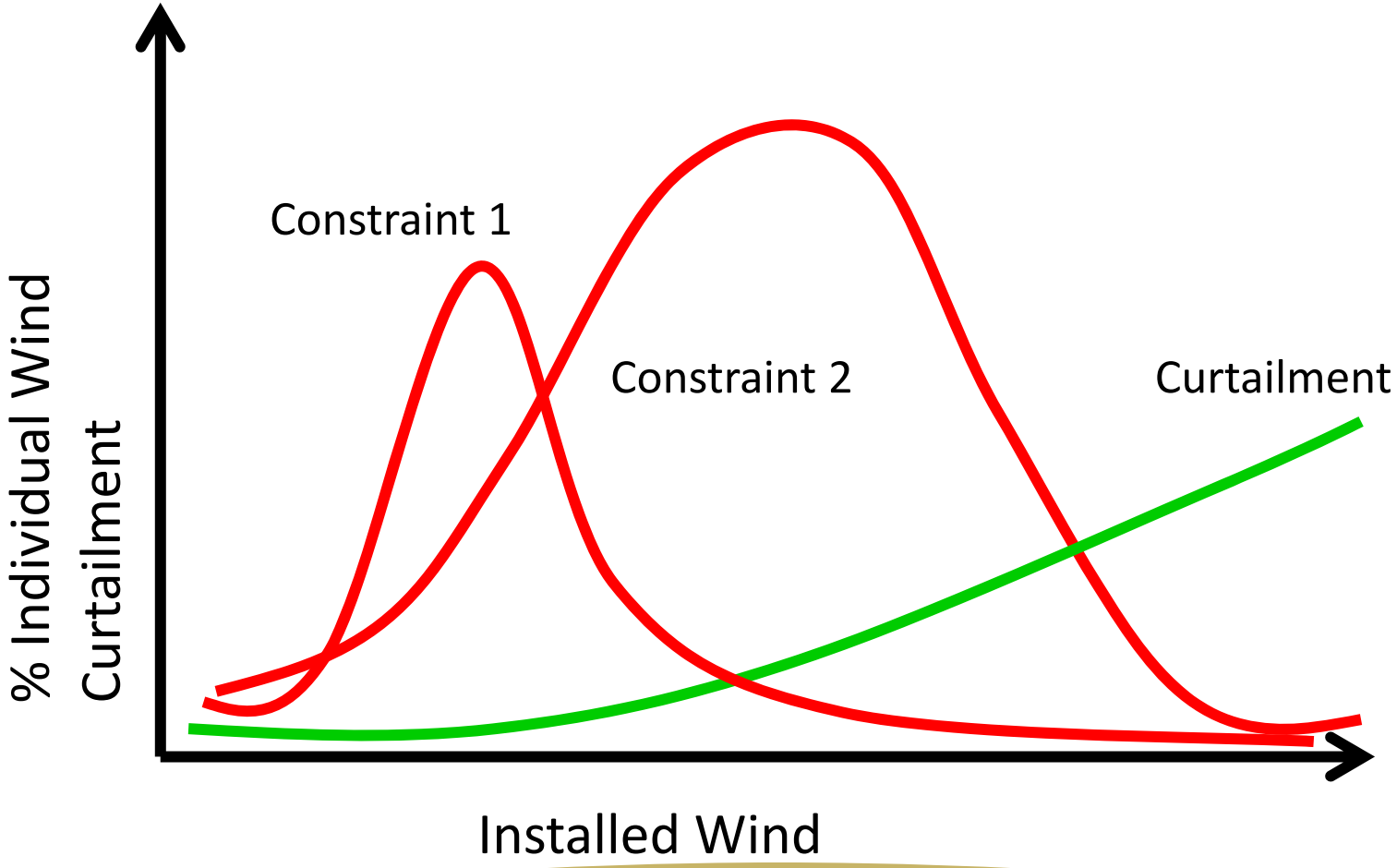
Constraints vs. Curtailment



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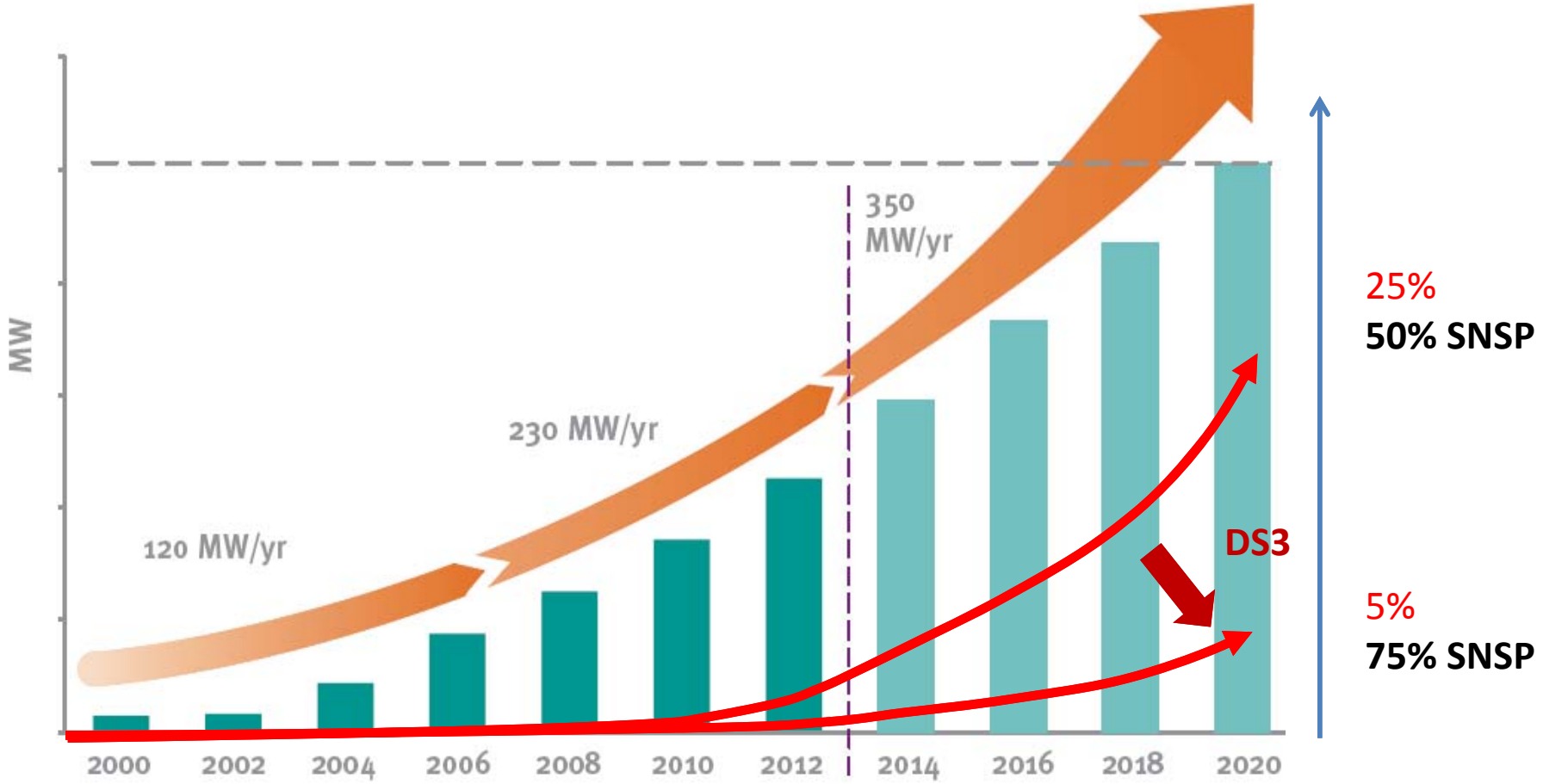
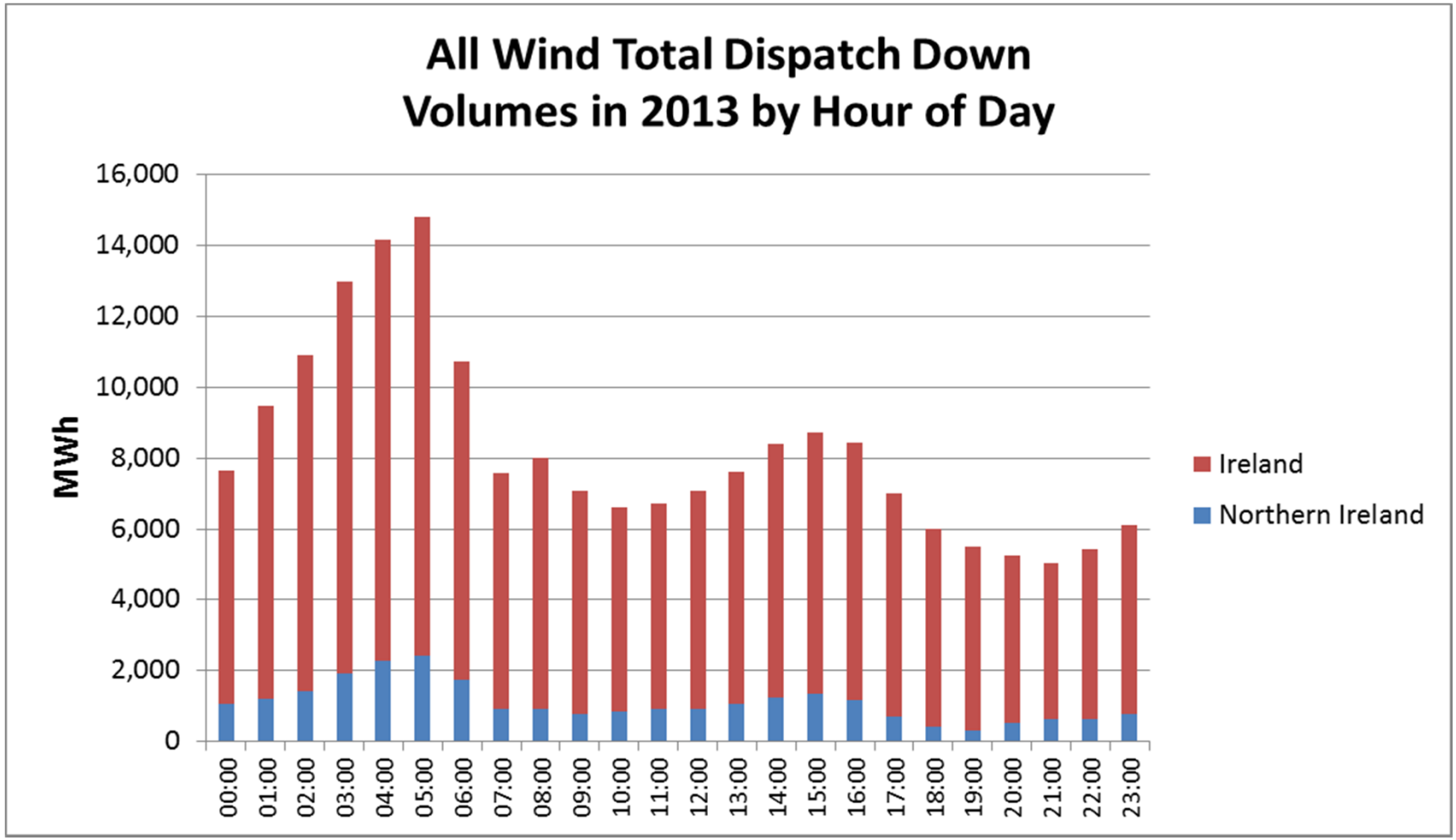
Effect of SNSP on Curtailment



Illustrative SNSP curves

IRE & NI: Dispatch Down by Hour of Day



Today: Enabling 50% in Real Time

1. Active and reactive control of windfarms
2. Best in class wind forecasting
3. On-line real-time dynamic assessment
4. Enforcement of standards on all generators

