Enduring Connection Policy 2.1

Constraints Analysis for Solar and Wind

Area J and G Main

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Delivering a cleaner energy future

AGENDA

- Introduction and Update
- ECP 2.1 Study Scenarios
- Modelling Approach to Dispatch Down
- Oversupply and Curtailment Calculation
- Constraint Sub-Group Logic
- Constraint Group Short Note
- Area overview
- ECP 2.1 Maintenance Sensitivity
- ECP 2.1 Battery Performance
- ECP 2.1 Contingency Binding
- Discussions and Questions

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ECP 2.1 QUERIES

COMPLETED IN THE LAST MONTH

A Frequently Asked Questions (FAQ's) document has been published which includes responses to individual customer queries.
A short report on:

- Maintenance sensitivity
- Renewable Energy Source (RES) % in the studies
- Battery performance during constraint dispatch down
- Contingency list for the year 2024 and 2026
- Short note on constraint groups used within ECP 2.1

ADDITIONAL DATA MADE AVAILABLE ON ECP 2.1 WEBSITE

- Node level results for Oversupply, Curtailment and Constraints in Excel format
- Hourly wind and solar area profiles used within the studies
- Wind and solar generation build out tables for Northern Ireland
- Line ratings used in the studies for the years 2024 and 2026
- Interconnector flow data in the core ECP 2.1 studies

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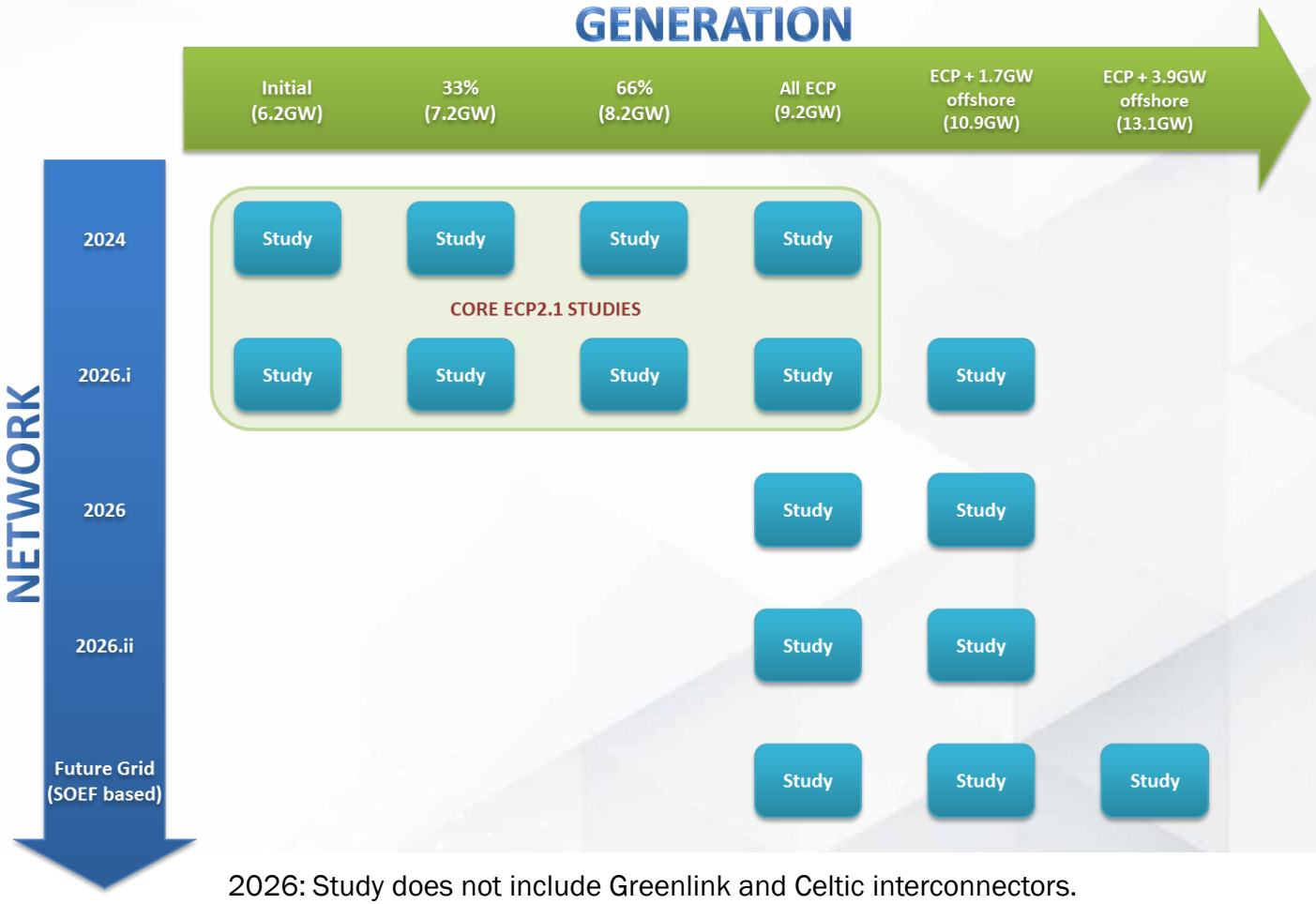
SCENARIO & SENSITIVITY OVERVIEW



- Large # of scenarios including sensitivities
- Core ECP 2.1 Study Years: 2024 & 2026
- Generation Scenarios Studied:
  - Core ECP Studies:
    - Initial (6.2 GW)
    - 33% of ECP (7.2 GW)
    - 66% of ECP (8.2 GW)
    - All ECP (9.2 GW)
  - Sensitivities requested by industry:
    - ECP + 1.7 GW offshore (10.9 GW)
    - ECP + 3.9 GW offshore (13.1 GW)
    - Greenlink & Celtic included
    - Future Grid (To align with SOEF)

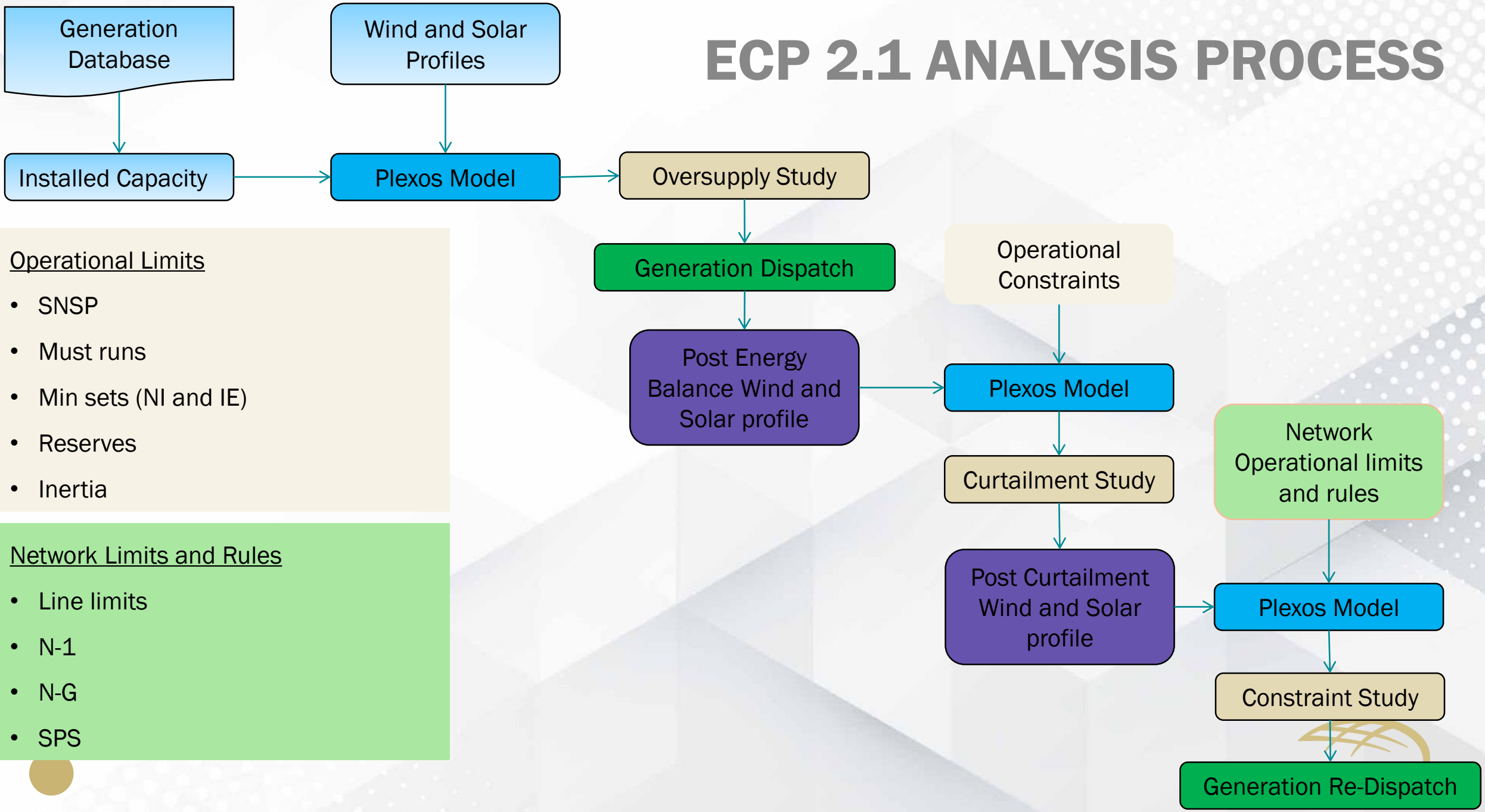
2026: Study does not include Greenlink and Celtic interconnectors.
2026.i: Study includes Greenlink but not Celtic interconnector.
2026.ii: Study includes Greenlink and Celtic interconnectors.

MODELLING APPROACH To DISPATCH DOWN

- Renewable generation modelled at 110 kV station
  - A 110 kV station can have Wind/Solar Priority, Non Priority or Uncontrolled generation connected.
  - Wind and Solar hourly profiles are used in model.

- Over-supply Dispatch Down
  - Applied if there is not enough demand, or export capability to meet renewable generation.
  - For each hour, the “non priority” generators are dispatched down first (pro-rata all island).
- Curtailment
  - Following dispatch down for oversupply reasons, curtailment is applied to meet operational limits e.g. SNSP, Inertia, Min Sets Rules, Generator Must Runs, Operating Reserve.
  - For each hour, curtailment is shared equally between “priority” and “non priority” generators (applied pro-rata all island).
- Constraint
  - Following curtailment, generation constraint is applied to solve localised transmission issues.
  - The model dispatches down by individual station to mathematically minimise the total renewable generation dispatch down.
  - For annual energy, the results are then averaged across adjacent 110 kV stations.
  - “priority” and “non priority” generators are dispatched down equally.

