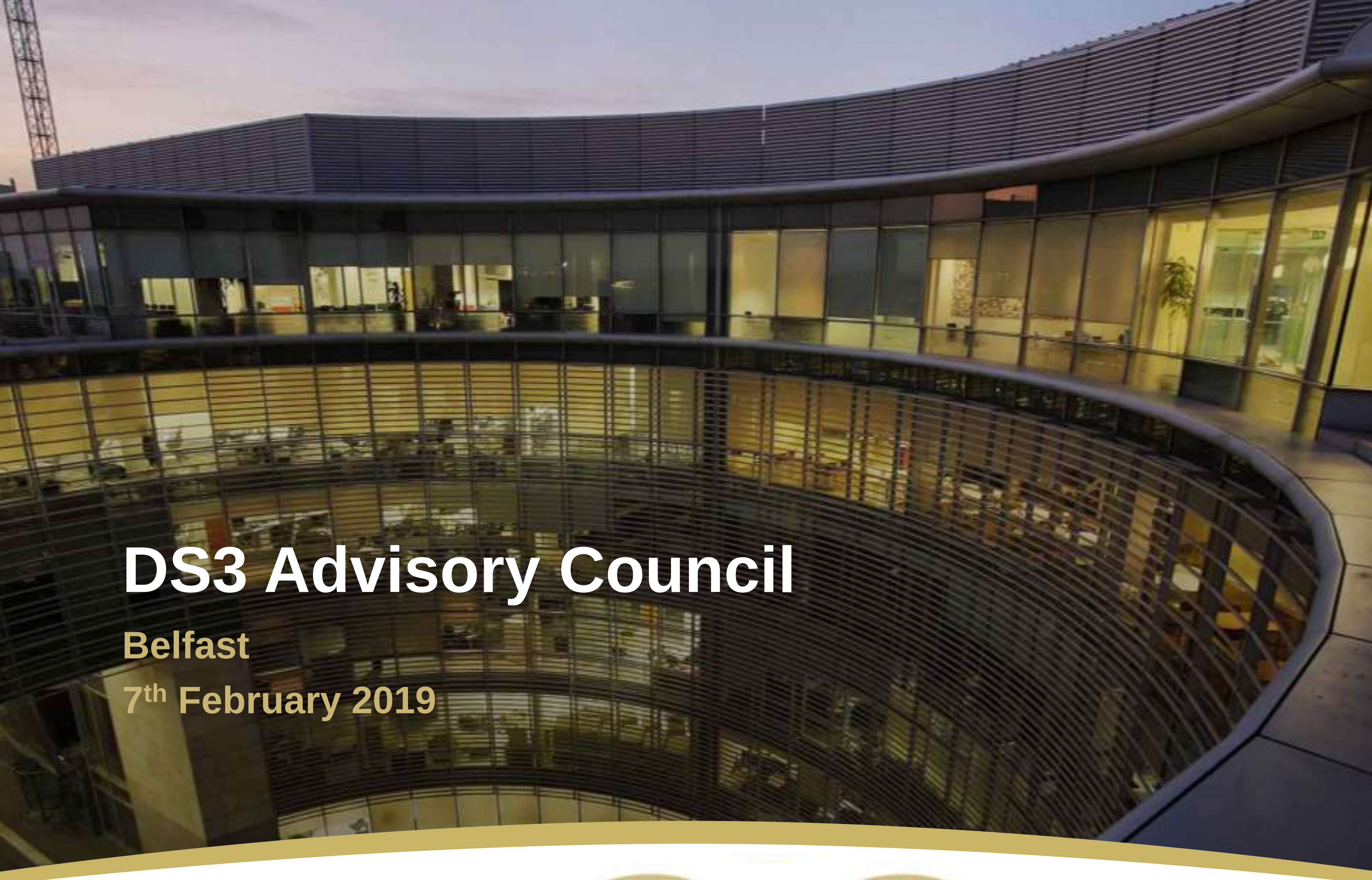


DS3 Advisory Council

Belfast

7th February 2019

EIRGRID SONI

Agenda - Morning

Topic	Time	Speaker
Introduction & Welcome	10:30	Jon O'Sullivan , Eirgrid (10 mins)
Industry Presentation	10:40	IWEA - SEAI project on curtailment of wind (40 mins inc. discussion)
DS3 Programme Status Update	11:20	Presentation: Ian Connaughton, EirGrid (10 mins) Discussion: All (10 mins)
Industry Presentation	11:40	Tynagh (Colin D'Arcy)- I-SEM experience (40 mins inc. discussion)
Lunch & Networking (12.20 – 13.05)		

EIRGRID SONI

Agenda - Afternoon

Topic	Time	Speaker
2018 Wind Update	13.05	Update: Noel Cunniffe, EirGrid (5 mins) Discussion: All (5 mins)
RoCoF	13.15	Update: John Young , EirGrid (5 mins) Update: Jon O’Sullivan/Noel Cunniffe, EirGrid (5 mins) Update: NIE Networks, ESB Networks (10 mins) Discussion: All (10 mins)
Beyond 2020 – EU-SysFlex	13:50	Presentation: Noel Cunniffe, EirGrid (15 mins) Discussion: (15 mins)
AOB	14:20	All (15 mins)
Closing Remarks and Actions	14.30	Jon O'Sullivan, EirGrid (10 mins)
Session Closed (14:35)		

EIRGRID SONI

Industry Presentation

IWEA – SEAI Project on wind curtailment

Contents

WP3 – 70% RES-E without mitigation

WP4 – Impact of SNSP / Min Gen

WP5 – Increasing Wind Capacity Factor

WP7 – Interconnectors and storage

WP8 – Demand Flexibility

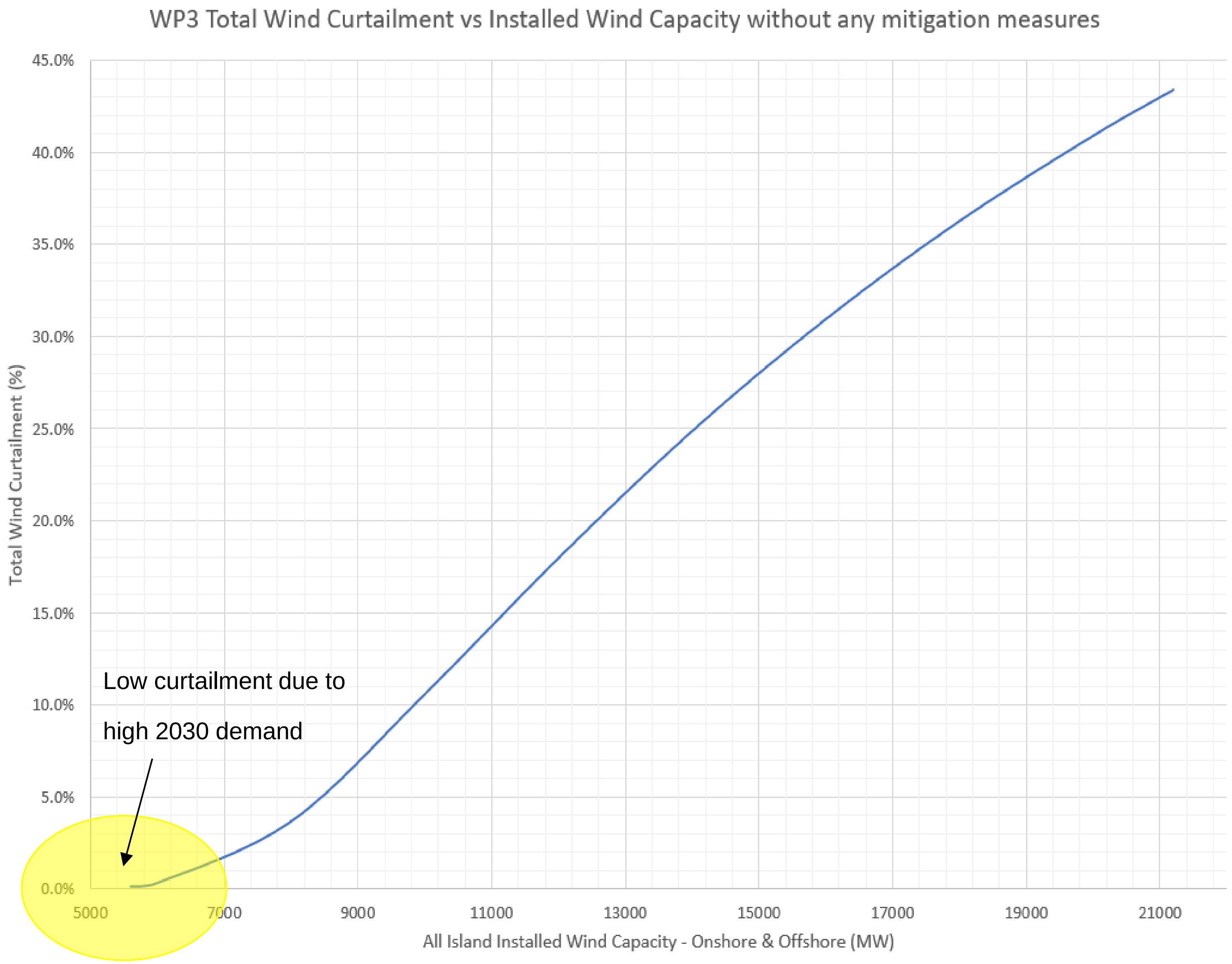
WP9 – Feasible 2030 scenarios

Preliminary results on WP11 – 2040 scenarios

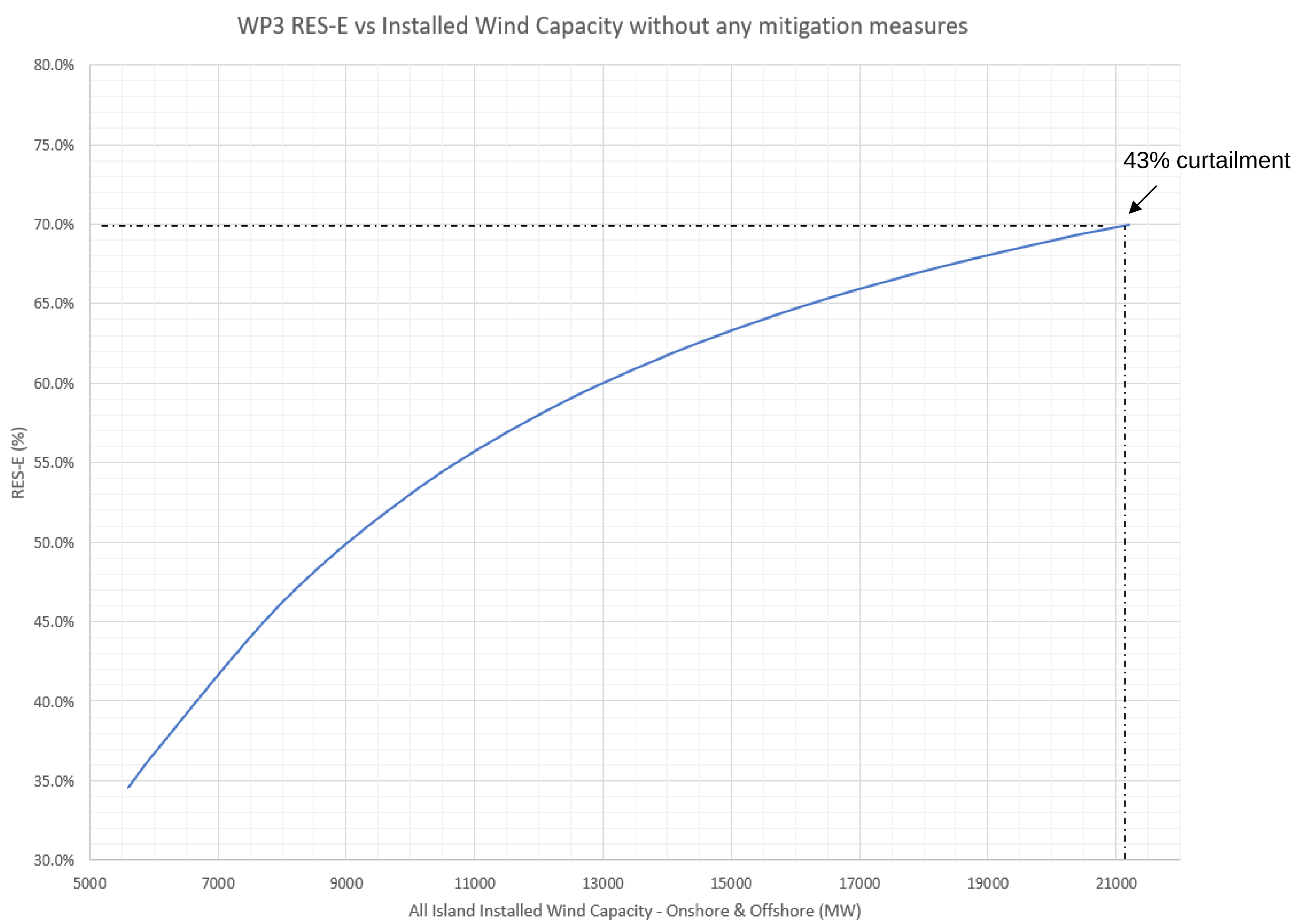
1. WP3 – 70% RES-E without mitigation - Wind

FIXED INPUT ASSUMPTIONS		
Total Solar	323	MW
Uncontrollable Wind	751	MW
Uncontrollable Solar	166	MW
Wind Capacity Factor	34.0%	
Solar Capacity Factor	10.0%	
Idealised Interconnectors	380	MW
Existing Pumped Hydro	219	MW
Existing Pumped Hydro	1314	MWh
New Pumped Hydro	0	MW
Batteries	0	MW
Total Demand	53,838,465	MWh
Included in this demand are:		
Additional datacentres above 2015	1,591	MW
Electric Vehicles	629,398	No.
Residential Heat Pumps	396,302	No.
SNSP	75%	
Conventional Minimum Generation	1400	MW

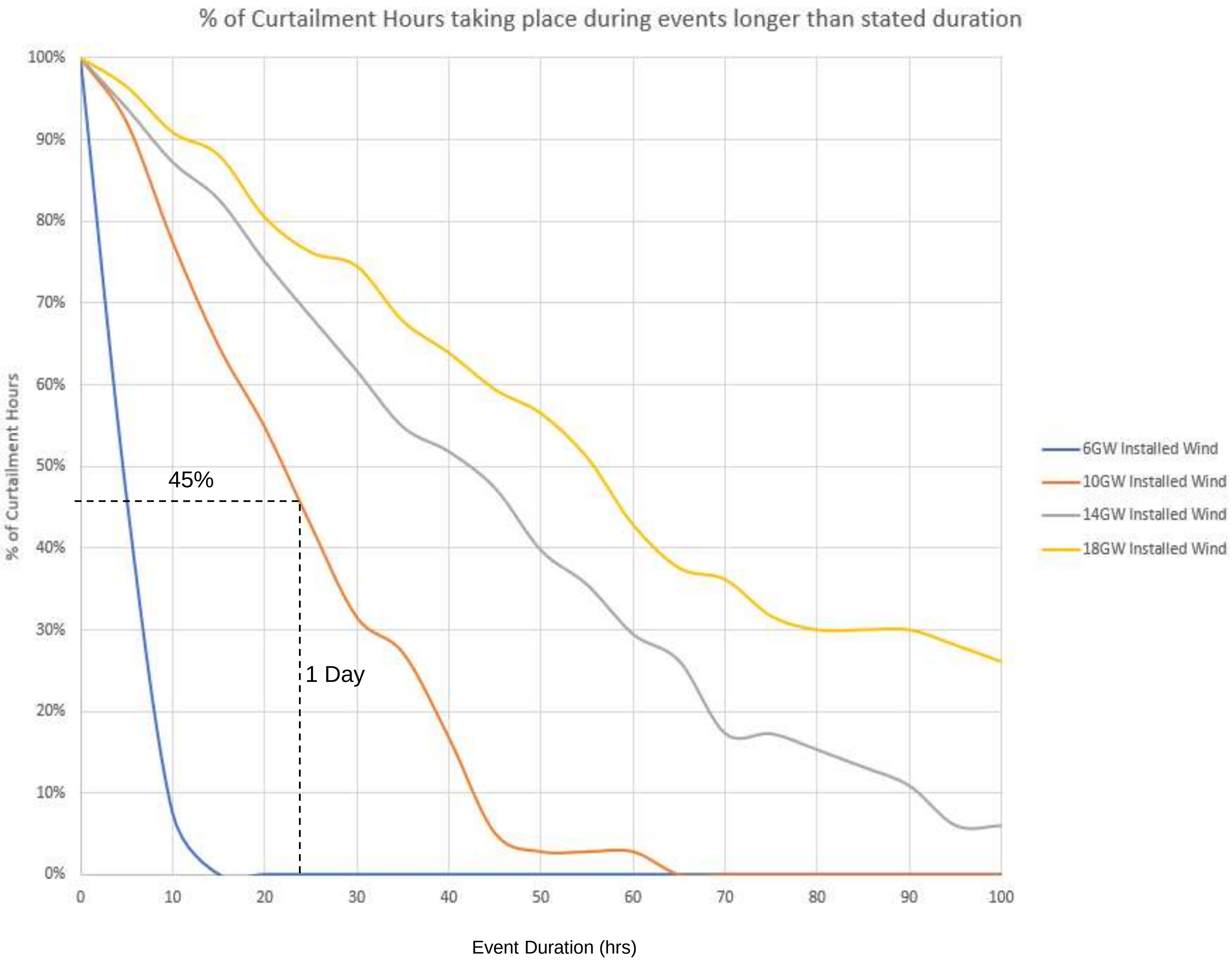
1. WP3 – 70% RES-E without mitigation - Wind



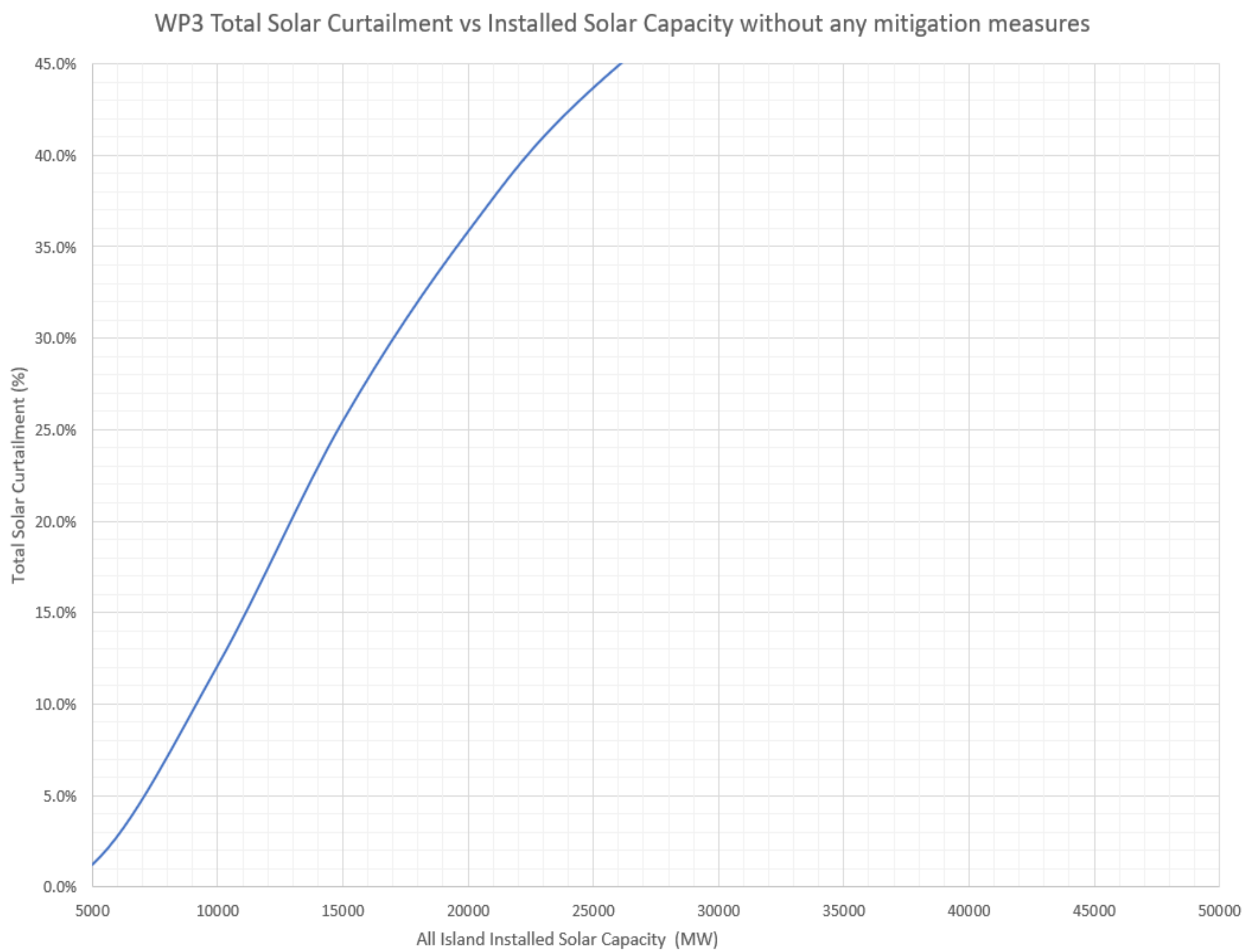
1. WP3 – 70% RES-E without mitigation - Wind



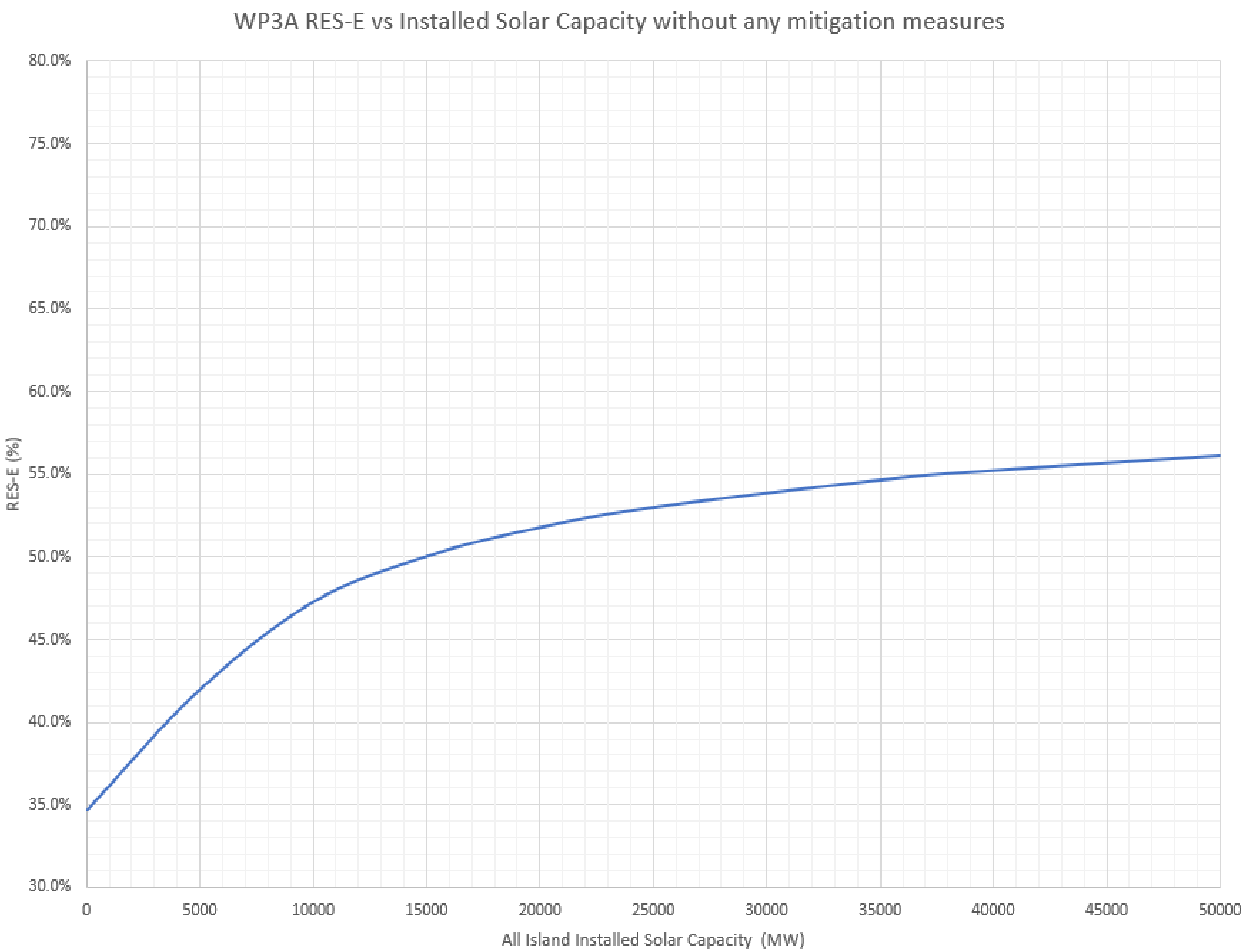
1. WP3 – 70% RES-E without mitigation - Wind



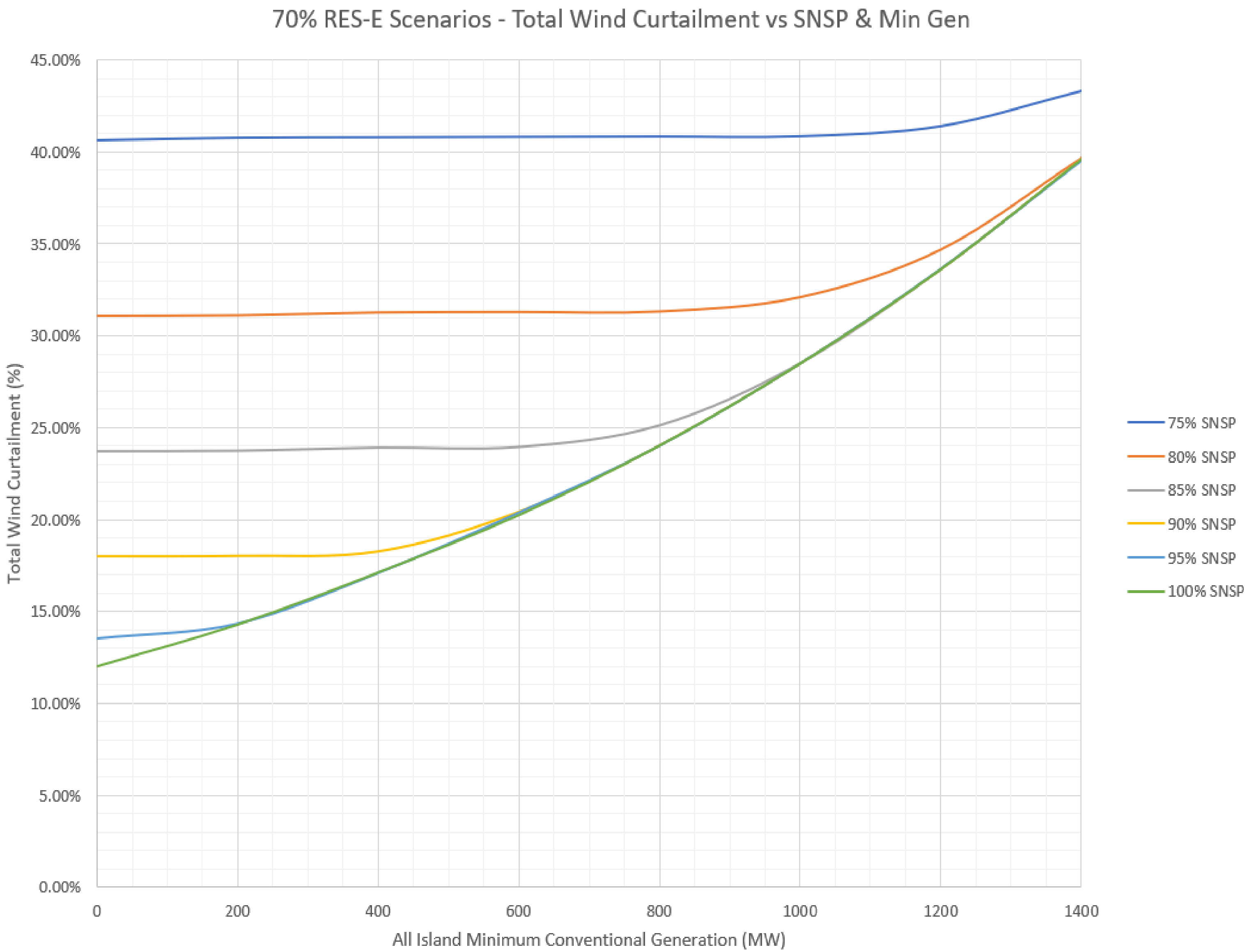
1. WP3 – 70% RES-E without mitigation - Solar



