Independent & Resilient Energy System with Green Hydrogen: System Requirements for Net-Zero Ireland

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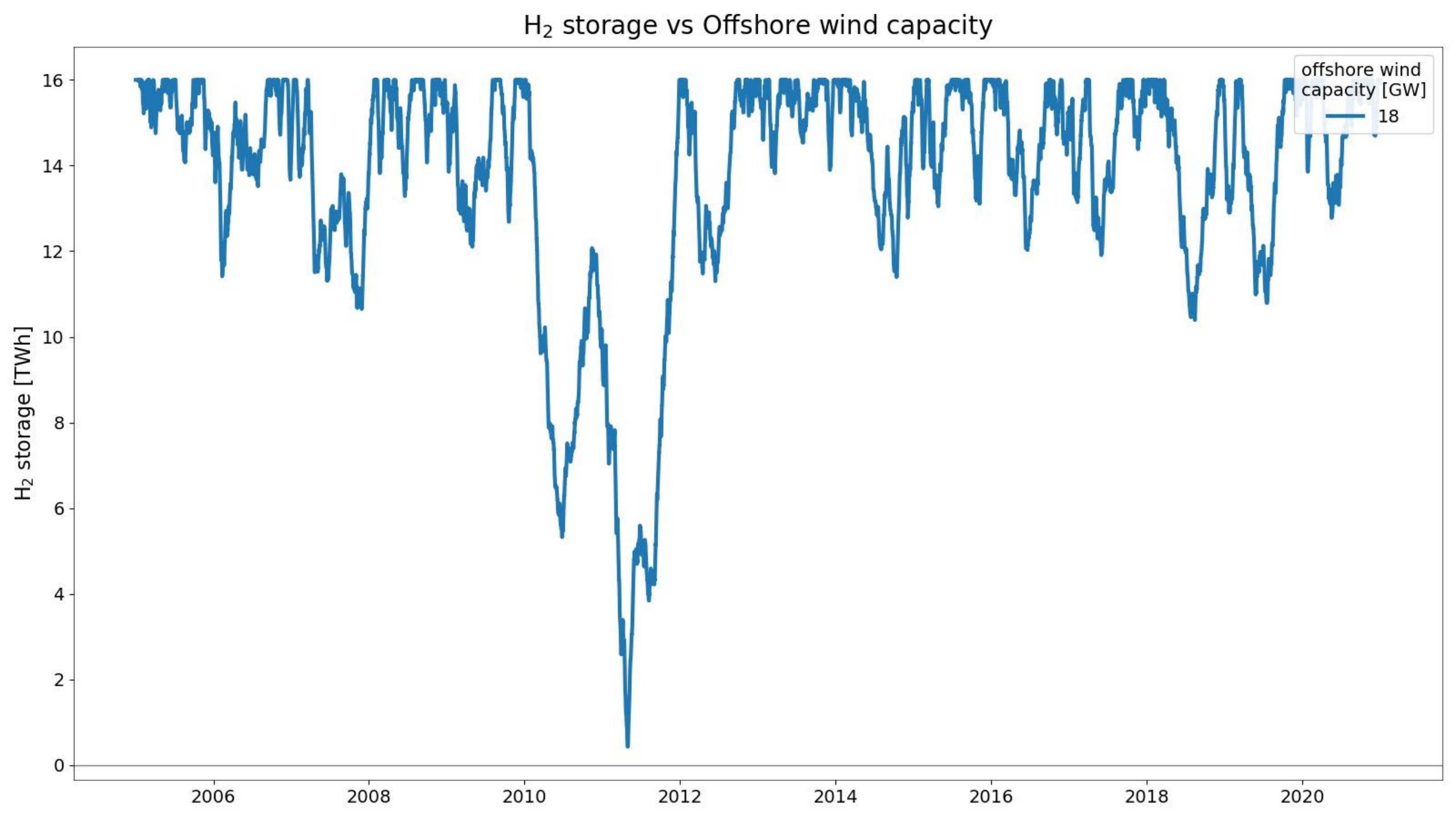
IEA Wind Topical Expert Meeting #113