ECP 2.1 ANALYSIS PROCESS



Operational Limits

- SNSP
- Must runs
- Min sets (NI and IE)
- Reserves
- Inertia

Network Limits and Rules

- Line limits
- N-1
- N-G
- SPS

OVERSUPPLY AND CURTAILMENT CALCULATION

Oversupply – Applied differently for priority and non priority generators

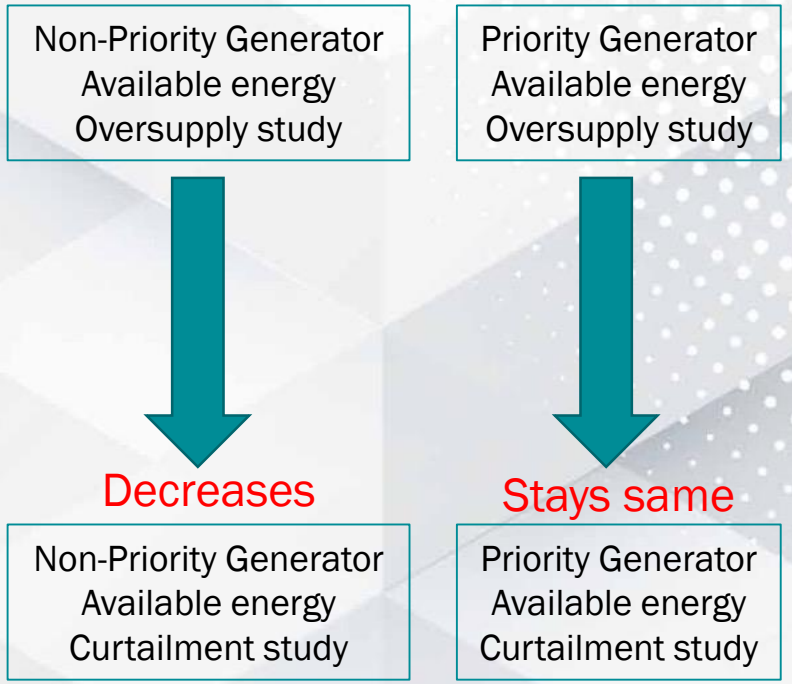
$$Oversupply\ \%\ (system) = \frac{Total\ Oversupply\ Dispatch\ Down\ (system)}{Total\ Available\ Energy\ in\ Oversupply\ study} \times 100$$

$$Oversupply\ \%\ (Generator) = \frac{Total\ Oversupply\ Dispatch\ Down\ pro-rata\ (Generator)}{Total\ Available\ Energy\ in\ Oversupply\ study\ (Generator)} \times 100$$

Curtailment – No distinction between priority and non priority generators

$$Curtailment\ \%\ (system) = \frac{Total\ Curtailment\ Dispatch\ Down\ (system)}{Total\ Available\ Energy\ in\ Oversupply\ study} \times 100$$

$$Curtailment\ \%\ (Generator) = \frac{Total\ Curtailment\ Dispatch\ Down\ pro-rata\ (Generator)}{Total\ Available\ Energy\ in\ Oversupply\ study\ (Generator)} \times 100$$



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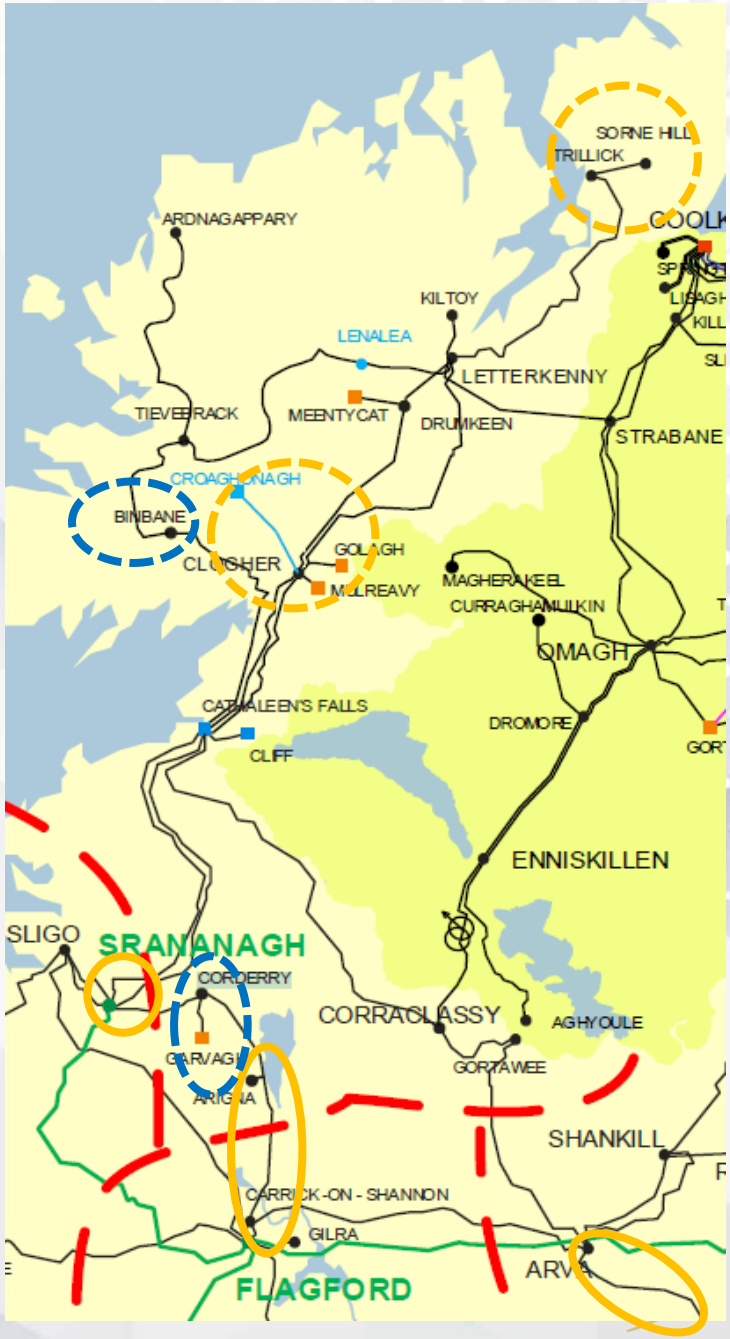
CONSTRAINT SUB-GROUP LOGIC

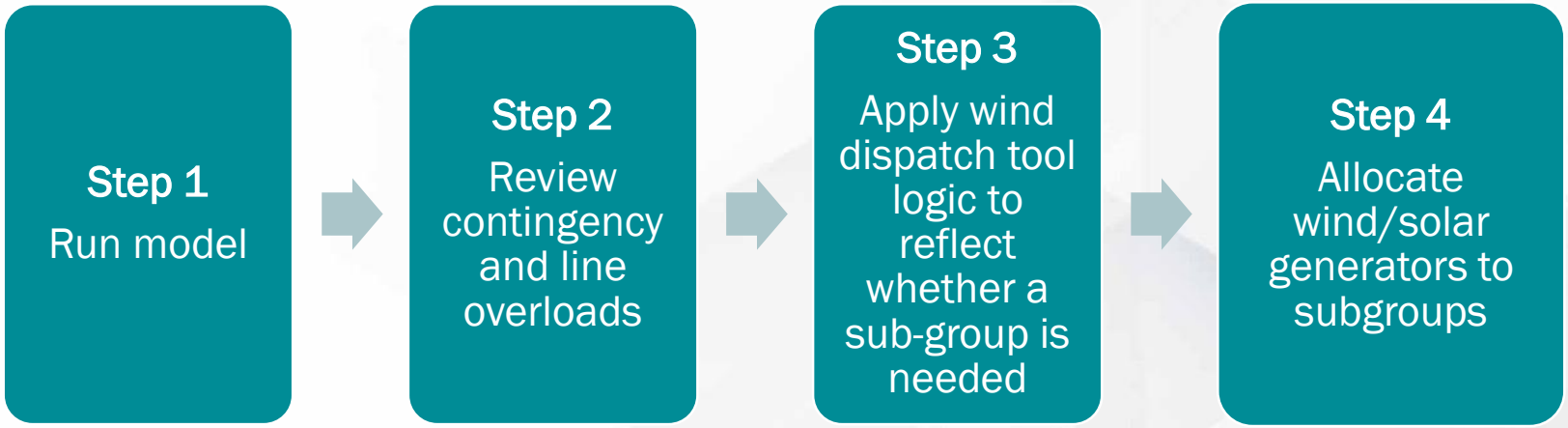
ANALYSIS SAMPLE

- Contingencies observed in a sample instance in the region
  - Loss of Carrick on Shannon - Arigna_110_1
  - Loss of Arva - Navan_110_1
  - Loss of Srananagh T2102
- Generators are selected for dispatch down at same location differently for managing issues in the region.
- The generators may not always be dispatched down at the same node as the contingency for managing the contingency.

Available and Dispatch Down (MWh)							
	Croaghonagh wind not priority	Sorne Hill wind priority	Mulreavy wind priority	Binbane wind not priority	Corderry wind not priority	Sligo wind priority	Garvagh wind priority
Available	127.1	44.3	87.6	34.2	15.0	13.7	75.4
Dispatch down	127.1	44.3	87.6	0	15.0	13.7	11.6



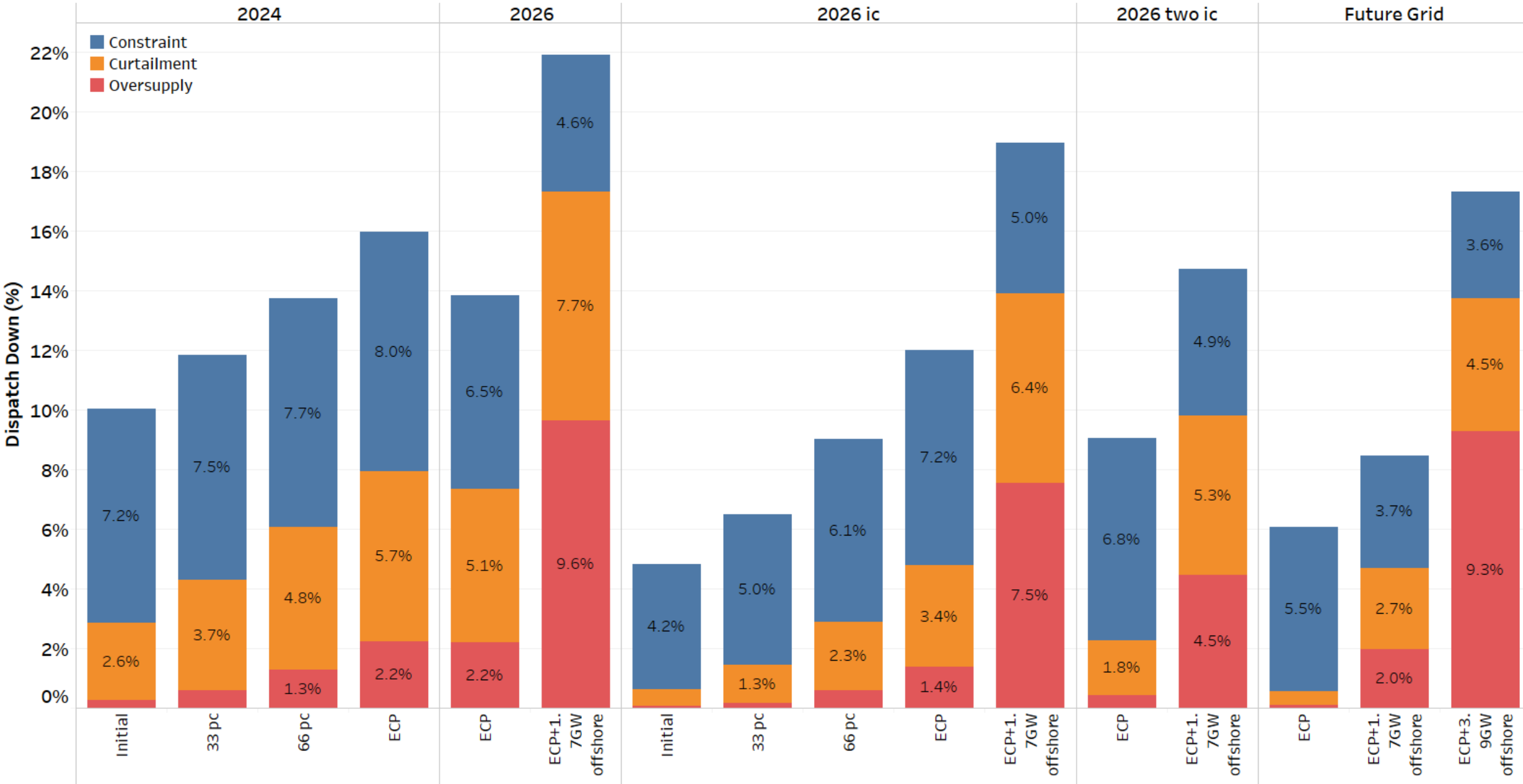
CONSTRAINT SUB-GROUP LOGIC



Caveats:

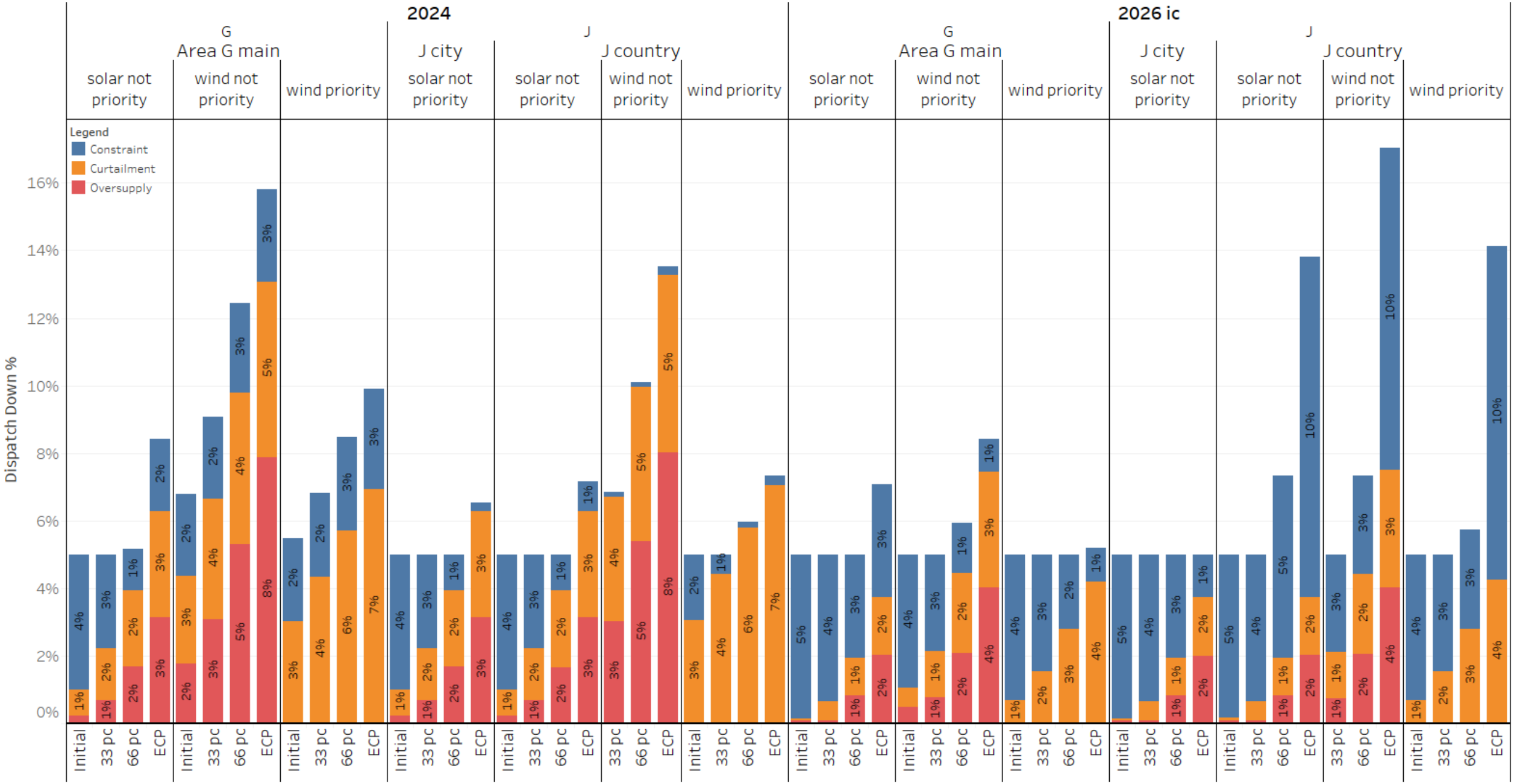
- Constraint groups are developed with the 2024/2026 studies.
- These sub-groups are not redefined for future years, this allows comparison across the study years.
- Constraint subgroupings are part of the ECP analysis to ensure balanced allocation of constraints, this is done to overcome the Plexos modelling limitations. e.g. Plexos is a cost optimisation model and may over constrain particular nodes for a given contingency.
- This study does not act to predict future wind dispatch tool sub-groups rather it aims to enable appropriate allocation of network constraints within the boundaries of the ECP 2.1 studies.
- Future iterations of the ECP constraint reports will re-assess these constraint groups.

System Dispatch Down (%)



AREA J AND G MAIN

Dispatch Down % (Area J and G main)



Key Overview of the Area J and G

- ECP 2.1 has a total of 285 MW of wind and 110 MW of solar in Area J. In Area G there is 49 MW of wind and 60 MW solar.
- Pre-ECP 2.1 there were 224 MW of onshore wind and 678 MW of solar in area J. Area G had 287 MW solar and 571 MW wind.
- In Area J, most of the generation is located on the 110 kV network west of Dublin and is trying to move towards the 220 kV stations.
- In Area G, the power tends to flow towards Dublin through the Louth and Gorman 220 kV stations.
- The prospective loss of any parallel 220 kV/110 kV line may cause an overload on other lines resulting in an operational dispatch down action.
- West of Dublin has 2,150 MW of offshore wind connected to the 220 kV stations.

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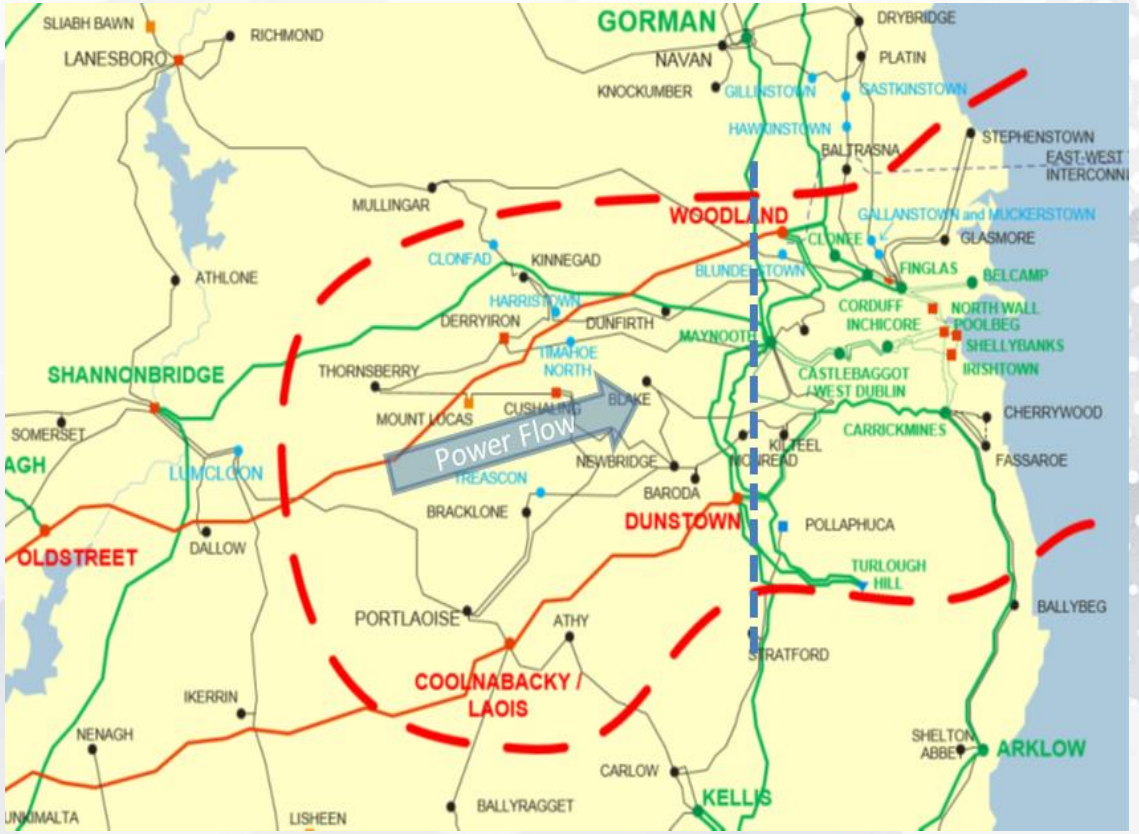
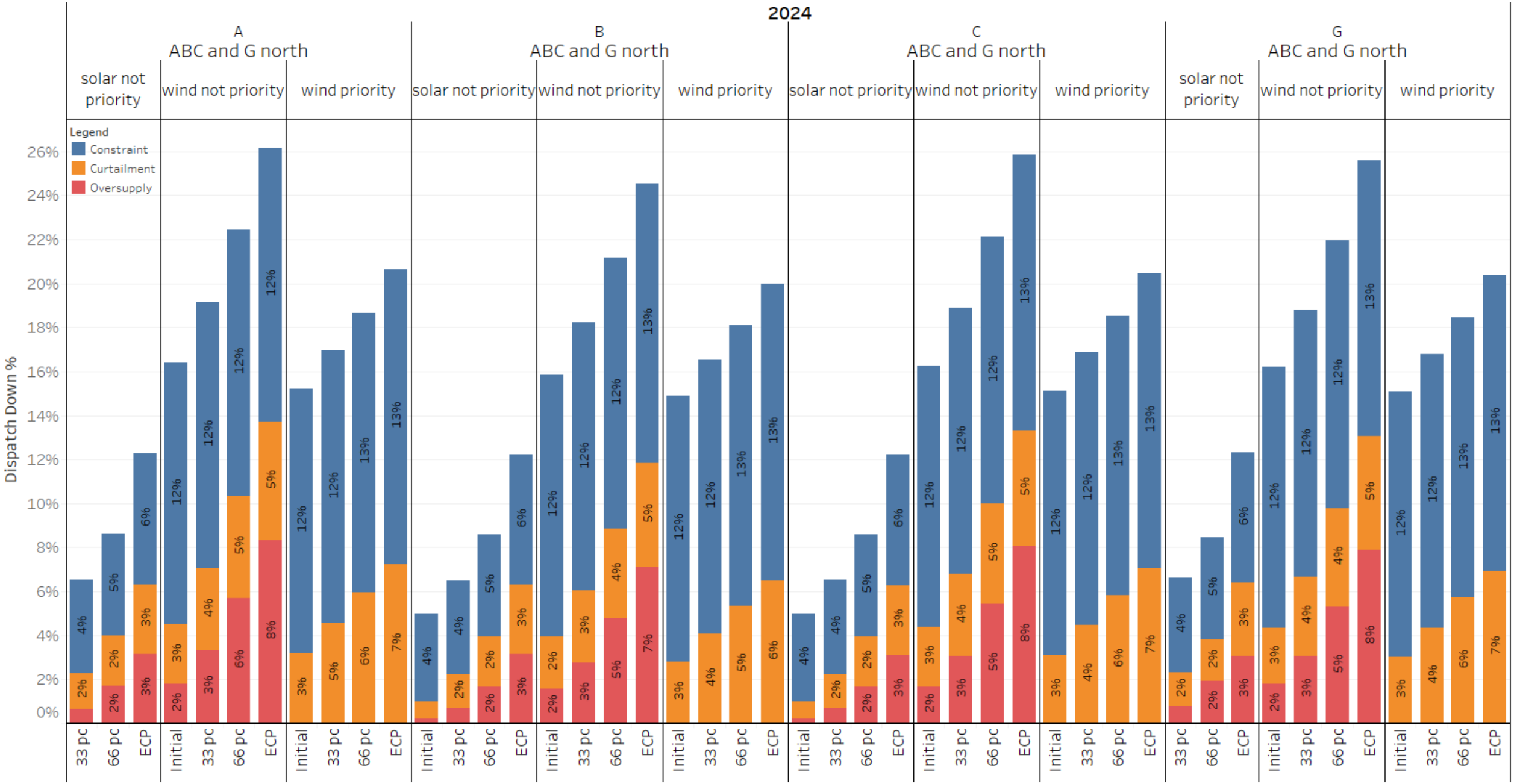
AREA OVERVIEW