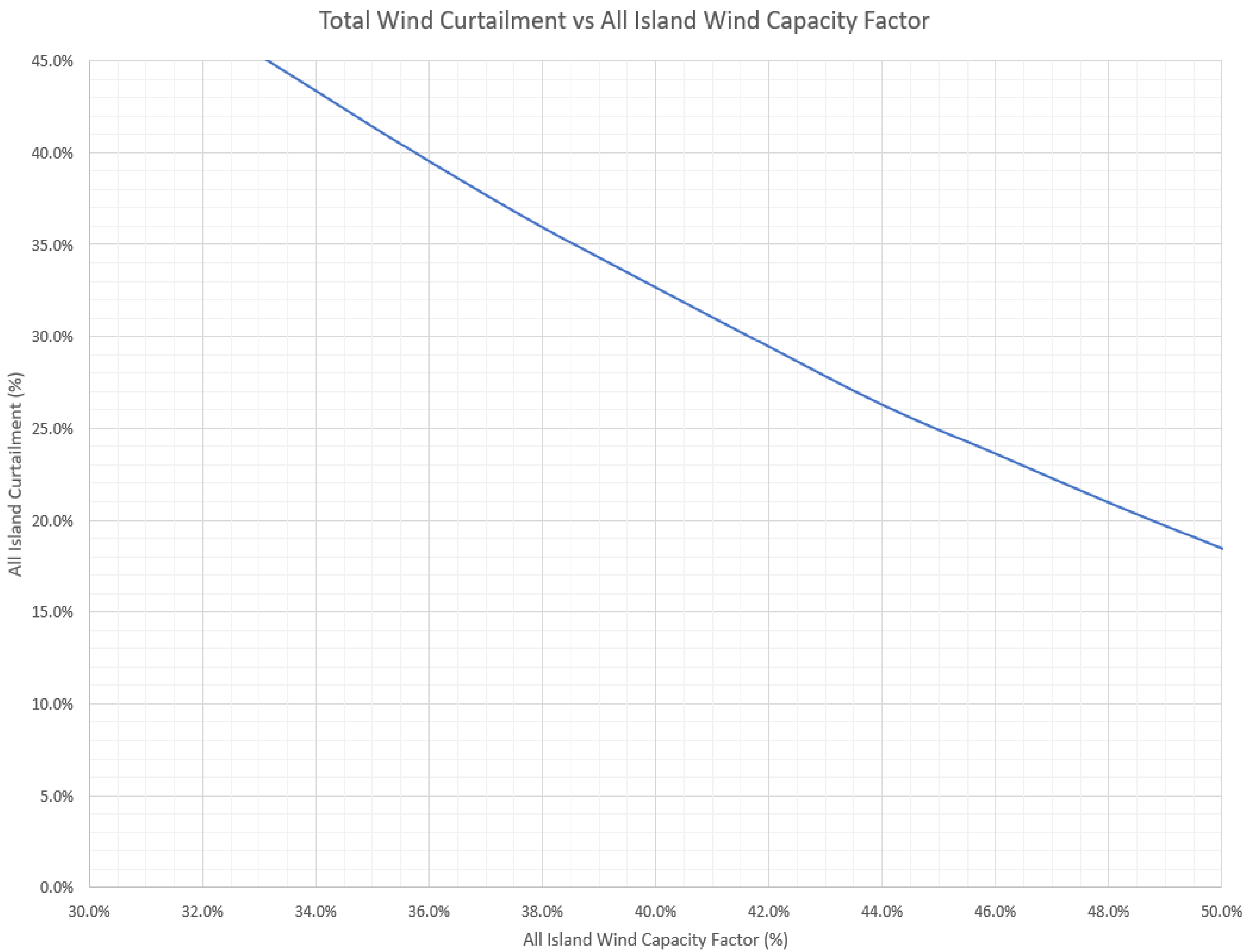
1. WP3 – 70% RES-E without mitigation - Solar



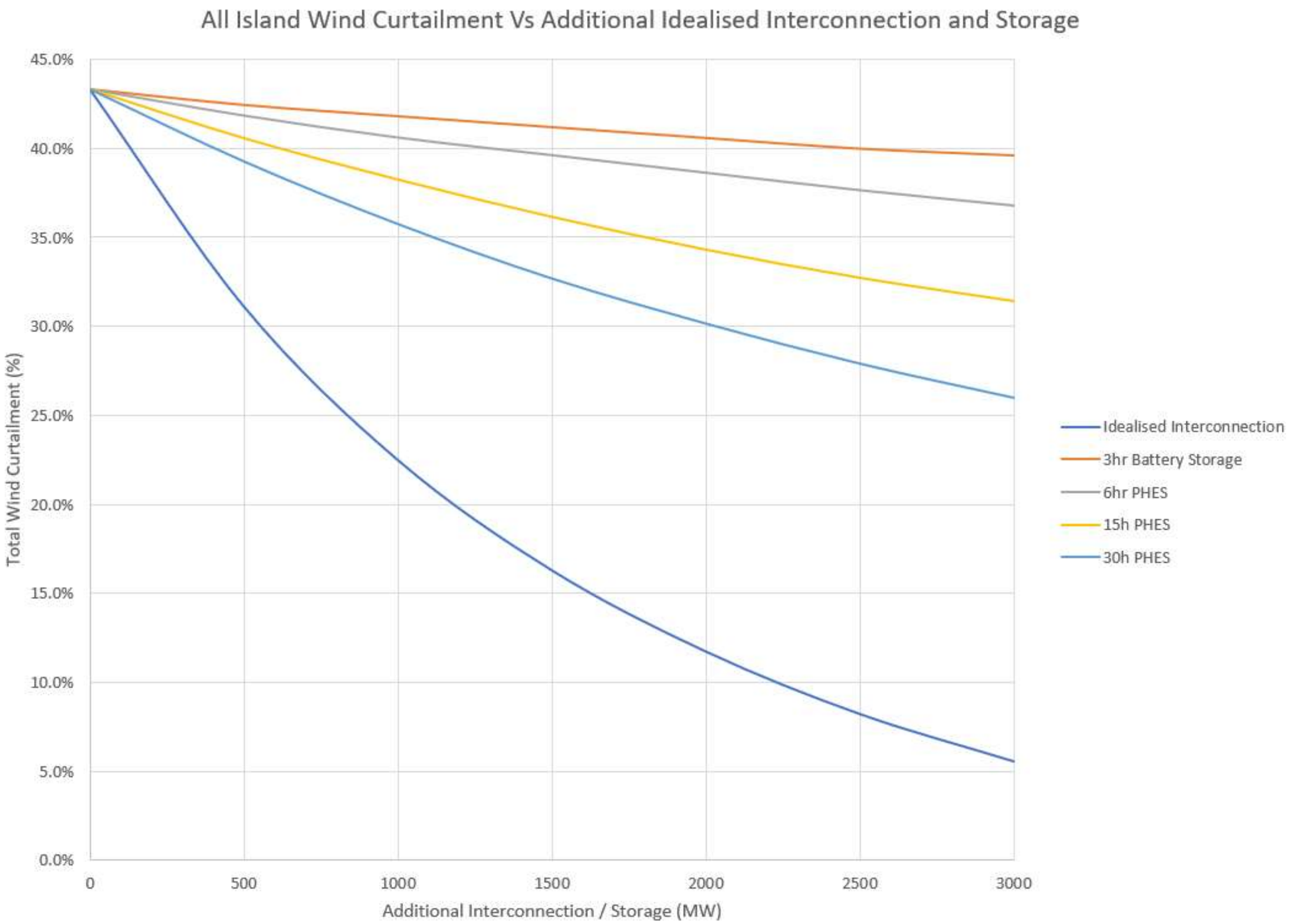
2. WP4 – Impact of SNSP / Min gen



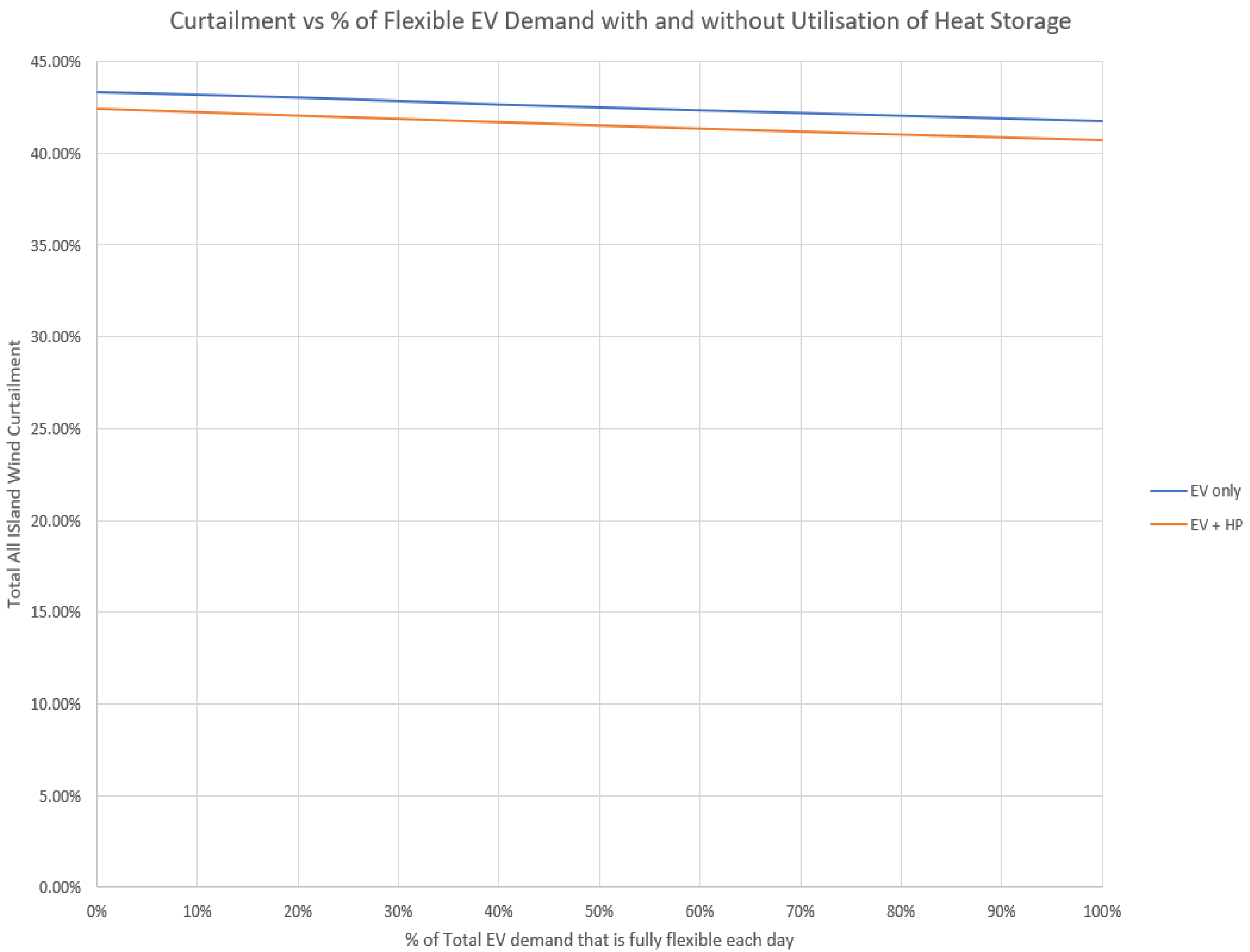
3. WP5 – Increasing Wind Capacity Factor

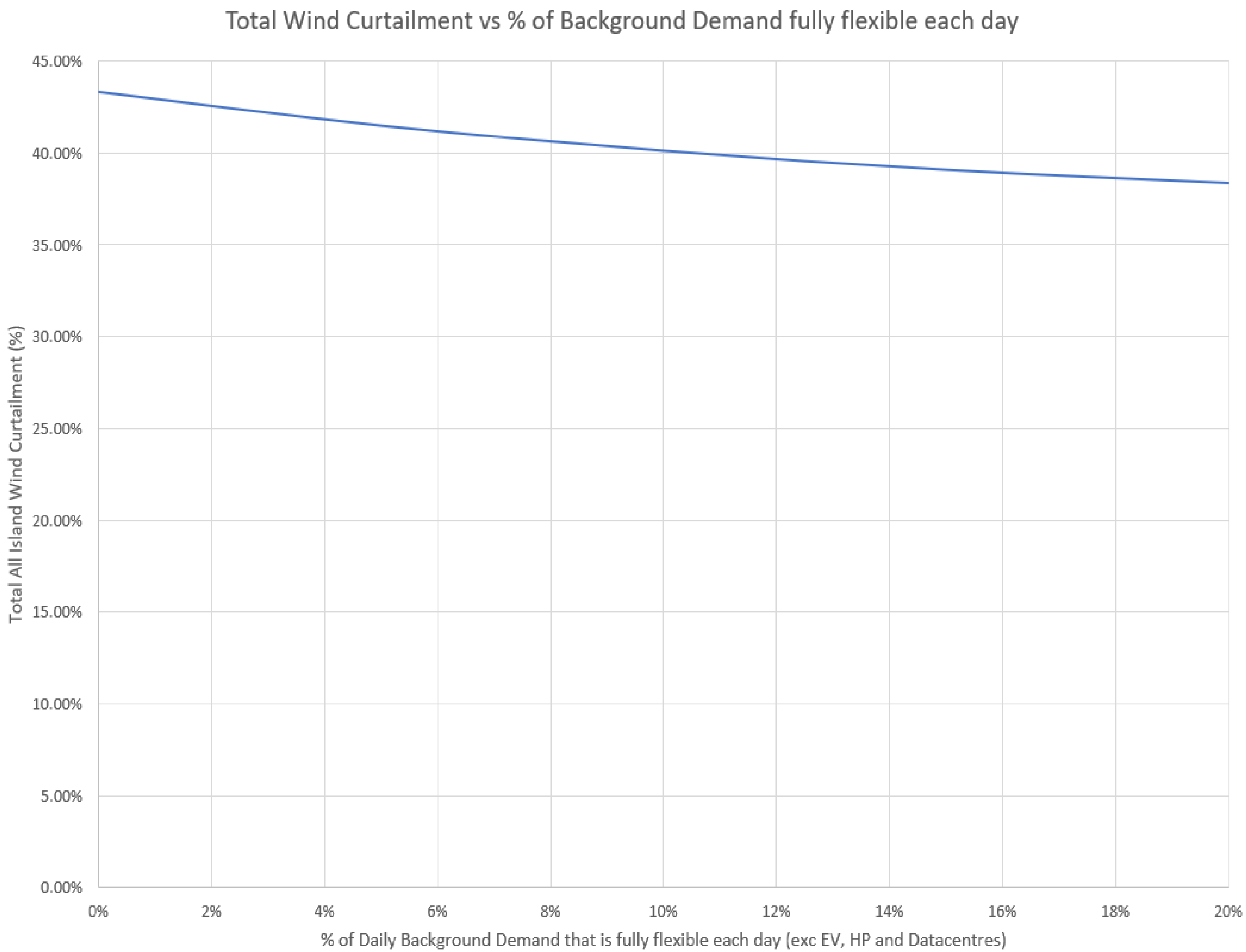


4. WP7 Adding Interconnection and storage



5. WP8 Demand Flexibility




Total Wind Curtailment vs % of Background Demand fully flexible each day
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Total All Island Wind Curtailment (%)
0%
2%
4%
6%
8%
10%
12%
14%
16%
18%
20%
% of Daily Background Demand that is fully flexible each day (exc EV, HP and Datacentres)

Note: Scenarios aiming to achieve 5% curtailment

Scenario 1 - Relieve existing operational constraints						
Scenario	Min Gen (MW)	SNSP (%)	All Island Wind Installed Capacity (MW)	Wind Curtailment (%)	Renewable Curtailment (%)	RES-E (%)
1	1400	75%	8420	4.98%	4.93%	47.9%
1.2	1100	80%	9010	4.98%	4.94%	51.0%
1.3	800	85%	9600	4.99%	4.95%	54.1%
1.4	700	90%	9850	4.99%	4.95%	55.4%

Scenario 1.4 operational constraint assumptions used as the starting point for 2.1

Scenarios 2 - Add Celtic & Greenwire interconnectors, assume all IC's are 90% effective						
Scenario	Installed IC capacity (MW)	Modelled IC Capacity (MW)	All Island Wind Installed Capacity (MW)	Wind Curtailment (%)	Renewable Curtailment (%)	RES-E (%)
2.1	580	522	10090	4.97%	4.93%	56.7%
2.2	1280	1152	11190	4.97%	4.94%	62.4%
2.3	1780	1602	11980	4.99%	4.96%	66.6%
2.4	2020	1818	12350	4.98%	4.95%	68.5%

Scenario 2.4 Interconnector assumptions used as the starting point for 3.1

Scenarios 3 - Increasing Blended Wind Capacity Factors					
Scenario	Blended Wind Capacity Factor (%)	All Island Wind Installed Capacity (MW)	Wind Curtailment (%)	Renewable Curtailment (%)	RES-E (%)
3.1	35.0%	12230	4.99%	4.96%	69.8%
3.2	36.0%	12110	4.99%	4.96%	71.1%
3.3	37.0%	12000	4.99%	4.96%	72.3%
3.4	38.0%	11870	4.96%	4.93%	73.5%

Scenario 3.4 Wind Capacity Factor assumptions used as the starting point for 4.1

Scenarios 4 - Adding solar capacity to the mix						
Scenario	Solar Installed capacity (MW)	All Island Wind Installed Capacity (MW)	Total Wind Curtailment (%)	Total Solar Curtailment (%)	Renewable Curtailment (%)	RES-E (%)
4.1	1000	11790	4.97%	1.52%	4.90%	74.1%
4.2	2000	11660	4.98%	1.93%	4.85%	74.9%
4.3	3000	11510	4.96%	2.36%	4.80%	75.6%
4.4	4000	11360	4.97%	2.86%	4.79%	76.3%
4.5	5000	11190	4.95%	3.39%	4.78%	76.8%
4.6	6000	11010	4.95%	4.10%	4.84%	77.3%
4.7	7000	10830	4.99%	5.01%	5.00%	77.6%

Scenario 4.7 Solar Capacity Assumptions used as starting point for Scenario 5.1

6. WP9 Feasible 2030 scenarios

Scenarios 5 - Adding demand side flexibility and additional wind

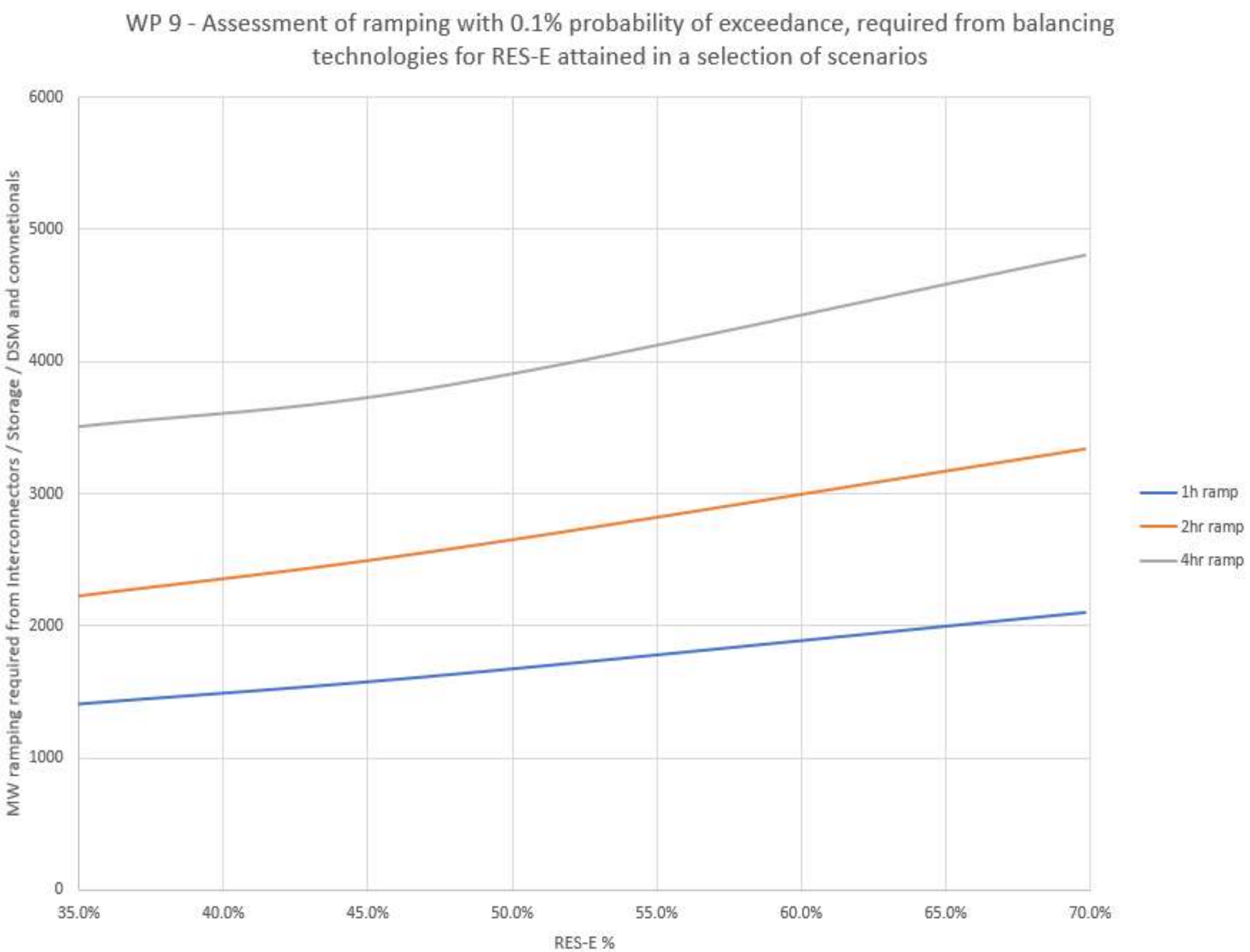
Scenario	Background Demand Flexible each day (%)	EV Demand Flexible each day (%)	All Island Wind Installed Capacity (MW)	Total Wind Curtailment (%)	Total Solar Curtailment (%)	Renewable Curtailment (%)	RES-E (%)
5.1	5%	20%	11260	5.00%	4.32%	4.90%	80.2%
5.2	10%	40%	11495	4.99%	3.99%	4.85%	81.7%
5.3	15%	60%	11650	4.99%	3.76%	4.82%	82.62%

Scenario 5.3 used as the starting point for Scenario 6.1

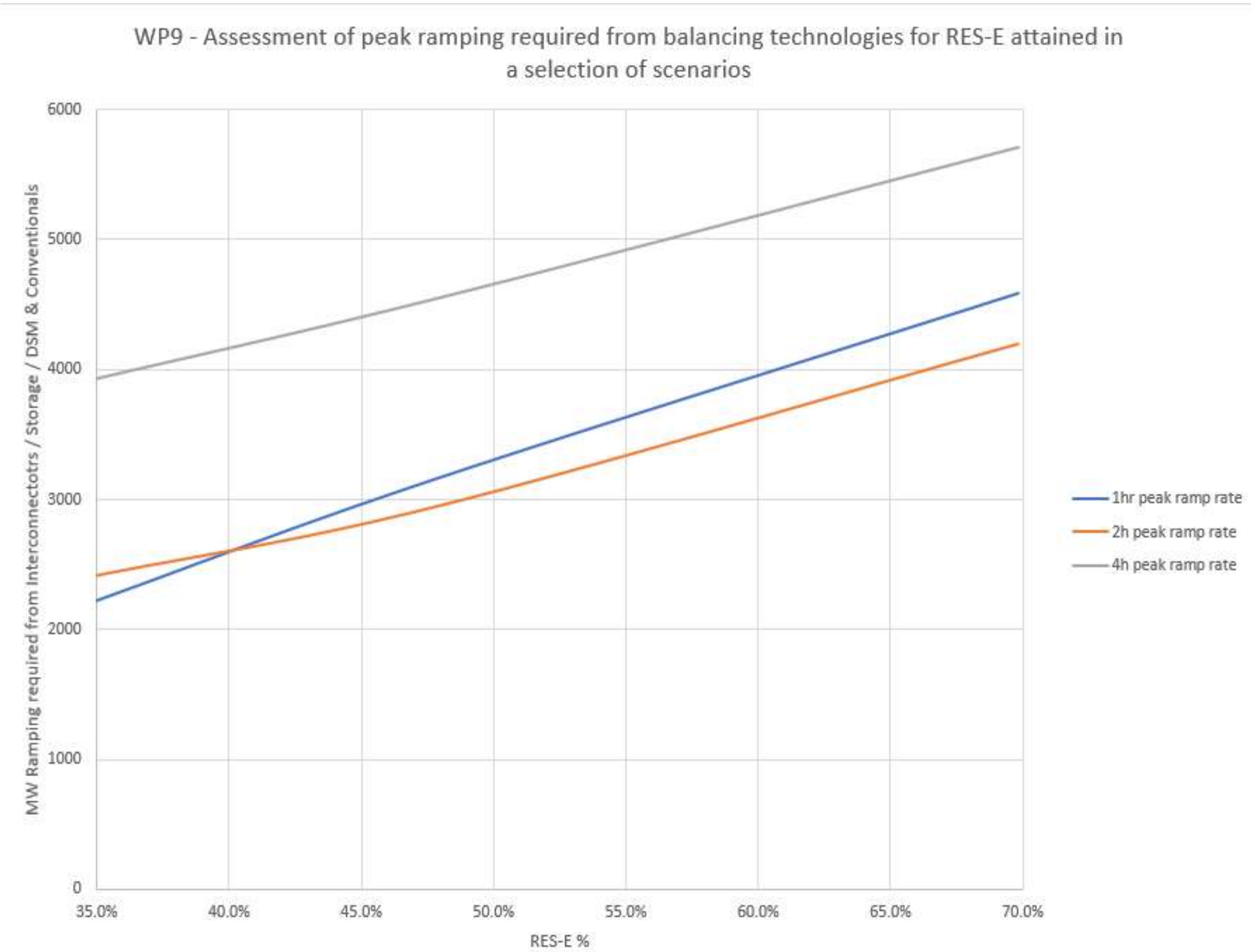
6. WP9 Feasible 2030 scenarios

Scenarios 6 - Utilise heat storage capacity of residential heat pump units						
Scenario	Heat Flexibility Utilised	All Island Wind Installed Capacity (MW)	Total Wind Curtailment (%)	Total Solar Curtailment (%)	Renewable Curtailment (%)	RES-E (%)
6.1	TRUE	11760	4.98%	3.77%	4.82%	83.2%

6. WP9 Feasible 2030 scenarios



6. WP9 Feasible 2030 scenarios



2040 - Preliminary additional measures 1 - Fully non-synchronous system						
Scenario	Min Gen (MW)	SNSP (%)	All Island Wind Installed Capacity (MW)	Wind Curtailment (%)	Renewable Curtailment (%)	RES-E (%)
7.1	0	100%	12990	4.98%	4.80%	90.5%

Scenario 7.1 operational constraint assumptions used as the starting point for 8.1

2040 - Preliminary additional measures 2 - Further improve C.F of wind fleet					
Scenario	Blended Wind Capacity Factor (%)	All Island Wind Installed Capacity (MW)	Wind Curtailment (%)	Renewable Curtailment (%)	RES-E (%)
8.1	42.0%	12470	4.97%	4.85%	95.1%

Scenario 8.1 Wind Capacity Factor assumptions used as the starting point for 9.1

2040 - Preliminary additional measures 3 - Further blend solar into mix						
Scenario	Solar Installed capacity (MW)	All Island Wind Installed Capacity (MW)	Total Wind Curtailment (%)	Total Solar Curtailment (%)	Renewable Curtailment (%)	RES-E (%)
9.1	9300	12100	4.99%	4.98%	4.99%	96.1%

Scenario 9.1 Wind Capacity Factor assumptions used as the starting point for 10.1

7. WP11 Preliminary assessments

2040 - Preliminary additional measures 4 - Accept higher curtailment						
Scenario	Solar Installed capacity (MW)	All Island Wind Installed Capacity (MW)	Total Wind Curtailment (%)	Total Solar Curtailment (%)	Renewable Curtailment (%)	RES-E (%)
10.1	9900	13000	7.69%	7.19%	7.61%	100.1%