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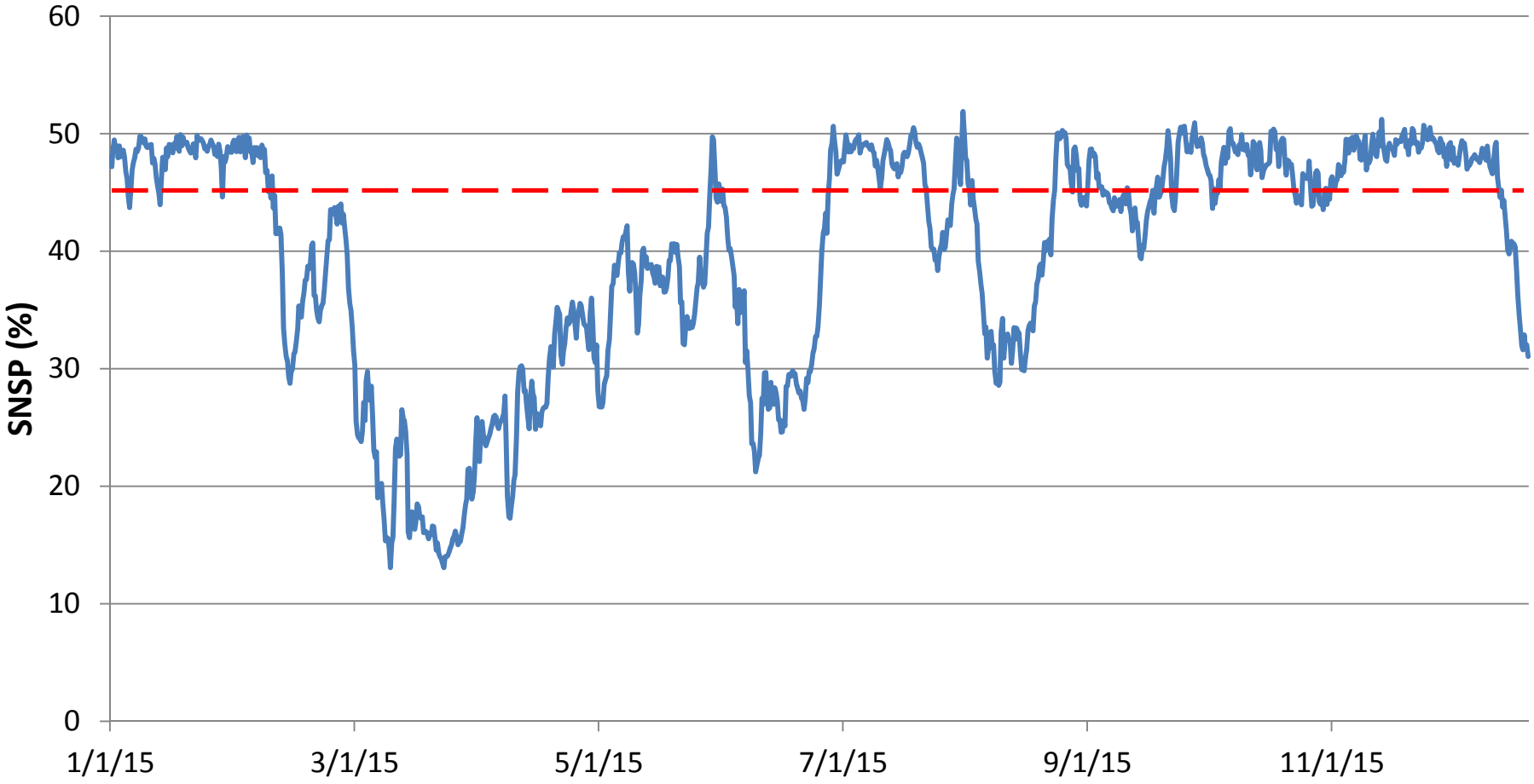
SNSP – Early 2015



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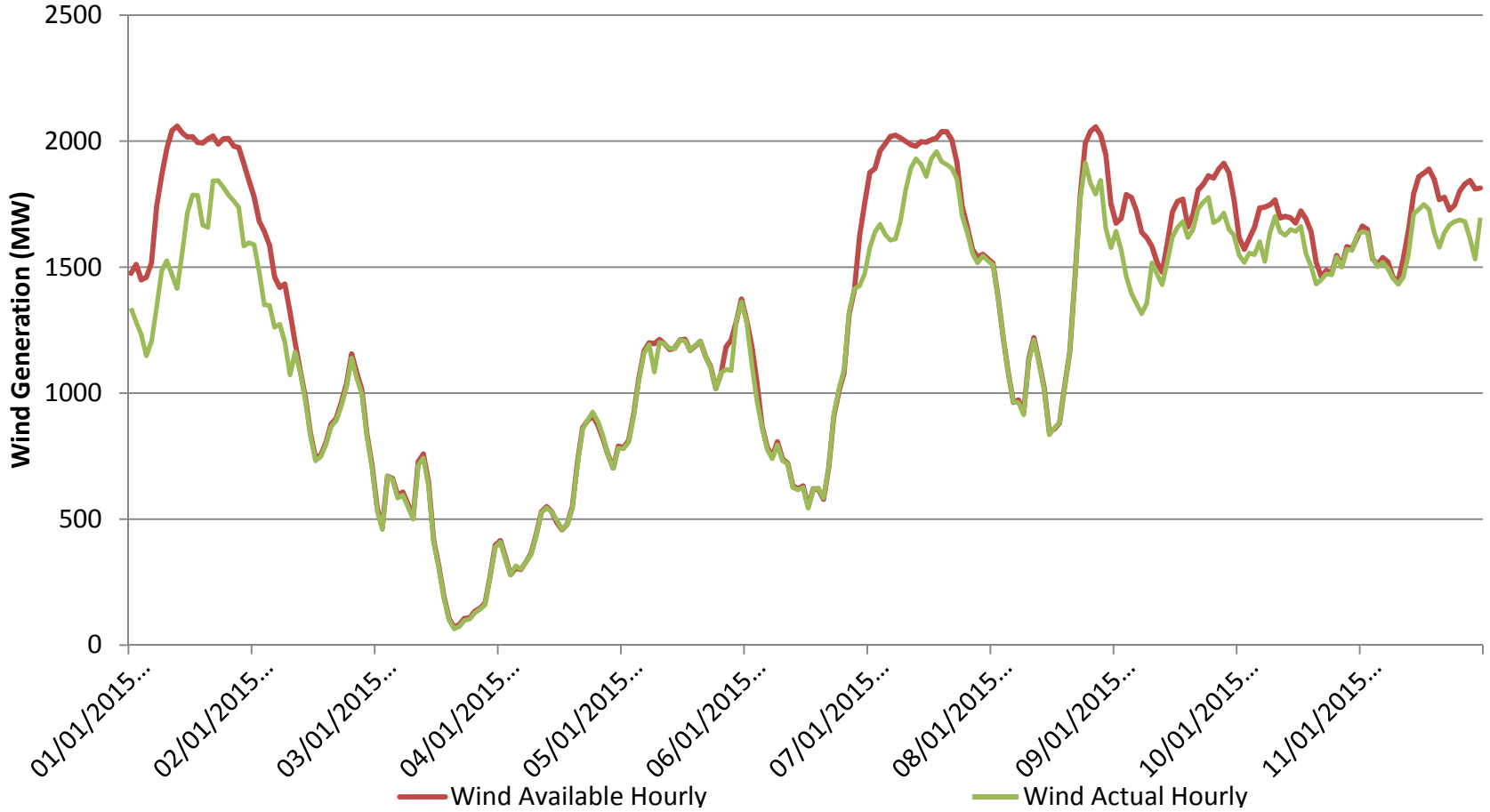
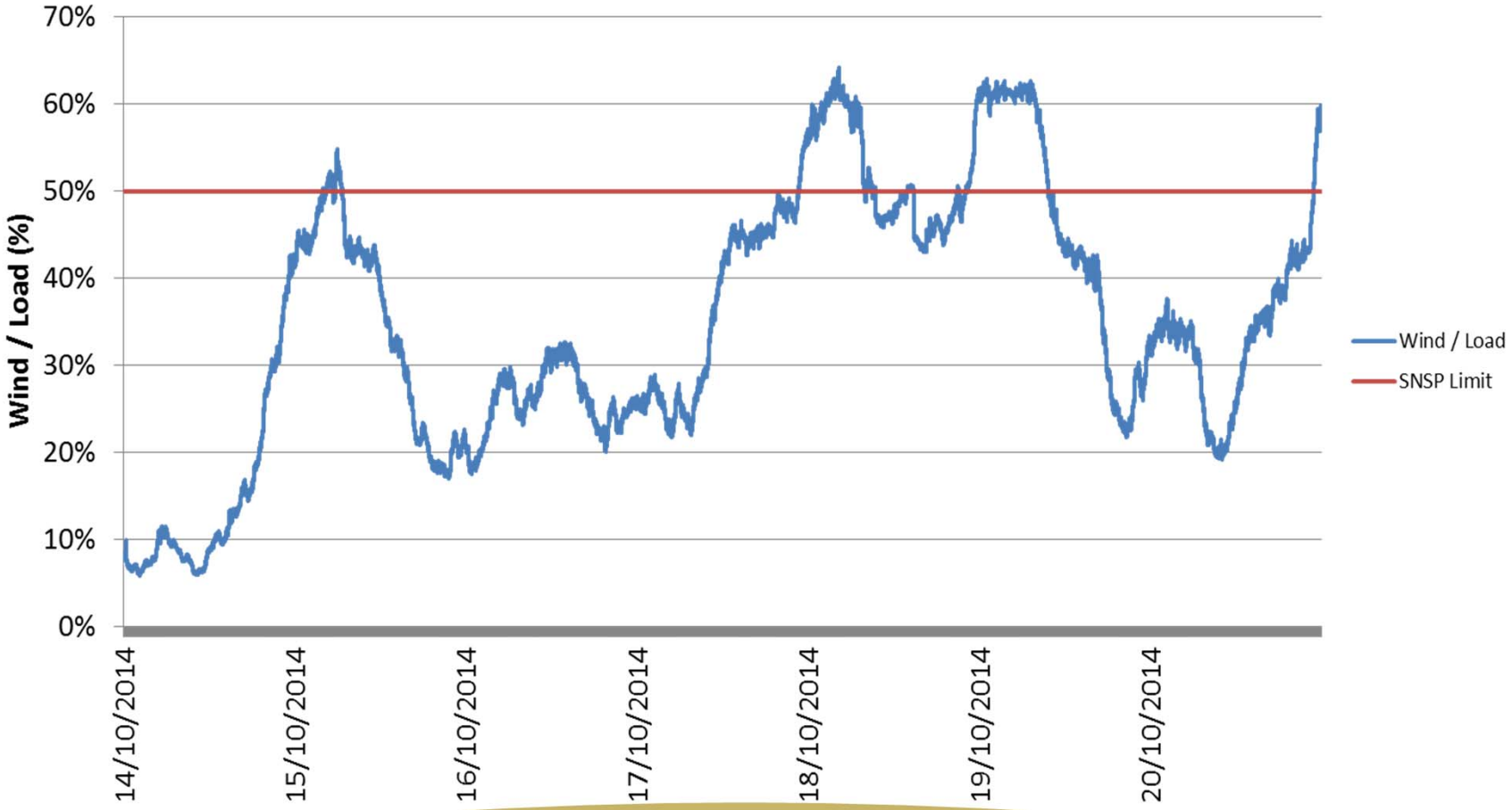
Wind Generation – Early 2015

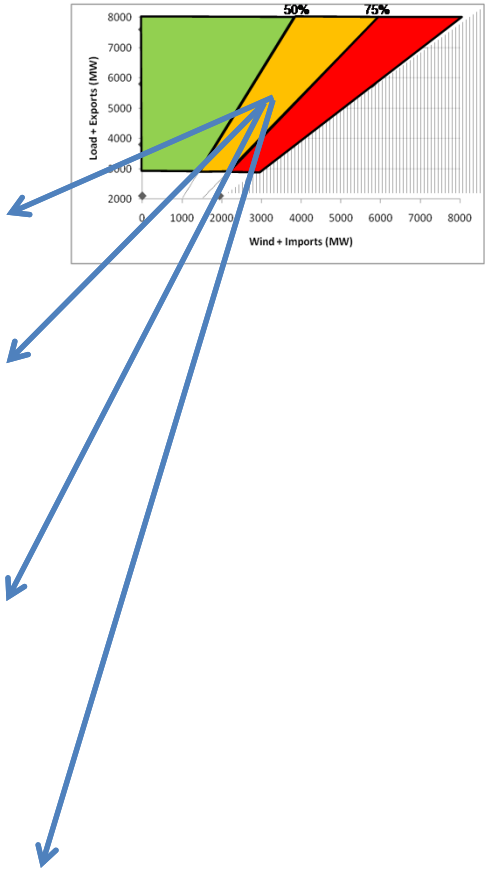


Example – Exporting When Wind/Load > 50%



Tomorrow: Enabling 75%.....