- Area J has the major load centres contributing to more than 50% of the total load in Ireland.
- Power from different areas across the country flow towards Dublin through the 220 kV and 400 kV Circuits.
- The prospective loss of any high voltage circuit can potentially congest the parallel circuit invoking redispatch/dispatch down of generation.
- Additionally, the increased generation (427 MW) in year 2026 for the area causes higher power flow in the 110 kV circuits.
- However, the 2nd N-S interconnector in 2026 has potential benefit on constraints to the area along with reduction in oversupply and curtailment.
- The area has a 400 kV station (Coolnabacky) in 2026 study that can create additional pathways for the nearby 110 kV lines.
- Uprates in Future Grid scenario for 110 kV
  - Baroda - Monread 110 kV uprate
  - Baroda - Newbridge 110 kV (DLR)
  - Coolnabacky - Portlaoise 110 kV uprate
  - Cushling - Newbridge 110 kV (DLR)
  - Derryiron - Kinnegad 110 kV uprate
  - Derryiron - Timahoe 110 kV uprate
  - Maynooth - Timahoe 110 kV uprate

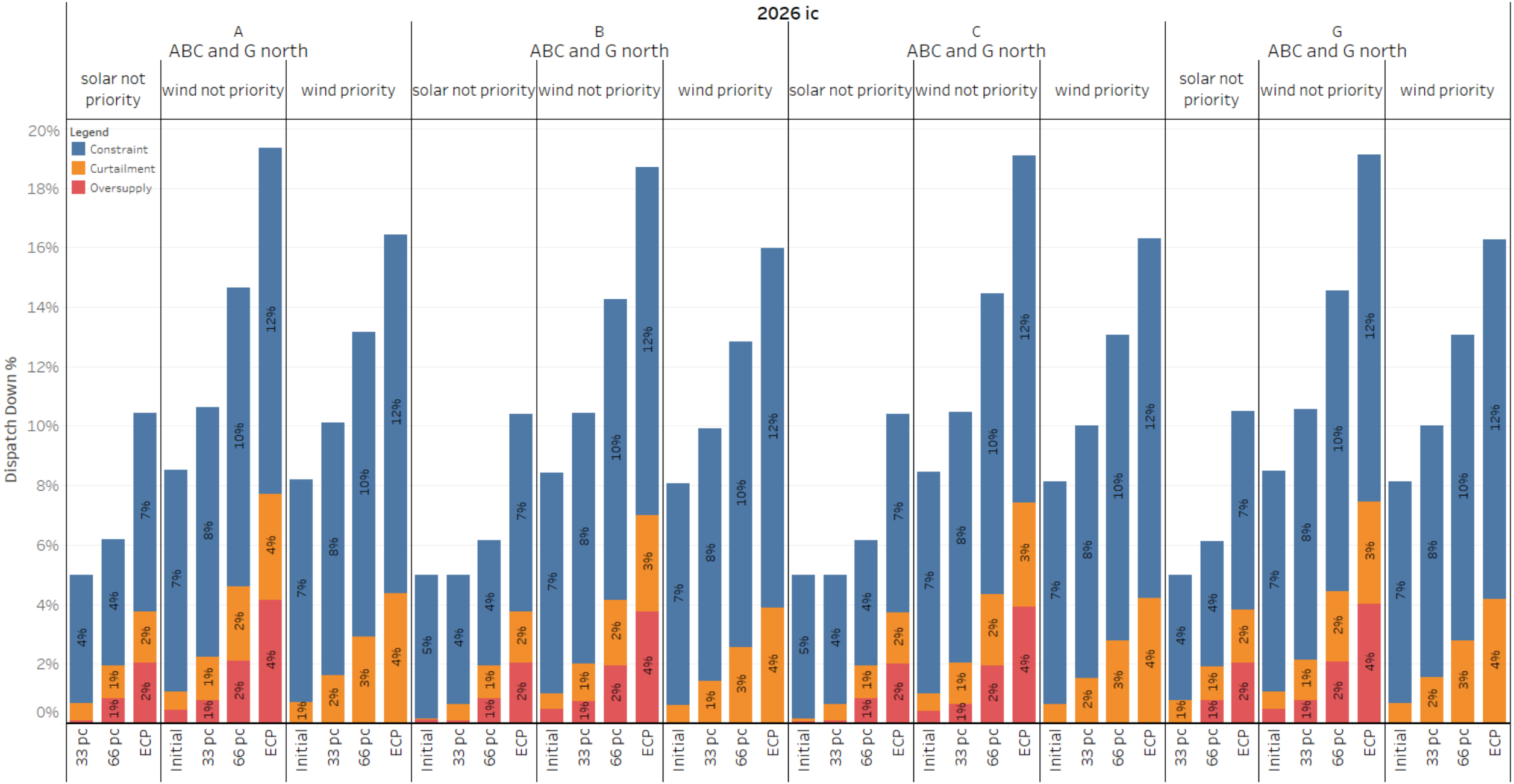


AREA A, B, C AND G NORTH

Area A, B, C and G North Dispatch Down % (2024)



Area A, B, C and G North Dispatch Down % (2026 with GL)



Key Overview of the Area A, B, C and G

- The region has high wind installed on the 110kV networks which feeds into Srananagh, Flagford and Louth 220kV stations.
- The general power flow is towards the Dublin load centres utilizing the 220kV circuits.
- The prospective loss of any parallel 220 kV/110 kV line may cause an overload on other lines resulting in an operational dispatch down action.
- For example, the rescue flow for contingency of Flagford – Louth 220kV/ Arva – Navan 110kV can invoke additional stress to the shankill – Lisdrum 110kV circuit and Shankill – Ratrussan – Louth 110kV circuit. This can in-effect induce dispatch down of generators connecting to these nodes.
- The North Connacht provides additional paths to generators and improves the congestion to certain level due to the loss of Cunghill – Sligo 110kV/Bellacorick Castlebar 110kV circuit.

Area	Pre ECP 2-1	ECP 2-1
A	Wind – 721MW, Solar – 40MW	Wind – 34MW
B	Wind – 902MW, Solar – 63MW Offshore wind – 392MW	Wind – 58MW, Solar – 4MW
C	Wind – 107MW, Solar – 109MW	Wind – 186MW, Solar – 132MW
G	Wind – 411MW, Solar – 287MW Offshore wind – 160MW	Wind – 49MW, Solar – 60MW