DS3 Programme Status Update – February 2019

Ian Connaughton

EIRGRID SONI

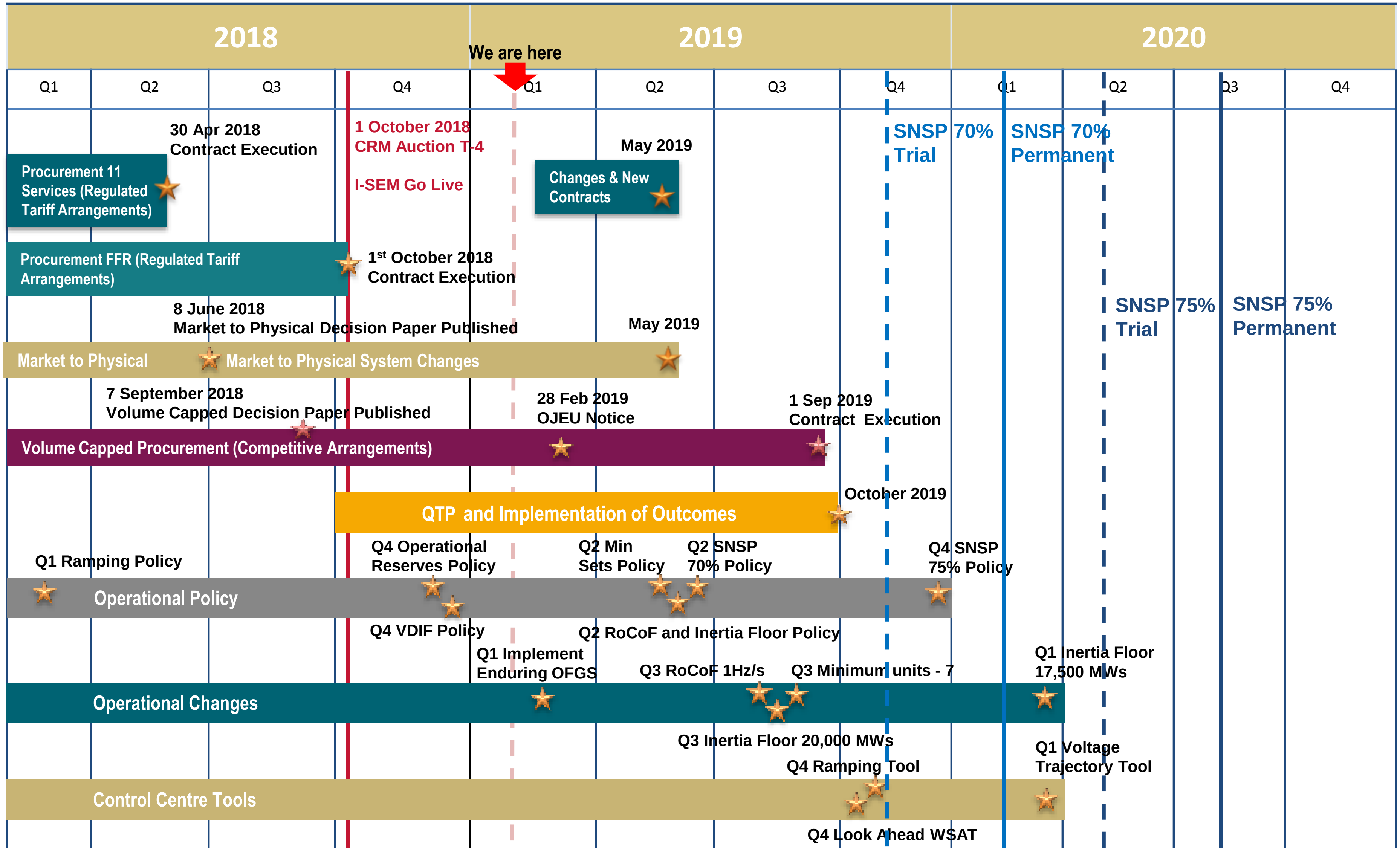
DS3 Highlights

- Ireland wind generators 100% compliant with RoCoF 1Hz/s **– Oct 18**
- Volume Capped Contracts Consultation **– Oct 18**
- DS3 System Services Procurement Outcomes published (outcomes on separate slides) – **Nov 18**
- DS3 System Services Industry Forum held – **Nov 18**
- DS3 Programme Transition Plan to 2020 published – **Dec 18**
- Volume Capped Contract Recommendation **– Feb 19**

EIRGRID GROUP

DS3 Major Deliverables for Remainder of Year

- Close out of DS3 System Services capex
- Run DS3 QTP, Volume Capped and Gate procurements – Q2, Q3, Q4
- New policy and Control Centre tools - Q4
- Progressing to 1 Hz/s RoCoF operational trial – Q4



EIRGRID GROUP

Work Stream 1 – 65% to 70% SNSP

Grouping	*Status*	*Update John Y*	*Delivery*
Operational Change			
RoCoF transition to 1Hz/s		Wind complete, SCG in NI 12%	Q3 2019
Inertia Floor – 20,000 MWs		Policy development underway and on track for delivery. Cannot move without change to 1 Hz/s RoCoF.	Q3 2019
Operational Policy			
Ramping Policy		Completed in March 2018	Q1 2018
SNSP 70% Policy		Studies for 70% SNSP trial to begin in Q2	Q2 2019
Operational Reserves Policy		Work underway on the new policy. First draft expected in February.	Q1 2019
RoCoF & Inertia Floor Policy		Studies for RoCoF compliance ongoing. Further analysis to move to 1 Hz/s RoCoF required in Q2 along with SNSP studies.	Q2 2019
Control Centre Tools			
Ramping Tool		Ongoing betta testing of scheduling functionality-vendor highlighting potential performance issues, forecast tendering and pre-trial assessment progressing	Q4 2019
Look Ahead WSAT		Tender Underway	Q4 2019
System Services			
Refresh Gate 1 - Volume Capped -		The timetable for Refresh Gate 1 has been confirmed as OJEU launch end March 2019 in which the 12 services procured in Phases 1 and 2 will be refreshed.	Q3 2018

GROUP

Work Stream 2 – 70% to 75% SNSP

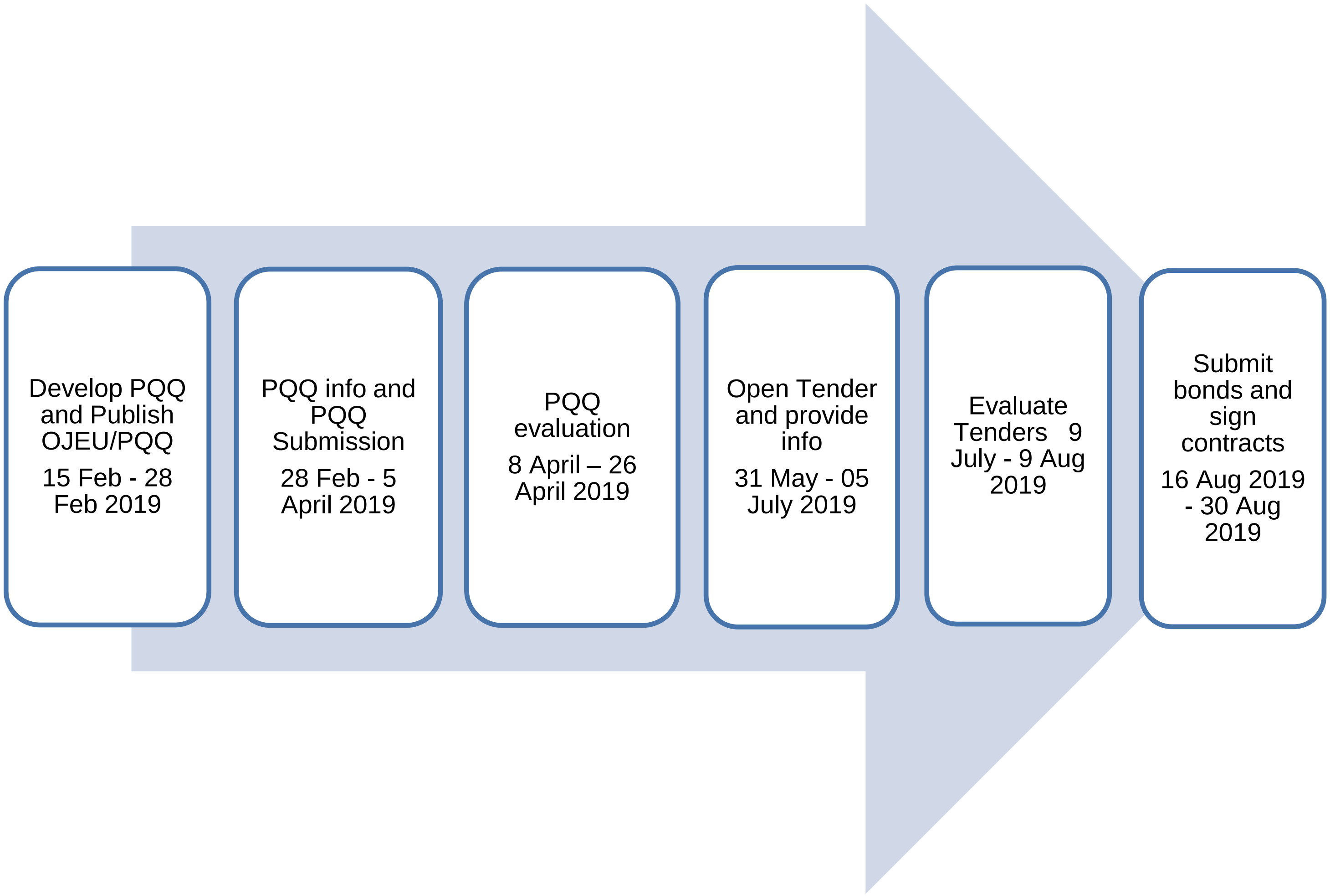
Grouping	*Status*	*Update*	*Delivery*
Operational Change			
Implement OFGS enduring		Studies have initiated and on schedule to be completed in late Q1/early Q2 2019. Rollout of new settings to being following this.	Q4 2019
Inertia Floor – 17,500 MWs		Dependent on successful trial of 20,000 MWs.	Q1 2020
Minimum Units Online - 7		Dependent on successful delivery of Voltage Trajectory Tool.	Q1 2020
Operational Policy			
Min Sets Policy (Voltage & Inertia)		Studies for 70% SNSP trial to begin in Q2 – issues in relation to DS3/EU-SysFlex resources overlap.	Q2 2019
SNSP 75% Policy		Studies to begin in Q4 2019.	Q4 2019
VDIF Policy		Work completed in 2018. Put on hold pending EU-SysFlex analysis and further information on DRR and FPFAPR product volumes in Q3 2019.	Q4 2019
Control Centre Tools			
Voltage Trajectory Tool		Tender PQQ evaluation on-going. On track for delivery.	Q1 2020
System Services			
11 existing services + FFR + DRR + DPFAPR		The 12 System Services currently procured will be refreshed in Refresh Gate 1 (contract execution September 1st 2019). The product definitions for DRR and FPFAPR are the process of being refined with a view to publishing the technical requirements. They can be procured at a subsequent gate of the Qualification System as needed.	Q3 2019

Additional Topics

Grouping	*Status*	*Update*	*Delivery*
Renewable Integration			
Renewable Policy		Briefing note on NECP prepared for EirGrid Group Exec and Management. RES Policy being included in all relevant EirGrid Group strategy workstreams. Consultation response to the NECP required by 22nd February.	
DS3 – EU-SysFlex Interactions		All 2018 EU-SysFlex deliverables met. EU-SysFlex technical studies initiated – likely that 90% SNSP will be required/is the goal for 2030.	
Knowledge Sharing – World Leading Business		Briefings held with UAE delegation, GE Technology department and IWEA Policy Forum.	

EIRGRID GROUP

System Services – Fixed Contracts



NIE NETWORKS' NODAL CONTROLLER PROJECT

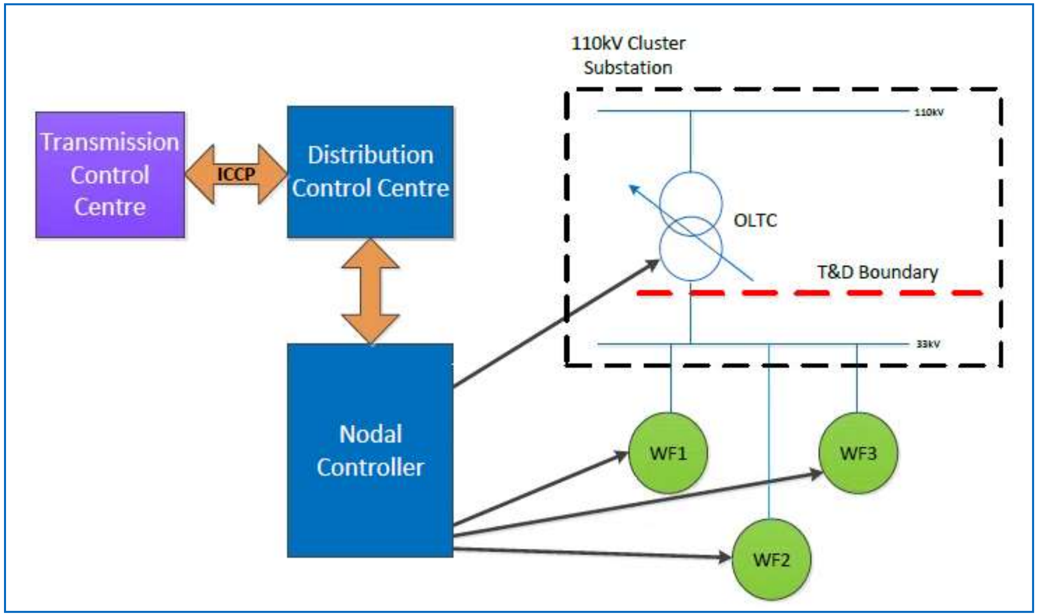
DS3 Advisory Council - 07/02/19

Purpose of the Nodal Controller

- Controller which regulates the reactive power of downstream generators to deliver a constant:
  - Power Factor
  - Reactive Power; or
  - Voltage

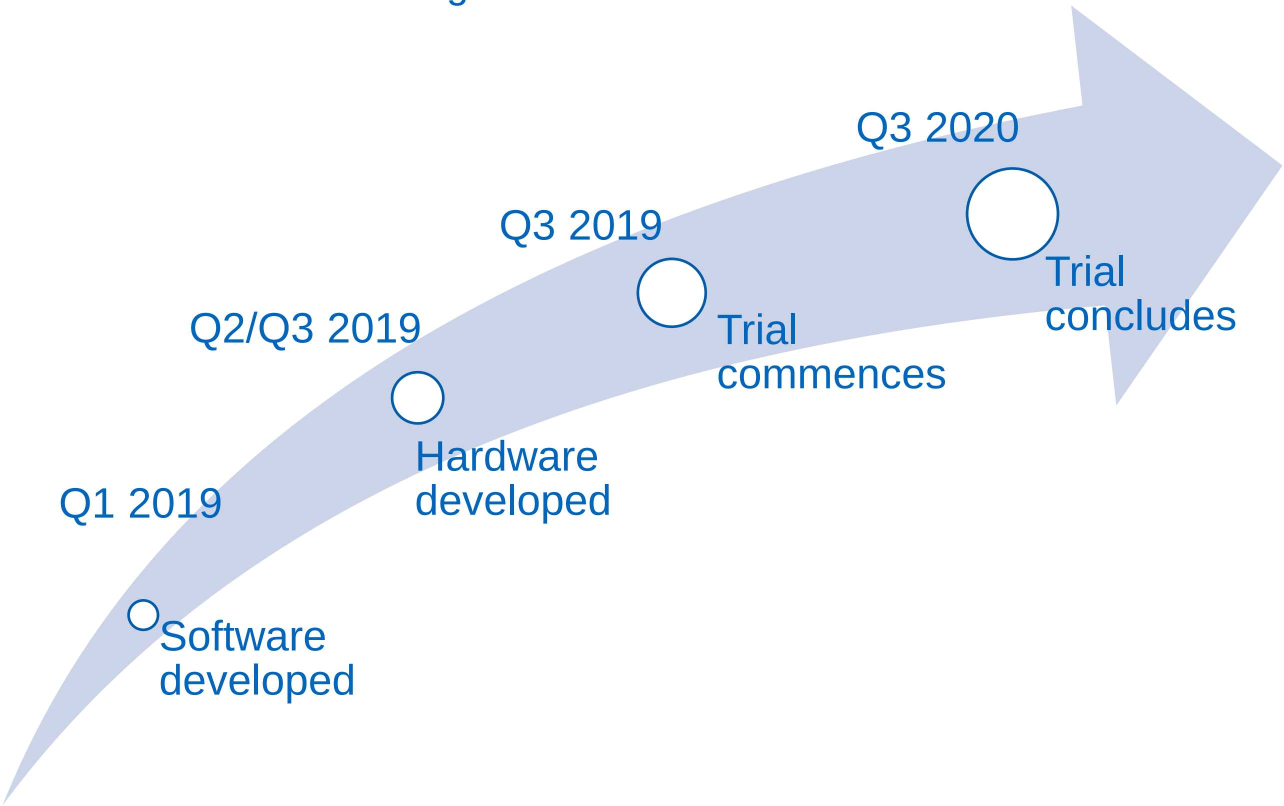
  set point at an upstream node.

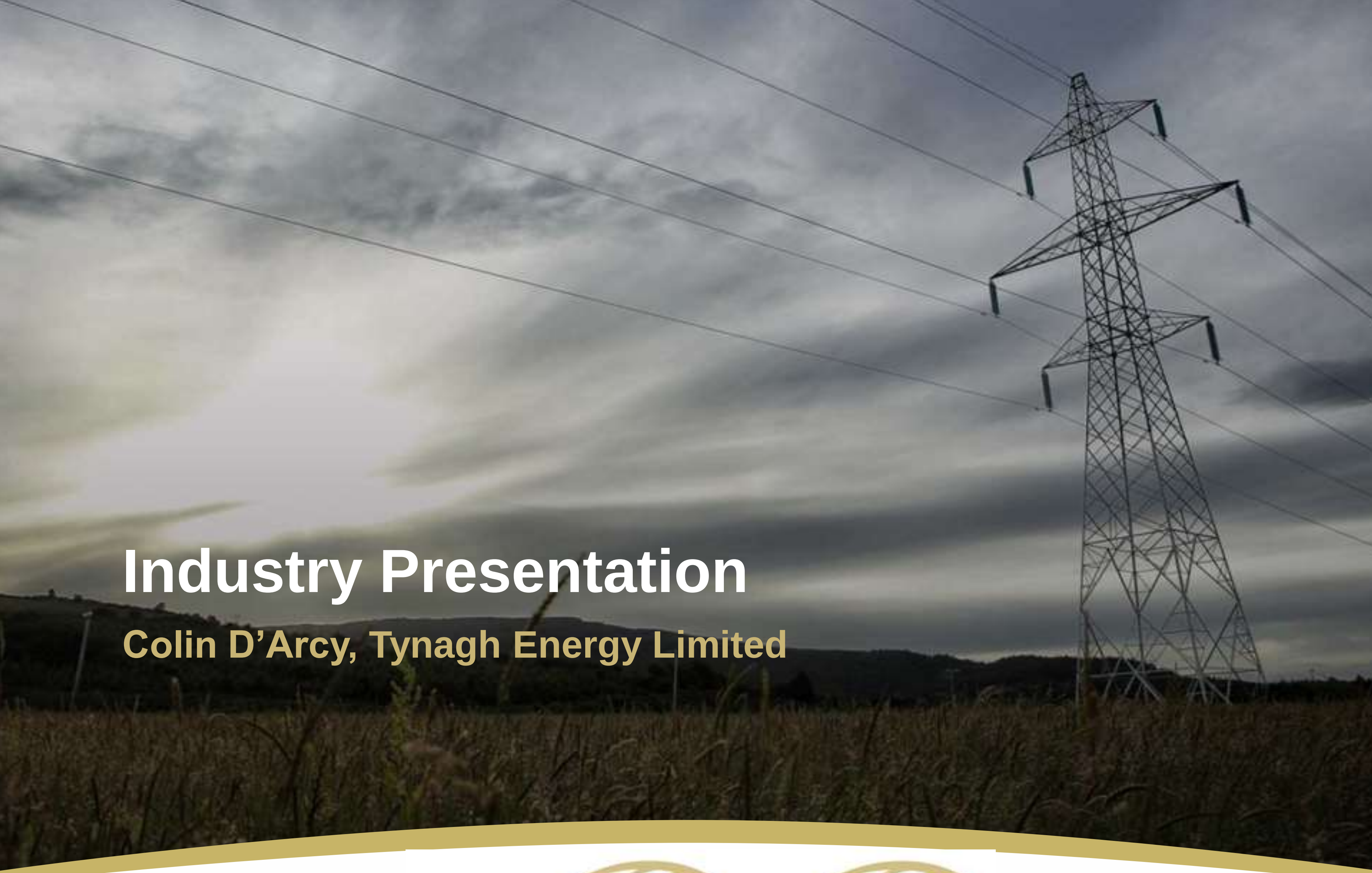
- Required to:
  - Provide coordinated dispatch of windfarms.
  - Ensure stable operation (no hunting from occurring).
  - Protect the distribution and transmission system from voltage and thermal violations.
  - Enable consistent Principles of Access to be applied.
  - Ensure efficient use of the system i.e. reduced OLTC operations.



Progress

- Nodal Controller trial will be at Magherakeel Cluster Substation:





Industry Presentation

Colin D’Arcy, Tynagh Energy Limited

EIRGRID SONI

TYNAGH ENERGY LIMITED

I-SEM – CCGT Physical Dispatch Risk

Colin D'Arcy

07/02/2019

SEM V's I-SEM

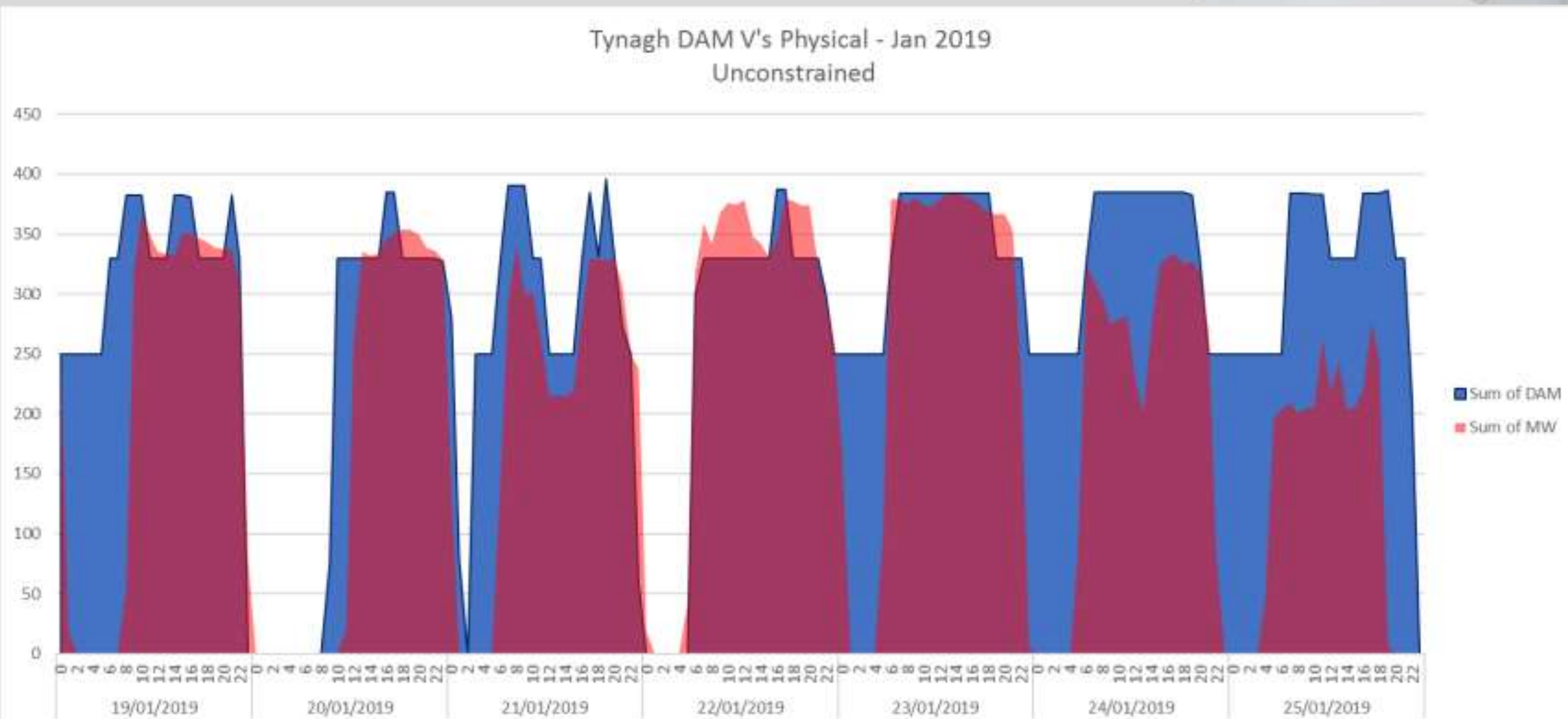
SEM:

- Ex-post Market with optimisation time horizon i.e. look at next day requirements.
- At times significant divergence between Mkt and Physical
- Extended running – regular 2 shifting was not a feature of the market.
- Historically Tynagh had circa 50 starts per year.

I-SEM:

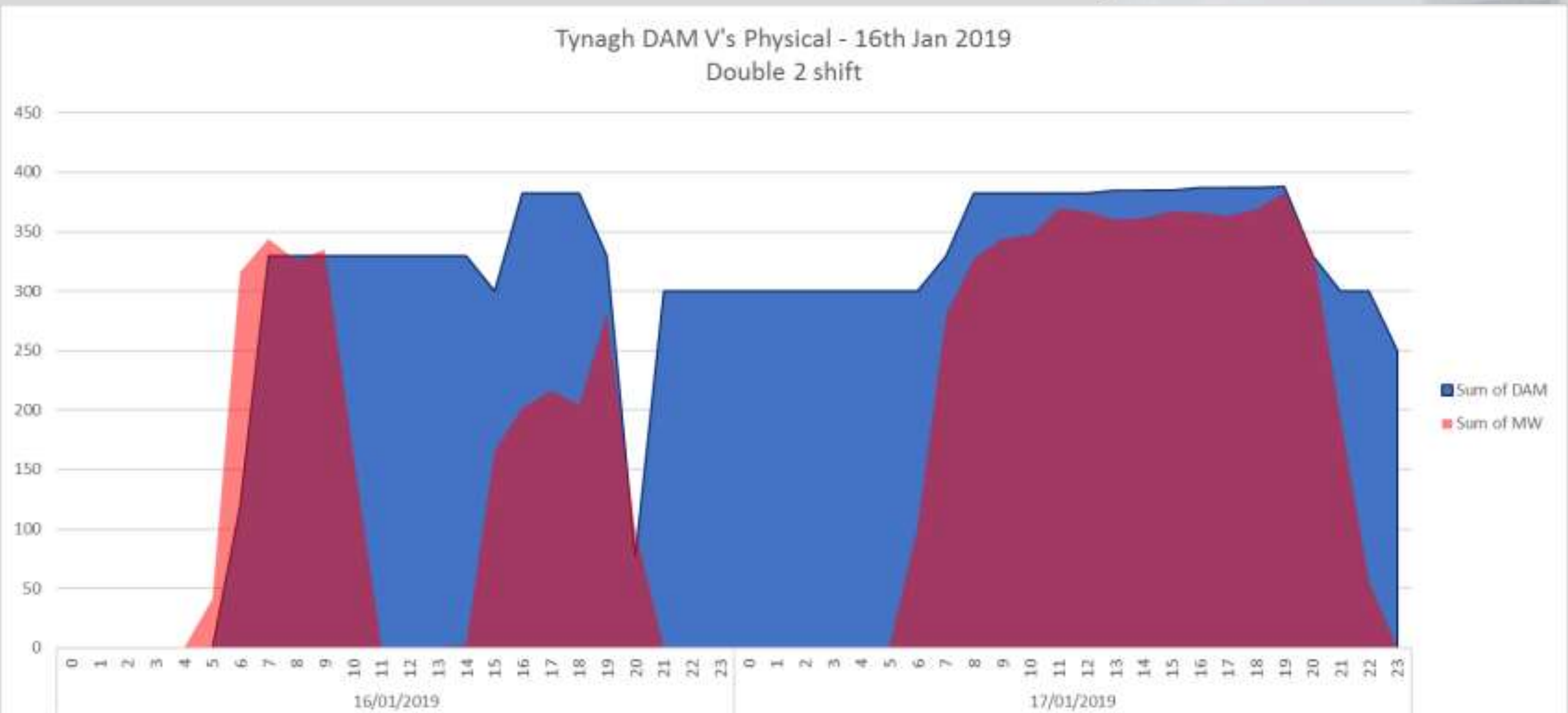
- Dispatch generally to PN
- Difficult to achieve consistent overnight market position
- Physical 2-shifting has increased.