1. Additional System Services
2. RoCoF to 1 Hz/s over 500 ms
3. Revised Operational Policies
4. New Control Centre Tools



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Driver for System Services

RoCoF

Lack of Synchronising Torque

Voltage Dip Induced Frequency Dips

Low System Inertia

Frequency Nadirs

System Ramping Capability

Reactive Power Shortfall

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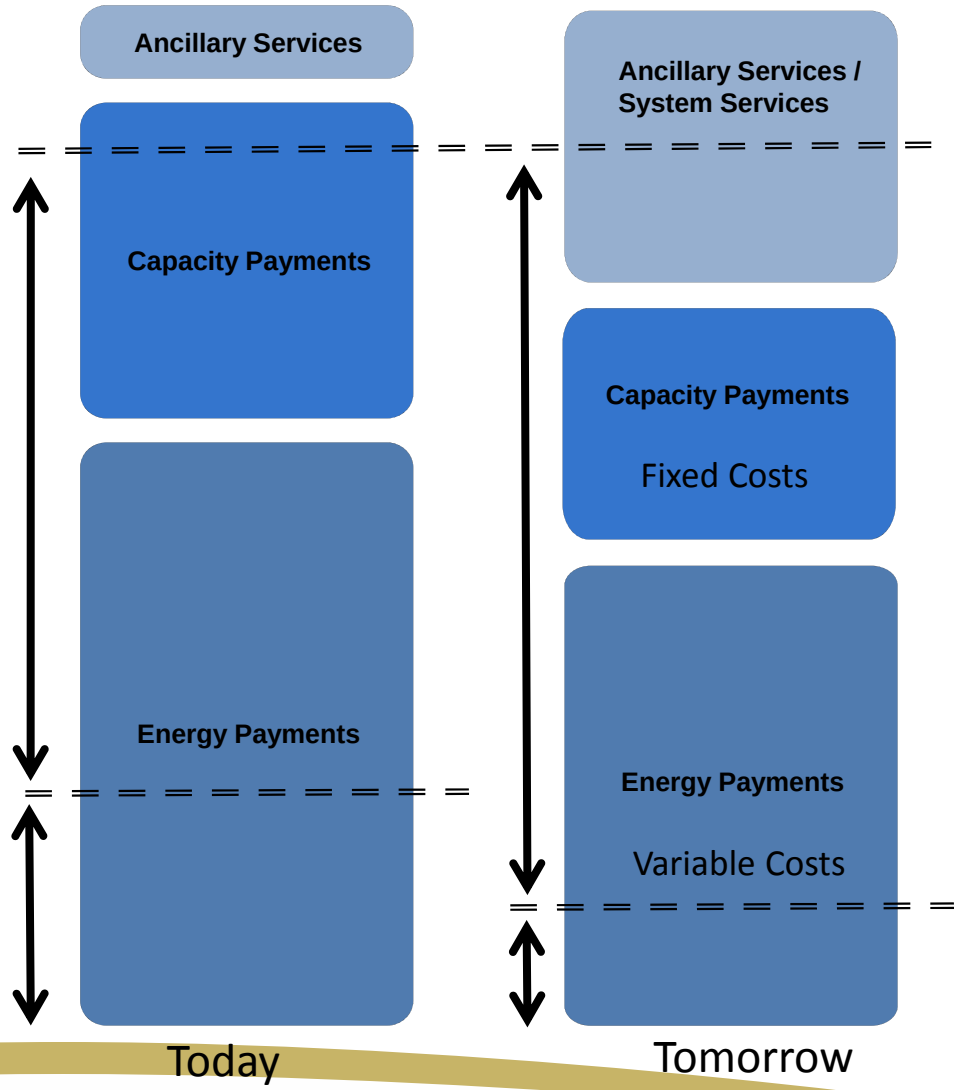
Incentivising the Portfolio: Market Signals

- Incentivising performance of plant
- Financial Mix will move to higher capital lower variable cost technologies
- Obtaining the plant mix that matches the system requirements and achieves the policy objectives



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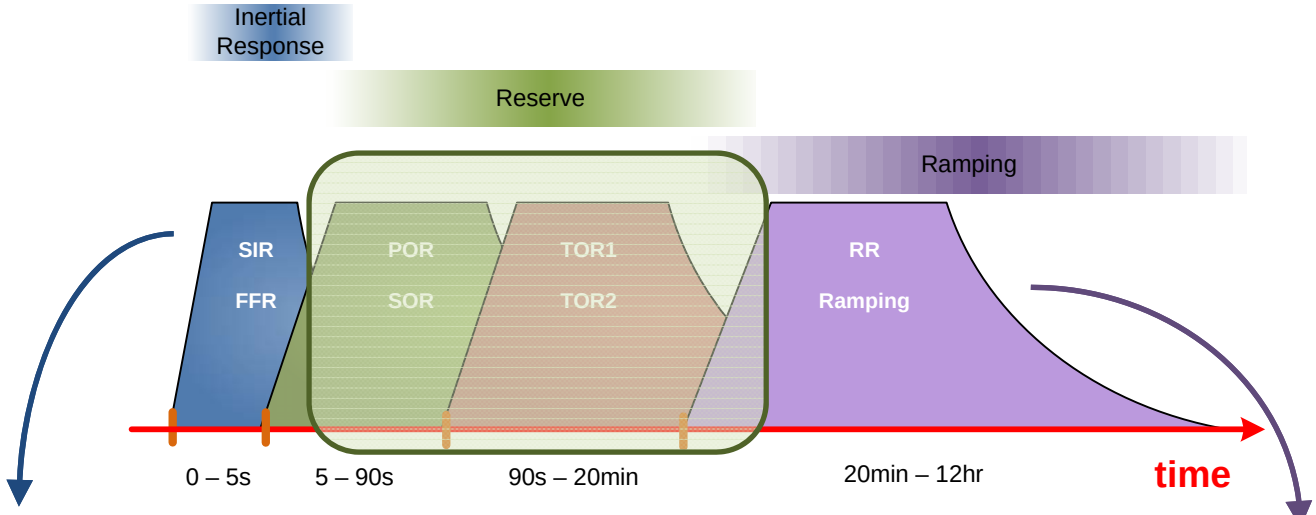
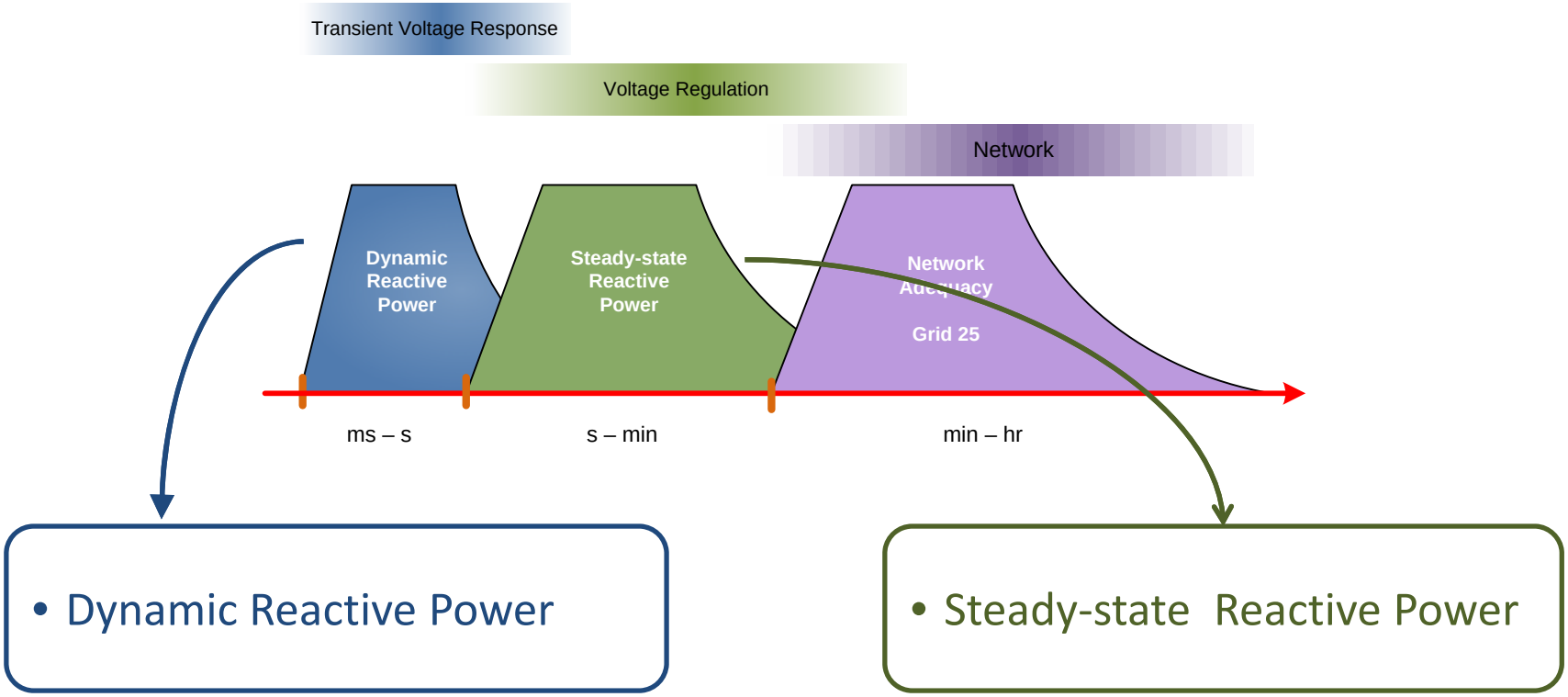
DS3 System Services Frequency Products



- Synchronous Inertial Response
- Fast Frequency Response
- Fast Post-Fault Active Power Recovery

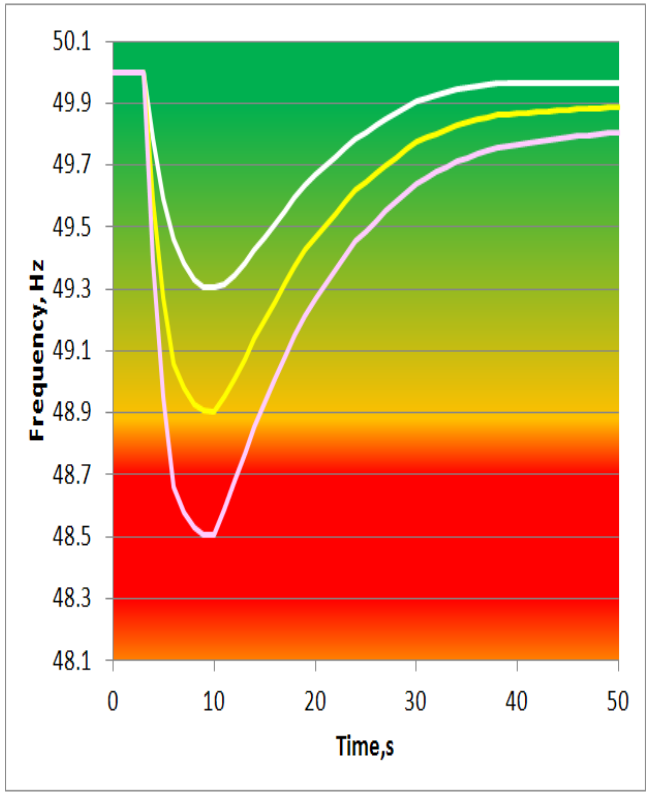
- Ramping Margin

DS3 System Services Voltage Products



RoCoF – Move to New Standard

- Current standard: 0.5 Hz/s
- Proposed standard:
  - 1.0 Hz/s measured over 500 ms
- Differing industry perspectives
  - Wind farms – no issues
  - DSOs require ‘LoM’ protection changes
  - Conventional generators have concerns