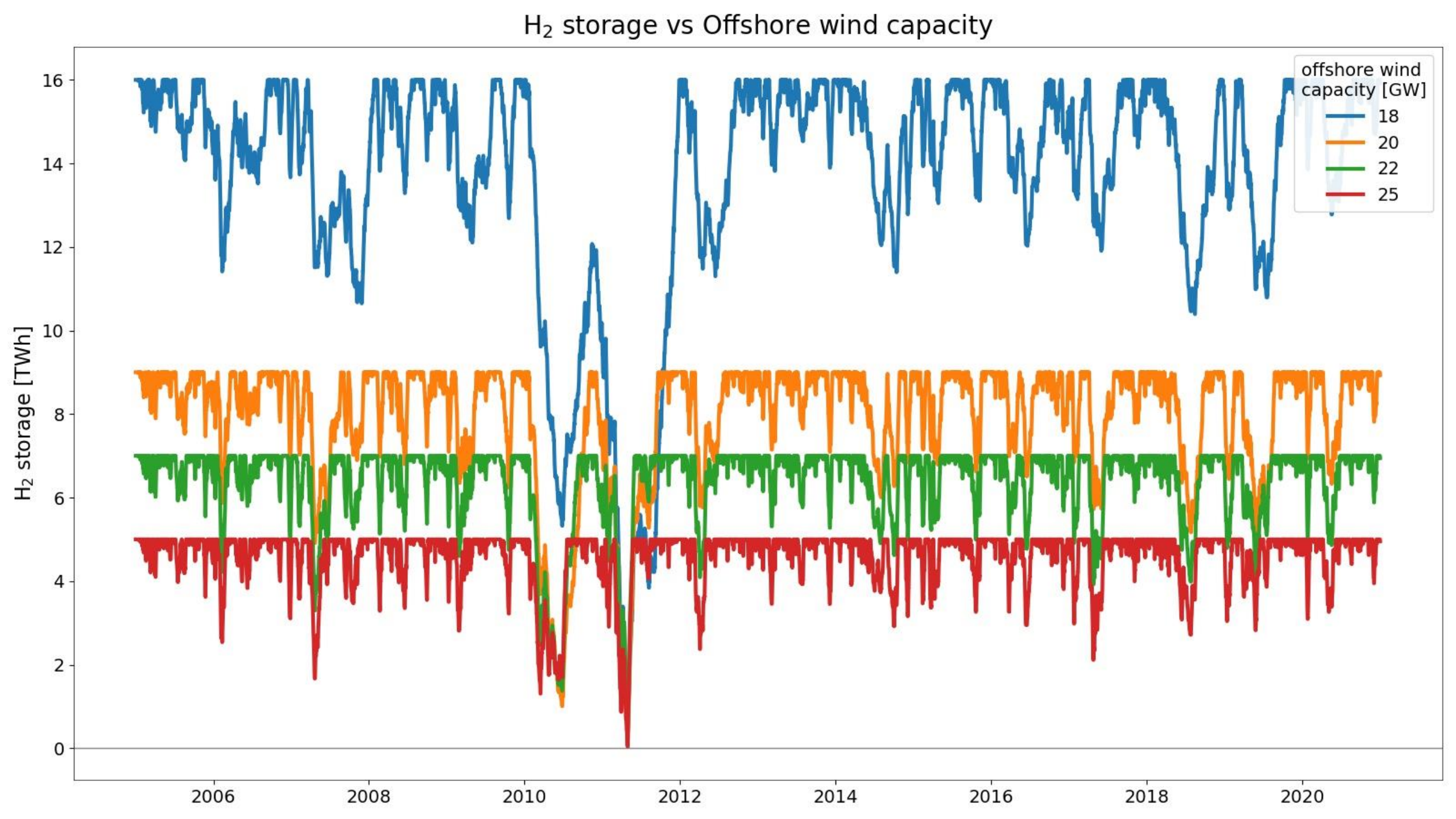
Monday, 8th April 2024 – Dublin, Ireland