Example of 2 Shifting regime



Plant cycled daily – some market related, but others occurring despite sustained market position.

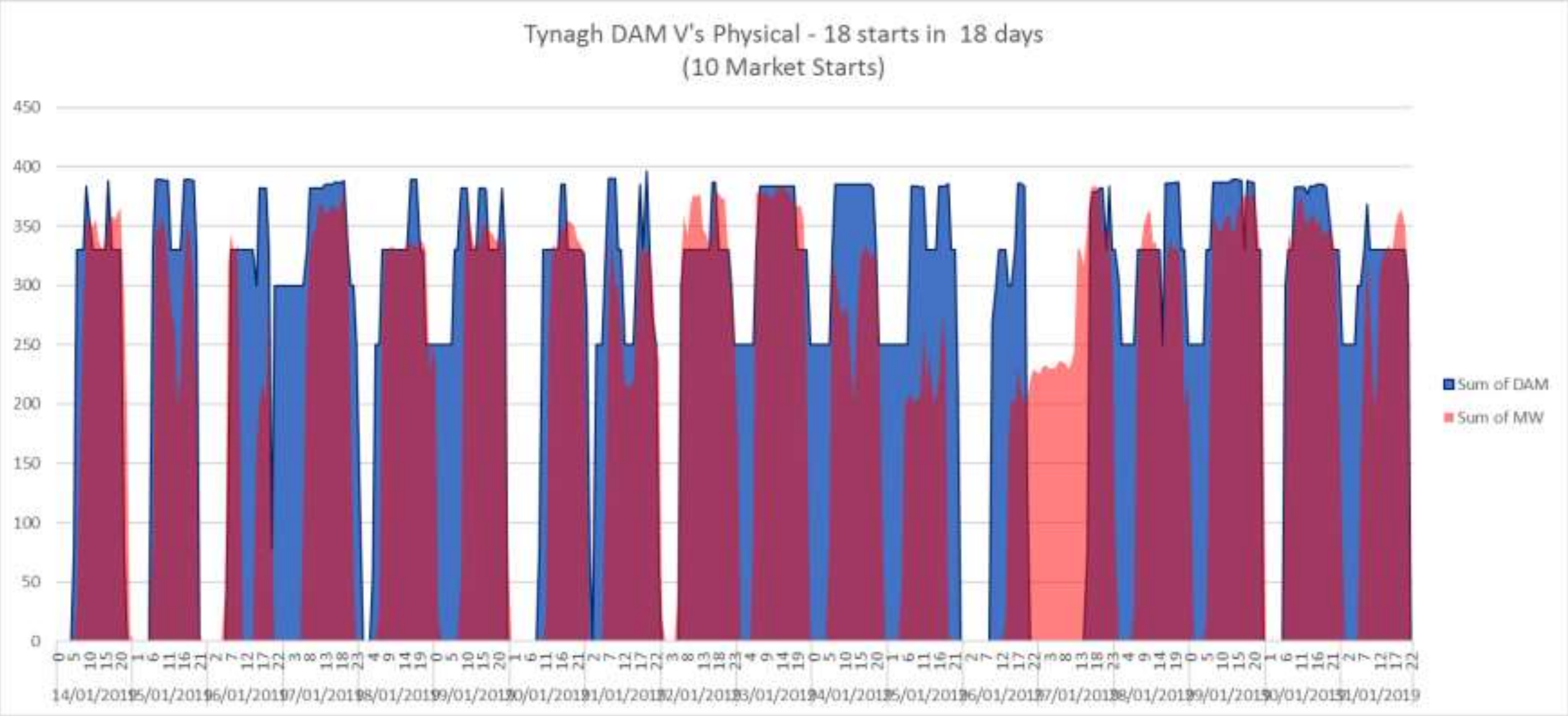
Double 2 Shift



3 starts in 24 hours! This rate of starts is unsustainable.

Unsustainable Start-up Rate

- Daily cycling and one double 2-shift despite maintaining market position.
- 18 starts in 18 days – 300+ per annum



Why was this happening?

2 Possibilities:

1. Constrained on plant forcing Tynagh off over night.

2. Application of Balancing Market Principles.

Balancing Market Principles Statement states….

Our Licences require us to take into account the following objectives:

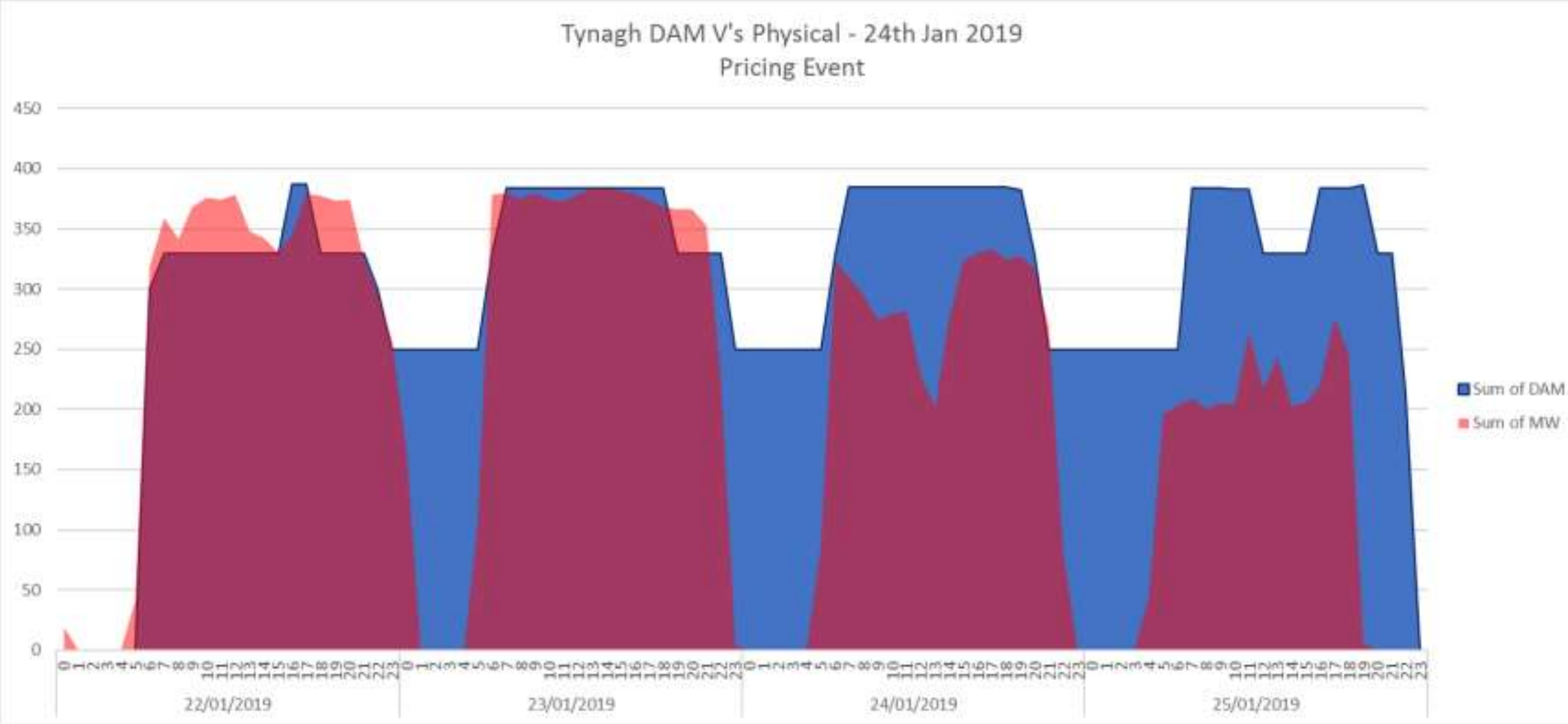
- minimising the cost of diverging from physical notifications;
- as far as practical, enabling the Ex-Ante Market to resolve energy imbalances; and
- as far as practical, minimising the cost of non-energy actions.

Minimising divergence from PNs is not an objective.

Start-up Risk

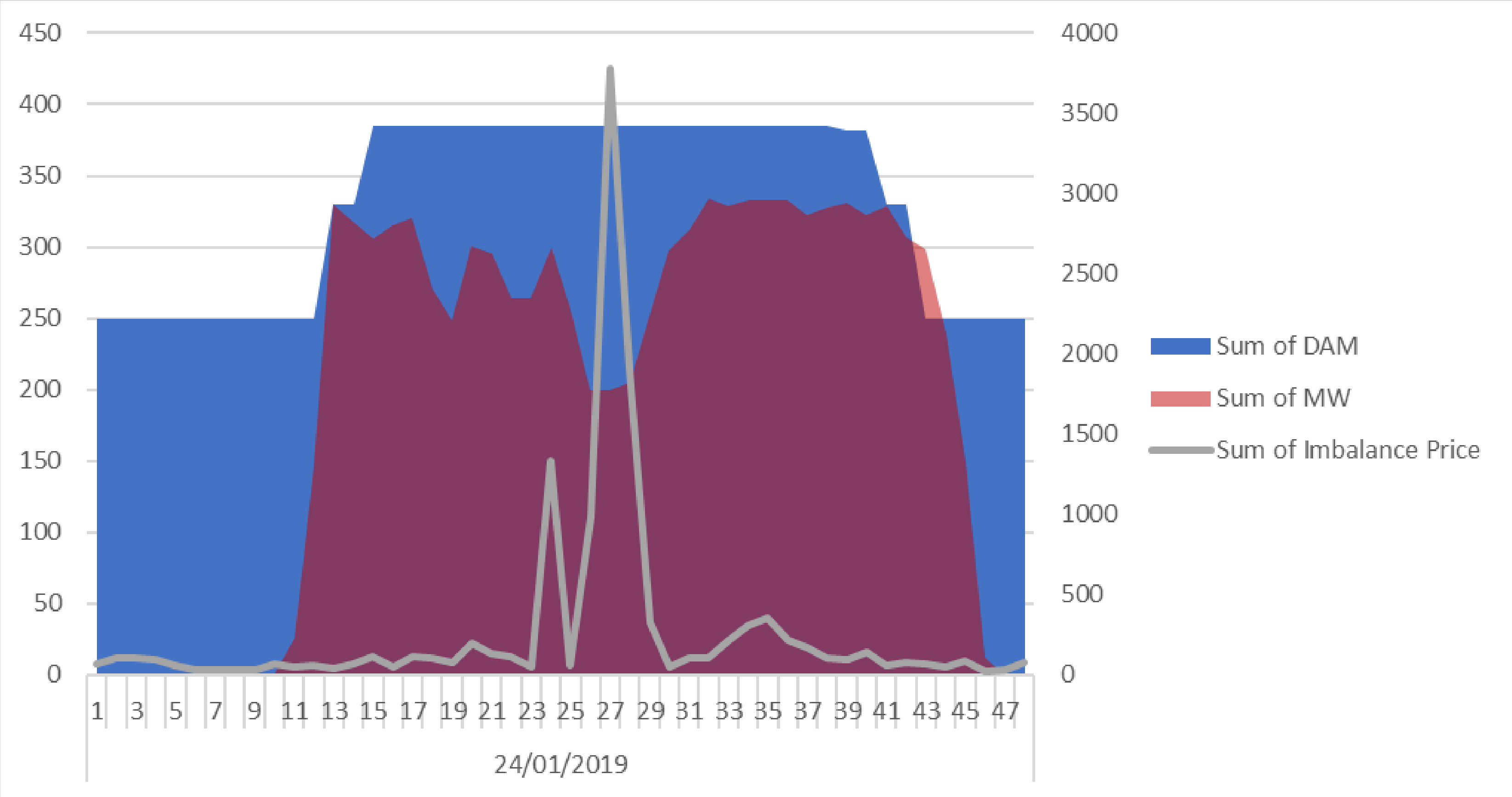
- Discounted offers to stay on overnight to avoid market start.
- Locking in loss as being Dec'd off complex i.e. SRMC.
- Incurring physical start despite market position
- Subsequent start only paid as part of make whole payment – therefore only received if little or no profit in Balancing market over 7 days.
- Huge exposure to a failed start.
- Consider Jan 24th pricing event

Jan 24th



- Tynagh should not have had any physical start-up risk exposure on the 24th Jan
- Continuous market running from 22nd – 25th

Jan 24th



- Significantly increased risk due to start.
- Potential exposure to pricing event due to failed start. Risk much lower if dispatched to PN.
- Exposure circa €1,000,000

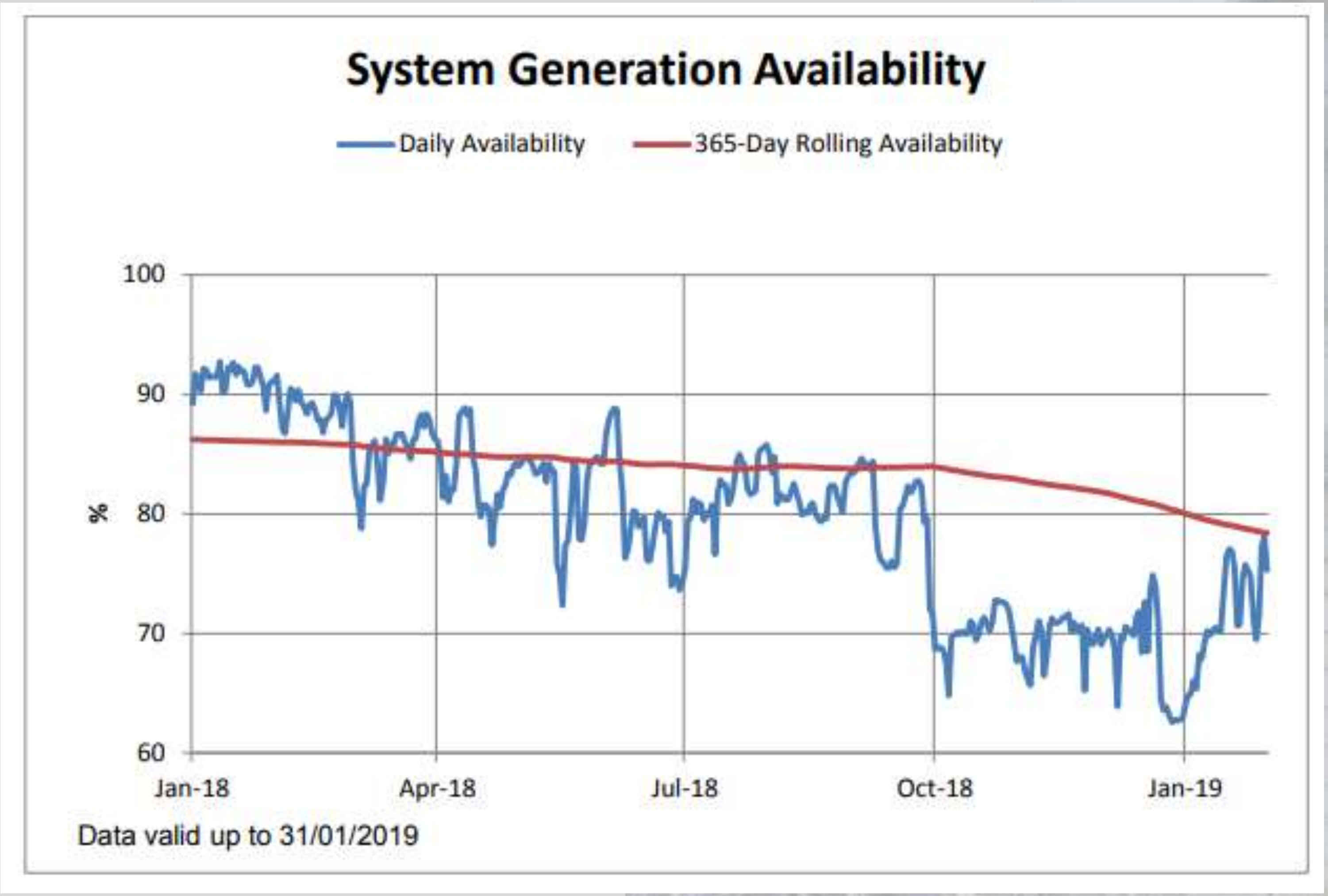
Conclusions

- All plants have increased dispatch risk in I-SEM.
- SND / Trip charges still apply but at 50%
- As we approach 75% SNSP all plants are potentially mid merit.
- Plants will complete to avoid starts through reduced BM decs and increased Start costs.
- BCOP – offers some flexibility.
- BMPCOP – Lead time for MMU approval of "residual risk". Plant could be trapped in this cycling status.

Conclusions

- Additional starts will impact availability / reliability and security of supply.
- Unnecessary cycling of plant for short term market social welfare will potentially have very high costs in the long term.
- DS3 – Delivering a Secure, Sustainable System. Operating the fleet at a high rate of cycling is not sustainable and will in time impact security.
- Recent system availability has been poor and operating plants in a high cycle mode will further drive metrics downwards; as follows.

System Availability



Lunch & Networking

12.20 – 13.05

EIRGRID GROUP

Agenda - Afternoon

Topic	Time	Speaker
2018 Wind Update	13.05	Update: Noel Cunniffe, EirGrid (5 mins) Discussion: All (5 mins)
RoCoF	13.15	Update: John Young , EirGrid (5 mins) Update: Jon O'Sullivan/Noel Cunniffe, EirGrid (5 mins) Update: NIE Networks, ESB Networks (10 mins) Discussion: All (10 mins)
Beyond 2020 – EU-SysFlex	13:50	Presentation: Noel Cunniffe, EirGrid (15 mins) Discussion: (15 mins)
AOB	14:20	All (15 mins)
Closing Remarks and Actions	14.30	Jon O'Sullivan, EirGrid (10 mins)
Session Closed (14:35)		

EIRGRID GROUP

2018 Wind Update

Noel Cunniffe

EIRGRID GROUP

Wind Generation (October-December 2018)

- In Q4 2018 wind generation accounted for **37%** of All-Island System Demand
- Wind generation provided up to **84%** of All-Island Demand at one point with maximum output of **3,939 MW** in December.
- The power system was operated above 50% SNSP for **30% of the time** in Q4 2018

EIRGRID GROUP

Wind Generation Update – 2018

- Per latest data wind generation met **29.9%** of All-Island demand in 2018
- Wind generation over **11GWh** of energy for 1st time
- Per latest data renewable generation met **32.8%** of All-Island demand in 2018
- The power system was operated above 50% SNSP for **21% of the time** in Q4 2018

EIRGRID GROUP

DS3 RoCoF Project

John Young

EIRGRID GROUP

RoCoF Status – February 2019

TOTAL (approx. 11,686 MW)

8,286 MW (71%) complete

Conventional Generation (8,550MW total)

5,472 MW (64%) complete

- Progress ongoing in Ireland and Northern Ireland
- A number of large units nearing completion (> 1.2 GW) within next couple of months
- 18 out of 24 high and mid-priority units compliant

IRE: 4,612/6,723 MW complete (69%)
NI: 860/1,827MW complete (47%)

Wind/Large-Scale (2,386 MW total)

2,386 MW (100%) complete

IRE: 1,266/1,266 MW complete (100%)
NI: 1120/1120 MW complete (100%)

- Roll-out completed in both jurisdictions as of January 2019

Small-scale/embedded (approx. 750 MW total)

**Agreed target*

428 MW (57%) complete

- Roll-out in IRE has completed 340 MW target
- Roll-out in NI targeting Sept 2019 completion – 3rd letter now sent

IRE: 338/340 MW* complete (99%)
NI: 90/410 MW complete (20%)

RoCoF 1Hz/s

DS3 RoCoF SSG Analysis

Noel Cunniffe

EIRGRID SONI

Background Information

- Significant portion of anti-islanding relays on distribution grid connected small scale generations (SSG) are not compliant with 1 Hz/s RoCoF standard

- Secondary tripping of SSG due to activation of anti-islanding relays will occur when high RoCoFs are experienced

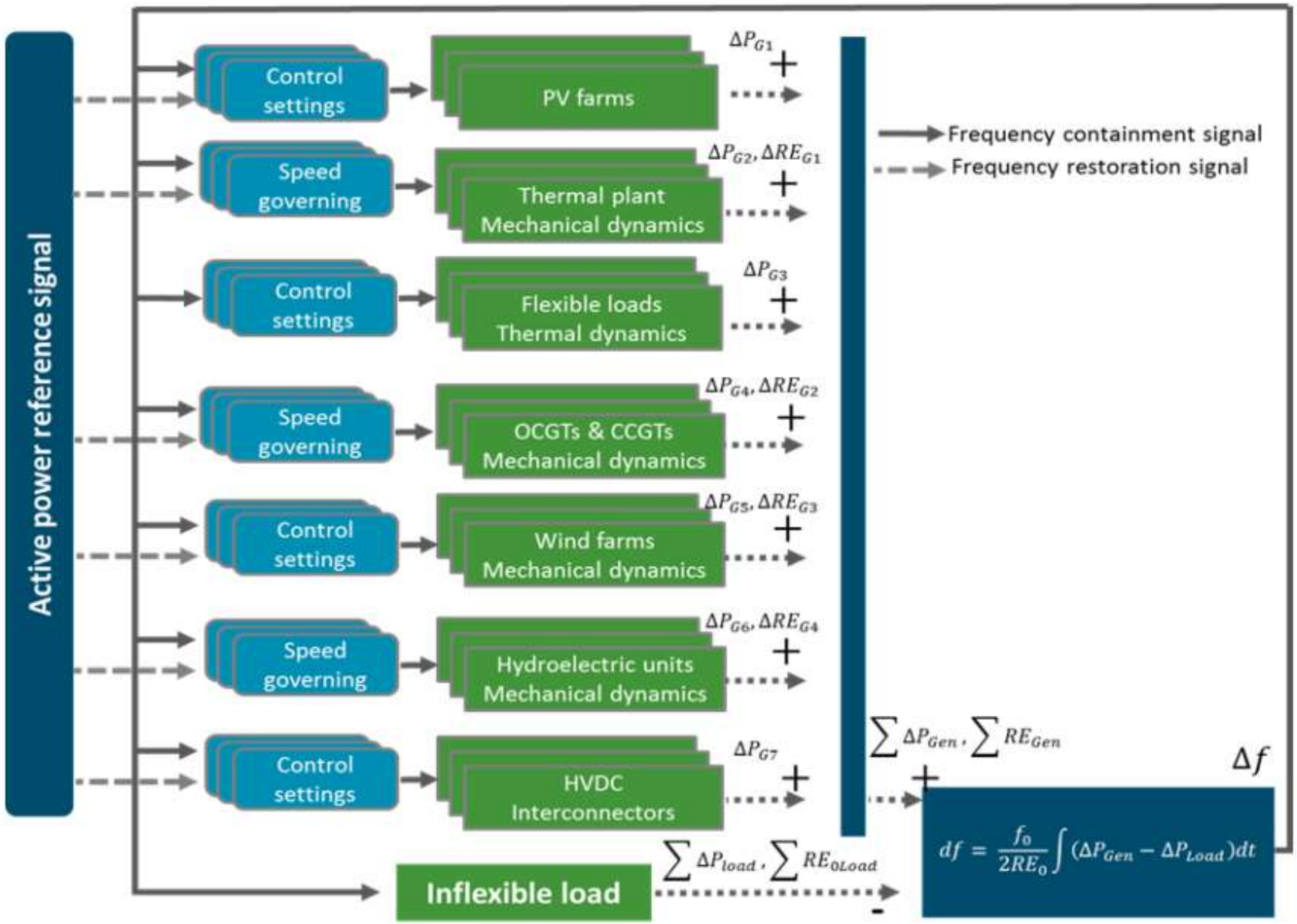
- Secondary tripping of SSG subsequent to initial imbalance can lead to lower frequency nadir → triggers under-frequency load shedding

Scope of Study:

Quantification of the volume of generation subject to secondary tripping that the system can sustain