RoCoF Implementation Project

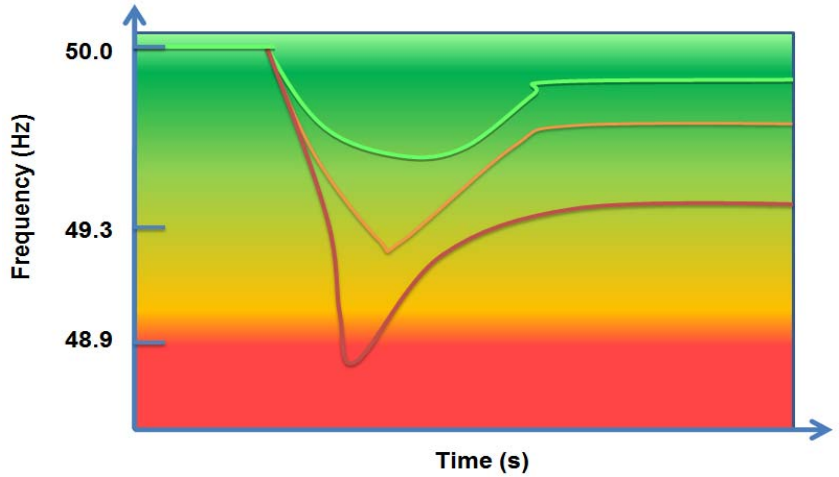
Generator Studies Project

TSO-DSO Implementation Project

"Plan A"

Alternative / Complementary Solutions Project

"Plan B"



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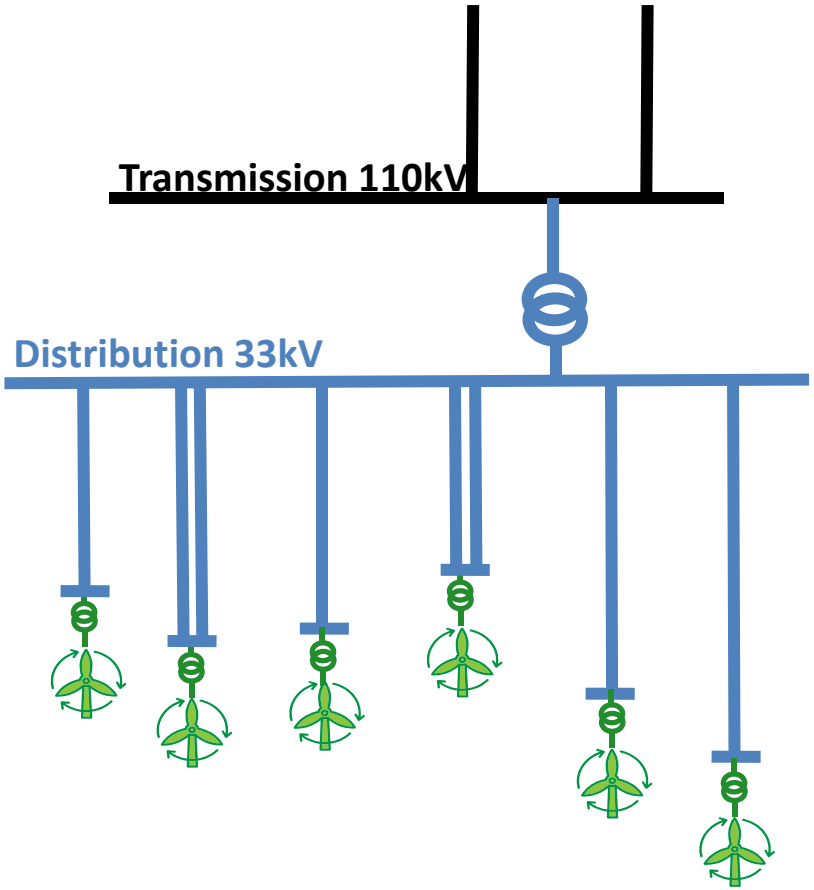
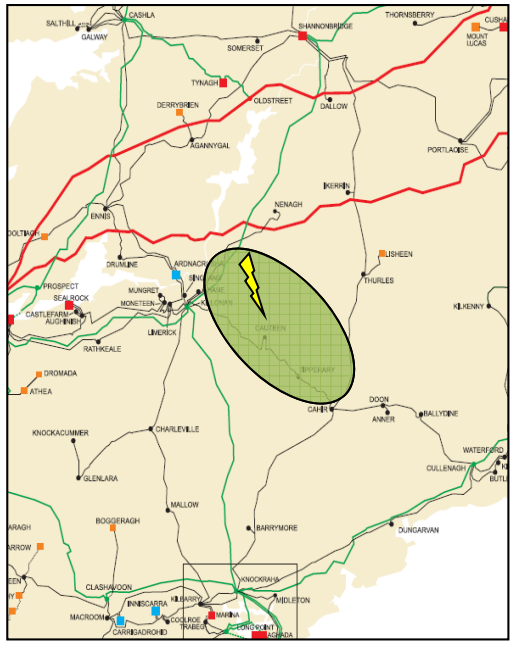
Realising Potential of DSO Generation



TSO-DSO Engagement

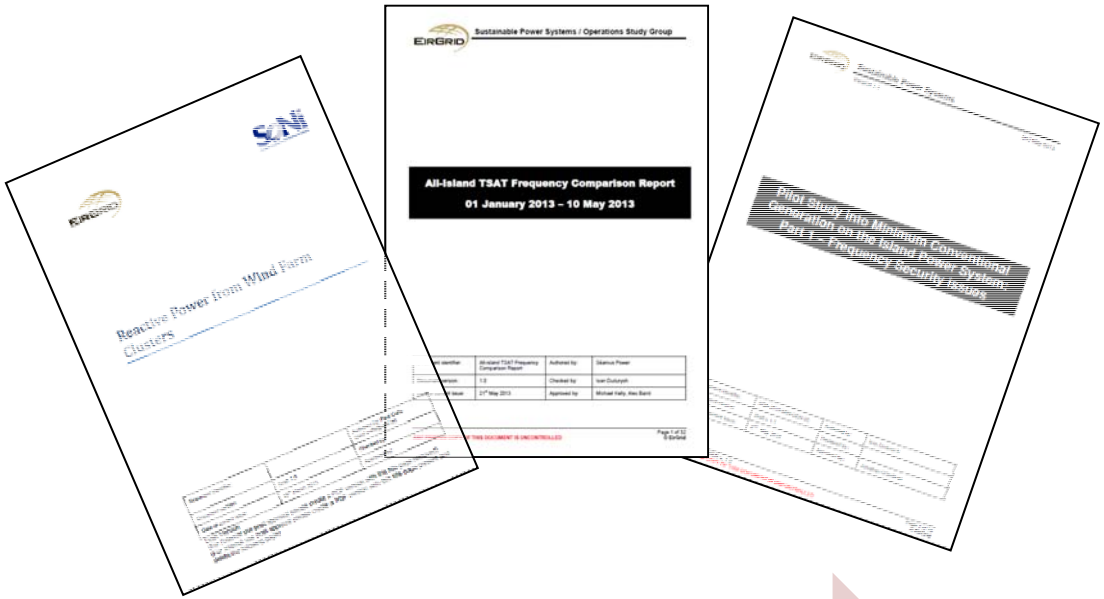
Voltage Control

- DSO implemented TSO-DSO agreed changes at Cauteen wind farm cluster
- Interim measure to improve voltage stability in the area
- Wider reactive compensation studies underway
  - Value of DSO windfarms: significant off setting of transmission reactive compensation requirements



2025	Power Factor of TYPE B Wind Farms	MVAr Required
WP	0.95 Leading	145
WP	0.98 Leading	105
WP	Unity Power Factor	55
WP	Voltage control ± 0.95	15

Operational Policies



Policy v1.0 → Pilot → Widespread Implementation v2.0

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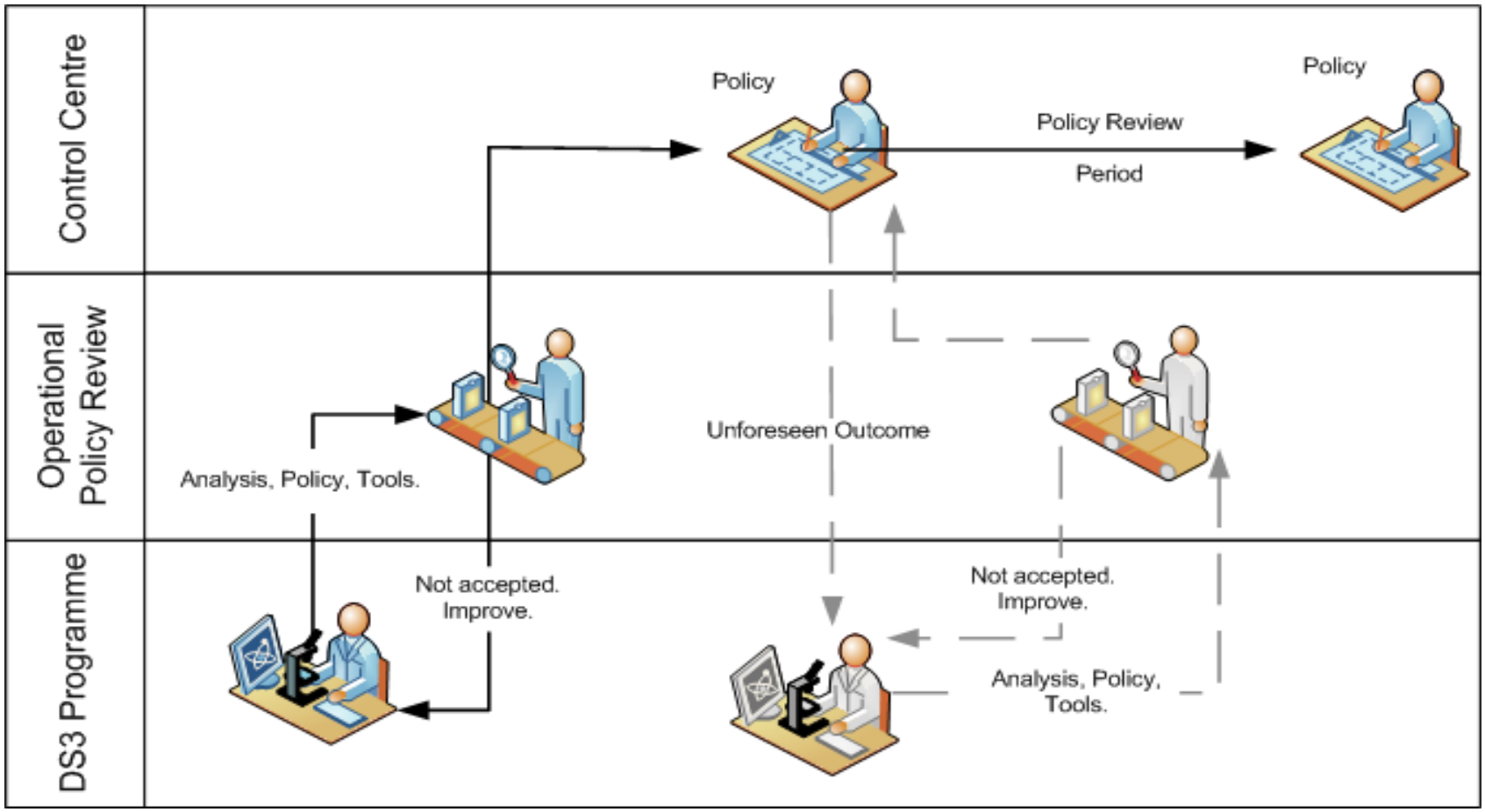
DS3: Operational Control Process