System Model

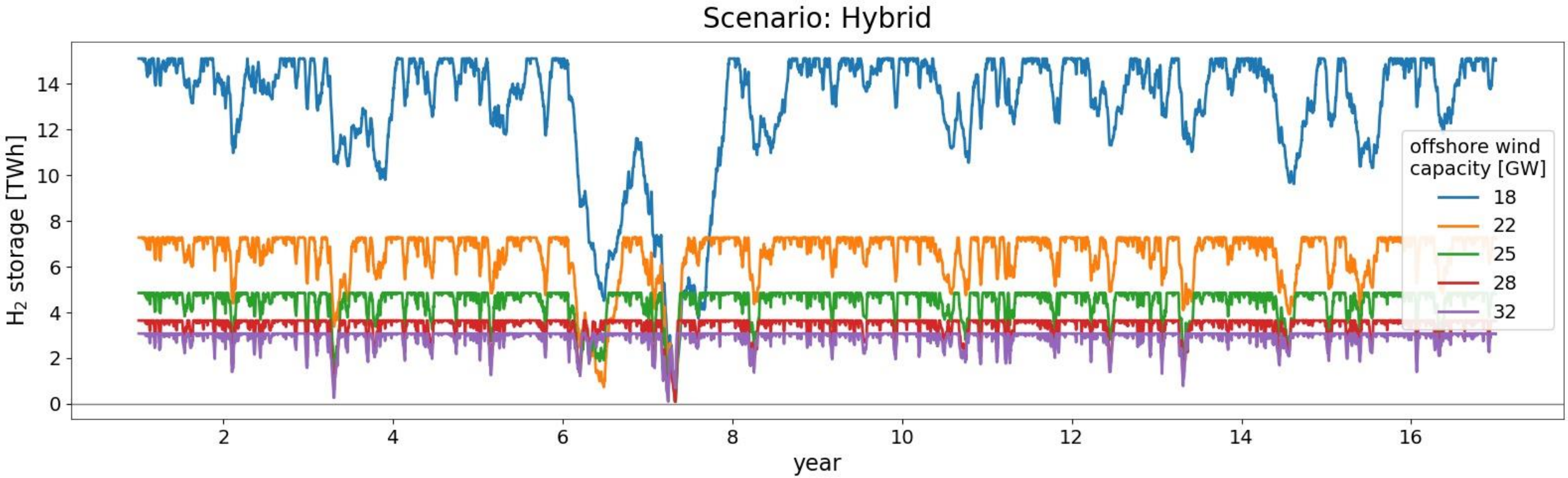
- Starting point – ESB Net-zero vision:
  - Specifies requirements in a typical year and provides **hourly electricity load profile**
  - Annual load is ~88 TWh
- Generation: 100% renewable power
  - **Hourly RES generation** based on historical weather: 16 consecutive years (2005-2020)
- System independence: no interconnectors nor energy import/export
- Storage: 100% green H_2

→ Hourly RES Generation – Hourly Load =
- surplus → store as H_2 (70% efficient)
- deficit → draw from H_2 → electricity (50% efficient)


H2 storage vs Offshore wind capacity
offshore wind capacity [GW]
18
H2 storage [TWh]
0
2
4
6
8
10
12
14
16
2006
2008
2010
2012
2014
2016
2018
2020


H2 storage vs Offshore wind capacity
H2 storage [TWh]
offshore wind capacity [GW]
18
20
22
25
0
2
4
6
8
10
12
14
16
2006
2008
2010
2012
2014
2016
2018
2020

Feasibility/Cost trade-off between RES capacity & H_2 storage



- All these options “technically” work
- Trade-off between RES capacity overbuild & H_2 storage size
- No optimisation performed in this ESB study → UCC/MaREI study

Results: UCC v ESB studies

Component		UCC Typical year	UCC Resilient	ESB Resilient & Independent
Solar PV [GW]		10	10	10
Onshore wind [GW]		9	9	9
Offshore wind [GW]		17.0	21.7	28.3*
RES generation (available) [TWh/year]		110	148	148
Interconnector [GW]		3.0	3.0	0
Batteries [GW]		2.7	2.7	0
H_2 storage size [TWh]	with I/C	2.0	5.7	-
	without I/C	-	8.1	3.6
Dispatchable fleet [GW]		10.6	10.6	13.0
Electrolyser [GW]		10.6	10.6	29.3
“Curtailed” electricity [TWh/year]		10	26	49