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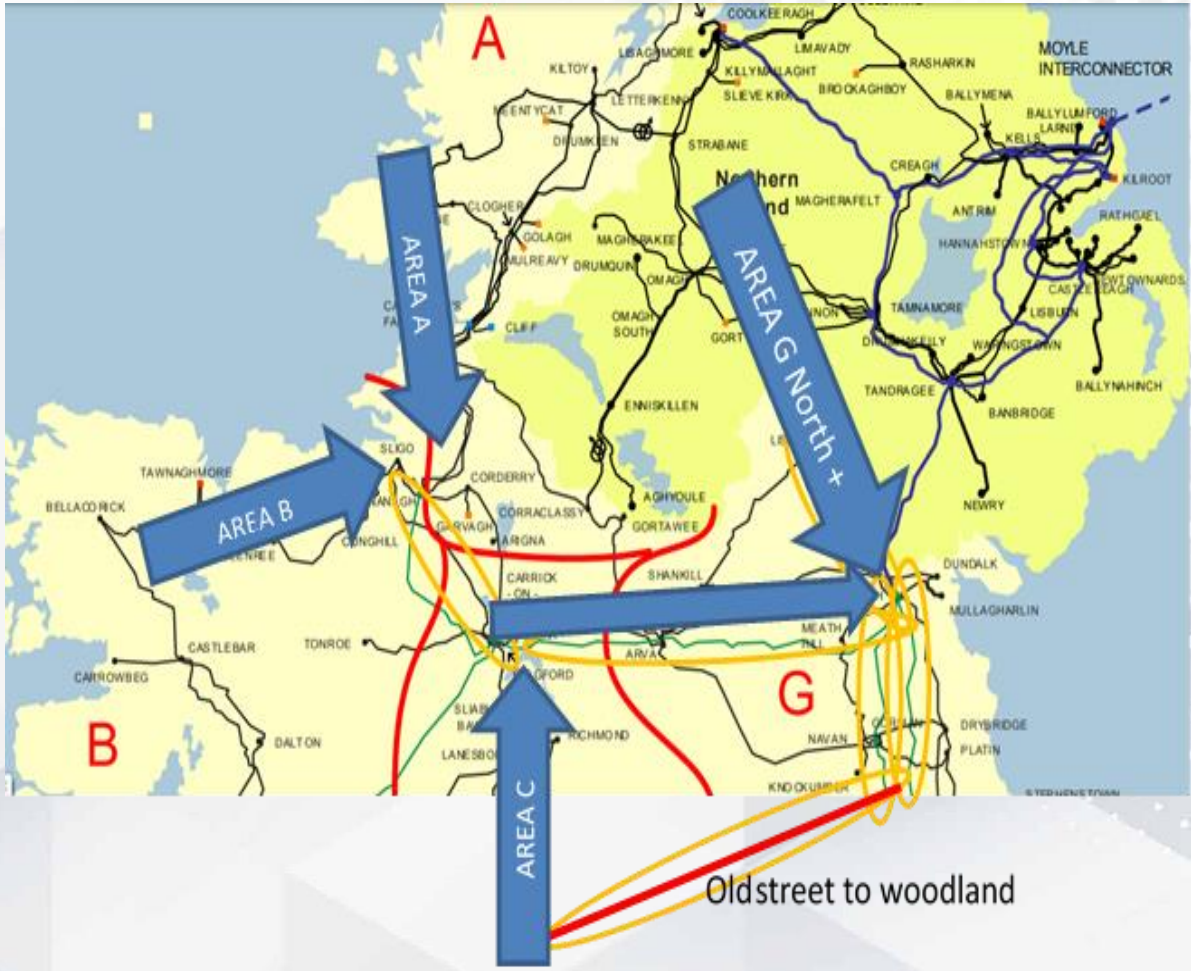
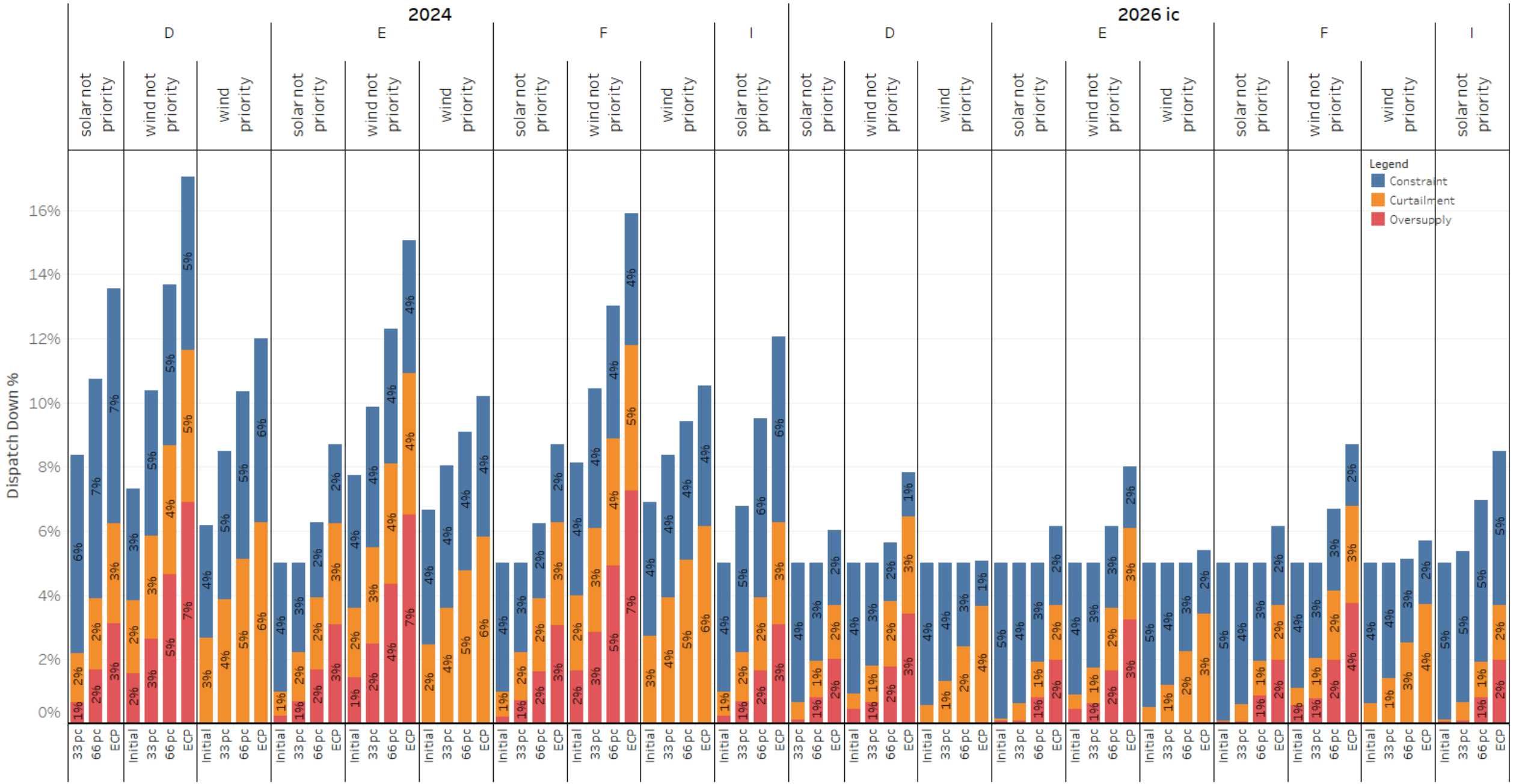
AREA OVERVIEW

- Power from different areas across the country flow towards Dublin through the 220 kV and 400 kV Circuits.
- The prospective loss of any high voltage circuit can potentially congest the parallel circuit invoking redispatch/dispatch down of generation.
- Additionally, the increased generation (180MW in Area B) in year 2026 for the area causes higher power flow in the 110 kV circuits.
- However, the 2nd N-S interconnector in 2026 has potential benefit on constraints to this region along with reduction in oversupply and curtailment as the transfer capacity between two jurisdictions increases.
- The area also has the North Connacht 110kV reinforcement in 2026 which provides additional paths for power flow to Flagford 220kV.
- The uprate of Louth – Ratrussan 110kV in 2026 has improved the congestion on the circuit, but yet, partially moved the congestion on to other parallel circuits.
- Uprates in Future Grid scenario for 110 kV
  - Arva - Carrick On Shannon 110 kV uprate
  - Sliabh Bawn – Lanesboro – Mullingar 110kV
  - Moy – Glenree 110kV uprate
  - Sligo – Srananagh 110kV uprate
  - Flagford – Srananagh 110kV upvoltage
  - Corderry – Srananagh 110kV uprate
  - Athlone –Lanesboro 110kV uprate
  - Clogher – Srananagh 220kV
  - Galway – Salthill 110kV uprate
  - Drumkeen – Clogher 110kV uprate
  - Binbane - Clogher - Cathaleen's Fall - 110 kV
  - Cashla – Salthill 110kV uprate
  - Cashla – Dalton 110kV (DLR)
  - Castlebar – Cloon 110kV uprate
  - Castlebar 110 kV station busbar
  - Cathaleen's Fall - Coraclassy 110 kV (DLR)



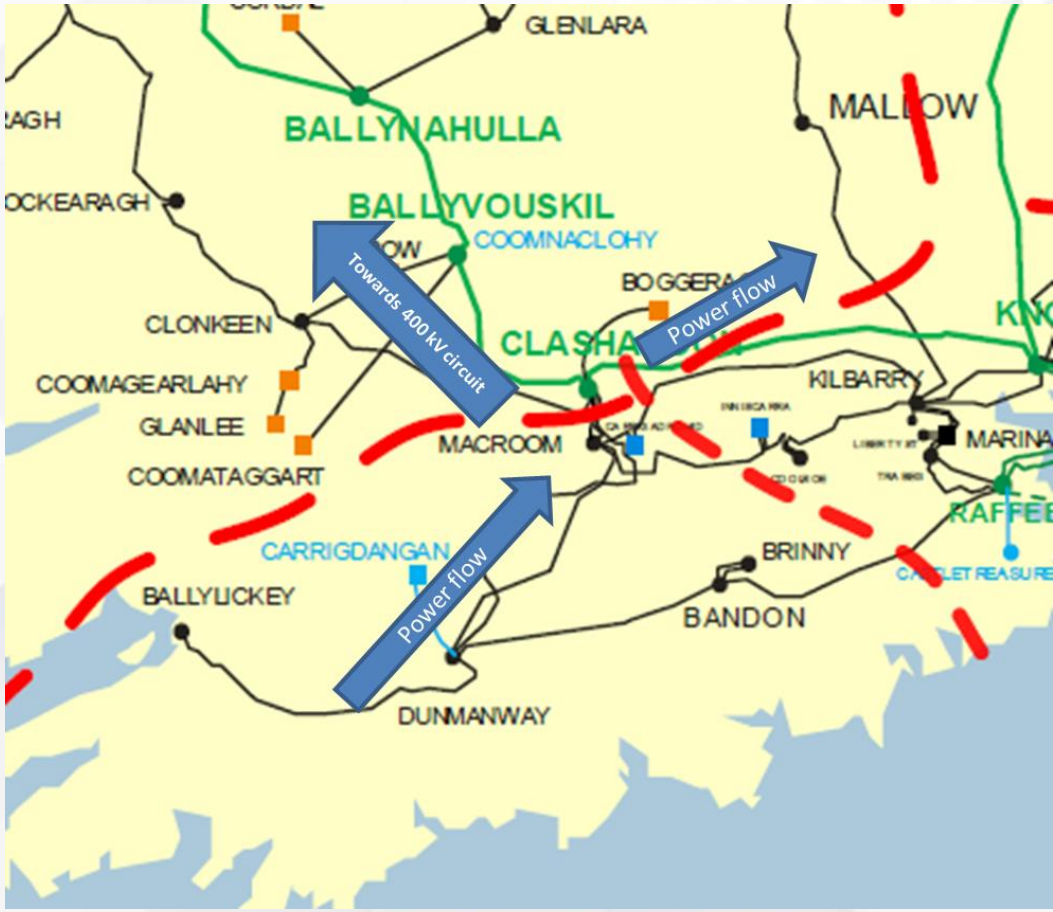
AREA D, E, F AND I

Area D, E, F and I Dispatch Down %



Key Overview of the Area D, E, F, and I

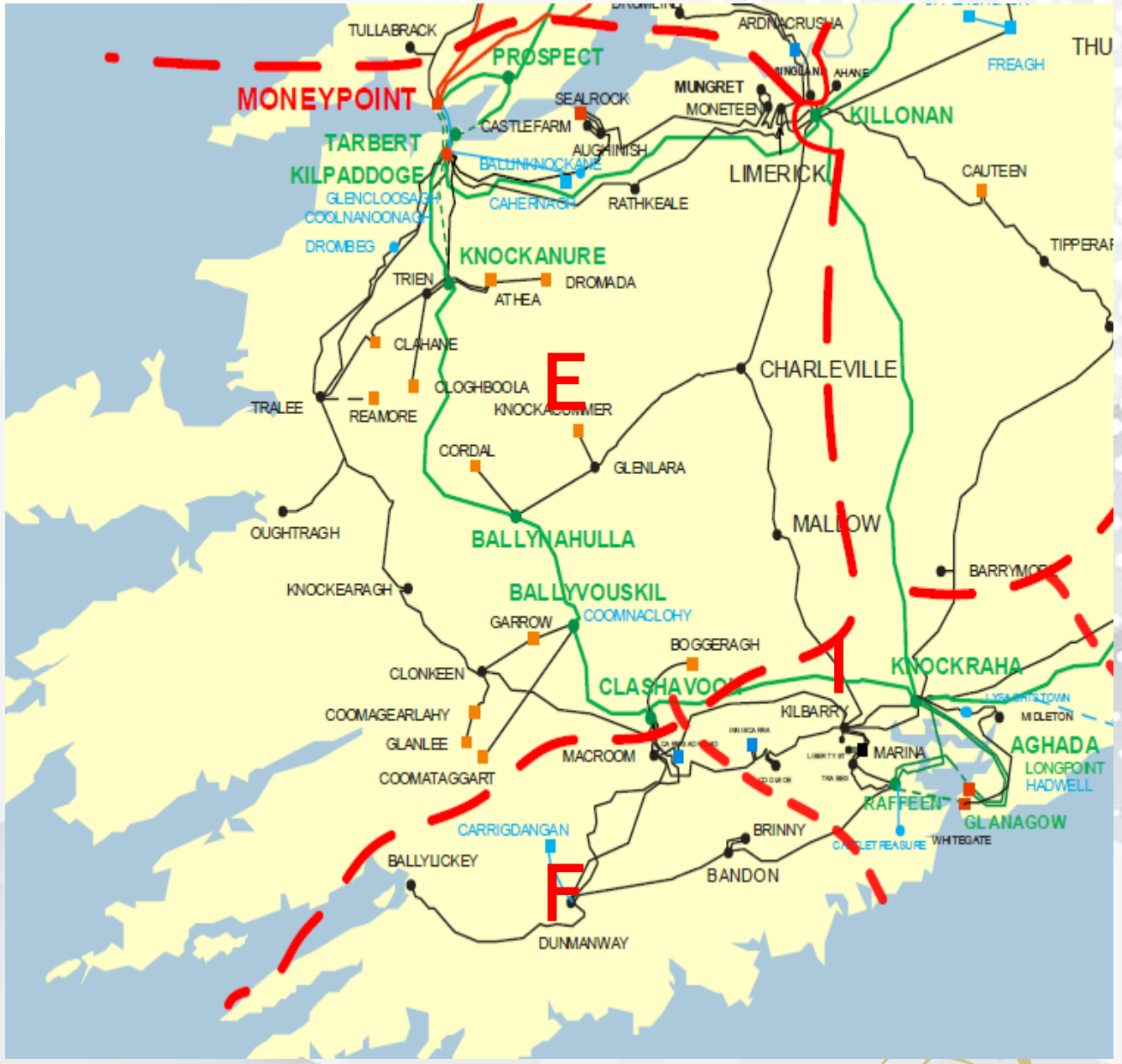
- The general power flow is towards the 220kV nodes and towards the 400kV circuits.
- The 220kV circuit from Knockraha to Kilpaddoge is parallel to the circuit from Knockraha to Killonan to Kilpaddoge and provides alternate paths additional to the 110kV circuits.
- The prospective loss of any parallel 220 kV/110 kV line may still cause an overload on other lines resulting in an operational dispatch down action.
- Uprate of Bandon Dunmanway 110kV circuit in 2026 relieves the congestion on the circuit due to the loss of Clashavoon Knockaraha 220kV circuit.
- The series capacitor on the 400kV circuits has increased the flow in these circuits for 2026 studies and has a positive impact to the area.