Control Centre Tools

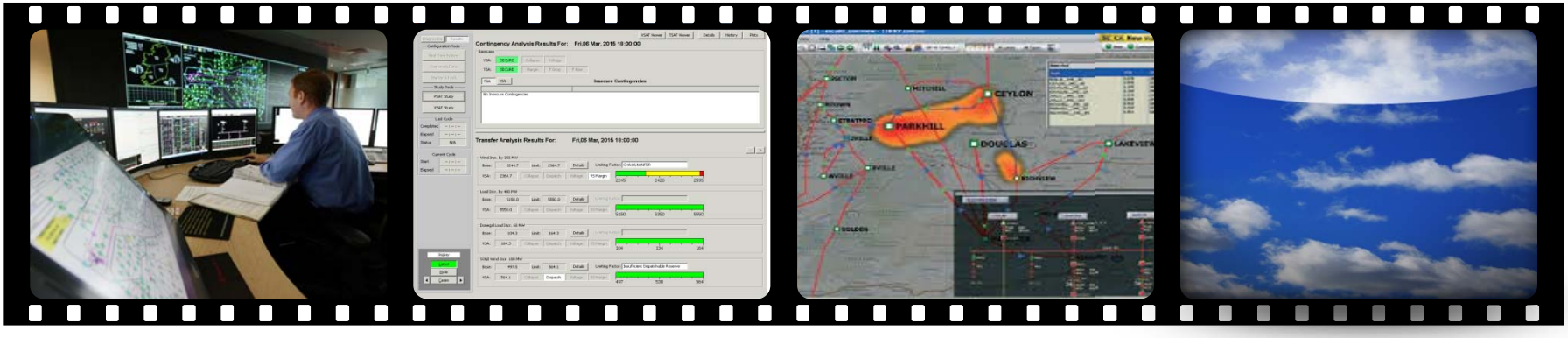
Existing Control Centre Tools

2011

New Tools

Regulation, Ramping, Voltage Trajectory….

2015 - 2017



Tools Delivered

WSAT, Short Circuit, Wind Dispatch, Synchrophasor….

2012 - 2015

Blue Sky Thinking

2017 - 2020

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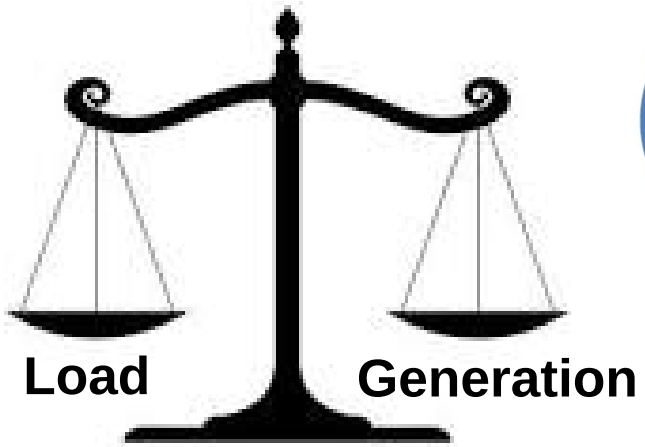
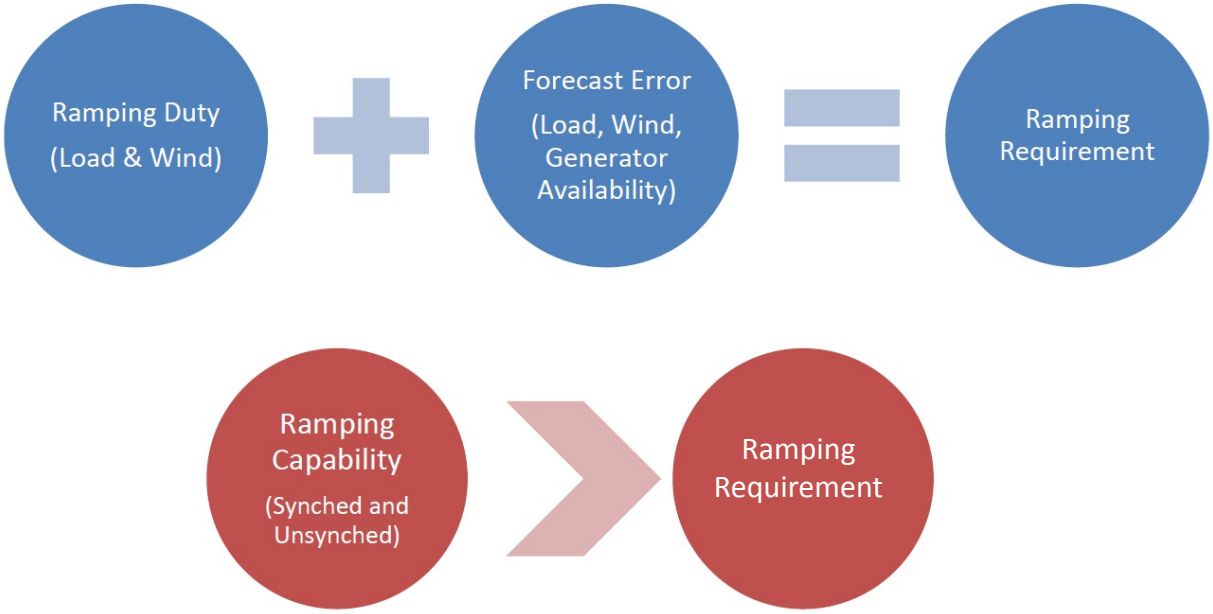
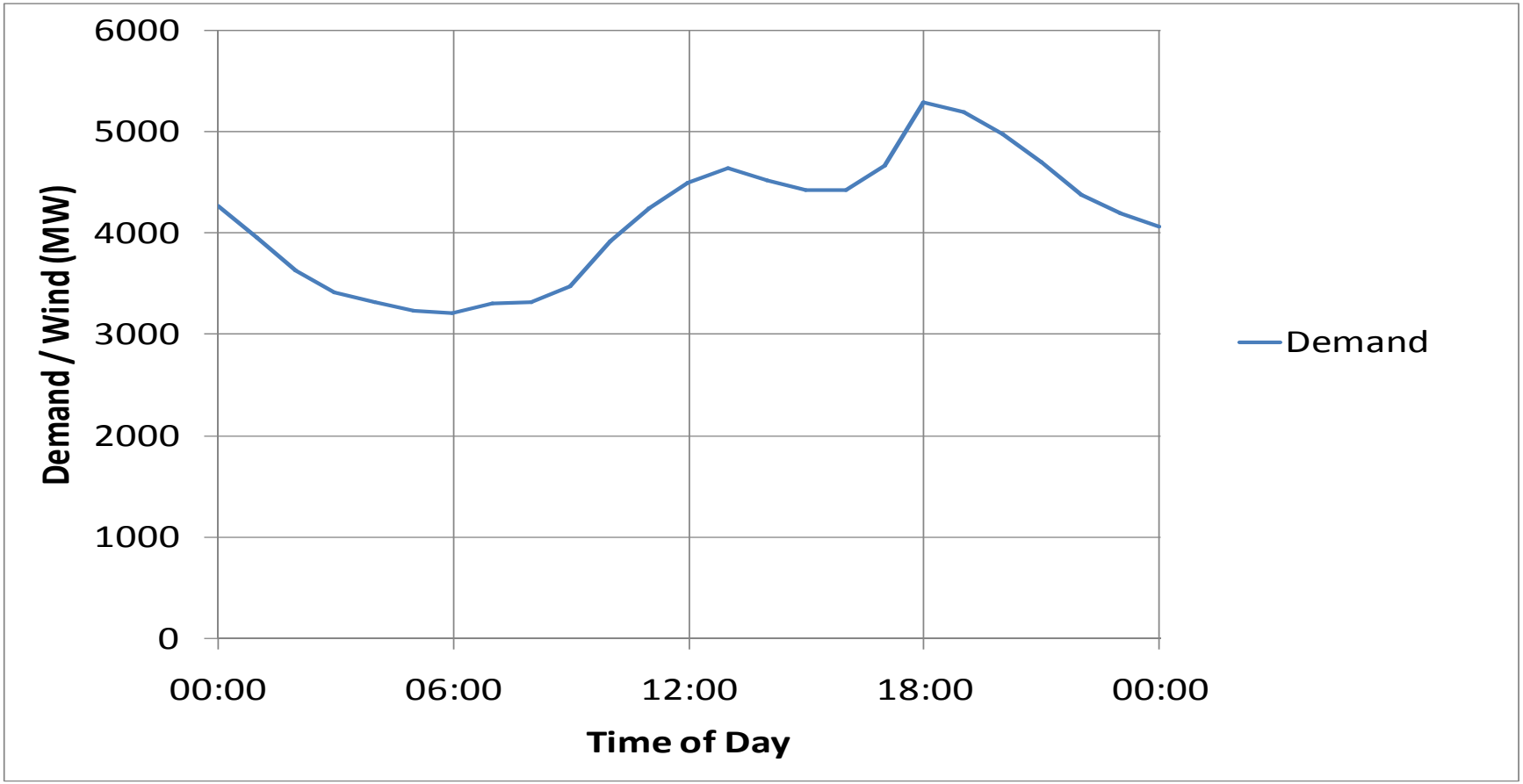
Ramping Example

Ramping

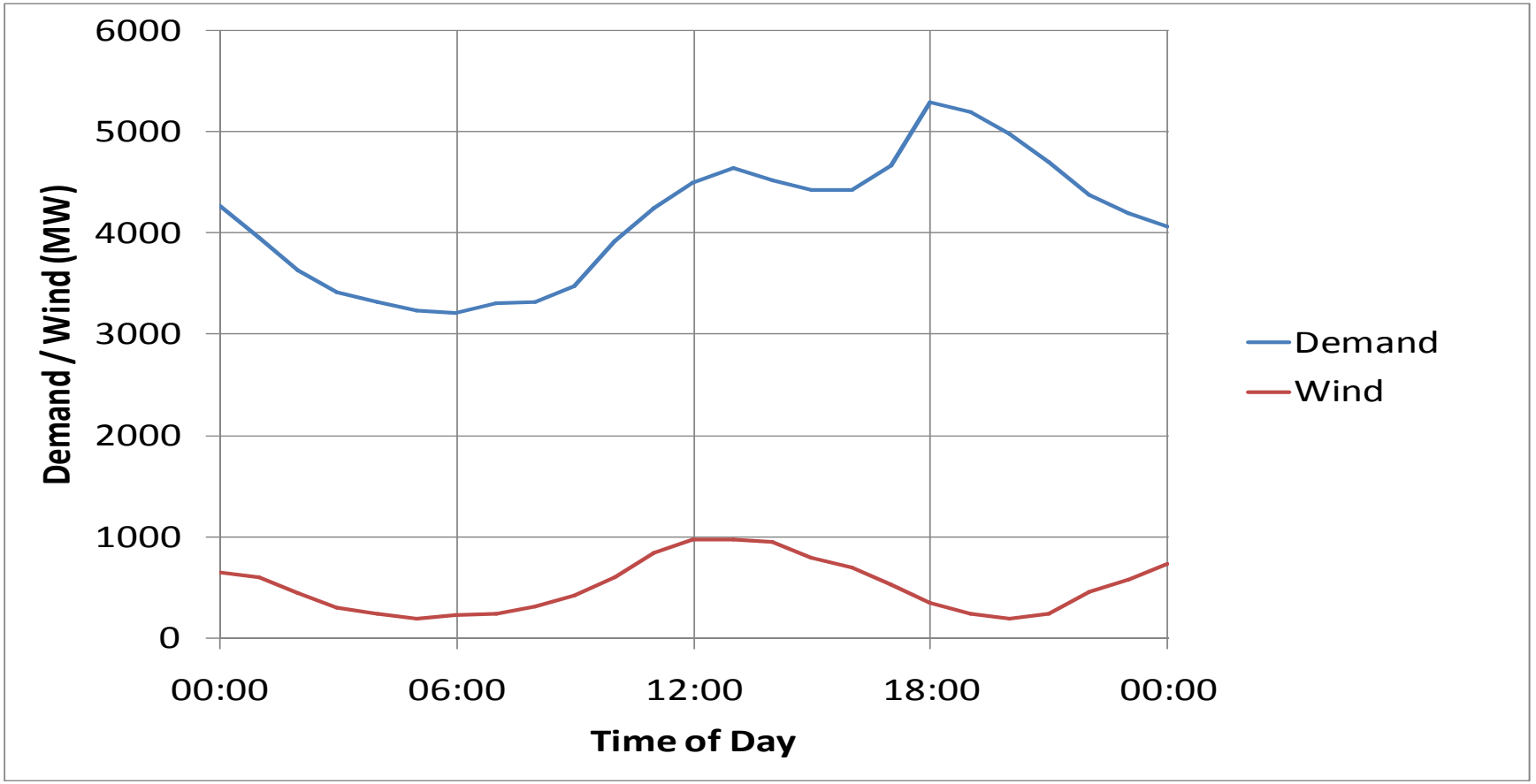

Load
Generation


Ramping Duty
(Load & Wind)
Forecast Error
(Load, Wind, Generator Availability)
Ramping Requirement
Ramping Capability
(Synched and Unsynched)
Ramping Requirement