Our Future – Delivering Ireland's Net-Zero Ambition

>30GW Renewables

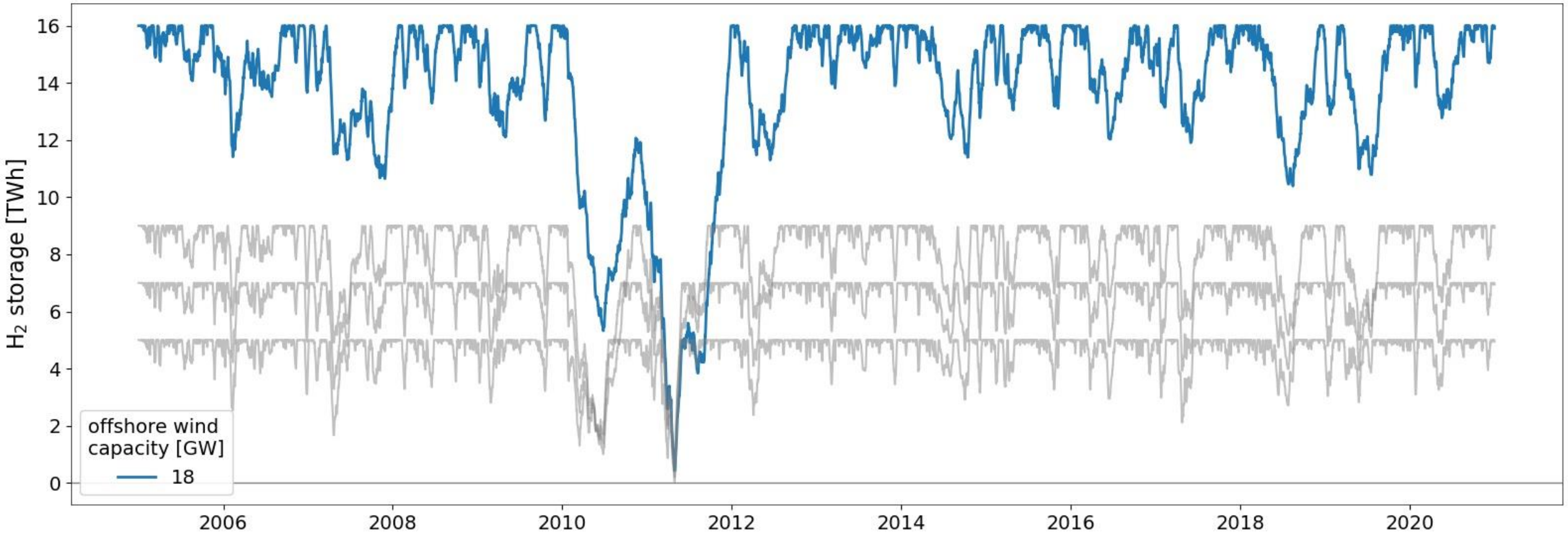
>10GW Hydrogen Production

>10GW Backup Dispatchable