EIRGRID GROUP

Single Frequency Model Architecture



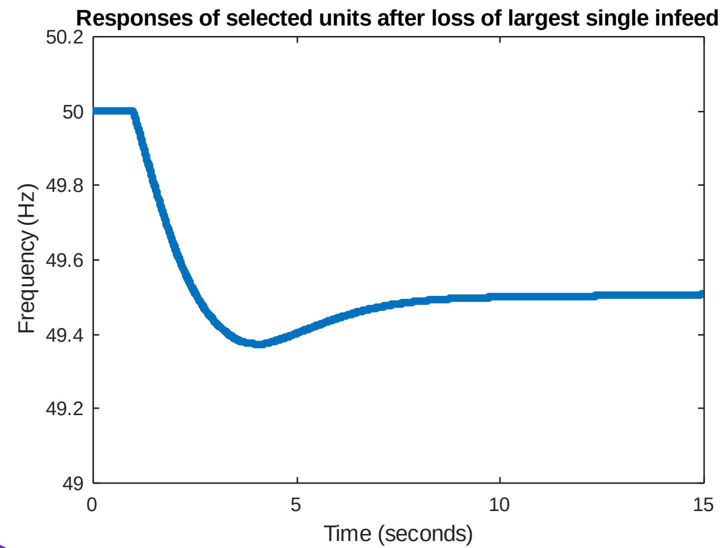
EIRGRID GROUP

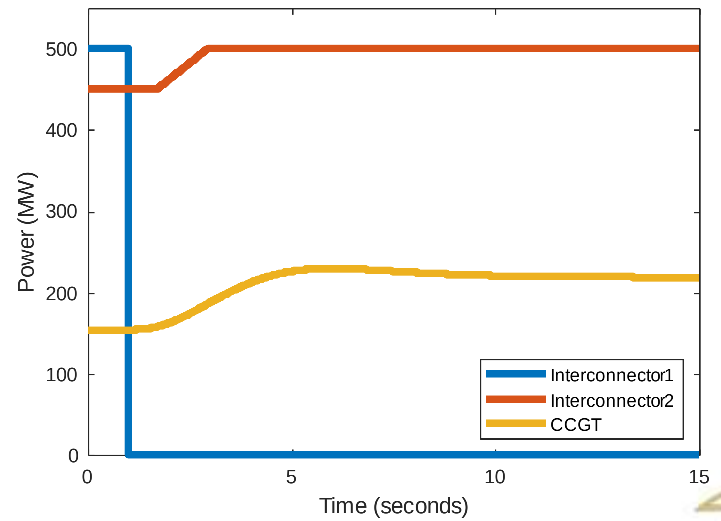
SFM Under Frequency Event

LSI* tripping

Hourly dispatch

Simulation in SFM

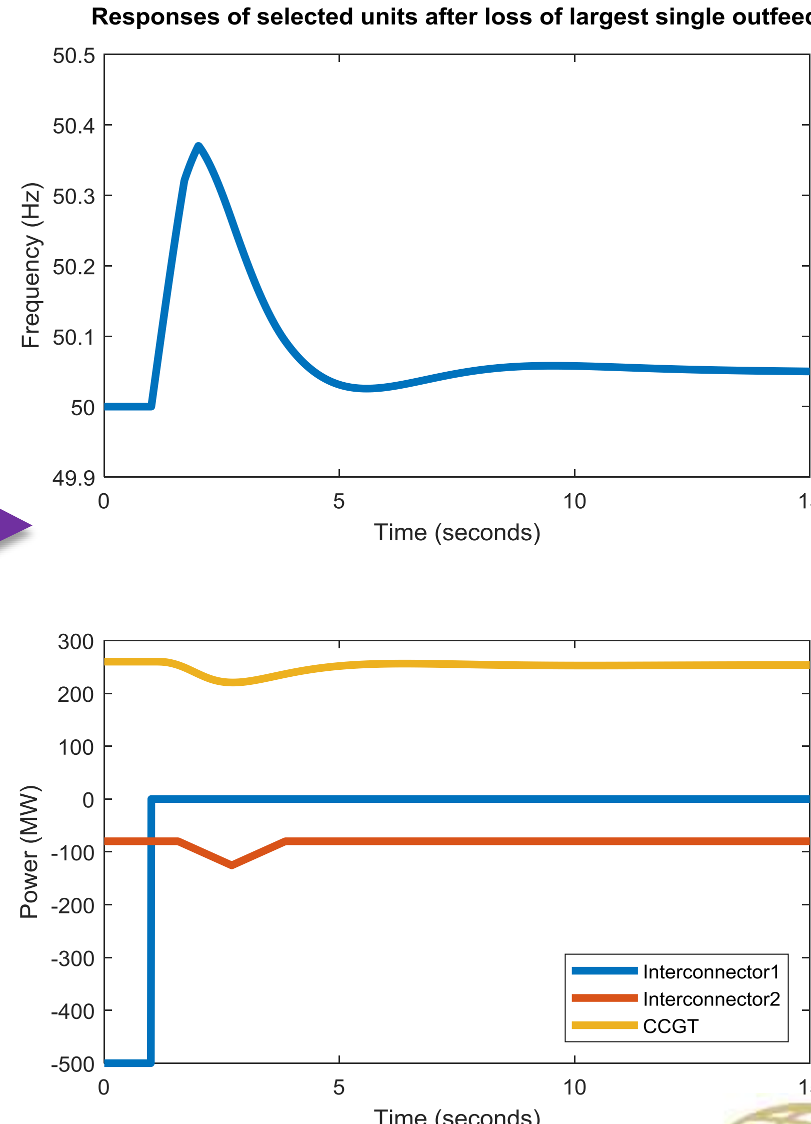




*LSI- Largest Single Infeed

EIRGRID GROUP

SFM Over Frequency Event

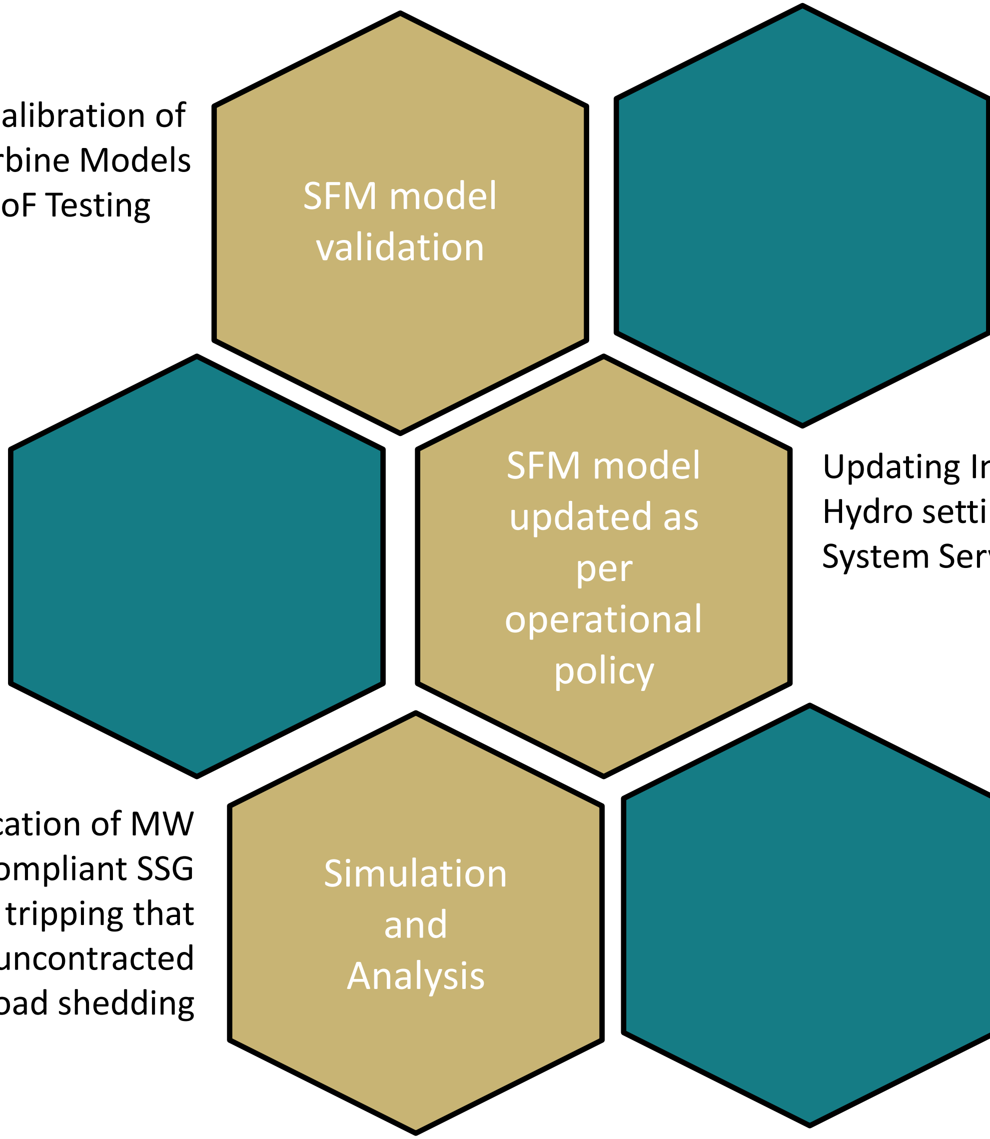


**LSO/L- Largest Single Outfeed/Load*

EIRGRID GROUP

Study Roadmap

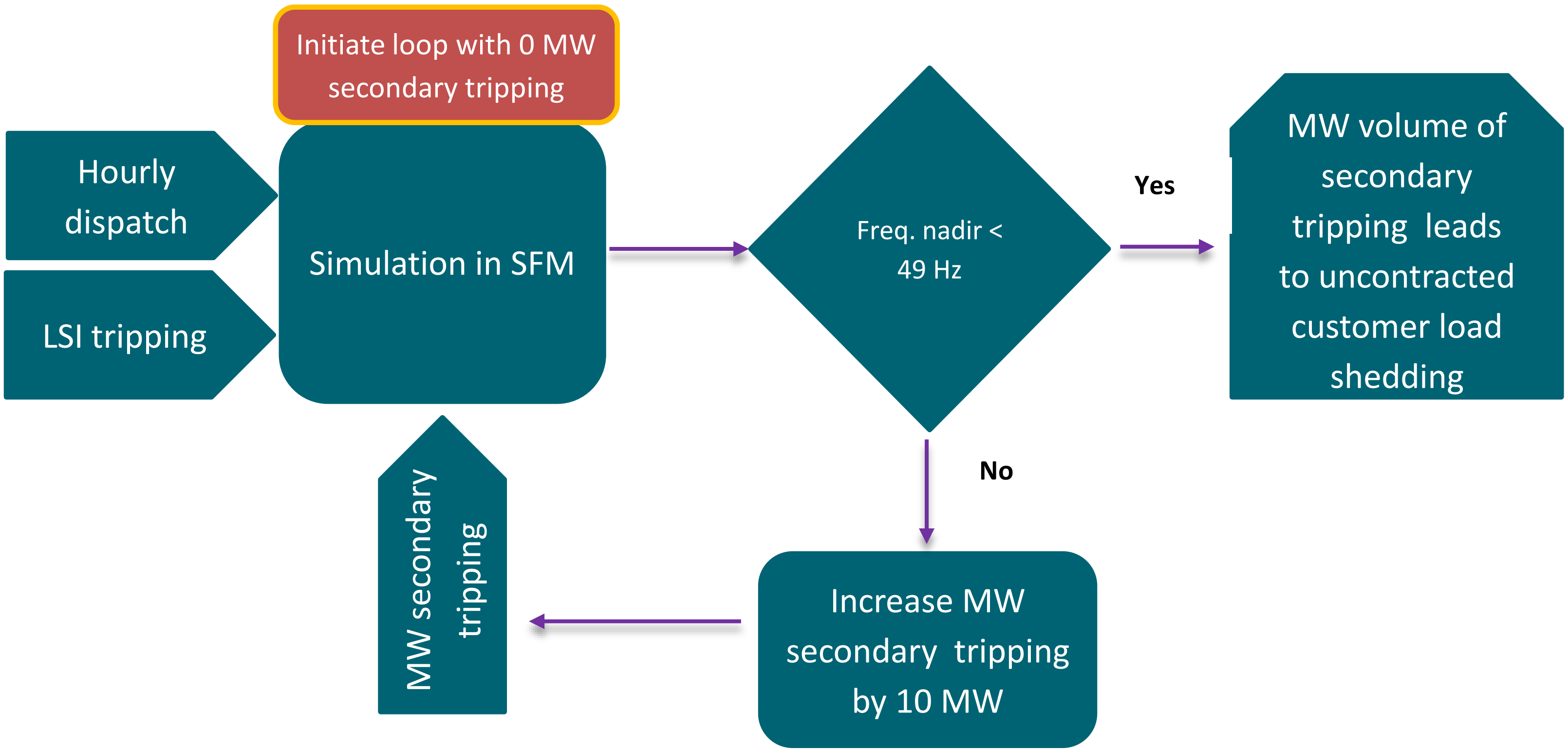
Tuning and Calibration of Governor-Turbine Models as per RoCoF Testing



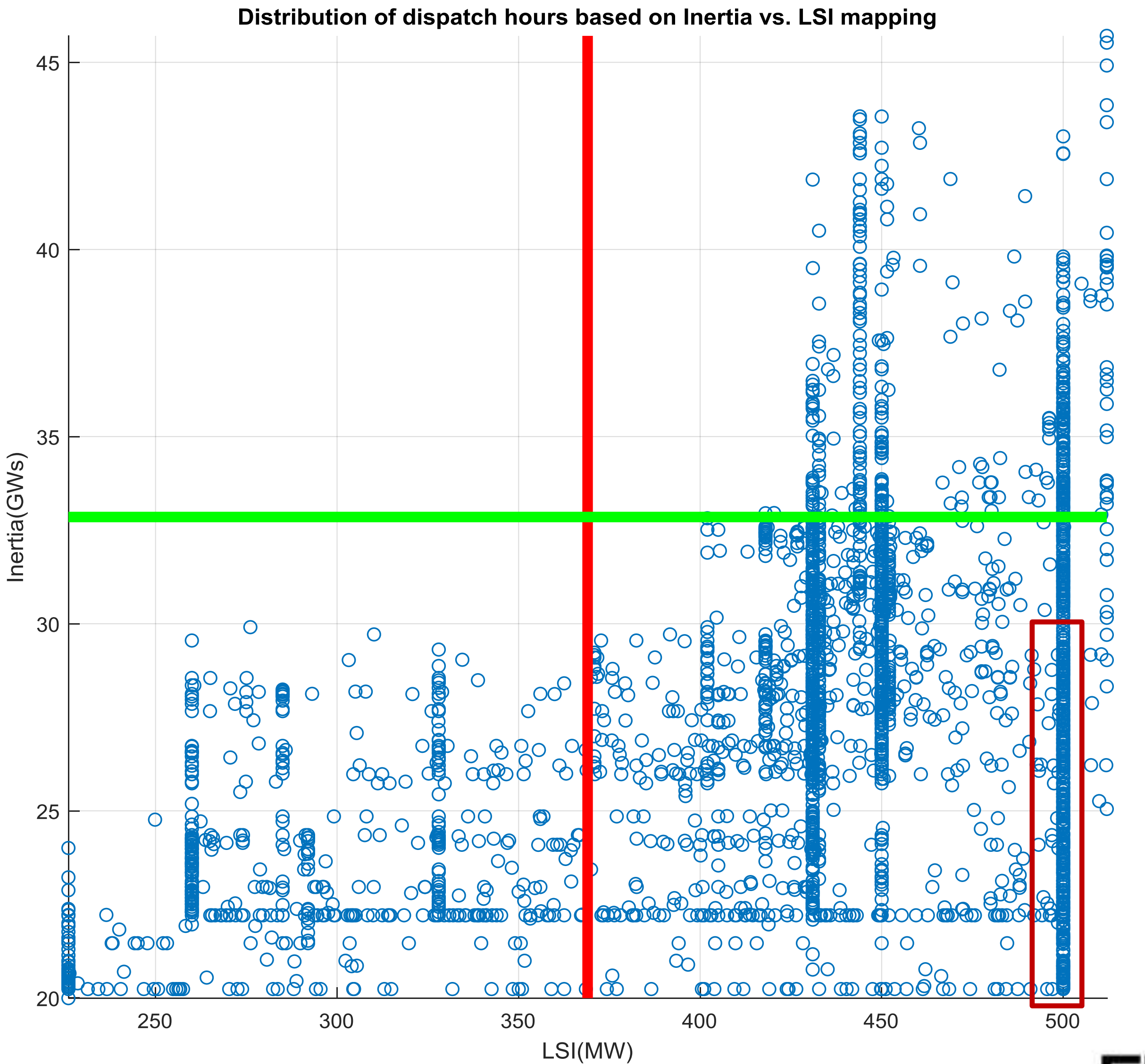
Updating Interconnector Settings, Pumped Hydro settings in SFM as per recent DS3 System Services Contracts

Quantification of MW volume of incompliant SSG generation tripping that leads to uncontracted customer load shedding

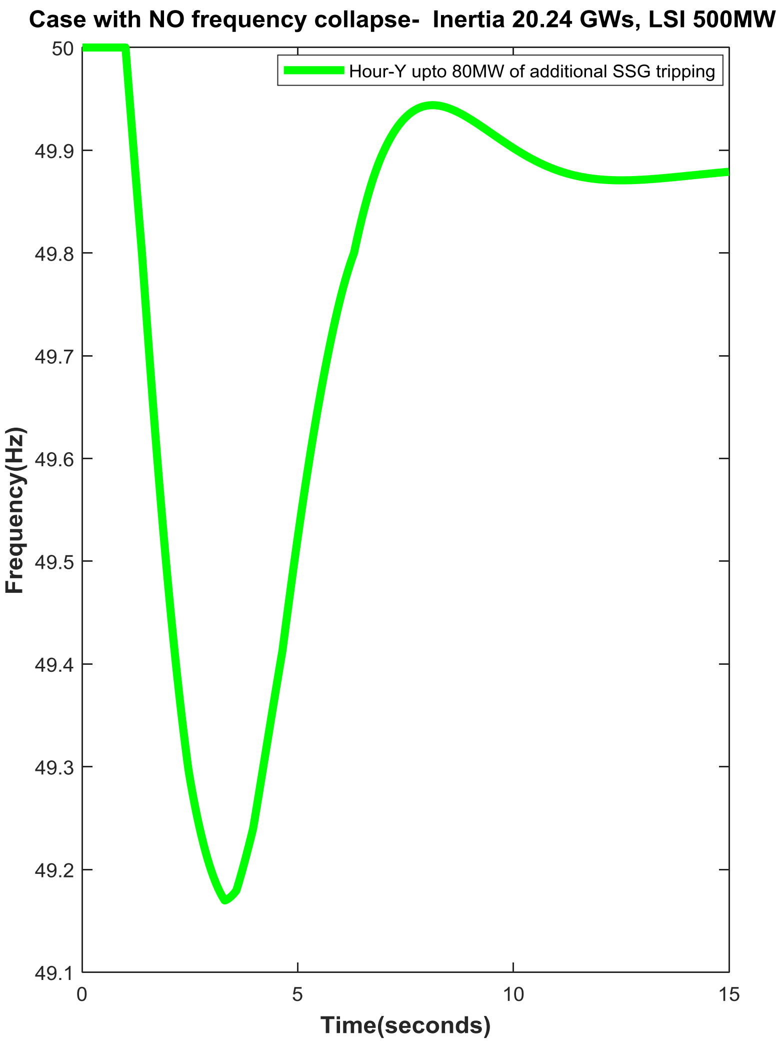
Overview of Simulation Process

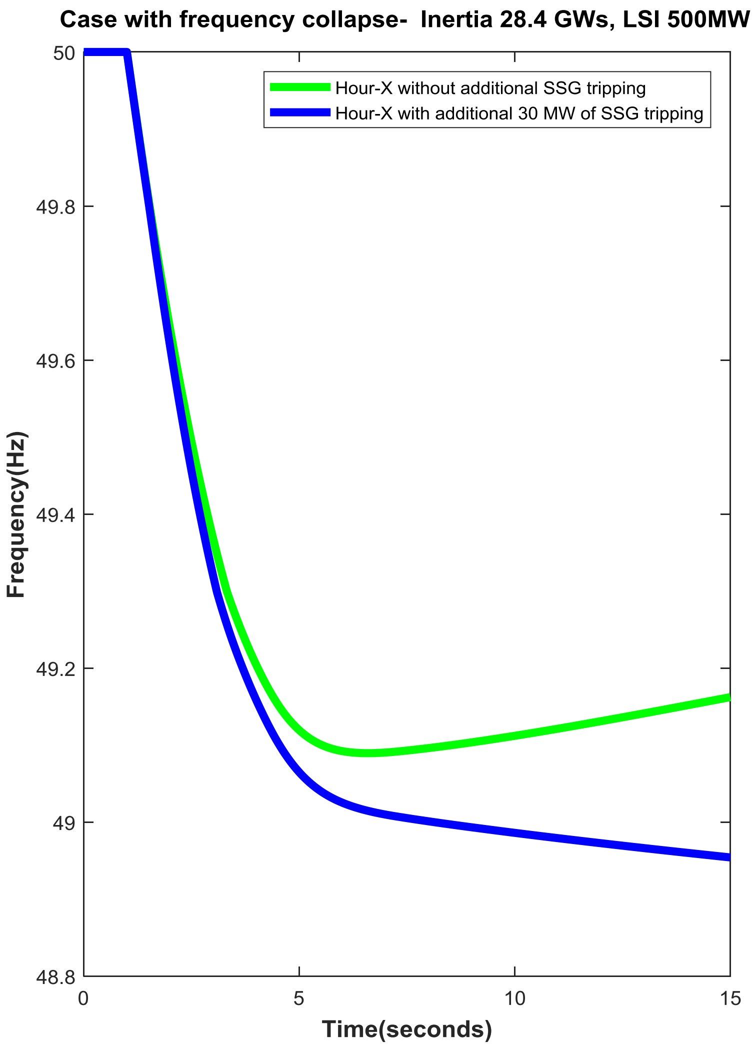


Assessment of Dispatches



Overview of Sample Results





EIRGRID GROUP

Next Steps

- Continue assessment of full 2020 simulation analysis
- Investigate reasons for high inertia system issues – likely lack of system reserve issue and resolvable
- Full results expected end of March 2019

ESB Networks – RoCoF Update
DS3 Advisory Council

Tony Hearne

7th February 2019

DSO RoCoF Project Wind Breakdown

Overall Summary		
Confirmed Returns: A total of 1266 MW of wind farm settings have been changed to date. **Wind Farms Remaining:** None		
Overall Status	G	
	October 2018	September 2018
Confirmed returns	100%	100%
Remainder to be Upgraded	0%	0%
Currently being considered for Derogation	0%	0%

Non Wind

- The total quantum of non-wind generator units is 423MW.
- It was agreed with the TSO to predominantly focus on the largest units and achieve a minimum compliance figure of 80% of this total.
- Therefore the target figure is approximately 340MW.
- ESBN have been informed verbally that the compliance value is now in excess 340 MW
- Awaiting the relevant formal documentation.

Generator Type	January 2019 (MW)	December 2018 (MW)
Customer Engagement (Stage 1 letters issued and returned)	387	387
OEM Engagement	367	367
RoCoF Compliant Generators	338	315.1

Mission Accomplished – for now…..

Roll of honour

- Keith Buckley
- James Kelly
- Brendan McGrath
- Padraig Lyons
- Ger Rafferty

ROCOF IMPLEMENTATION PROGRAMME

DS3 Advisory Council Update 07/02/19

LSG RoCoF Progress – Complete

- **All LSG sites >5MW have been changed to new RoCof setting**
- **1120 MW of 1Hz/s RoCoF compliant Large Scale Generation (including sites that have connected since the programme started)**
- **68 LSG sites have been changed**

SSG RoCoF Implementation

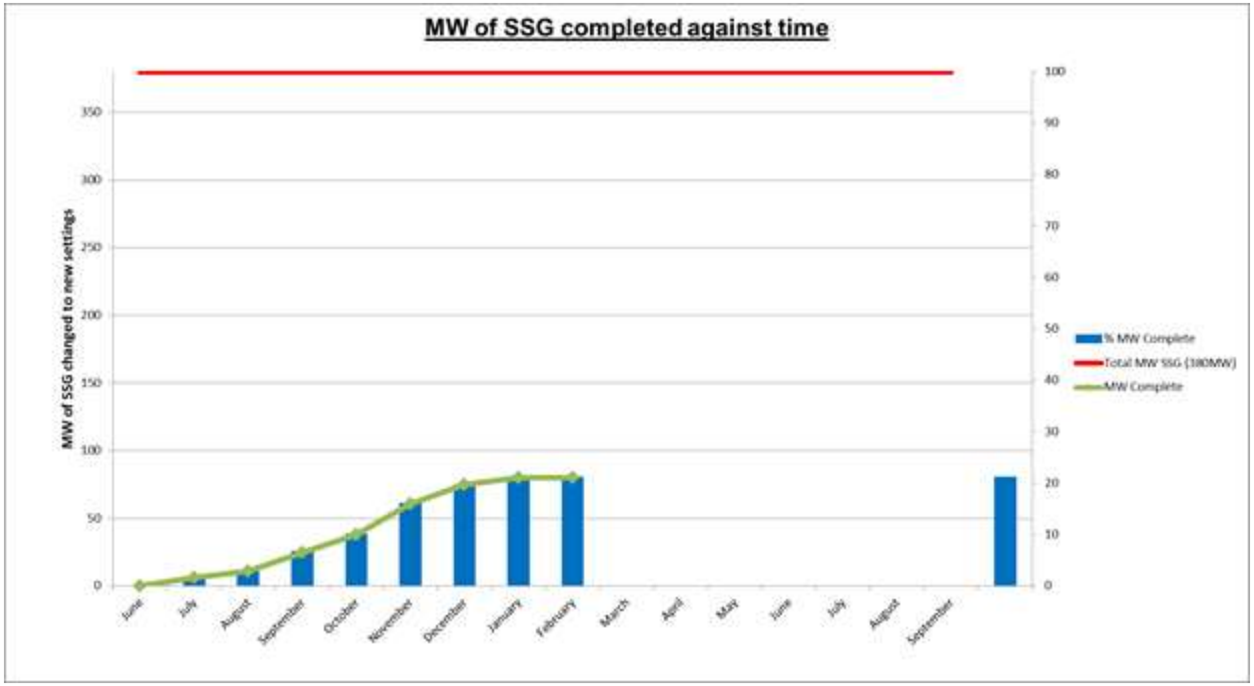
- **Letters requesting G59 changes sent out 01 June 2018**
- **SSG owners to acknowledge receipt**
  - Online or by return pre-paid envelope
- **For assurance purposes SSG owners to use G59 approved contractors**
  - List of approved contractors on NIE Networks website
- **G59 approved contractor list established following procurement exercise**
  - c20 contractors on list
- **SSG owners to make the changes by 30 September 2019**
- **Costs associated with making the changes borne by SSG owners**

SSG RoCoF Progress – Correspondance

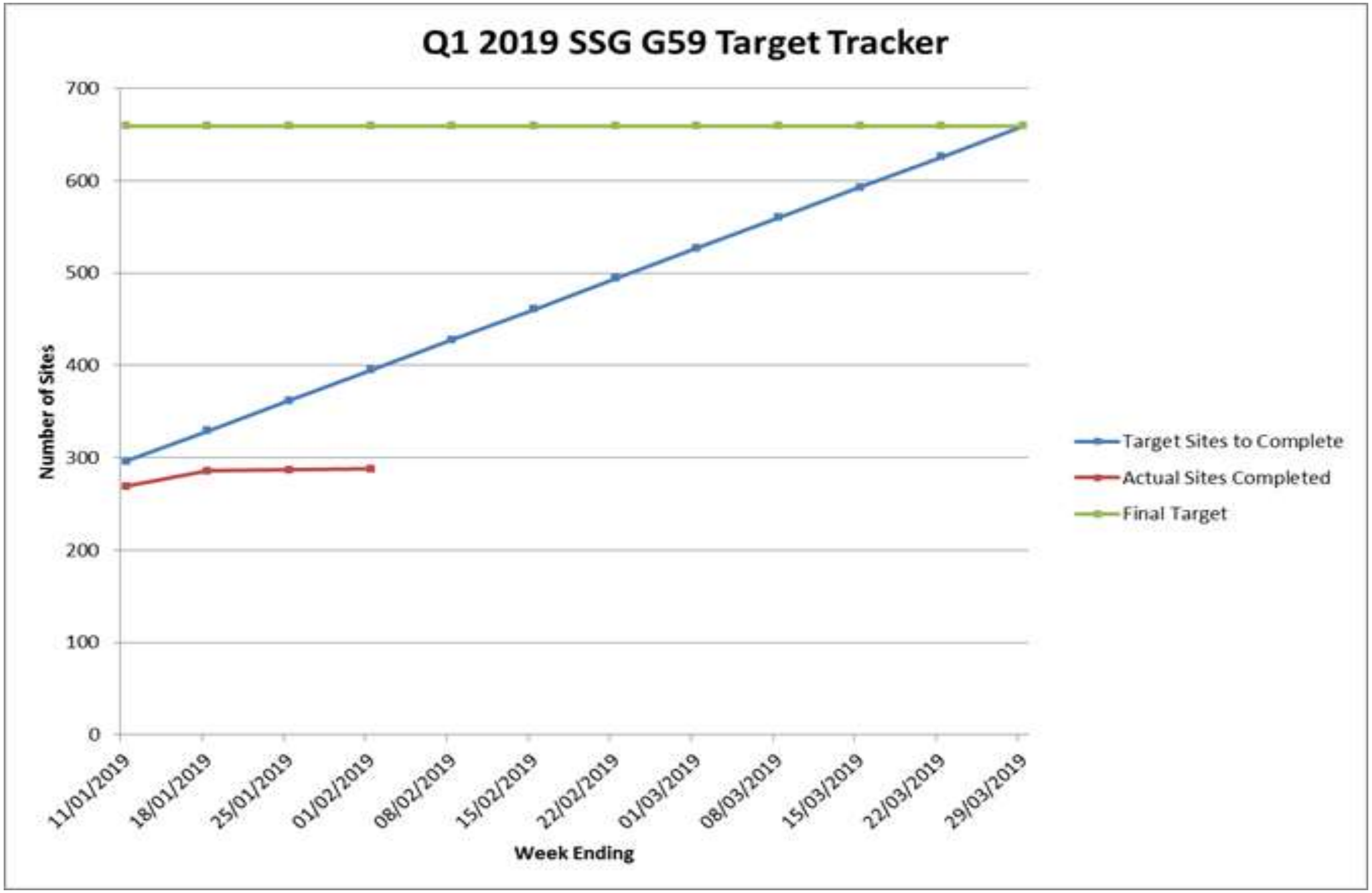
- **c1500 letters sent to SSG owners**
  - c1000 (66%) acknowledgement responses – 302MW
- **c500 follow up letters sent to non-responders at the end of October**
  - c191 acknowledgment responses – 52MW
- **Total acknowledgments to date 1185 – 354MW**
- **c285 generators (56MW) still to acknowledge either letter**
  - 161 Wind (33MW)
  - 88 PV (5MW)
  - 20 AD/Biogas (7MW)
  - 11 Diesel (9MW)

SSG RoCoF Progress – Totals

Letter 1 Returns	Letter 1 Acknowledgement (kW)	Letter 2 Returns	Letter 2 Acknowledgement (kW)	Total Returns	Total Acknowledgement (kW)	Changes Complete	Changes Complete (kW)	Changes Complete (% kW)
994	302276	191	52304	1185	354580	288	80313	21.1



SSG RoCoF Progress – Tracking



SSG RoCoF Progress – Next Steps

- UR – SONI – NIE Networks progress review meetings.
- Continued engagement with the approved G59 contractors to ensure effective programme delivery.
- January 2019 – Re-engagement with NIRIG, UFU, Industry, multiple site owners.
- 1st February 2019 – 3rd letter to 285 non-responders pointing out that non-compliance will lead to de-energisation notices being issued which may have implications for generators' contractual obligations.
- 8th February 2019 – Follow up letter to all Generators that haven't made the changes reminding them of the need to be compliant by 30th September 2019 and pointing out that non-compliance will lead to de-energisation notices being issued which may have implications for generators' contractual obligations.
- March 2019 – NIE Networks hosting 4 information evenings where generators can discuss the required changes with NIE Networks technical staff.

SSG RoCoF Progress – 2nd Reminder letter

G59 SETTINGS NOTIFICATION – URGENT ATTENTION REQUIRED

We previously wrote to you regarding changes that you are required to make to the G59 protection at your generator. To date we have not received the required acknowledgement return included in the earlier correspondence.

YOUR GENERATOR IS NOW SCHEDULED FOR DE-ENERGISATION AFTER 1st OCTOBER 2019. YOU MUST TAKE THE REQUIRED ACTIONS BELOW WITHOUT DELAY.

REQUIRED ACTIONS:

- Engage a qualified engineer to update the G59 protection settings at your generator. Full details of G59 contractors are available online at www.nienetworks.co.uk/G59contractors.
- Confirm to NIE Networks that you have received this letter and that you have engaged a G59 contractor. This can be done online at www.nienetworks.co.uk/G59replyform or by post using the enclosed acknowledgement form.
- For generators with a connection point at 11kV and above, book an appointment for an NIE Networks' engineer to witness a protection test of the new G59 settings.

FURTHER DELAY IN ENGAGING A G59 CONTRACTOR MAY AFFECT YOUR ABILITY TO ENSURE COMPLIANCE WITH THE DISTRIBUTION CODE BEFORE 1st OCTOBER 2019.