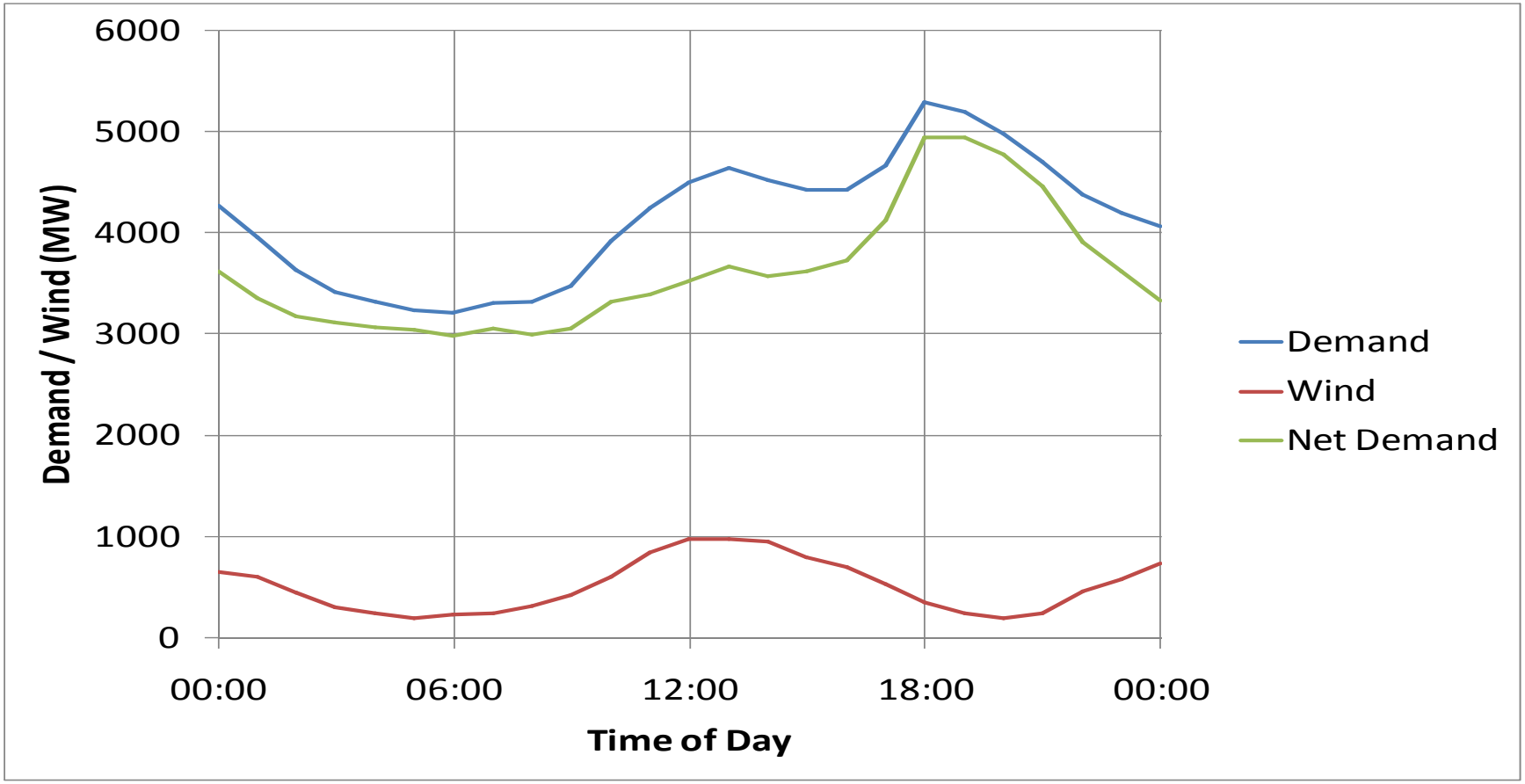
Ramping Concept



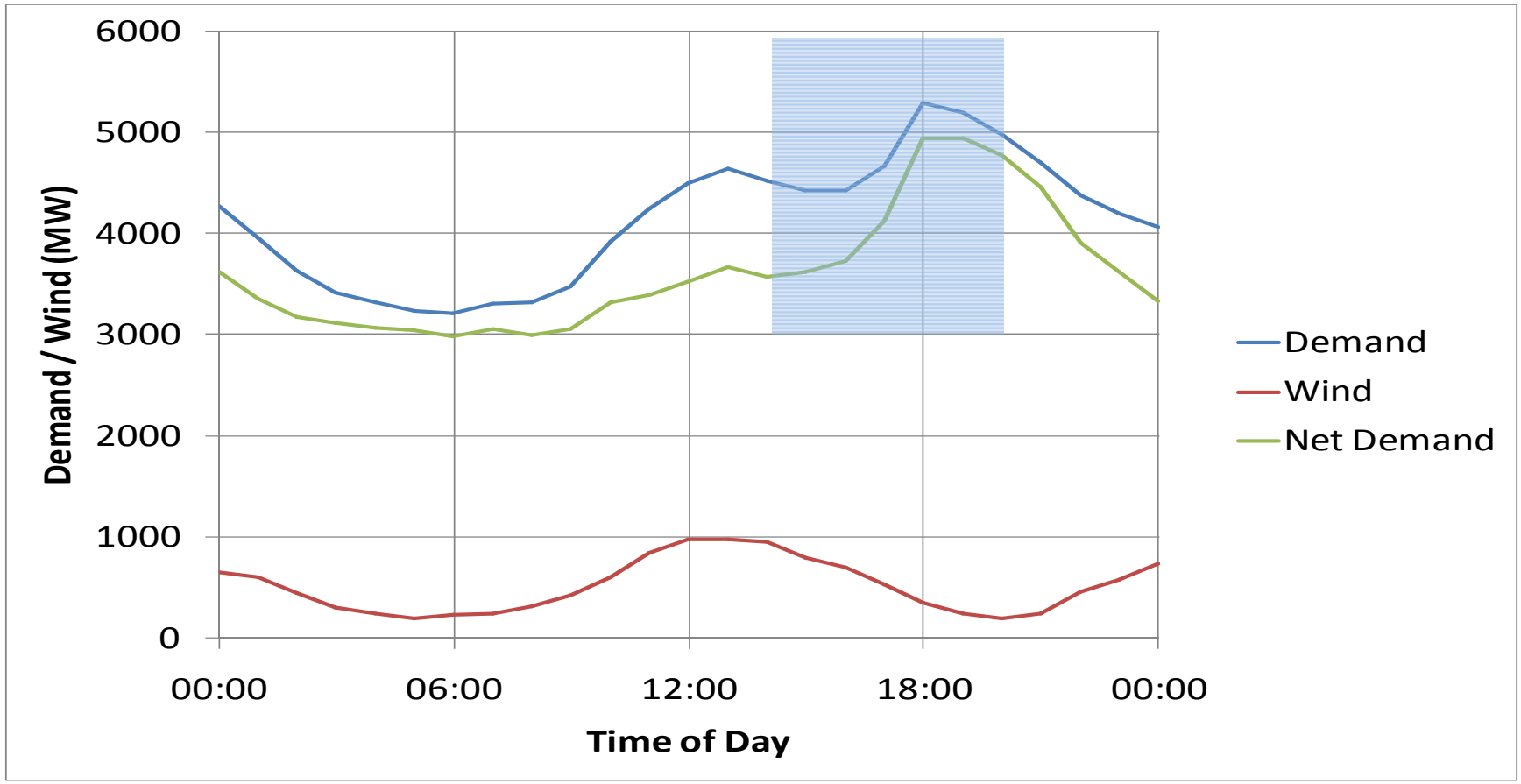
Ramping Concept



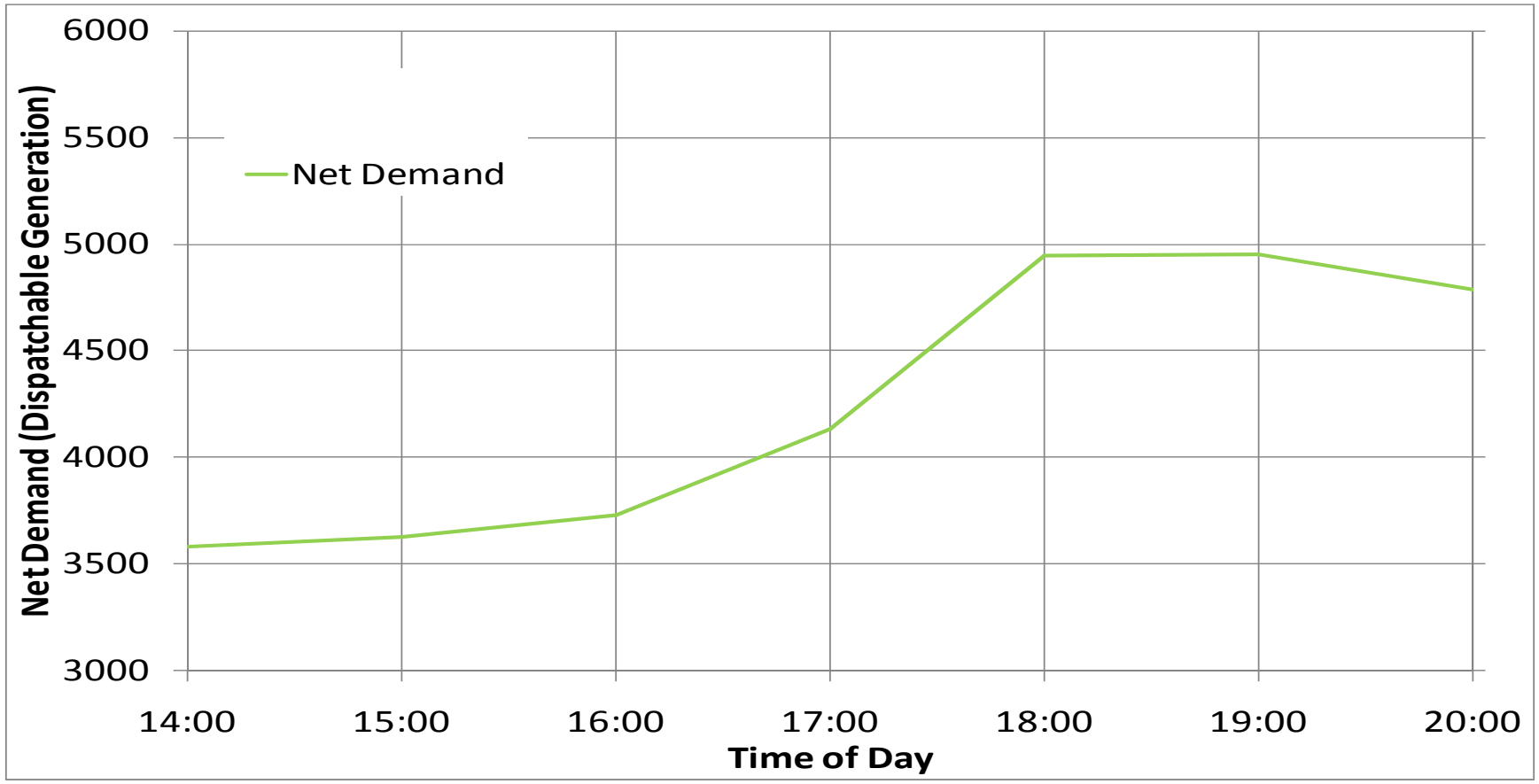
Ramping Concept



Ramping Concept



Ramping Concept