Area	Pre ECP 2-1	ECP 2-1
D	Wind – 284MW, Solar – 12MW	Wind – 14MW, Solar – 14MW
E	Wind – 1399MW, Solar – 199MW	Wind – 72MW, Solar – 38MW
F	Wind – 199MW, Solar – 21MW	Solar – 12MW
I	Solar – 68MW	Solar – 147MW

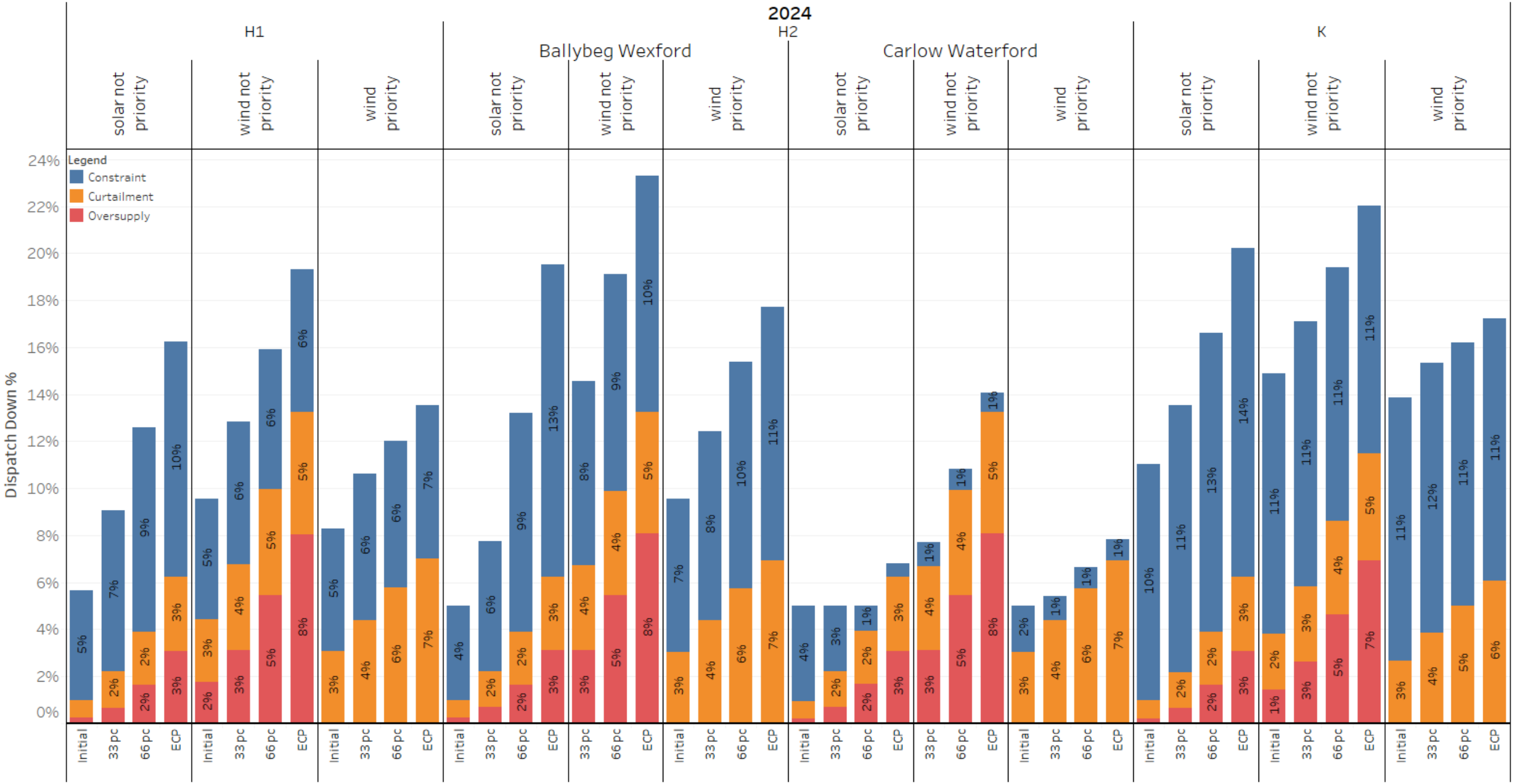
AREA OVERVIEW

- Power from different areas across the country flows towards Dublin load centres and interconnectors through the 220 kV and 400 kV Circuits.
- The prospective loss of any high voltage circuit can potentially congest the parallel circuit invoking redispatch/dispatch down of generation.
- Additionally, in year 2026 14MW is connected as the SRCE generators.
- Uprates in Future Grid scenario for 110 kV
  - Aghada Station Busbar Reconfiguration
  - Ballynahulla and Ballyvoskill Station – Statcom
  - Ballyvouskill - Ballynahula - Knockanure 220 kV uprate
  - Bandon - Dunmanway 110 kV uprate
  - Kilpaddoge - Knockanure 220 kV cable
  - Kilpaddoge - Moneypoint 400 kV Project (Cross Shannon)
  - Knockraha - Cahir 110 kV uprate
  - Knockraha station works

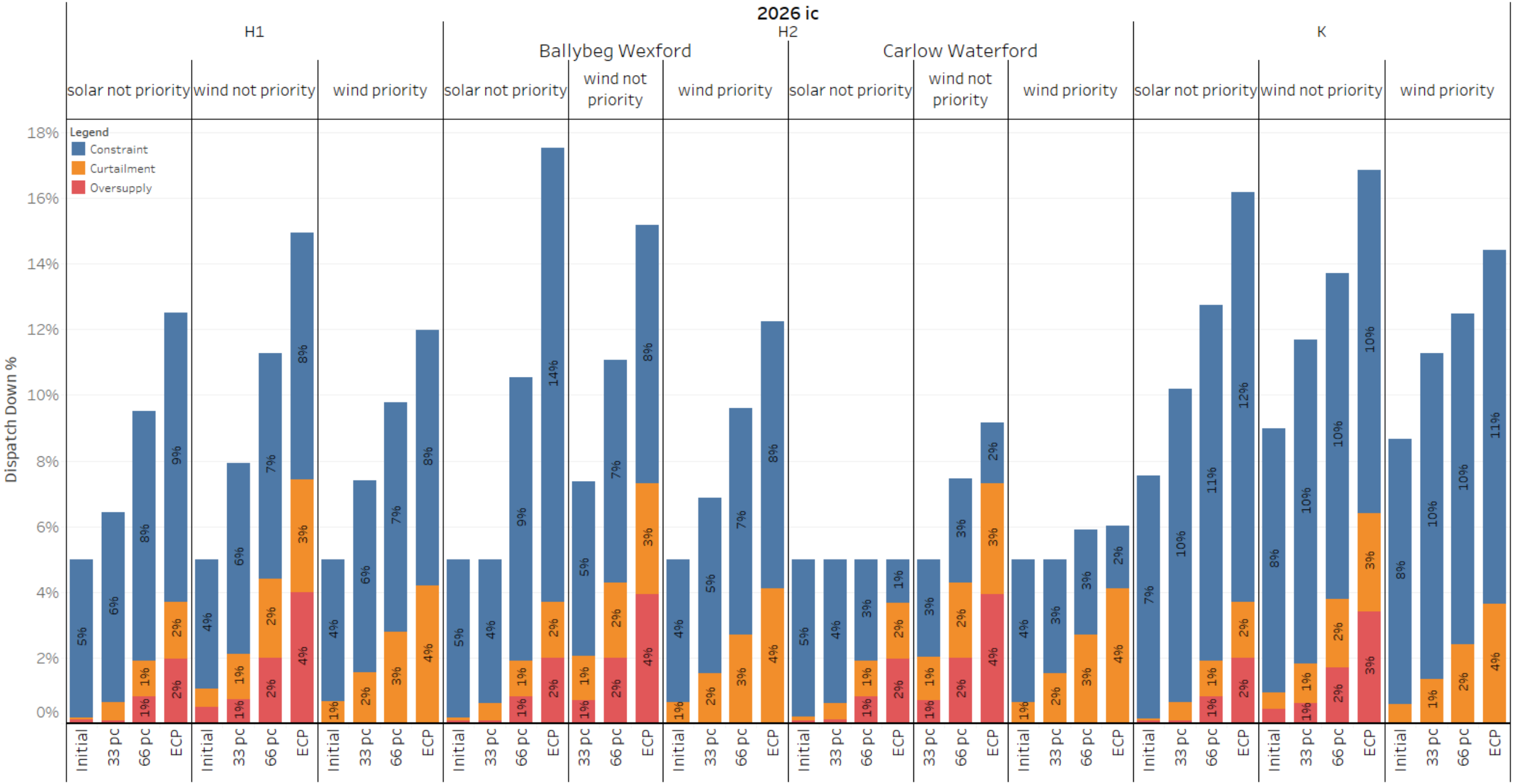


AREA H1, H2 AND K

Area H1, H2 and K Dispatch Down % (2024)