Those generators who have not made the required G59 protection changes by 1st October 2019 will receive a 'Notice of De-Energisation' and will not be permitted to operate their generation facility in parallel with the Distribution System after that date. Failure to update the G59 protection settings after 1st October 2019 may result in disconnection of your generator from the network and withdrawal of the export capacity allocated to it. Resumption of generation after withdrawal of export capacity would require a new application for capacity to be made to NIE Networks, however no guarantee can be given that capacity will be available.

NIE Networks will inform your electricity supplier that de-energisation may occur on 1st October 2019 as this may have implications for the power purchase contracts that you may have in place with your supplier. De-energisation may also affect any contractual arrangements in place with Ofgem and the funder of your generation plant. For all queries on this matter please email G59@nienetworks.co.uk.

SSG RoCoF Progress – Information Evenings

Date	Venue	Time
Monday 4th March 2019	Glenavon Hotel, Cookstown	7.30 – 9.00PM
Wednesday 6th March 2019	Silverbirch Hotel, Omagh	7.30 – 9.00PM
Monday 11th March 2019	Seagoe Hotel, Portadown	7.30 – 9.00PM
Wednesday 13th March 2019	Tullyglass Hotel, Ballymena	7.30 – 9.00PM

EU-SysFlex

Noel Cunniffe

EIRGRID GROUP

EU-SysFlex

WP2
RESULTS OF YEAR 1

Noel Cunniffe – WP Leader

EirGrid, SONI, Imperial College London, EDF, PSE, NCNR, innogy, Fraunhofer IWES, VTT, INESC TEC, VITO/Energyville, KU Leuven

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773505.

Work Package 2 Overview

- Work Package 2 seeks to answer three key questions for EU-SysFlex:

1. What are the **technical scarcities** of the future European System?
2. What is the **value** of future **System Services** provision to operate at high RES-E?
3. What **technical** and **market solutions** are needed to address **technical scarcities** and **improve the resilience** of the future European System?

Work Package 2 Tasks & Deliverables

FASTTRACK

2.1 - State-of-the-Art Literature Review of System Scarcities
→ WP 3 | Imperial College London | Nov 17 – Apr 18

LONGTRACK

2.2 - EU-SysFlex Scenarios and Network Sensitivities
MS1 M4
→ WP 3,6,7,8,9 | EIRGRID | Nov 17 – Oct 18

2.3 – Models for Simulating Technical Scarcities on the European Power System
MS2 M6
→ WP 4 | EDF | Nov 17 – Oct 18

2.4 - Determining Technical Scarcities of the Future European Power system
EIRGRID | Jul 18 – Oct 19

2.5 - Financial & Economical Analysis of EU-SysFlex Scenarios
EIRGRID | Oct 18 – Oct 19

2.6 – Determining Technical and Market Solutions for Technical Scarcities
← WP 3,6,7,8,9 | EIRGRID | Oct 19 – Apr 21
→ WP 10

Deliverables completed in Year 1

Deliverable 2.1 – State-of-the-Art Literature Review of System Scarcities at High Levels of Renewable Generation

- **April 2018** – **Imperial College London**, EirGrid, EDF, VTT, NCNR, PSE, INESC TEC

Deliverable 2.2 – EU-SysFlex Scenarios and Network Sensitivities

- **October 2018** – **EirGrid**, EDF, VTT, PSE, innogy, Imperial College London

Deliverable 2.3 – Models for Simulating Technical Scarcities on the European System with High Levels of Renewables

- **October 2018** – **EDF**, EirGrid, PSE, INESC TEC, VTT, VITO/EnergyVille

EU-SysFlex

Deliverable 2.1 – State of the Art Literature Review

- **Key conclusion**: Several technical scarcities exist at high levels of non-synchronous renewable generation and there is a need for system flexibility
- Scarcities identified were categorised as:
  - **Lack of frequency control** – Inertia, Operating Reserves, Ramping Capability
  - **Lack of voltage control** – Steady-state & Dynamic Control, Short Circuit Power
  - **Rotor angle instability** – Small-signal Stability, Large-disturbance Stability
  - **Network congestion** – Hosting Capacity, RES Curtailment, Capacity Allocation
  - **Need for improved system restoration** – Black-start Capability, Network Configuration, Load Restoration
  - **Degradation of system adequacy** – Variable RES Uncertainty, System Interdependencies

Deliverable 2.1 – State of the Art Literature Review

- Literature review covers 28 projects, grid codes and studies covering the majority of European power systems and input from US and Australia studies

LITERATURE REVIEWED	LACK OF FREQUENCY CONTROL	LACK OF VOLTAGE CONTROL	ROTOR ANGLE INSTABILITY	NETWORK CONGESTION	NEED FOR SYSTEM RESTORATION	SYSTEM INADEQUACY
DS3	■	■	■			
All-Island Grid study	■	■				
Facilitation of Renewables (FOR) Study	■	■	■			
Massive Integration of Renewable Energy (MIGRATE) project	■	■	■			
System Operability Framework	■	■				
Technical and Economic Analysis of the European Electricity Power System with 60% Renewable Energy Sources	■			■		■
PROMOTION	■	■				
Challenges and Opportunities for the Nordic power system	■			■		■
100% RES in Baltic sea countries	■					
e-Highway 2050	■	■	■	■		
MARKET4RES	■					
NORTHSEAGRID						
GRID4EU		■		■	■	
RESERVICES	■	■				
GRIDTECH				■		■
RAOM/RAO tool				■		
UMBRELLA				■		
CIGRE - Innovation in power systems industry				■		
Coordinating cross-country congestion management				■		
Future system inertia 2	■					
Future Power System Security Program	■	■				
Eastern Renewable Generation Integration Study (ERGIS)	■			■		
Western Wind and Solar Integration Study (WWSIS)	■	■	■			
Mid-term Adequacy Forecast						■
European Power System 2040: Completing the map & assessing the cost of non-grid	■					
ENTSO-E RfG	■	■	■		■	
ENTSO-E HVDC	■	■			■	
ENTSO-E DCC	■	■		■		

Technical Scarcities – Frequency Control

What are the issues?

1. Inertia
2. Reserves
3. Ramping

Why is it becoming a scarcity?

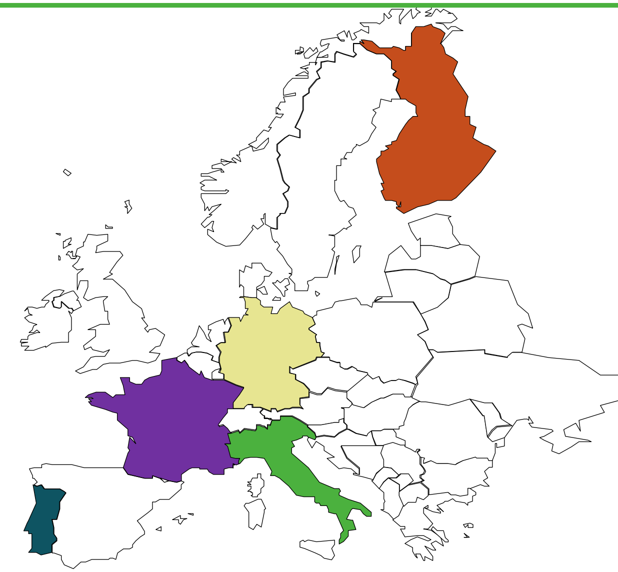
- Reduced synchronous generation on the system providing inertia and reserve capability means that frequency changes happen more quickly and are less manageable.

What are the solutions?

Technical Solutions: Technologies providing frequency response in various timeframes, in the range of seconds to hours, e.g. compensators, wind, fast frequency response (FFR), energy storage, demand side response, cross-border interconnection, and other forms of RES services

System Control: TSO-DSO coordination, increased real-time monitoring of issues.

Enhanced Market Design: Design of new services (e.g. reserves, response, etc.).



EU-SysFlex

Technical Scarcities – Voltage Control

What are the issues?

1. Short circuit power
2. Steady state voltage control
3. Dynamic voltage control

Why is it becoming a scarcity?

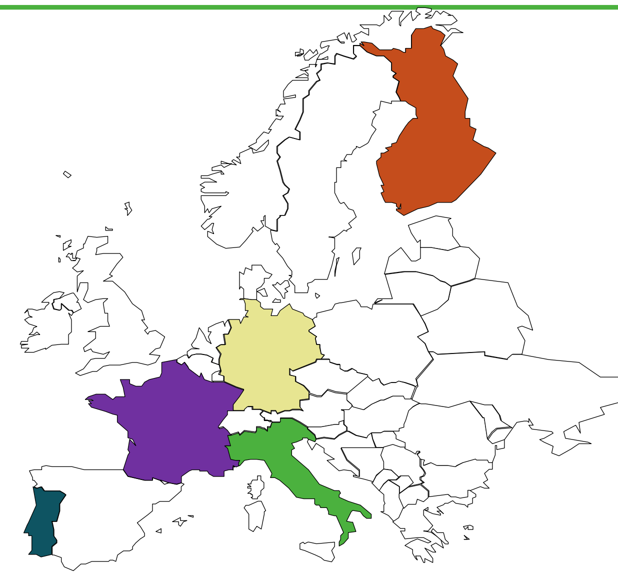
- Reduced short circuit power due to the replacement of synchronous machines and the limited capacity of converters in terms of short-circuit current injection
- Voltage variation effects due to connection of RES in the distribution system

What are the solutions?

Technical Solutions: Synchronous compensators, reactive power static compensator, inductance, condenser, wind, PV, SVCs, OLTCs

System Control: TSO-DSO coordination, increased real-time monitoring of issues

Enhanced Market Design: (reactive): Design of new services (e.g. steady-state reactive power and dynamic reactive power)



EU-SysFlex

Technical Scarcities – Rotor Angle Stability

What are the issues?

1. Small signal stability
2. Transient stability

Why is it becoming a scarcity?

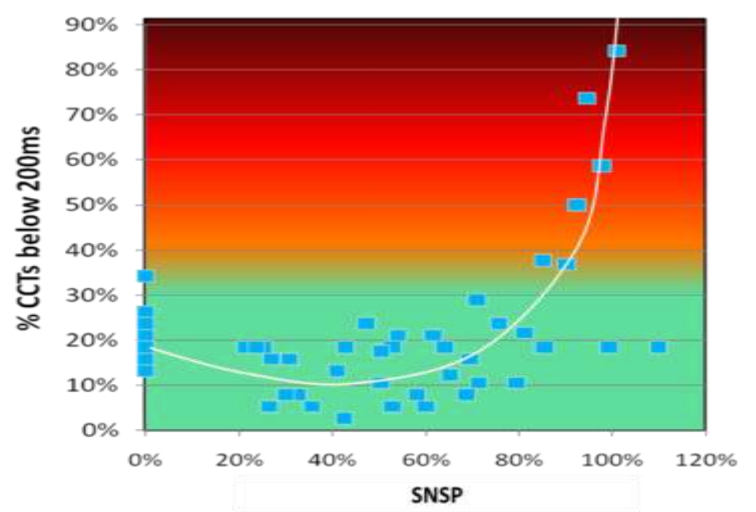
- Less synchronous generation to maintain inertia and stability
- Reduction in synchronising torque deteriorates stability margins
- Reduction of transient stability margins due to the displacement of conventional plants
- Introduction of new power oscillation modes. Reduced damping of existing power oscillations

What are the solutions?

Technical Solutions: Some solutions are identified, e.g. voltage support from modern variable renewable generators, but further studies are needed for this complex phenomenon

System Control: Within the review, no such solutions have been identified to mitigate rotor angle instability issues.

Enhanced Market Design: Design of new services (e.g. dynamic reactive power to increase transient stability).



Source : EIRGRID AND SONI, 2011

Technical Scarcities – Congestion

What are the issues?

1. Network capacity
2. RES curtailment
3. Capacity allocation

Why is it becoming a scarcity?

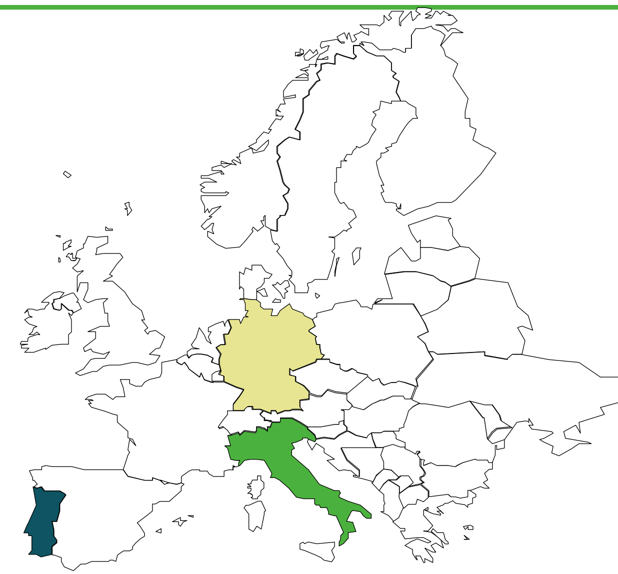
- Increase in distance between generation and load, and generation variability.
- Increased feed-in power (e.g. solar PV plants) and bidirectional power flows noted in distribution networks.

What are the solutions?

Technical Solutions: Application of network control and measurement technologies, distributed energy resources, advanced control and forecasting tools

System Control: TSO-TSO coordination, TSO-DSO coordination

Enhanced Market Design: Nodal network pricing, market for non-network technologies providing network flexibility services.



EU-SysFlex

Technical Scarcities – System Restoration

What are the issues?

1. Black-start capability
2. Network reconfiguration
3. Load restoration

Why is it becoming a scarcity?

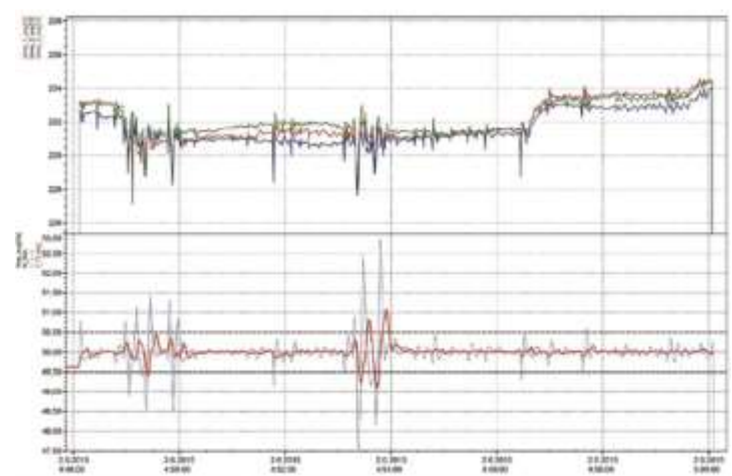
- Less black start capable plants on the grid.
- Current restoration strategy mainly refers to large synchronous generation.

What are the solutions?

Technical Solutions: Utilisation of DER, MGs, flexible technologies

System Control: TSO-DSO coordination, enhanced restoration strategy

Enhanced Market Design: Black-start market, black-start in capacity market



Black-start operation of LV network via CHP unit. Source : GRID4EU, 2016

EU-SysFlex

Technical Scarcities – System Adequacy

What are the issues?

1. Uncertainty of RES generation
2. System interdependencies

Why is it becoming a scarcity?

- Reduction in load factors and decommissioning of conventional generation driven by penetration of renewables.

What are the solutions?

Technical Solutions: Potential solutions lie in the utilisation of conventional generation, distributed generation, energy storage, demand side response, interconnection

System Control: Cross-border coordination, TSO-TSO & TSO-DSO coordination

Enhanced Market Design: Capacity market, incorporation of non-generation technologies in capacity market, cross-border capacity market, etc.

EU-SysFlex

Deliverable 2.2 – EU-SysFlex Scenarios

Core Scenarios

- **Based on EU Reference Scenario 2016**
- Generation portfolios, demand, IC, storage
- Pan-European to ensure consistency

Network Sensitivities

- Scenarios to **further test:**
  - Continental European System
  - Nordic System
  - IE and NI system

EU-SysFlex

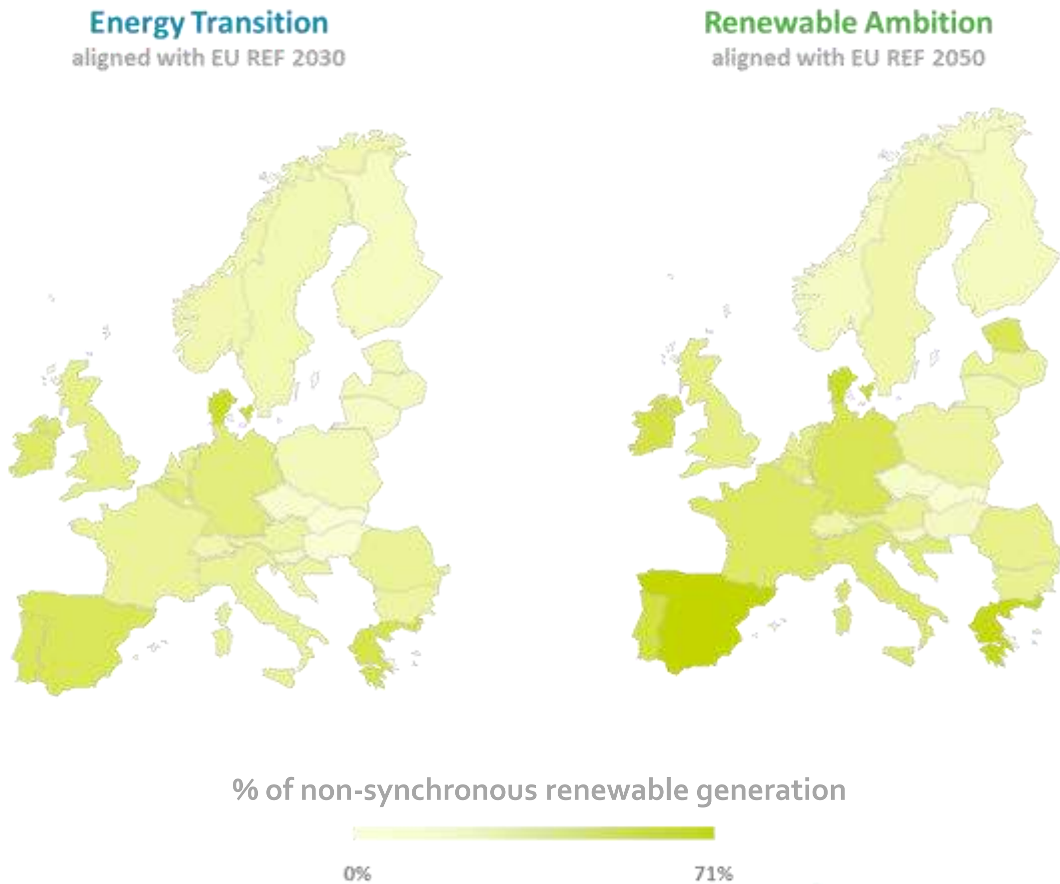
Deliverable 2.2 – EU-SysFlex Scenarios

Energy Transition

52% RES-E for Europe in 2030

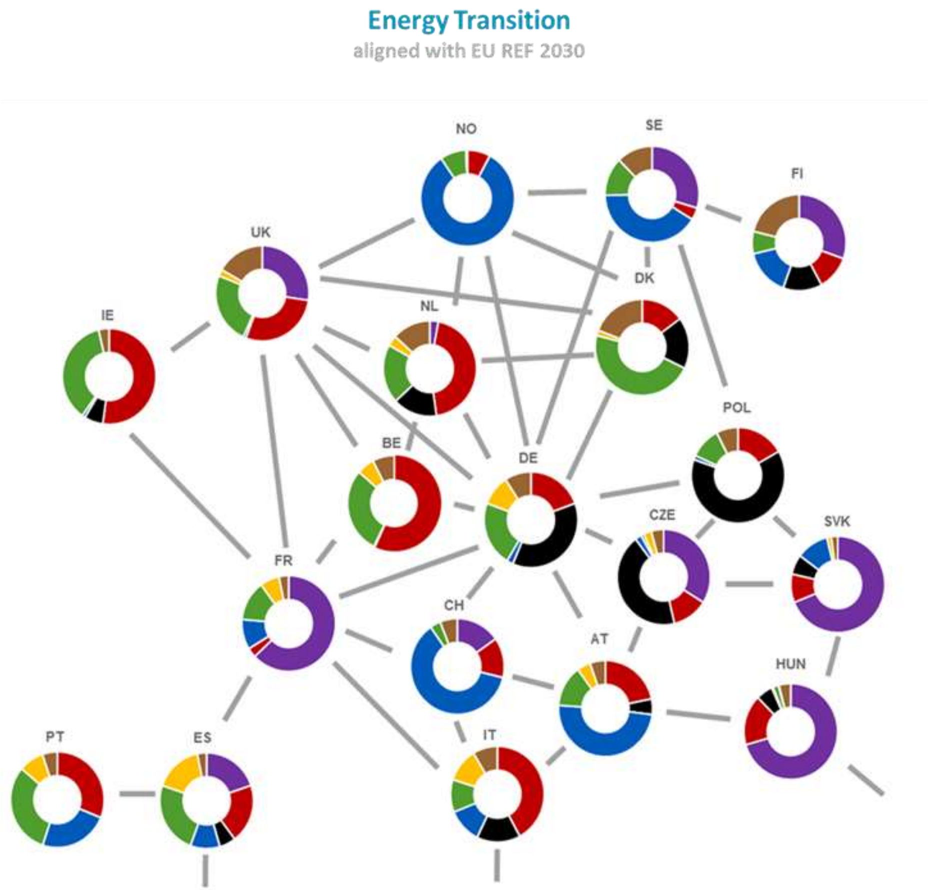
Renewable Ambition

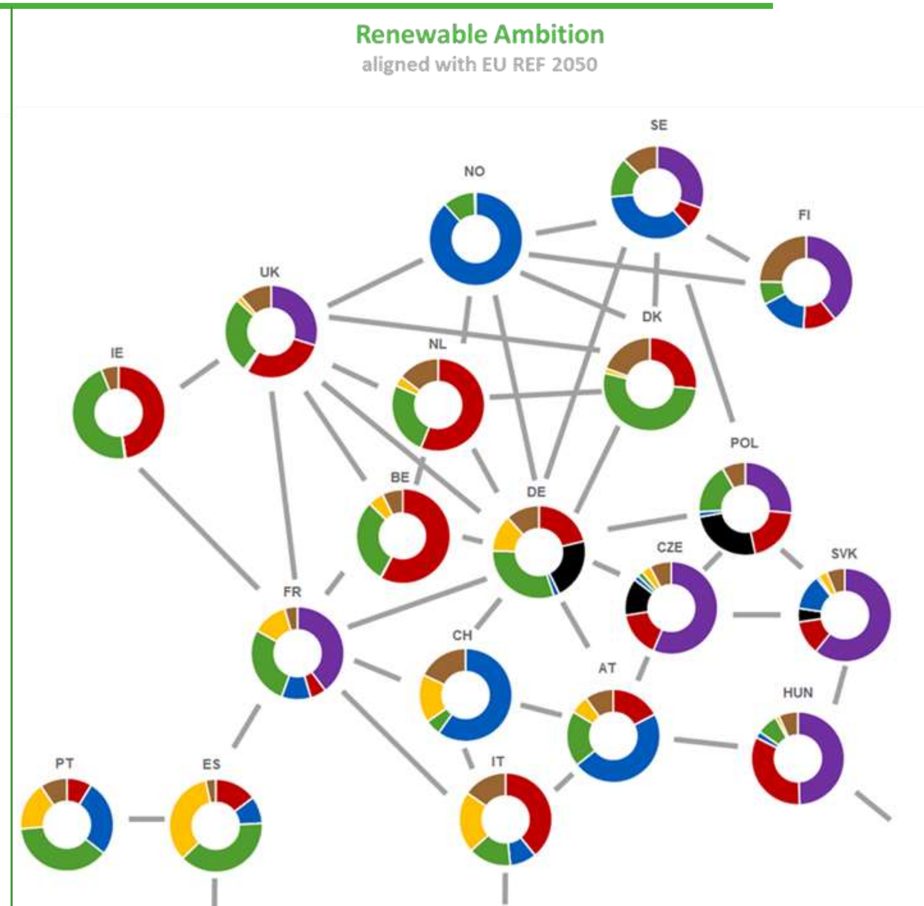
66% RES-E for Europe in 2030



EU-SysFlex

Production Outputs
Energy Transition and Renewable Ambition





EU-SysFlex

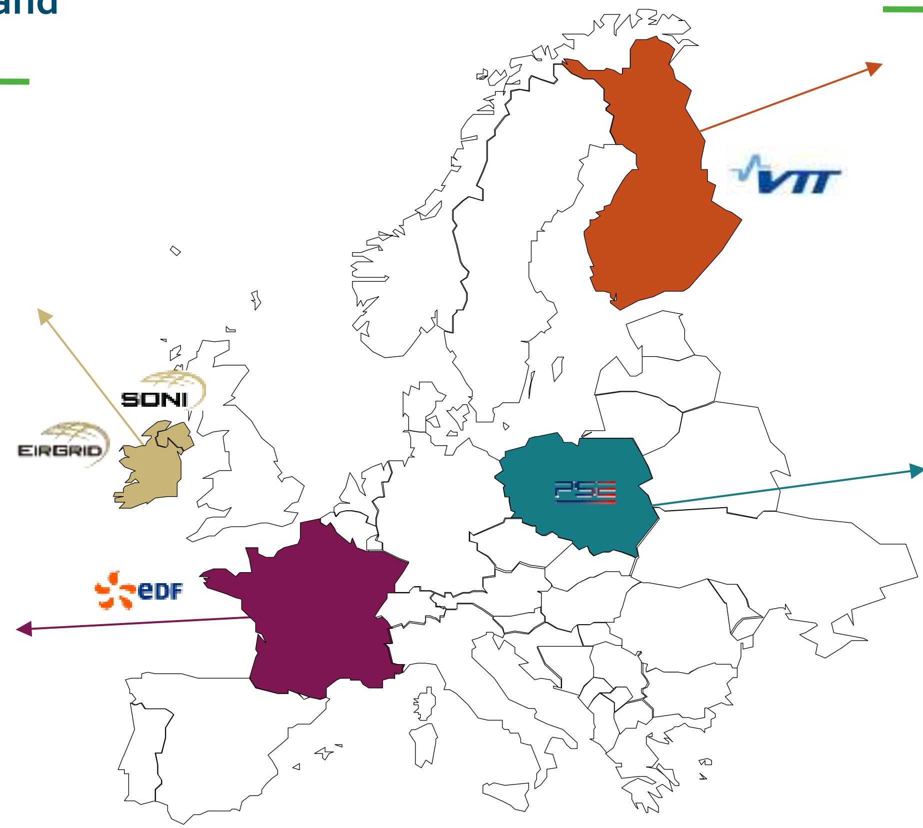
Core Scenarios and Network Sensitivities

Ireland and Northern Ireland Power System

- Energy Transition
- Renewable Ambition
- Steady Evolution
- Consumer Action
- Low Carbon Living

Continental Europe Power System

- Energy Transition
- Renewable Ambition



Nordic Power System

- Energy Transition
- Renewable Ambition
- High Solar

Continental Europe Power System

- Energy Transition
- Renewable Ambition
- Gone Green
- Distributed Renewables

EU-SysFlex

Summary of the Scenarios

Installed Capacity by Fuel Type (MW)	EU-SysFlex Core Scenarios		IE and NI Network Sensitivities		
	Energy Transition	Renewable Ambition	Steady Evolution	Low Carbon Living	Consumer Action
	All-Island	All-Island	All-Island	All-Island	All-Island
Conventional Fuel Generation	**5562**	**5826**	**6096**	**5530**	**5980**
Wind (Onshore)	5650	7268	6678	7040	6922
Wind (Offshore)	25	25	700	3000	1000
Wind-Total	5675	7293	7378	10040	7922
Hydro	237	237	237	237	237
Biomass	287	310	487	847	528
Solar PV	369	420	900	3916	2916
Ocean (Wave/Tidal)	-	-	50	98	73
Renewable Generation	**6568**	**8260**	**9052**	**15188**	**11725**

Disclaimer: This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773505.