Zero-Carbon Power & Flexibility

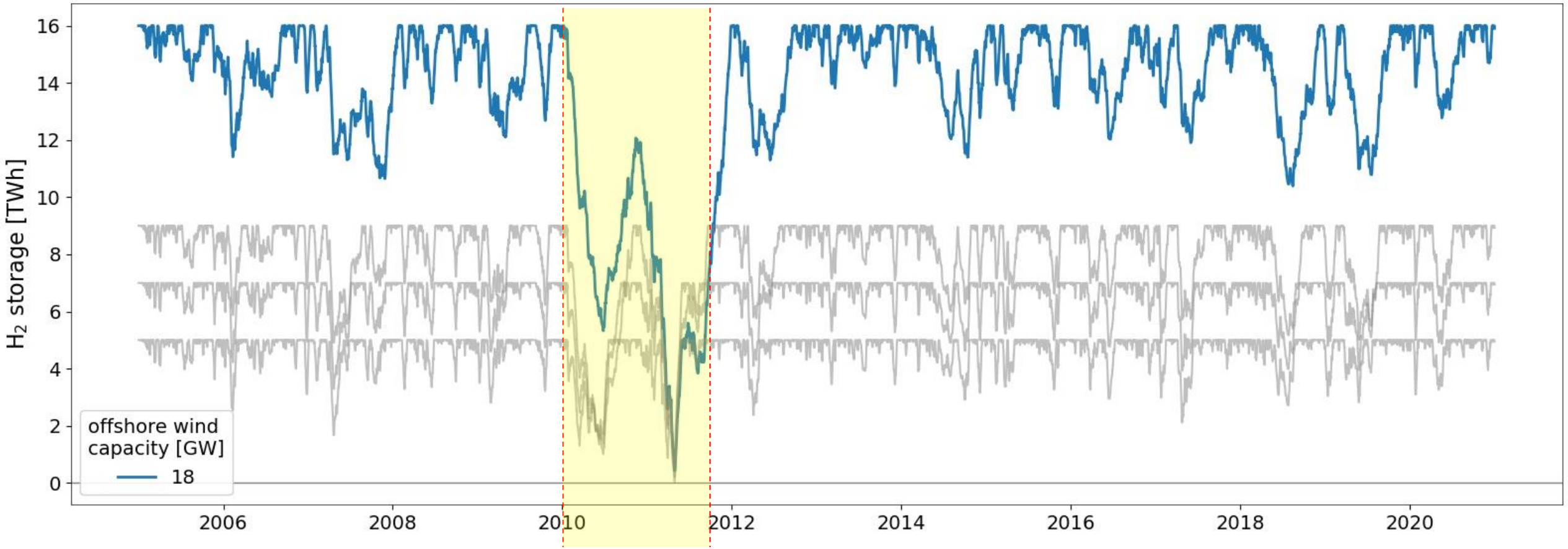
5 – 10TWh Storage

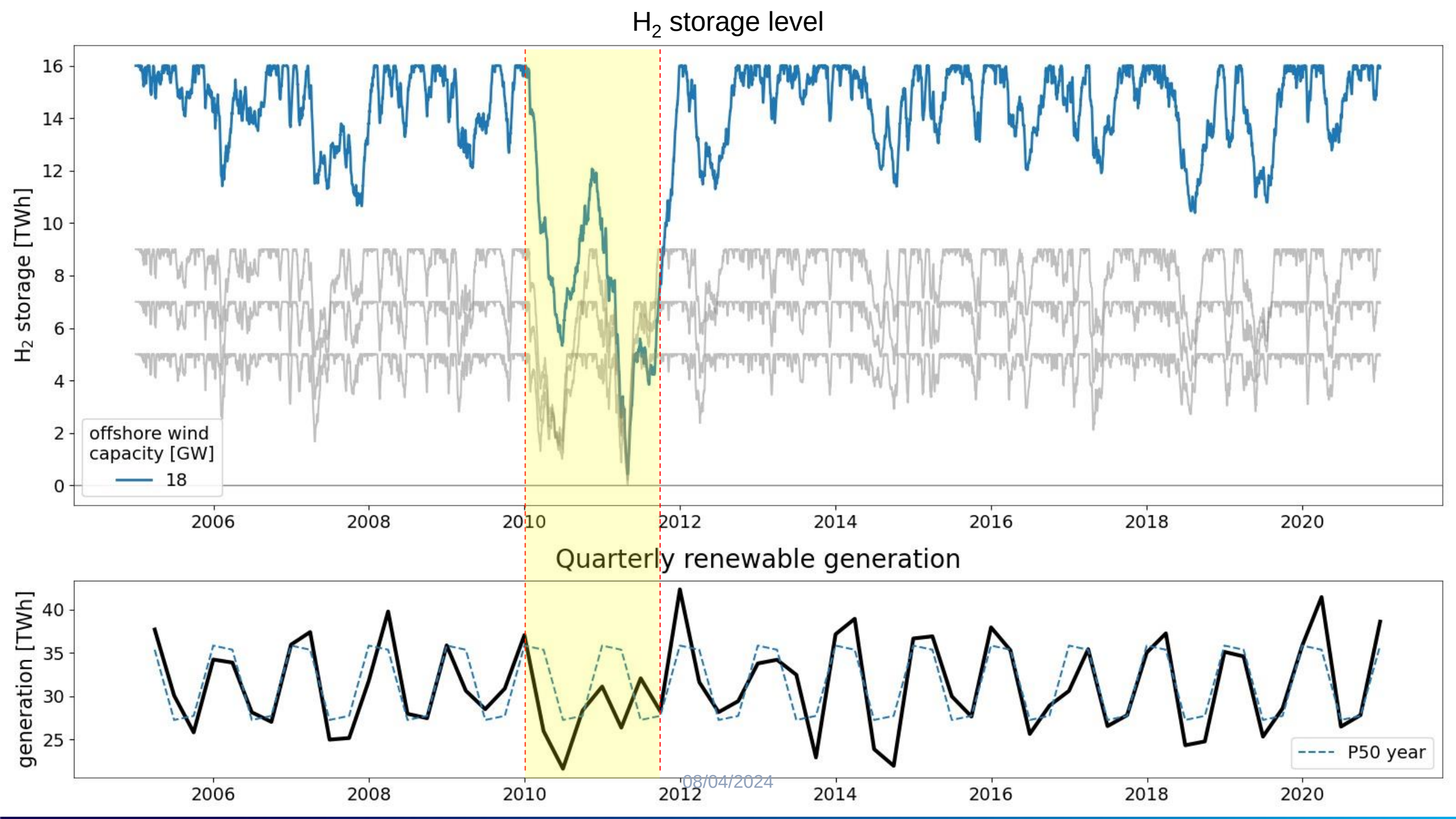
Wind droughts

H_2 storage level



H_2 storage level




H_2 storage level
H_2 storage [TWh]
offshore wind capacity [GW]
18
Quarterly renewable generation
generation [TWh]
P50 year
2006
2008
2010
2012
2014
2016
2018
2020