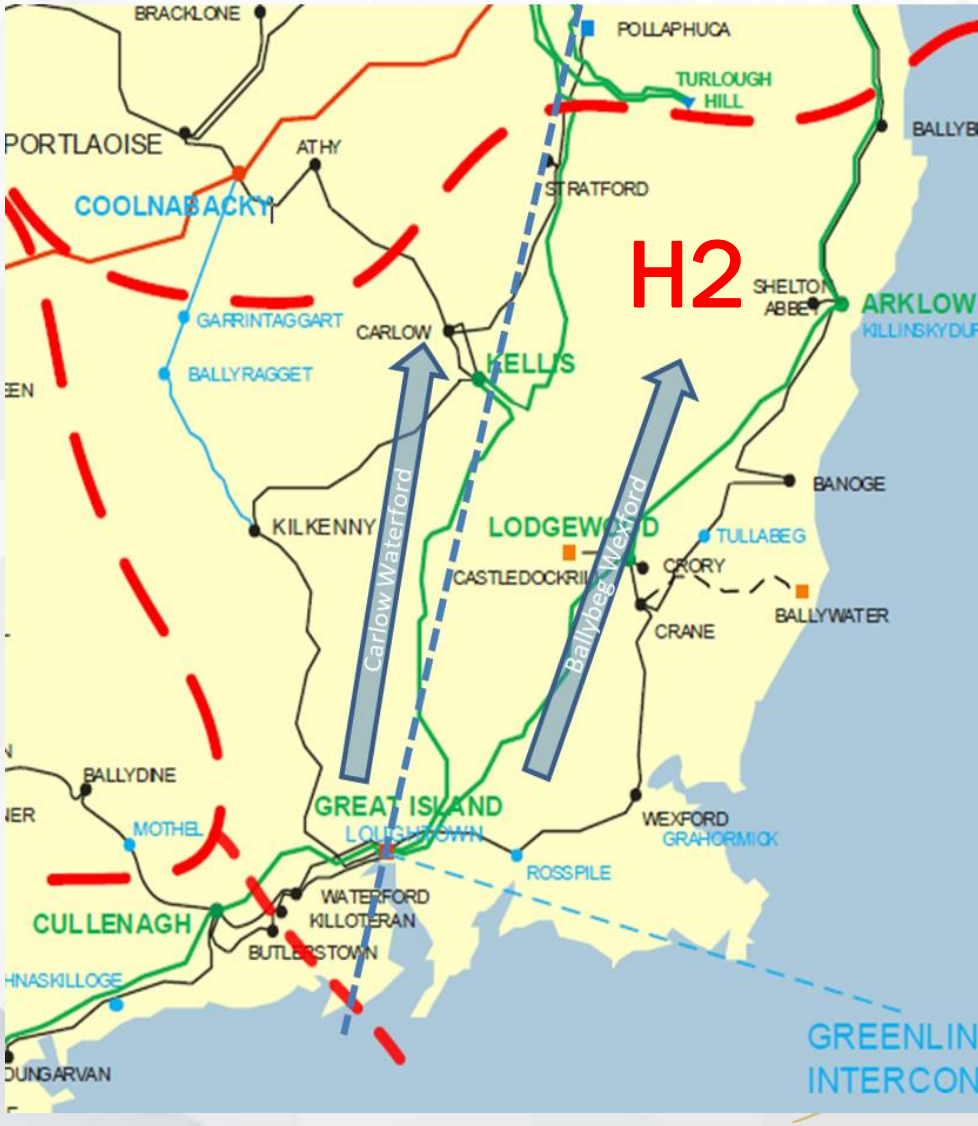
Area H1, H2, and K Dispatch Down % (2026 with GL)



Key Overview of the Area H1, H2 and K

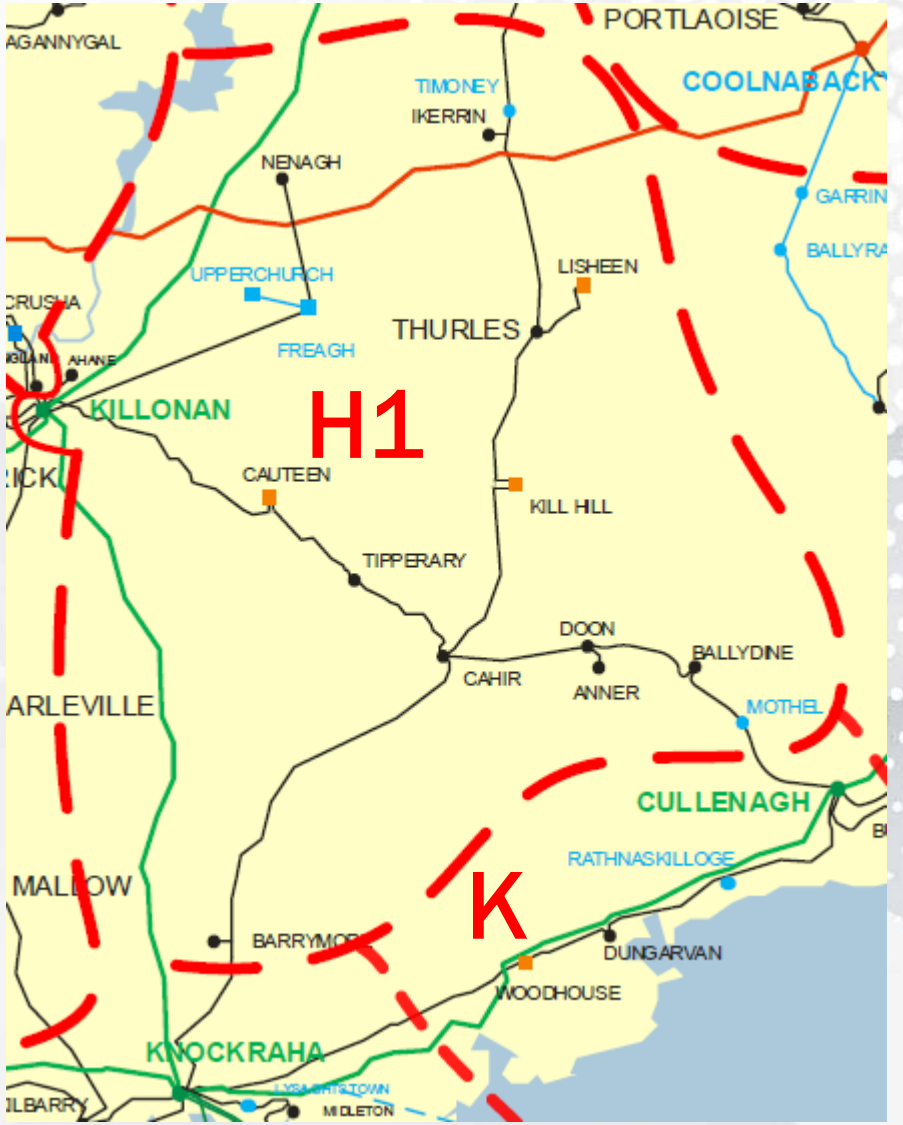
- The general power flow is towards the Dublin load centres utilizing the 220kV and 110kV circuits.
- The area H2 mainly has 220kV circuits parallel with 110kV circuits.
- The prospective loss of any parallel 220 kV/110 kV line may cause an overload on other lines resulting in an operational dispatch down action.
- For example, the rescue flow for contingency of Great Island – Lodgewood 220kV can invoke additional stress to the Arklow transformer.
- This can in-effect induce dispatch down of generators connecting to these lines and stations.
- The loss of Arklow - Carrickmines 220 kV circuit causes additional stress to the other parallel sections in the area.

Area	Pre ECP 2-1	ECP 2-1
H1	Wind – 543MW, Solar – 117MW	Solar – 86MW
H2	Wind – 803MW, Solar – 233MW	Wind – 106MW, Solar – 315MW
K	Wind – 54MW, Solar – 196MW	



AREA OVERVIEW

- Power from different areas across the country flow towards Dublin through the 220 kV and 400 kV Circuits.
- The prospective loss of any high voltage circuit can potentially congest the parallel circuit invoking redispatch/dispatch down of generation.
- Additionally, the increased generation (88MW in Area H2 and 98MW in H1) in year 2026 for the area causes higher power flow in the 110 kV circuits.
- However, the Greenlink interconnector in 2026 has potential benefit on constraints to this region along with reduction in oversupply and curtailment.
- The Area H1 is meshed towards 4 different 220kV stations. Any loss of one/multiple of the sections will have rescue flow flowing towards other lines and can potentially cause congestion on those lines.
- The 400 kV station (Coolnabacky) in 2026 study (in Area J) that can create additional pathways for the nearby 110 kV lines.
- Uprates in Future Grid scenario for 110 kV
  - Arklow - Ballybeg - Carrickmines 220 kV
  - Athy - Carlow 110 kV uprate
  - Crane - Wexford 110 kV uprate
  - Great Island - Kellis 220 kV uprate
  - Great Island - Kilkenny 110 kV uprate
  - Great Island 220/110 kV transformer No.3
  - Killoteran - Waterford 110 kV uprate
  - Thurles Station - Statcom



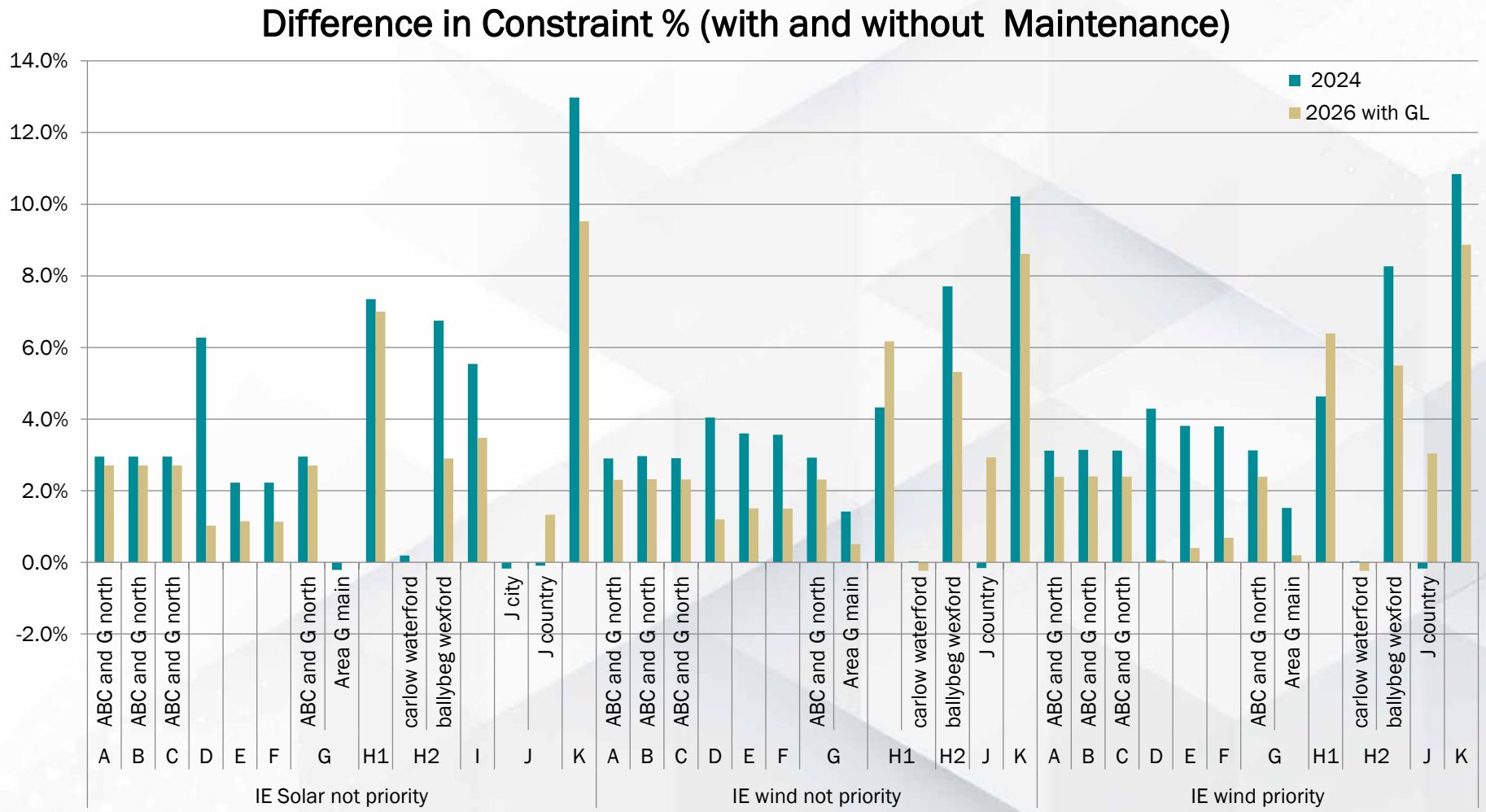
Maintenance Sensitivity

Maintenance Sensitivity

- Following on from ECP 1 feedback a maintenance schedule was included in the ECP 2.1 studies.
- For ECP 2.1, a representative maintenance schedule was developed to represent an outage season in each area.
- The maintenance schedule was kept the same for all studies to ensure consistency in the results.
- This additional study was prepared following an industry request regarding the sensitivity of the maintenance schedule used in ECP 2.1.
- Two representative studies (2024 (All ECP) and 2026 with Greenlink (All ECP)) were chosen to conduct the maintenance sensitivity.
- The results show the difference in constraints in in each Area/subgroup with respect to maintenance.