EU-SysFlex

Deliverable 2.3 – Models for Simulating Technical Scarcities

Ireland and Northern Ireland Power System

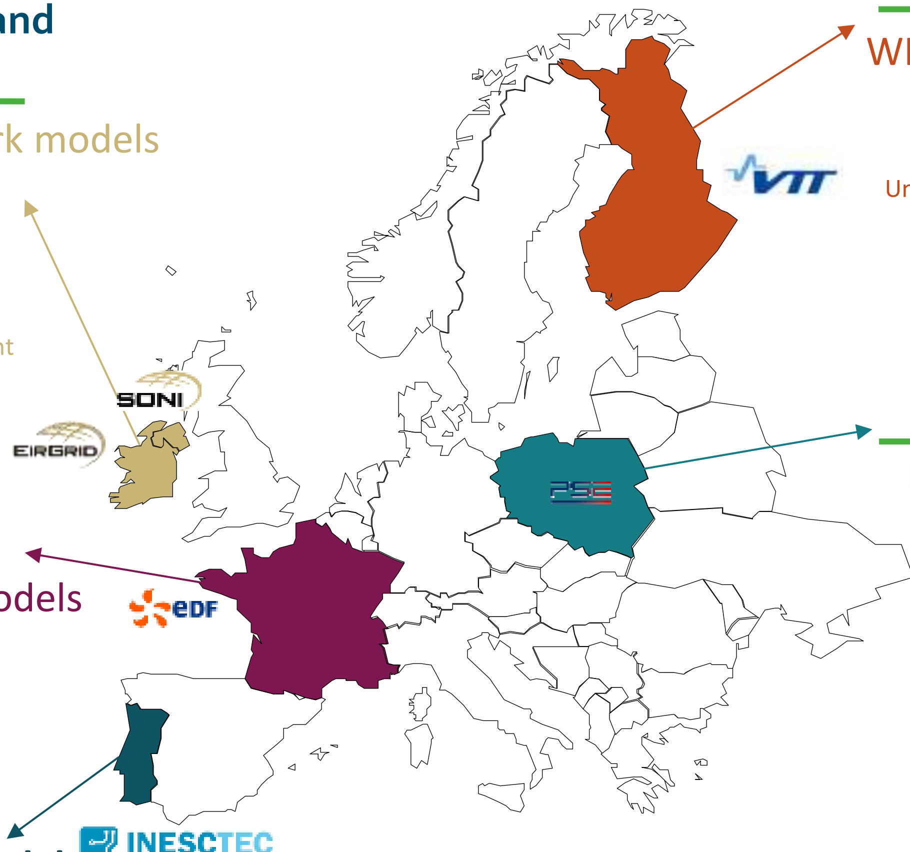
PLEXOS and detailed network models

- Unit commitment
- Frequency stability
- Voltage stability
- Rotor angle stability
- Congestion assessment
- System restoration

Continental Europe Power System

CONTINENTAL & PALADYN models

- Unit commitment
- Frequency stability



Nordic Power System

WILMAR & frequency stability models

- Unit commitment
- Frequency stability

Continental Europe Power System

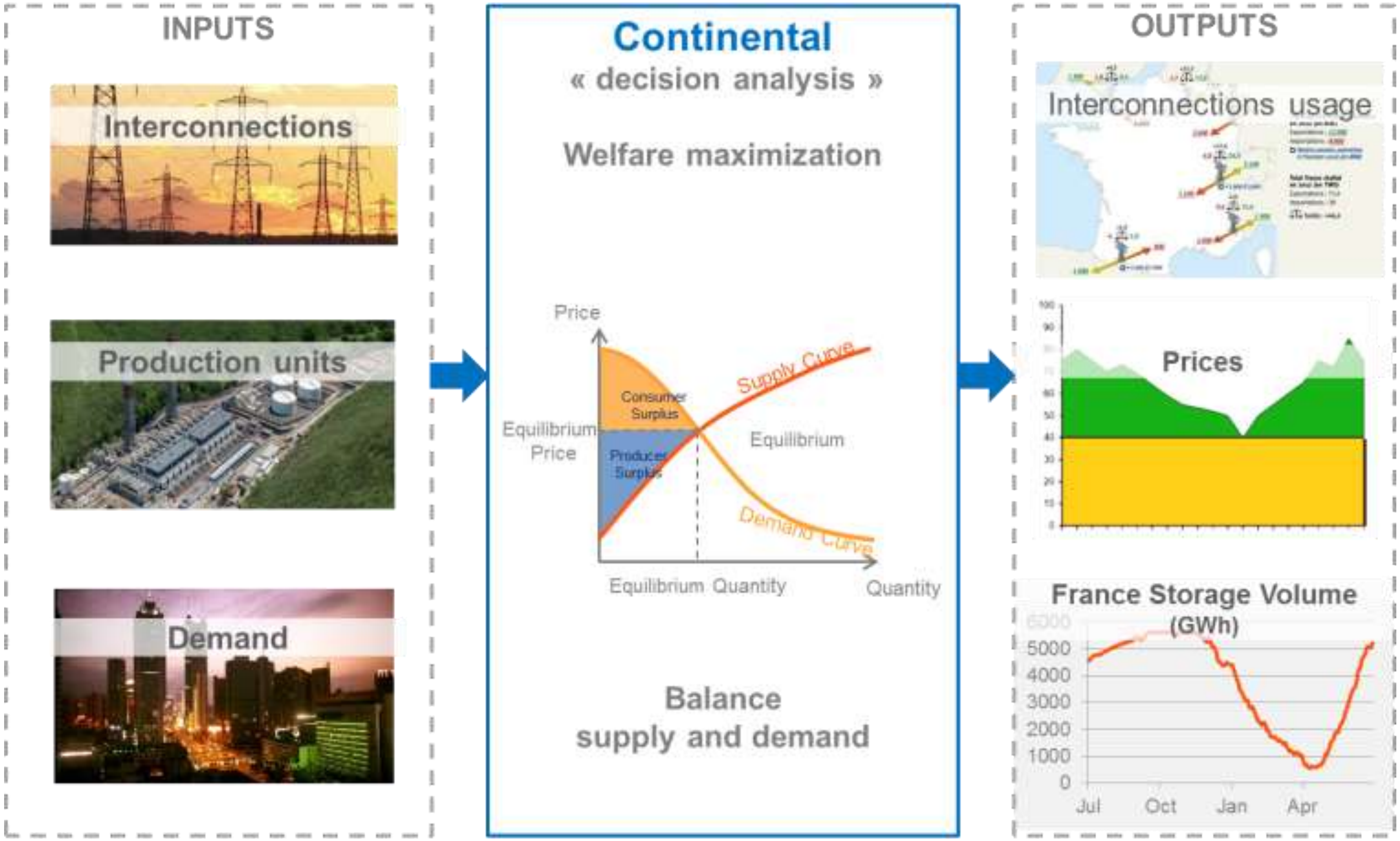
Detailed network models

- Voltage stability
- Rotor angle stability

Generic distribution grid model to represent the TSO/DSO border behaviour

EU-SysFlex

Overview of EDF models on Continental Europe



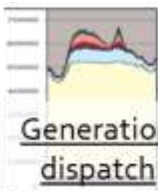
What scarcities are being assessed?		
Frequency Stability	Voltage Stability	Rotor Angle Stability
Congestion	System Restoration	**System Adequacy**

EU-SysFlex

Overview of EDF models on Continental Europe

INPUTS

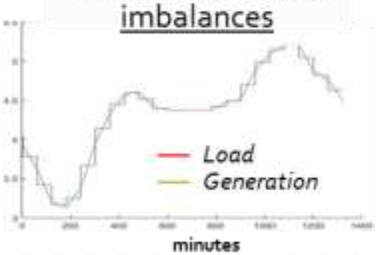
From CONTINENTAL & OPIUM



Generation dispatch

FCR & aFFR dispatch, inertia of generation units

Generation/demand imbalances



PALADYN

Simulation platform for electrical system frequency

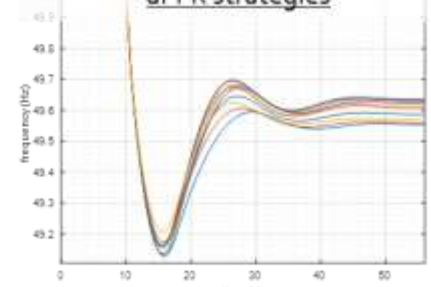
Multi-area model of Western Europe system

Dynamic model for each technology of generation unit

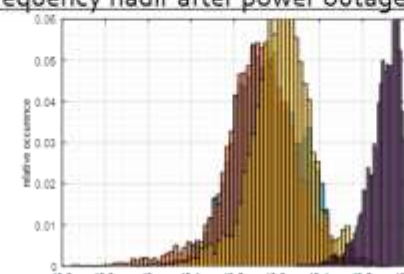
OUTPUTS

Frequency dynamic behavior for various scenarios (inertia reduction, RES frequency control, ...)

Impact on frequency of FCR & aFFR strategies



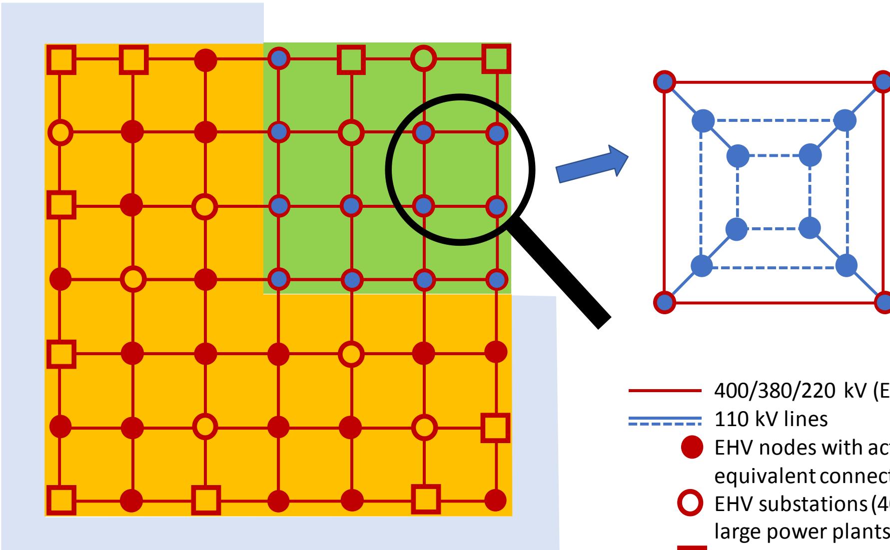
Frequency nadir after power outage (Hz)



Source : EDF R&D

What scarcities are being assessed?		
Frequency Stability	Voltage Stability	Rotor Angle Stability
Congestion	System Restoration	System Adequacy

Overview of PSE models on Continental Europe



PL
DE, AU, CZ, SK, HU
rest countries in Continental Europe

400/380/220 kV (EHV) lines
110 kV lines
EHV nodes with active distribution system equivalent connected
EHV substations (400/220 kV or 380/220 kV) or large power plants connected to EHV network
boundary EHV nodes with transmission (syn. or asyn.) system equivalent connected
EHV/110 kV substations with 110 kV lines connected
110 kV/MV substations with MV active distribution system equivalent connected

- Operation scenarios to be studied for PL, PL+DE, PL+DE+AU+CZ+SK+HU, and all CE:
  - Minimum inertia in the system
  - Maximum power demand
  - Minimum reactive power margins for synchronous generators

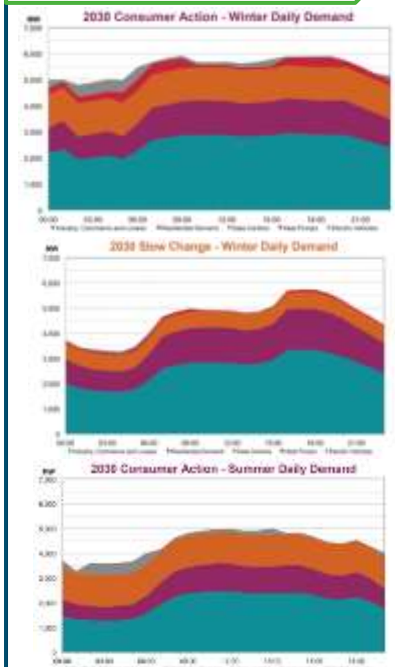
What scarcities are being assessed?		
Frequency Stability	**Voltage Stability**	**Rotor Angle Stability**
Congestion	System Restoration	System Adequacy

EU-SysFlex

Overview of Ireland and Northern Ireland Models

Production Cost Model

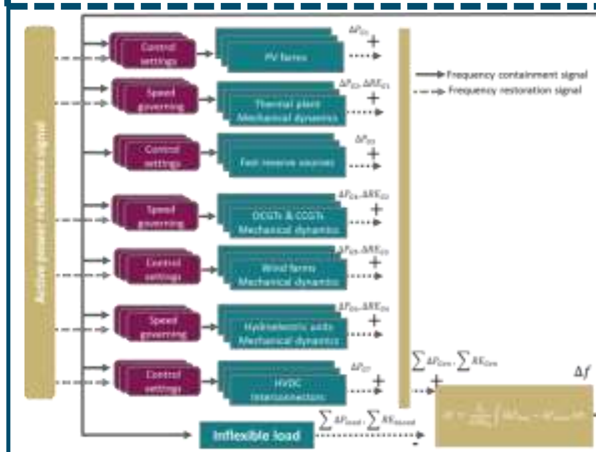
PLEXOS model



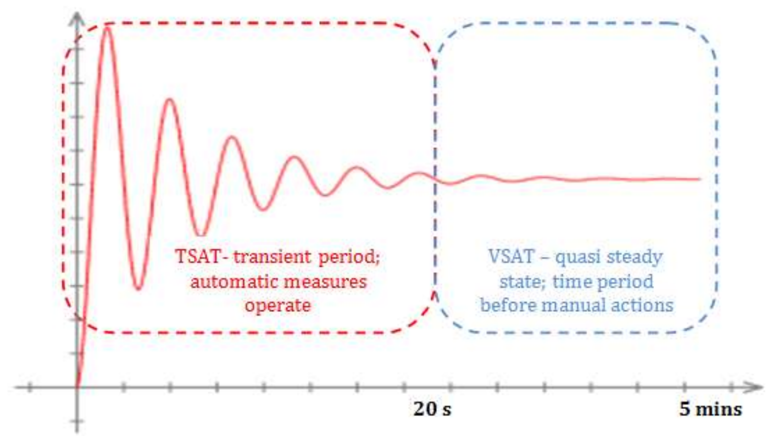
Dynamic Automation Simulation Tool

- **Dispatch – electrical model interface + initialisation engine**

Electrical Models



Single Frequency Model

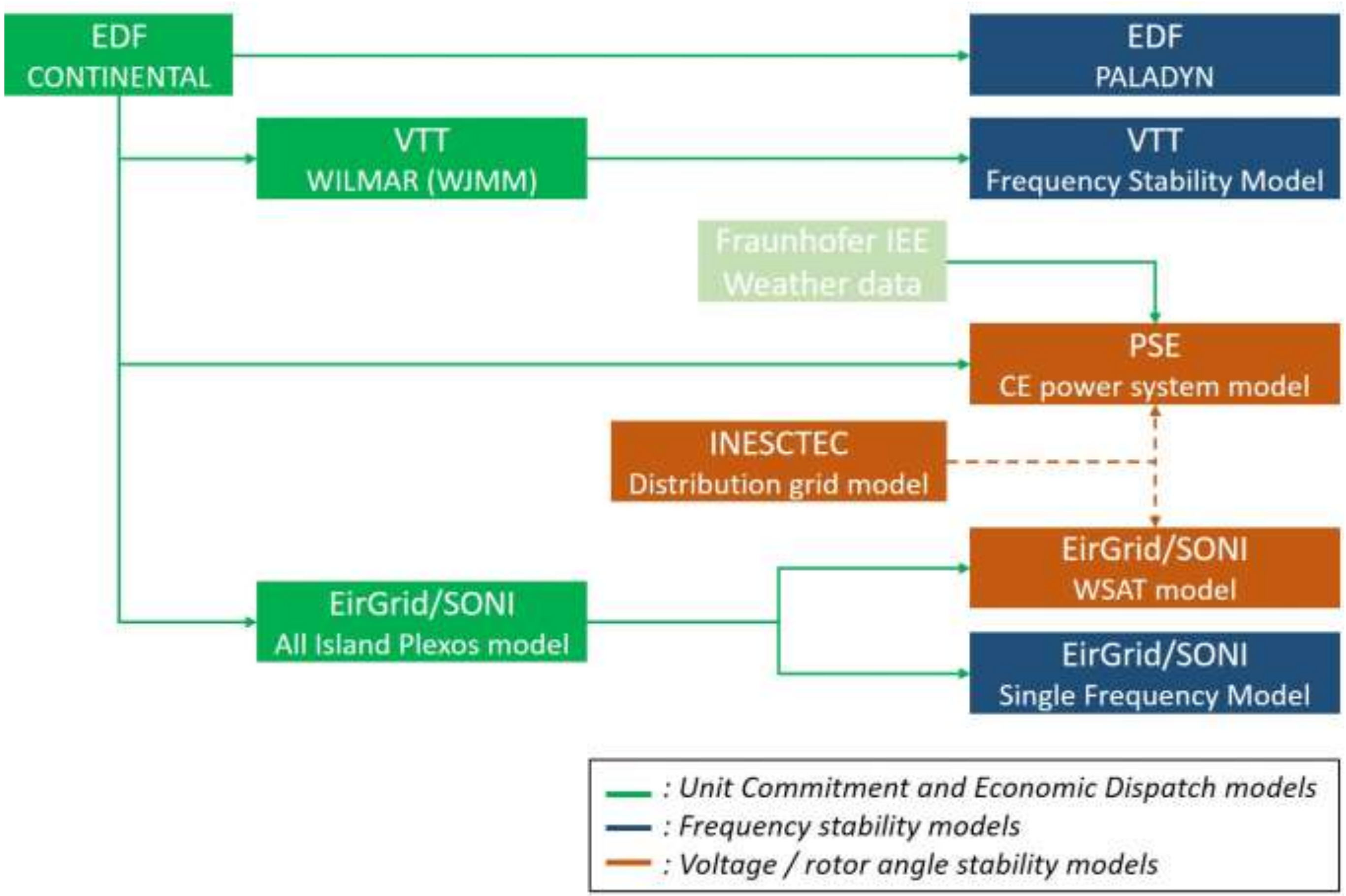


TSAT **VSAT**

What scarcities are being assessed?		
Frequency Stability	Voltage Stability	Rotor Angle Stability
Congestion	System Restoration	System Adequacy

EU-SysFlex

Overview of interactions between models



EU-SysFlex

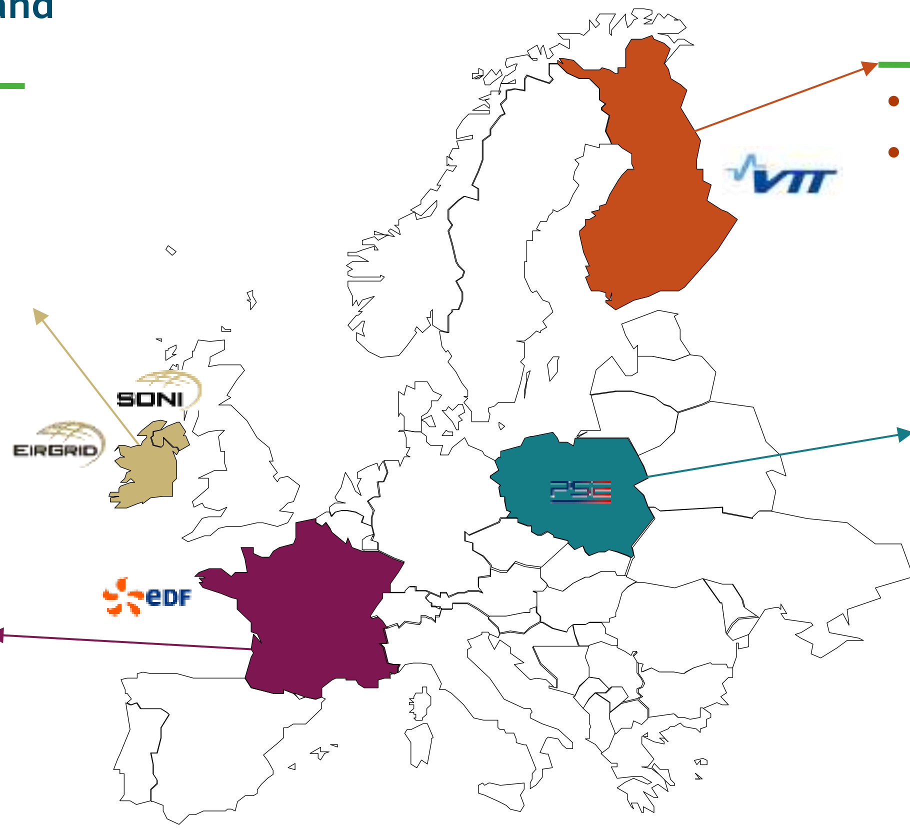
Simulations to identify and value future system scarcities

Ireland and Northern Ireland Power System

- Frequency Stability
- Voltage Stability
- Rotor Angle Stability
- Congestion
- System Restoration
- System Adequacy

Continental Europe Power System

- Frequency Stability
- Congestion
- System Adequacy



Nordic Power System

- Frequency Stability
- Congestion

Continental Europe Power System

- Voltage Stability
- Rotor Angle Stability

Scenarios will also be used to value System Services in future

DRAFT – Initial Simulation Results

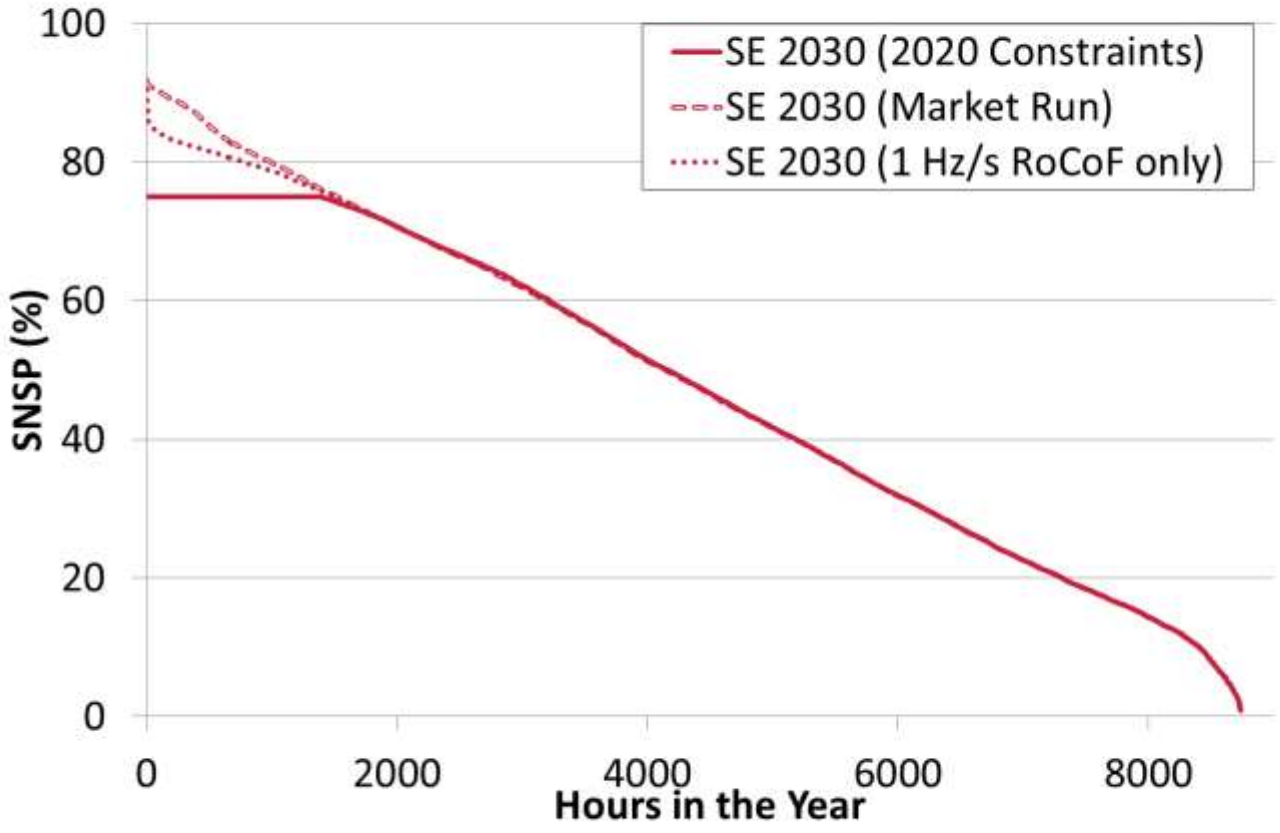
- Initial outputs from Ireland and Northern Ireland network sensitivities – these will be used in detailed network analysis

- Three 2030 cases assessed:
  - **Market Run** – No operational constraints
  - **2020 Constraints** – 2020 RoCoF, Inertia and SNSP constraints
  - **1 Hz/s RoCoF** – RoCoF constraint only

- These results are still being validated and will not be officially published until Q4 2019