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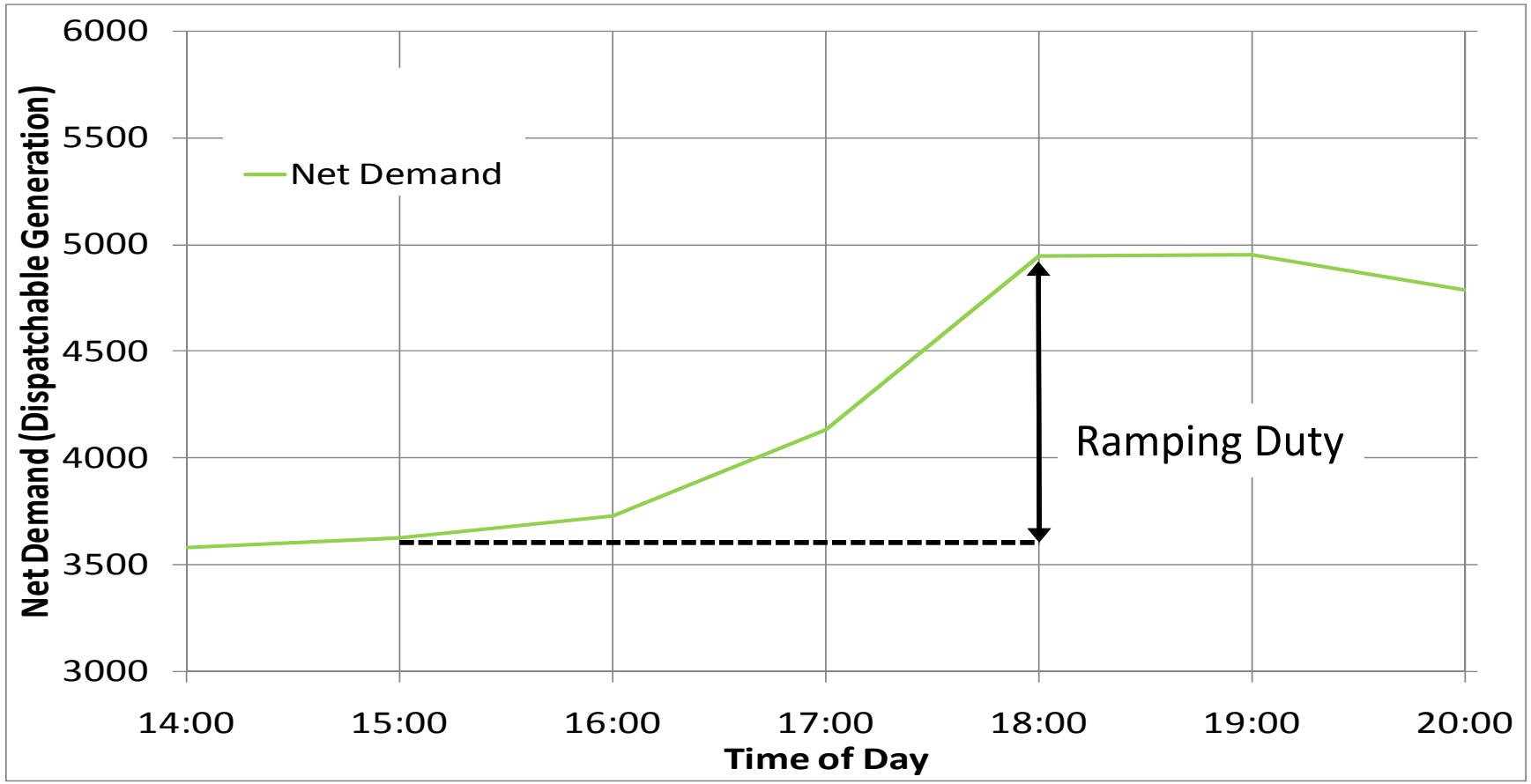
Ramping Concept



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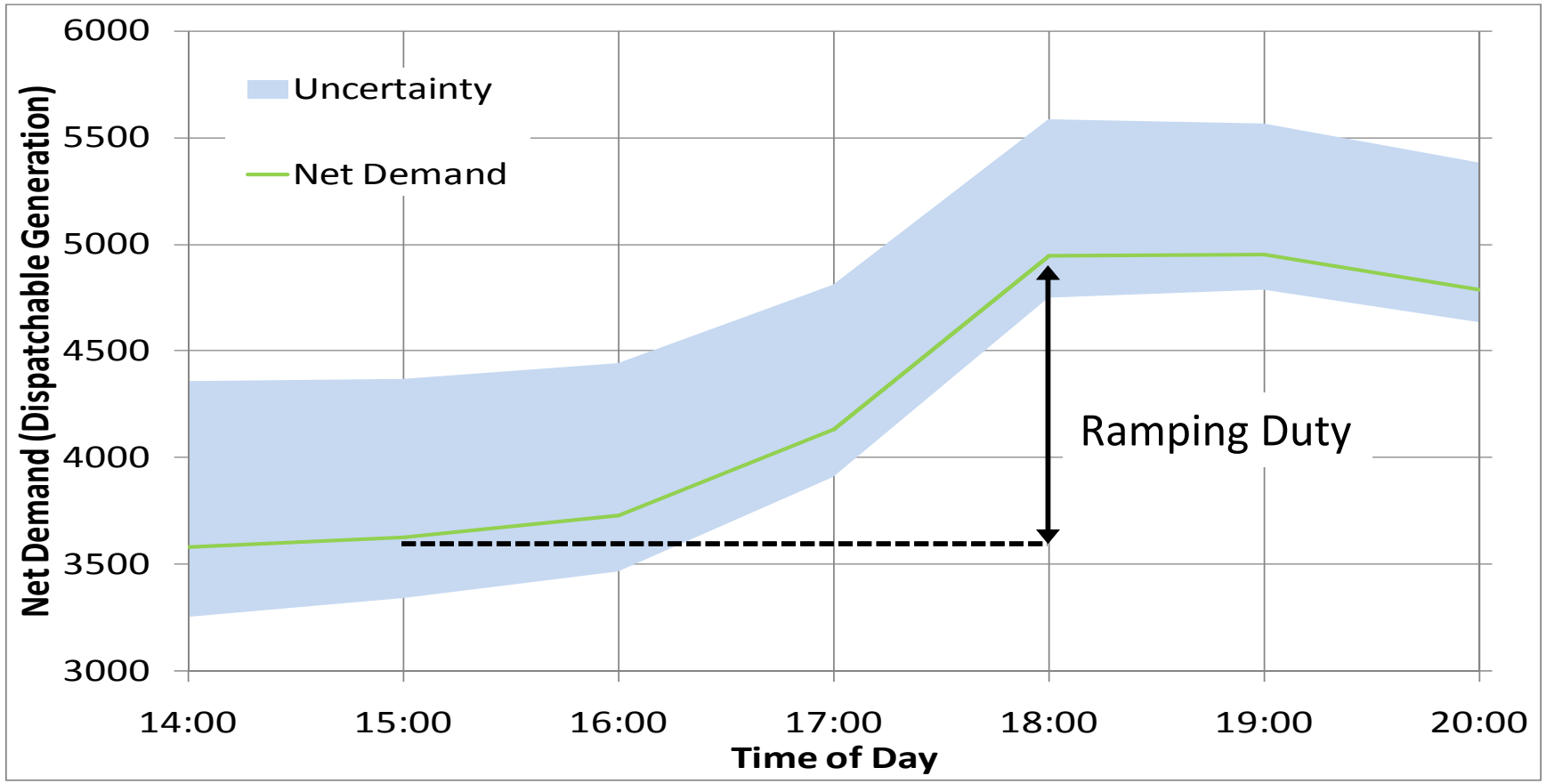
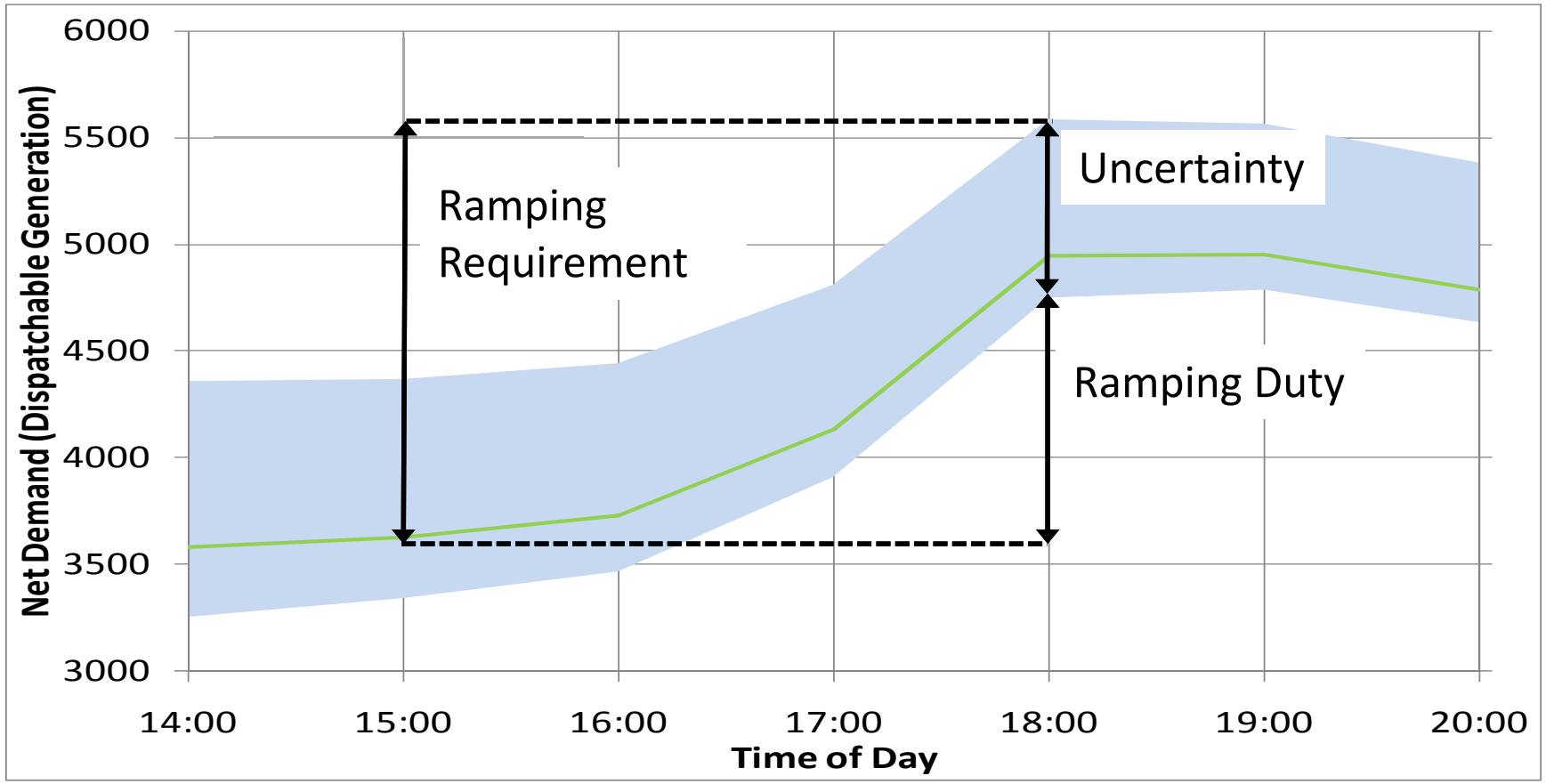
Ramping Concept