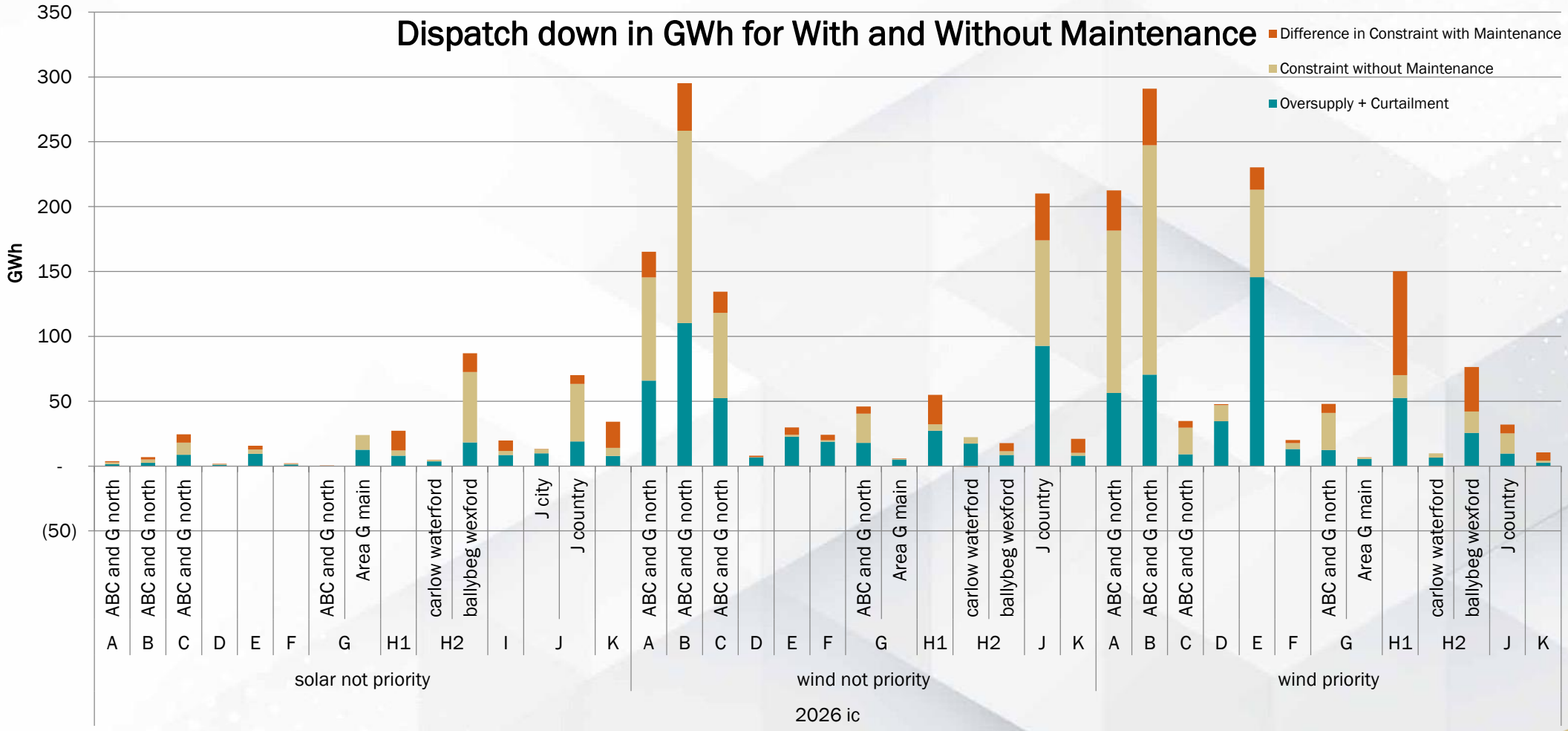
ECP 2.1 MAINTENANCE SENSITIVITY

FOR 2024 AND 2026 WITH GREENLINK ALL ECP SCENARIO



ECP 2.1 MAINTENANCE SENSITIVITY

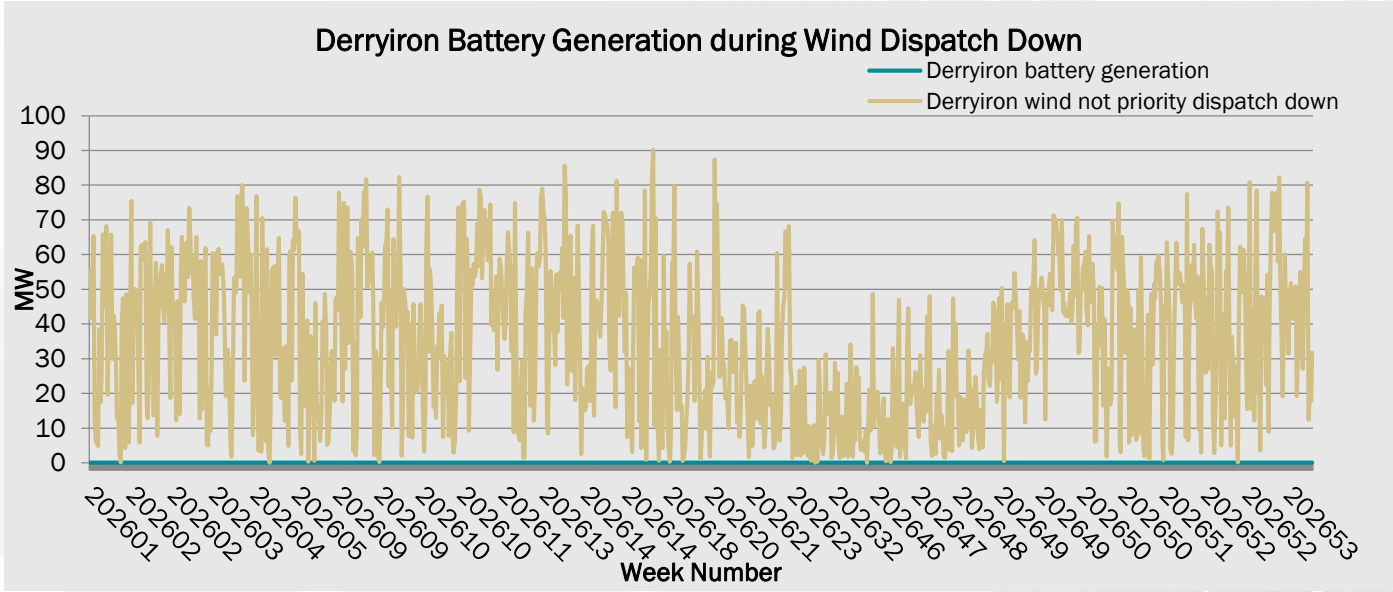
FOR 2026 WITH GREENLINK ALL ECP SCENARIO

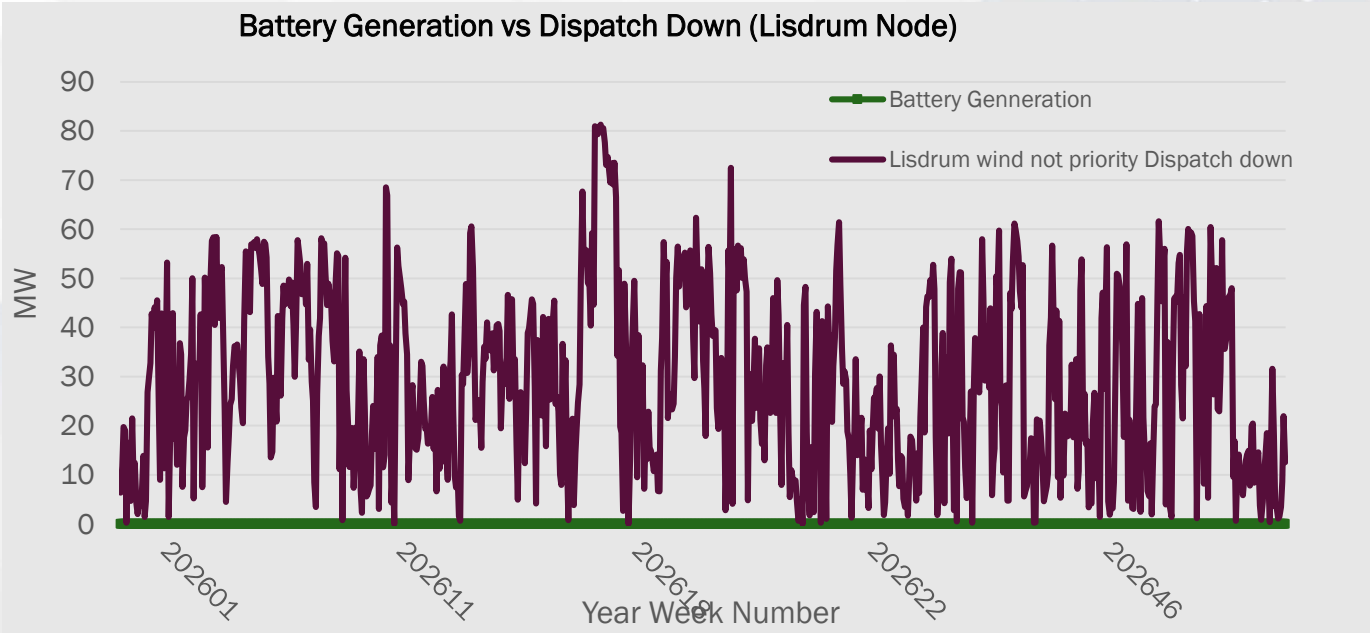


ECP 2.1 BATTERIES

BATTERY CHARGING VS RENEWABLE DISPATCH DOWN

- The batteries charging and discharging is based on the system level price.
- However, the batteries are not generating when renewable generation is dispatched down at the node.
- Sample node data for Derryiron and Lisdrum (**Dispatch Down > 0**).





DISCUSSION