EU-SysFlex

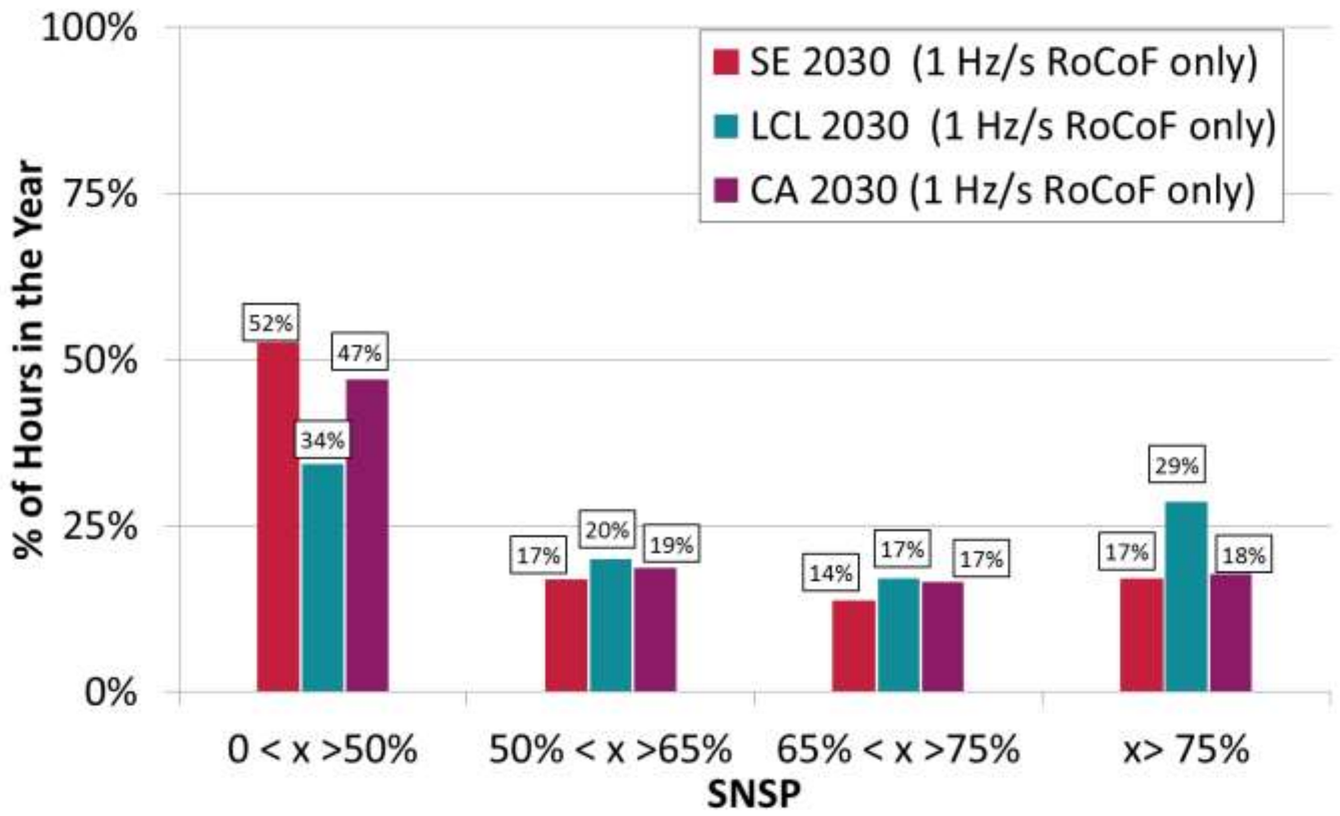
SNSP Duration Curve



DRAFT – Final version in Q4 2019

EU-SysFlex

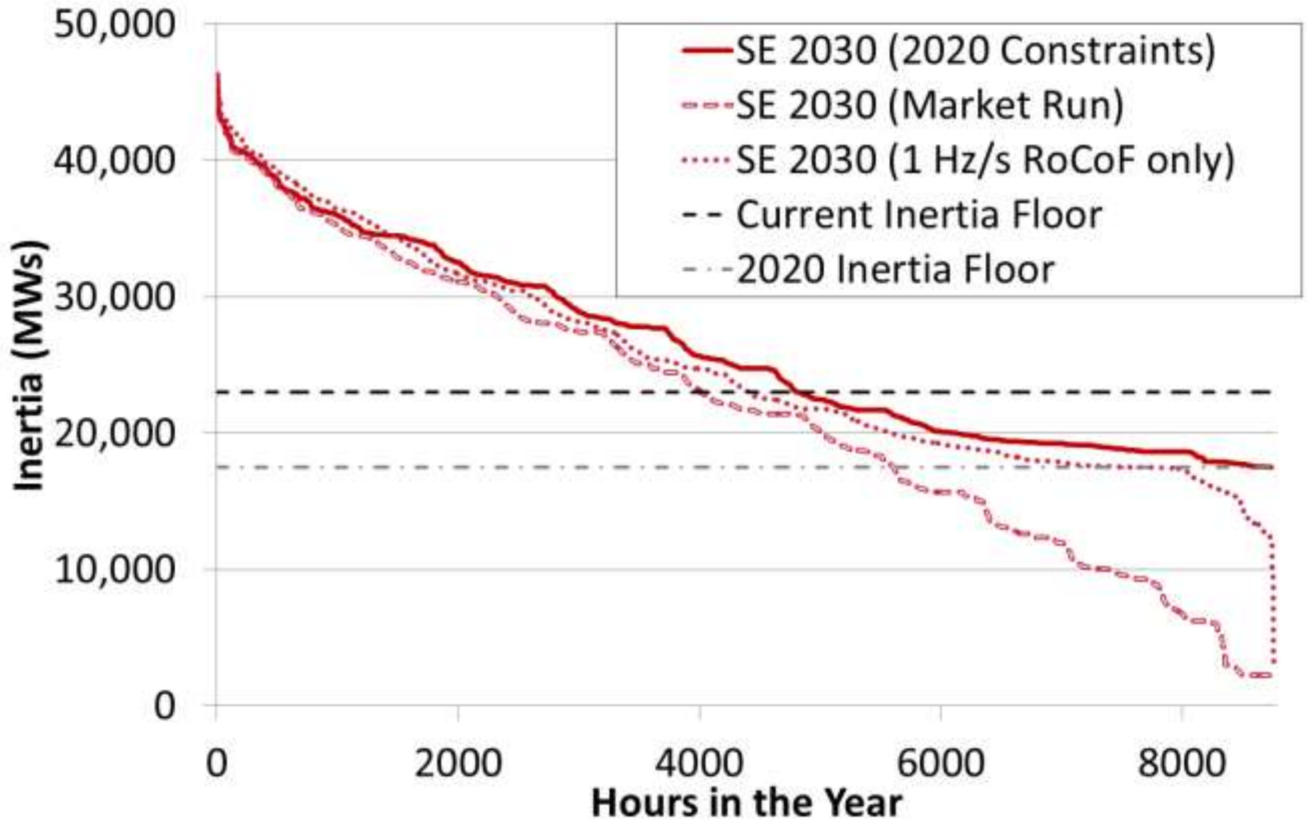
SNSP Histogram – All Scenarios



DRAFT – Final version in Q4 2019

EU-SysFlex

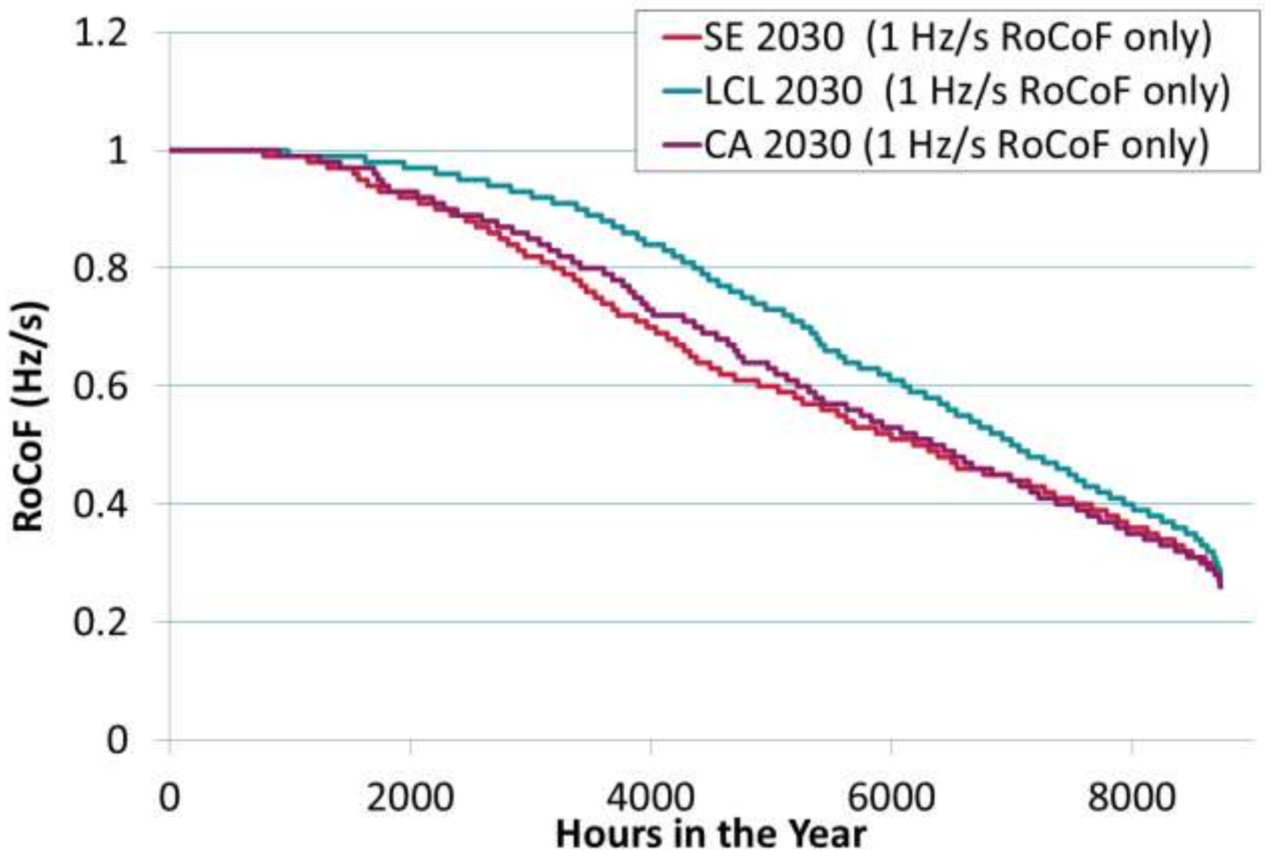
Inertia Duration Curve



DRAFT – Final version in Q4 2019

EU-SysFlex

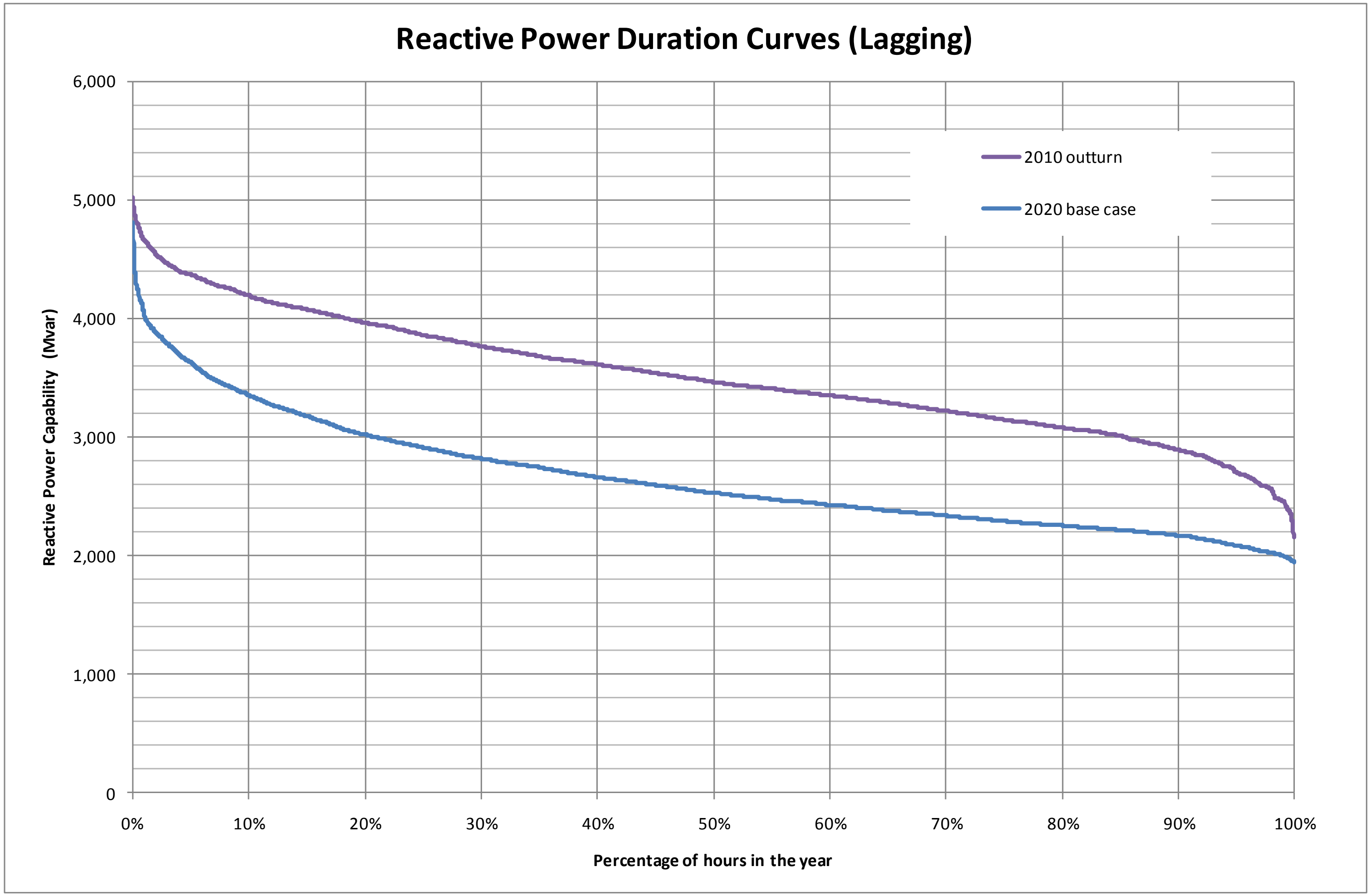
RoCoF Comparison – All Scenarios



DRAFT – Final version in Q4 2019

EU-SysFlex

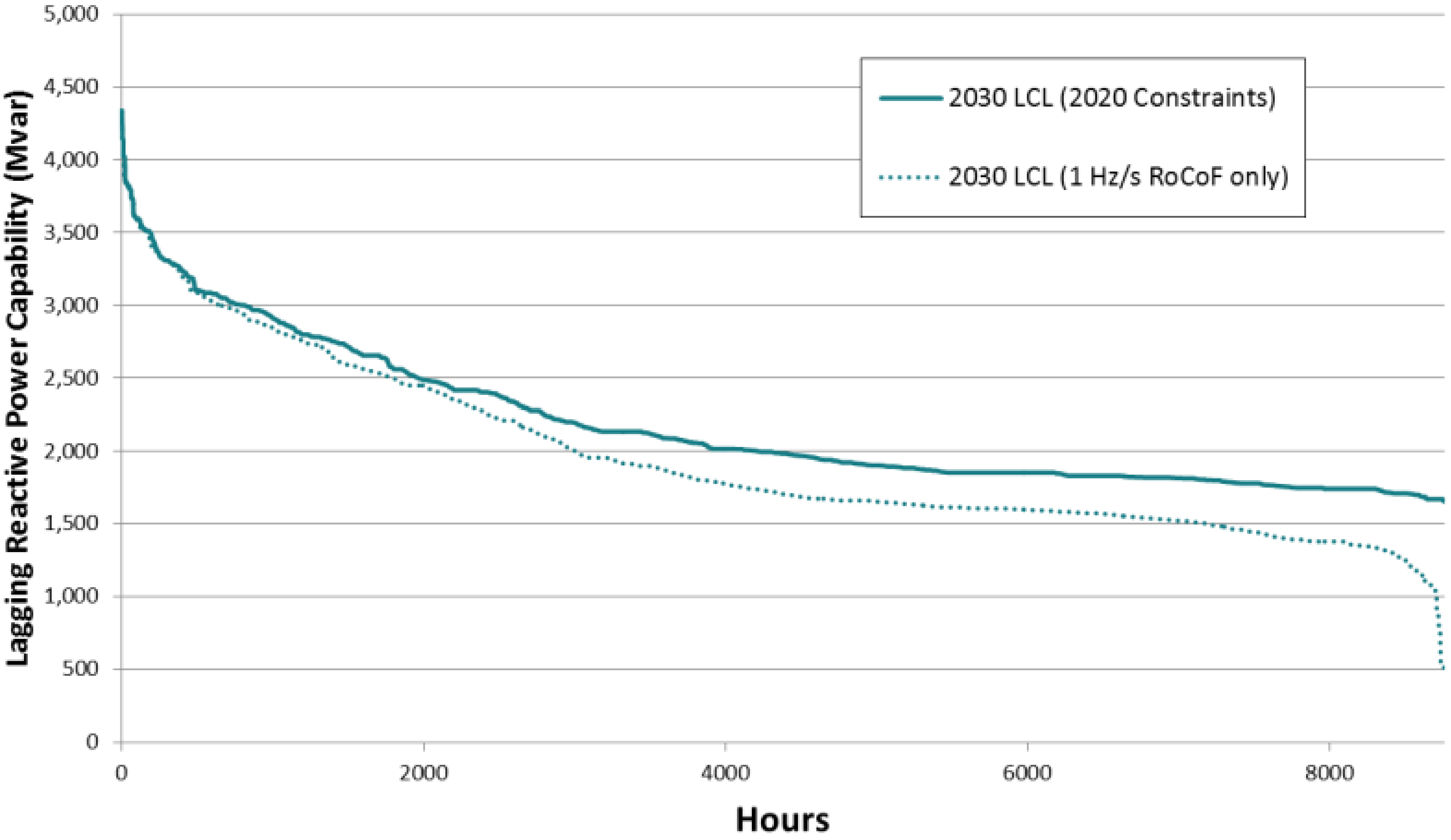
FOR (2010) -Reactive Power Duration Curves (Lagging)



DRAFT – Final version in Q4 2019

EU-SysFlex

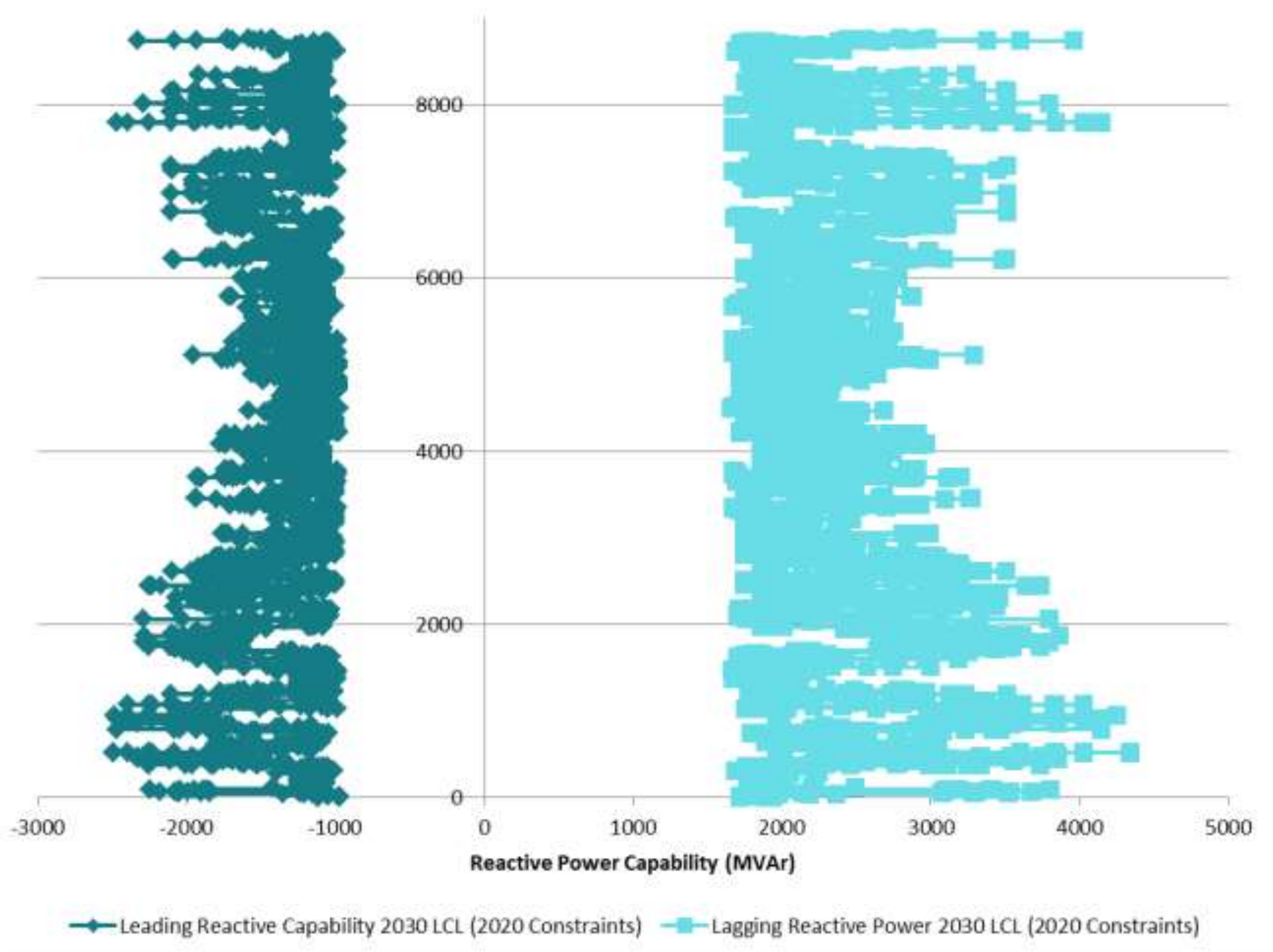
Reactive Power Duration Curves (Lagging)



DRAFT – Final version in Q4 2019

EU-SysFlex

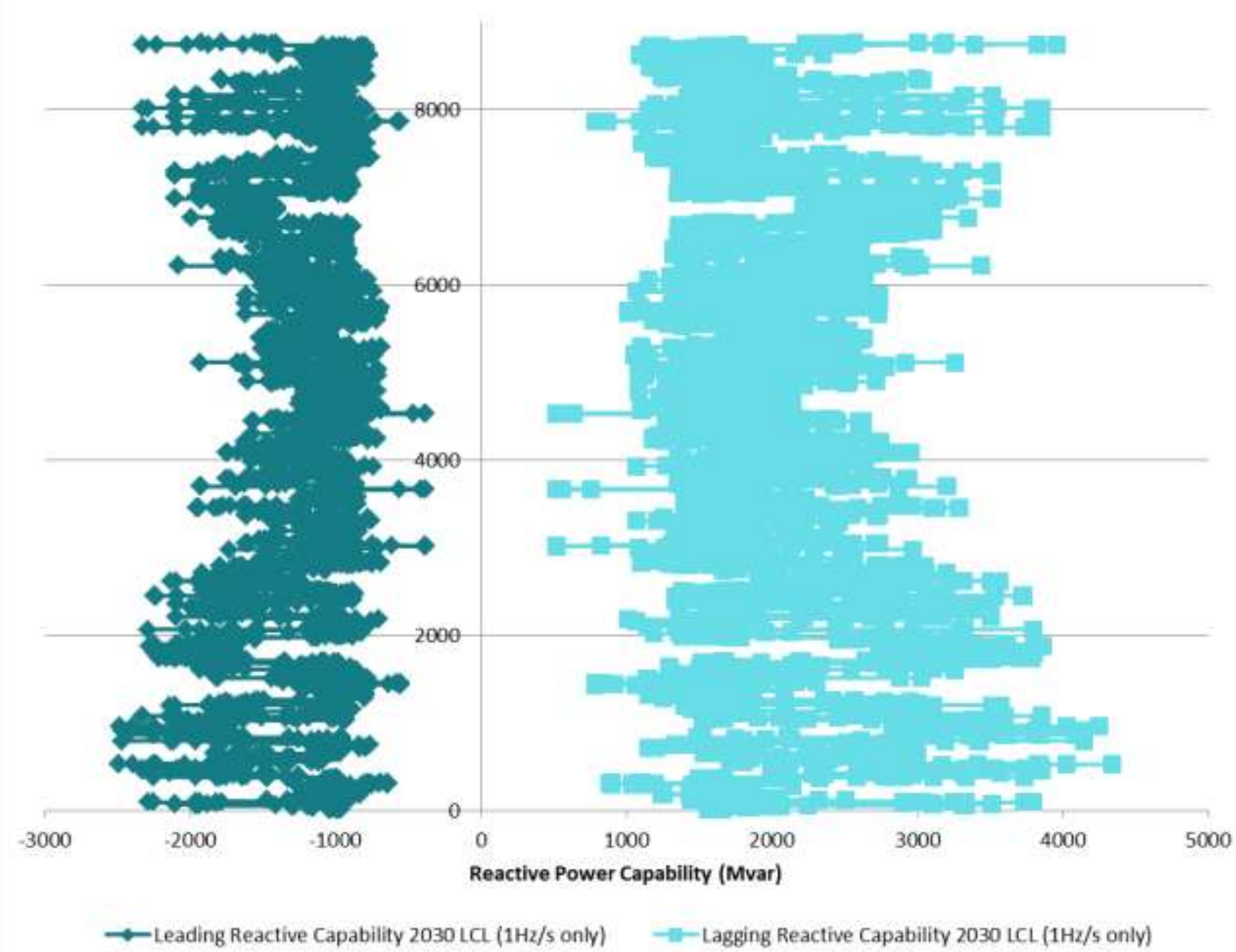
2030 Low Carbon Living – 2020 Constraints



DRAFT – Final version in Q4 2019

EU-SysFlex

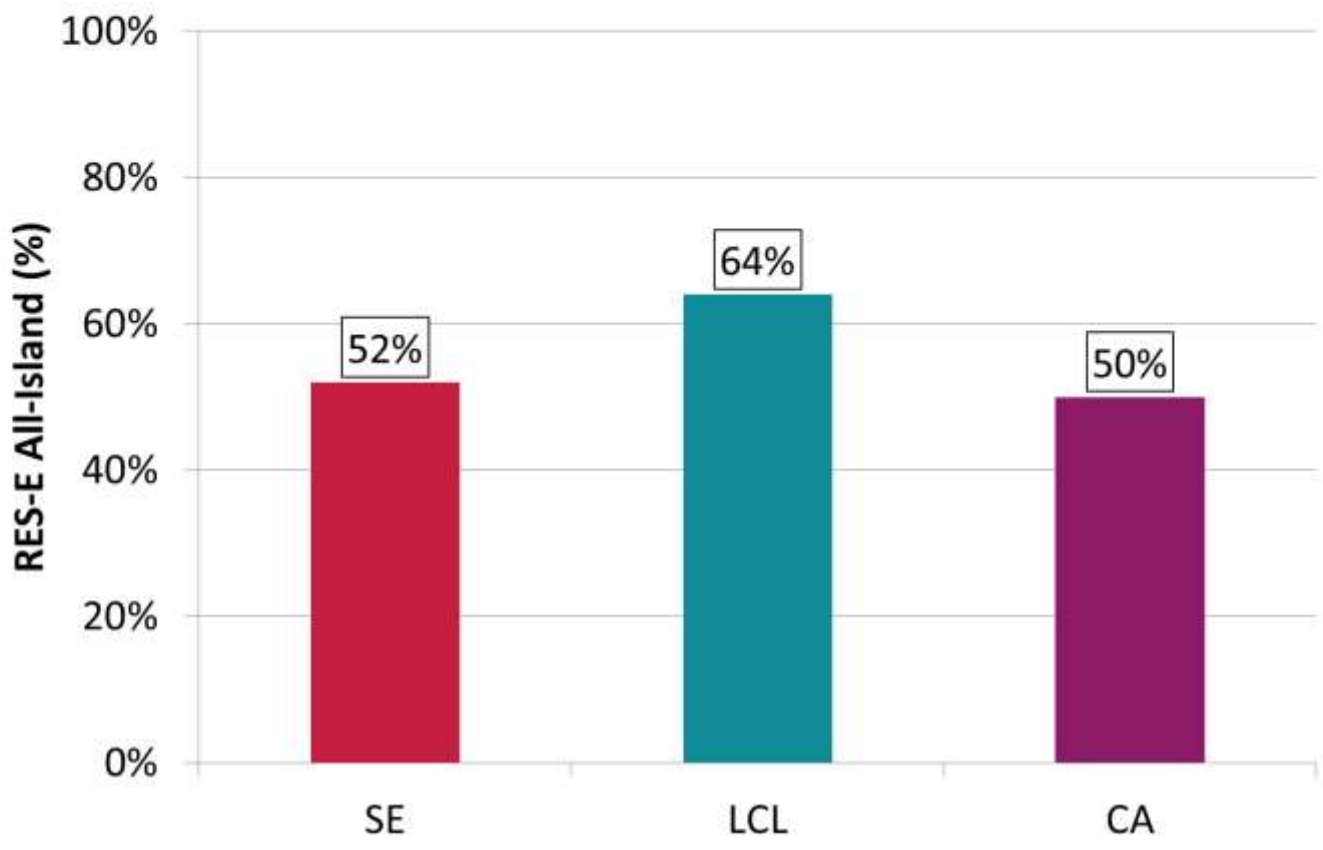
2030 Low Carbon Living – 1 Hz/s RoCoF only



DRAFT – Final version in Q4 2019

EU-SysFlex

All-Island Annual RES-E Comparison – 1 Hz/s RoCoF



DRAFT – Final version in Q4 2019

EU-SysFlex

Continental Europe Outputs

Spain & Portugal

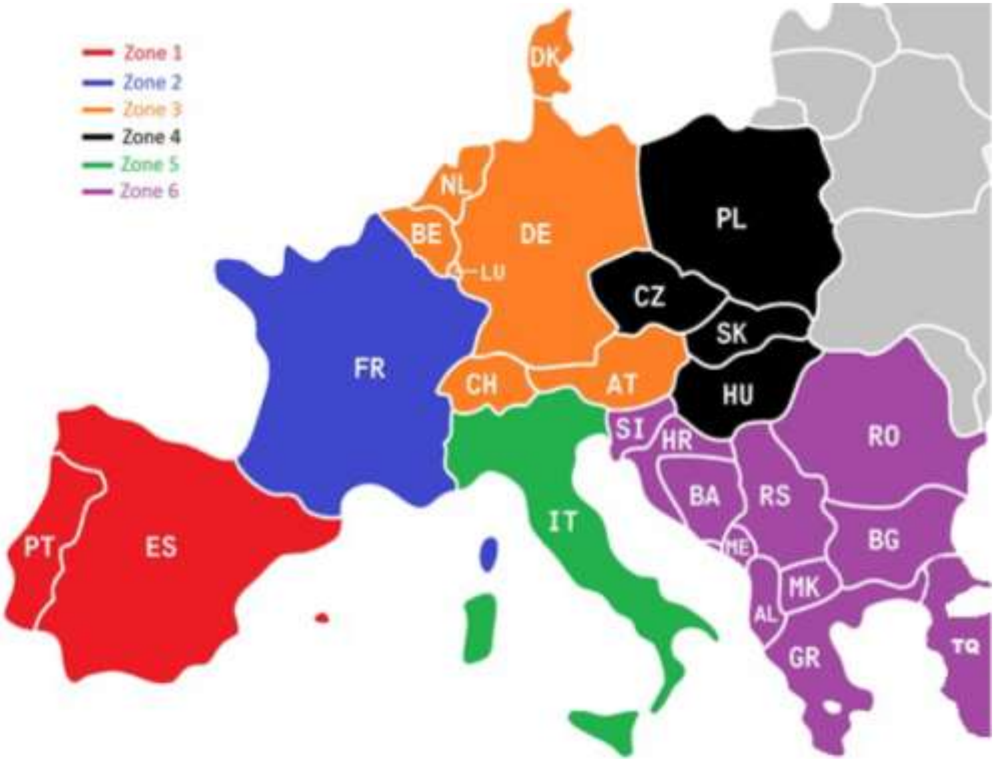
- Very high RoCoF levels (> 1 Hz/s)
- Very low sync. Gen

Italy

- Very high RoCoF levels (> 1 Hz/s)

Central Europe

- Large decrease in sync generators



DRAFT – Final version in Q4 2019

EU-SysFlex

AOB