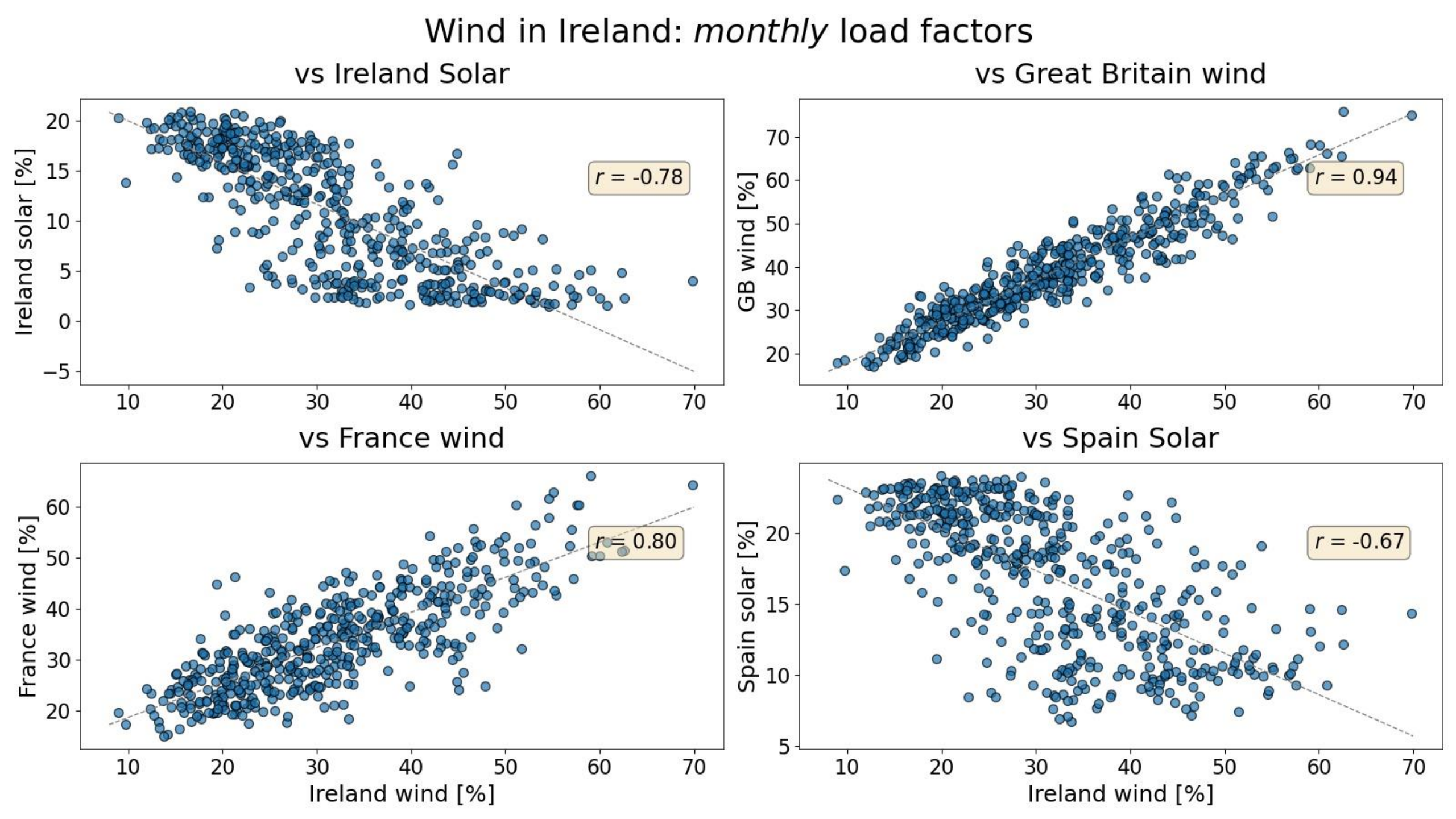
Net-Zero Ireland – Key conclusions

- Net-Zero world is electric – electricity demand is huge → more of 'everything' is required:
- Actual infrastructural requirements will depend on cost/feasibility trades-offs:
  - H_2 storage size and 'overbuild' of RES generation capacity;
  - Technology blend of RES generation capacity (solar PV complements wind);
  - Desired level of independence: full vs practical – Dispatchable fleet & Electrolysers vs Interconnection.
- Resilience is a multi-seasonal issue (~1.5 year wind drought) [see also "Royal Society (2023) – Large-scale electricity storage report"]
- Cost of resilience is:
  - ~5 GW of offshore wind and
  - ~4 TWh of H_2 storage.
- 5 TWh of H_2 storage is a low regret option.