Ramping Concept



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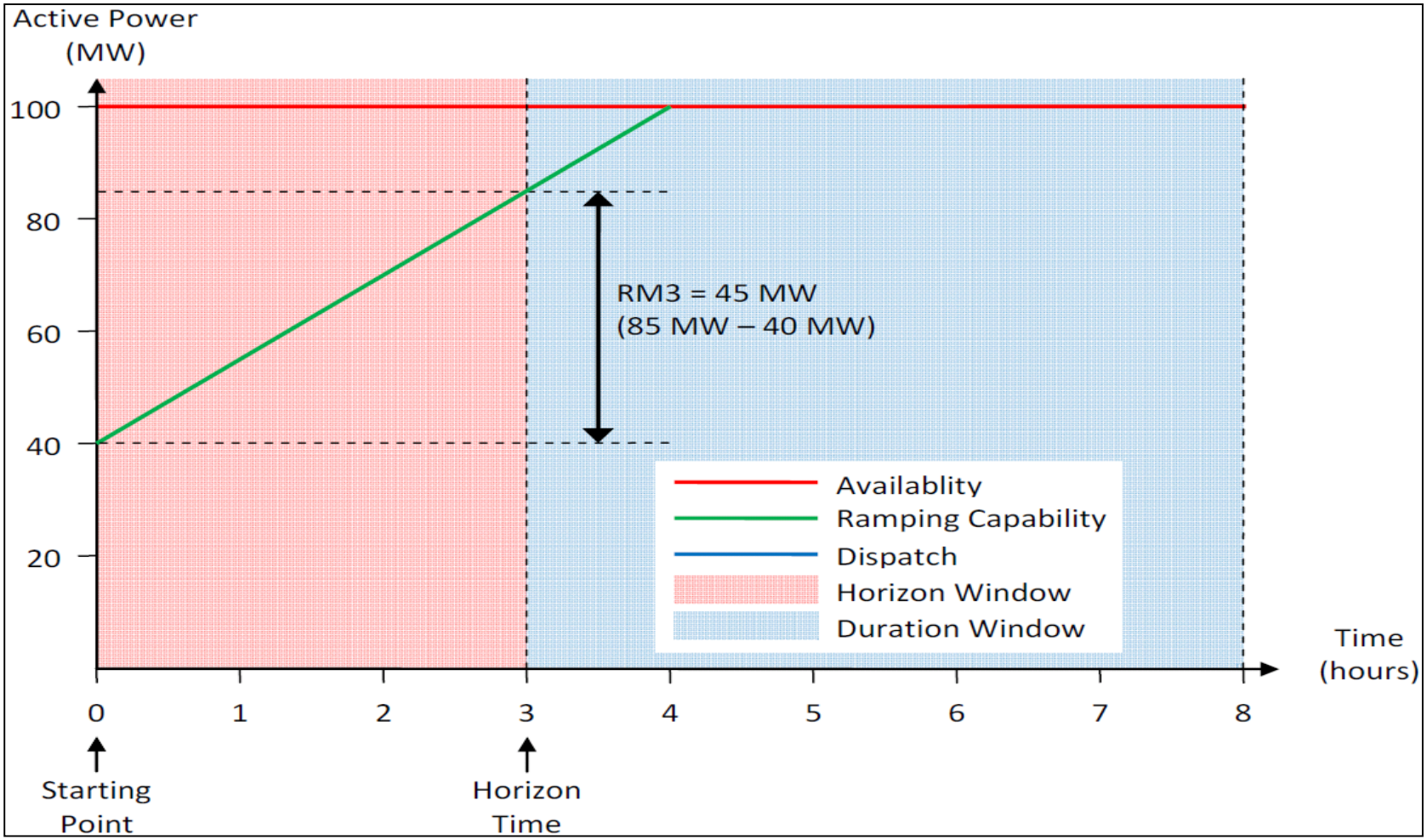
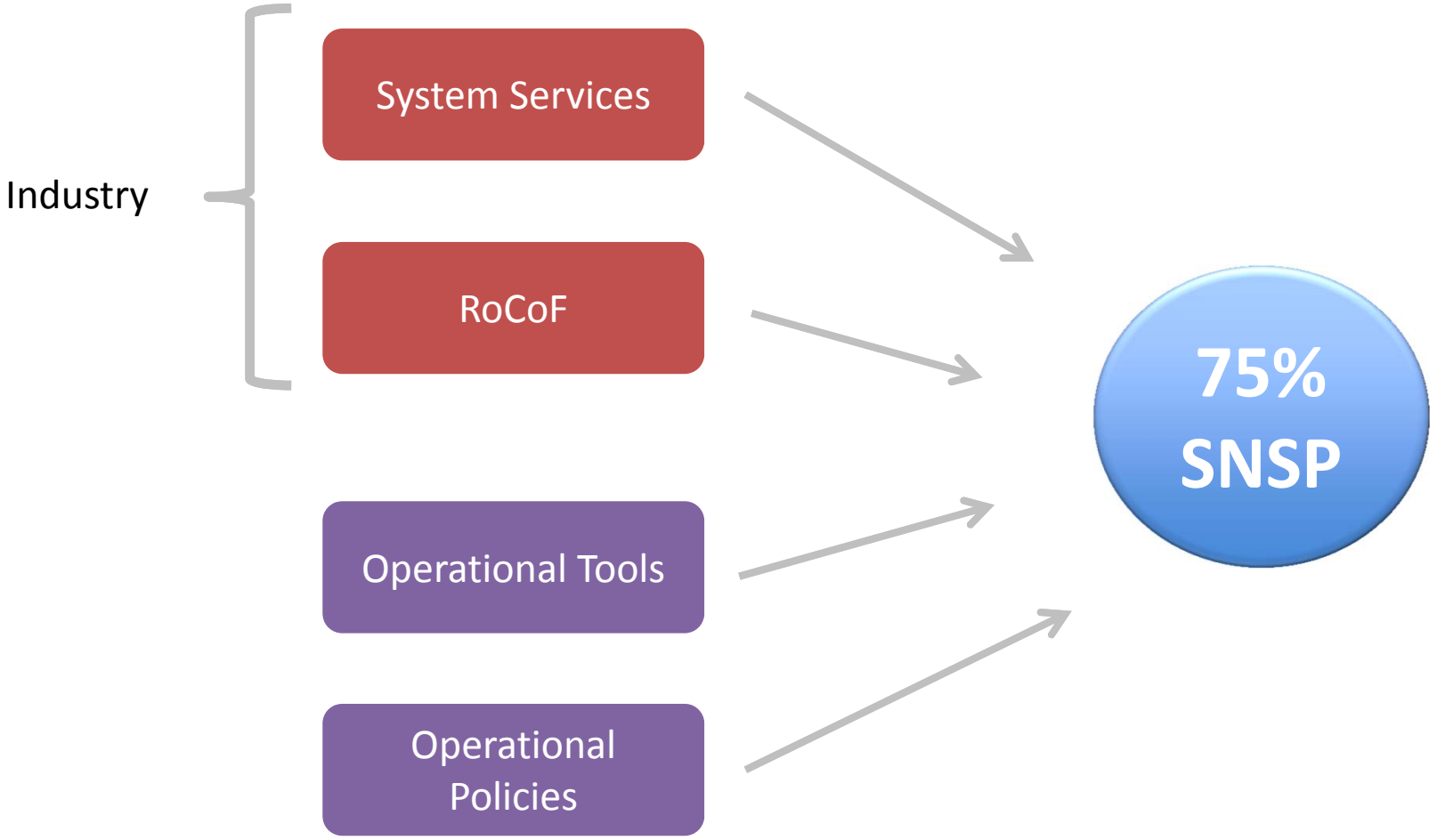
Ramping Margin (RM1, RM3 & RM8)



Summary

Complementary Progress Essential



DS3 Programme Summary

- Regularly operating at 50% SNSP and 65% wind/load
- RoCoF workstream progressing
- System Services underway but significant design and implementation issues need to be worked through
- Need to maximise contribution from embedded generation – DSO/DNO input key
- Operational policy and tools need to be developed in parallel in a considered manner

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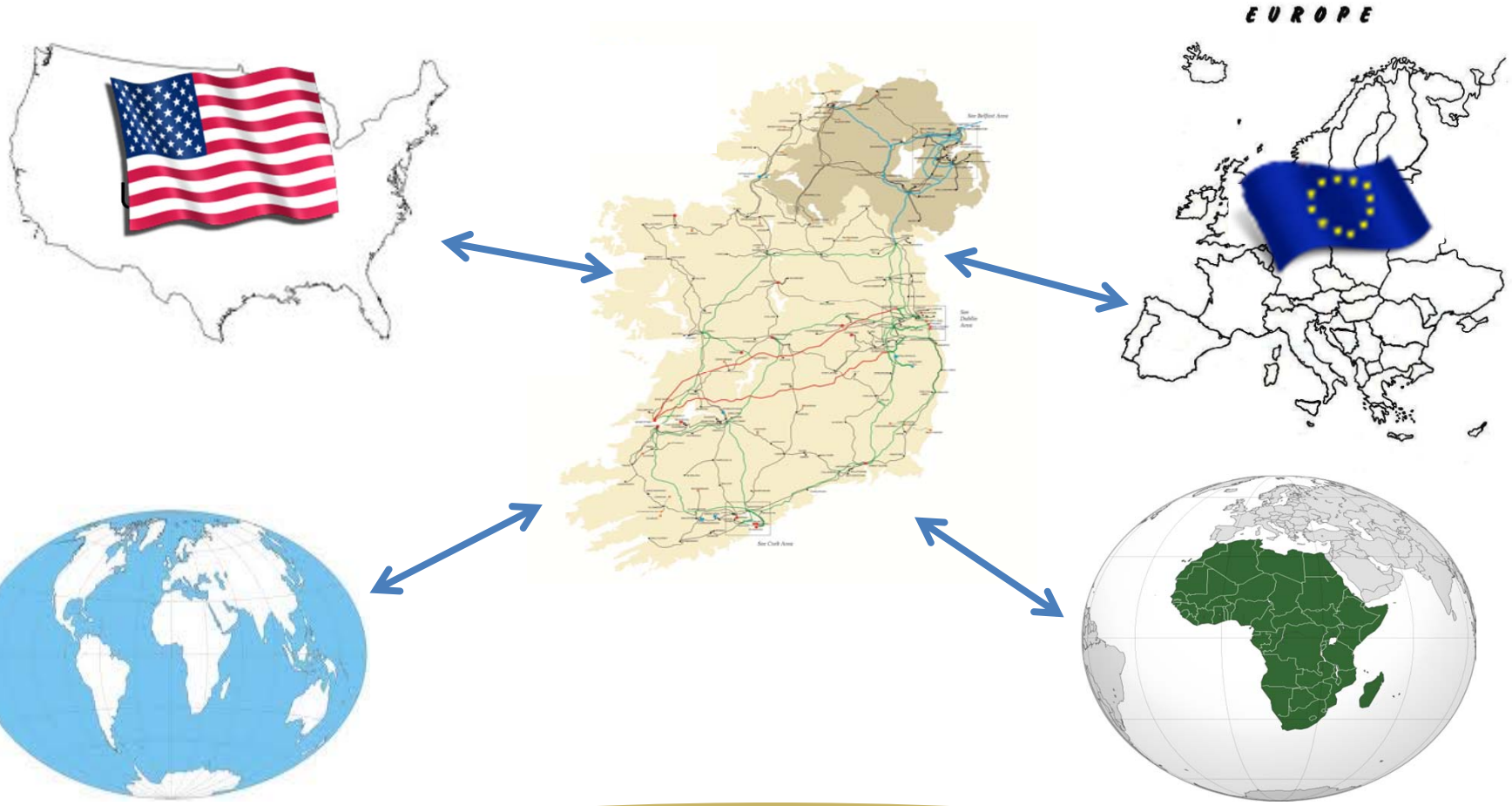
Energy sector is going through a period of remarkable transition

EirGrid's experience can be leveraged to benefit other power systems



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Sowing the Seeds of solution