Weather correlation

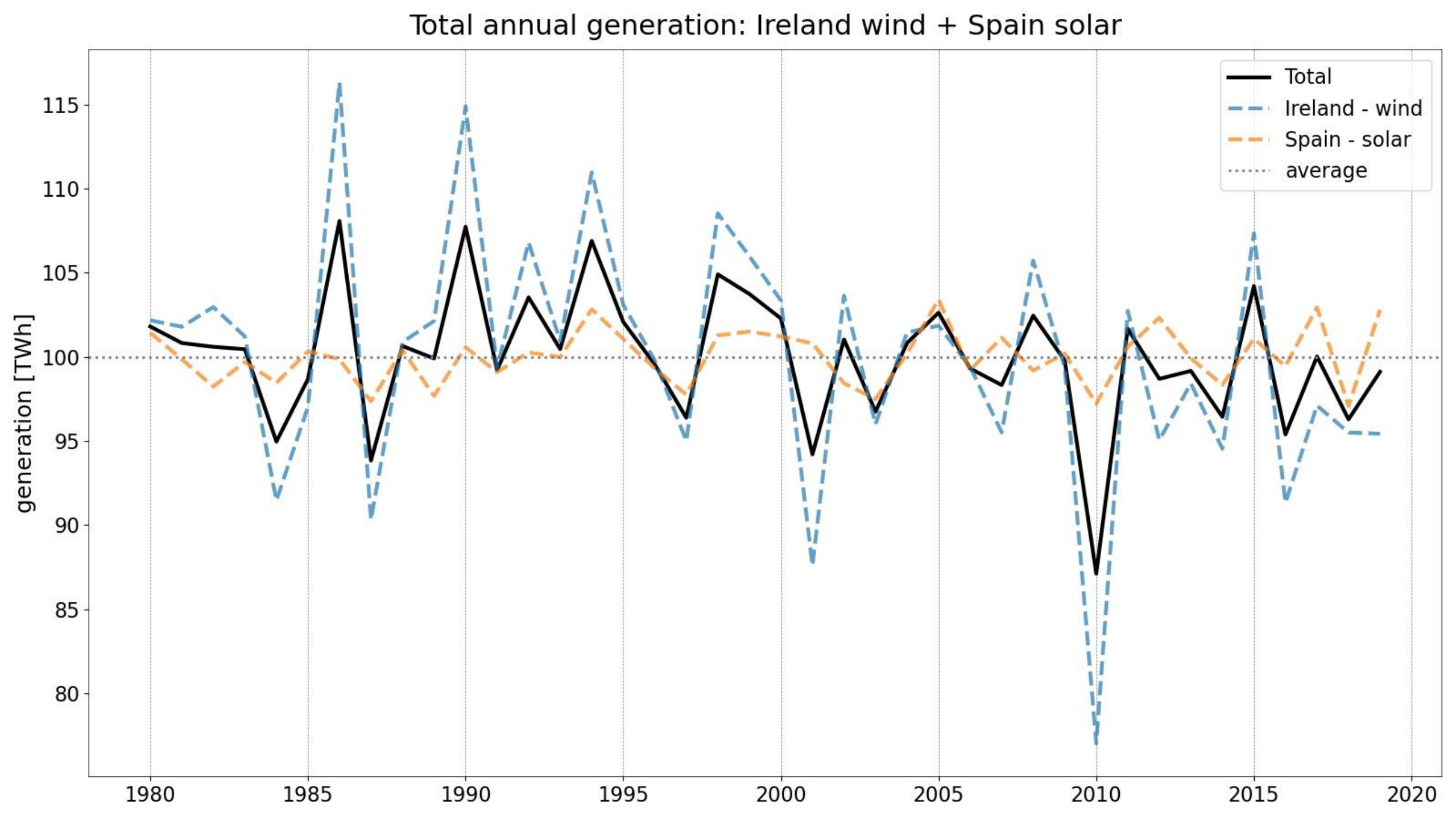
Weather correlation

- Analyse the correlation between wind in Ireland and wind & solar in other European regions:
  - Great Britain
  - France
  - Spain


Wind in Ireland: *monthly* load factors
vs Ireland Solar
Ireland solar [%]
r = -0.78
vs Great Britain wind
GB wind [%]
r = 0.94
vs France wind
France wind [%]
r = 0.80
Ireland wind [%]
vs Spain Solar
Spain solar [%]
r = -0.67
Ireland wind [%]

Weather correlation

- Assume enough capacity and interconnection to combine domestic wind generation with solar generation in Spain
- Average annual generation = 100 TWh/year


Total annual generation: Ireland wind + Spain solar
Total
Ireland - wind
Spain - solar
average
generation [TWh]
115
110
105
100
95
90
85
80
1980
1985
1990
1995
2000
2005
2010
2015
2020

Weather correlation – Key conclusions

- While there is a strong negative correlation between wind and solar at a monthly level, the two sources *do not complement each other at an annual level*.
- Interconnection alone cannot solve the problem of surplus or shortage of renewable energy → *long-duration energy storage* is necessary.
- Importance of analysing weather-dependent generation over *multiple years*, rather than just on a single, average year.