Féidearthachtaí as Cuimse
Infinite Possibilities

Renewable generation and green hydrogen: infrastructural requirements for a resilient, independent, net-zero energy system

Dr Gianni Goretti

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ESB

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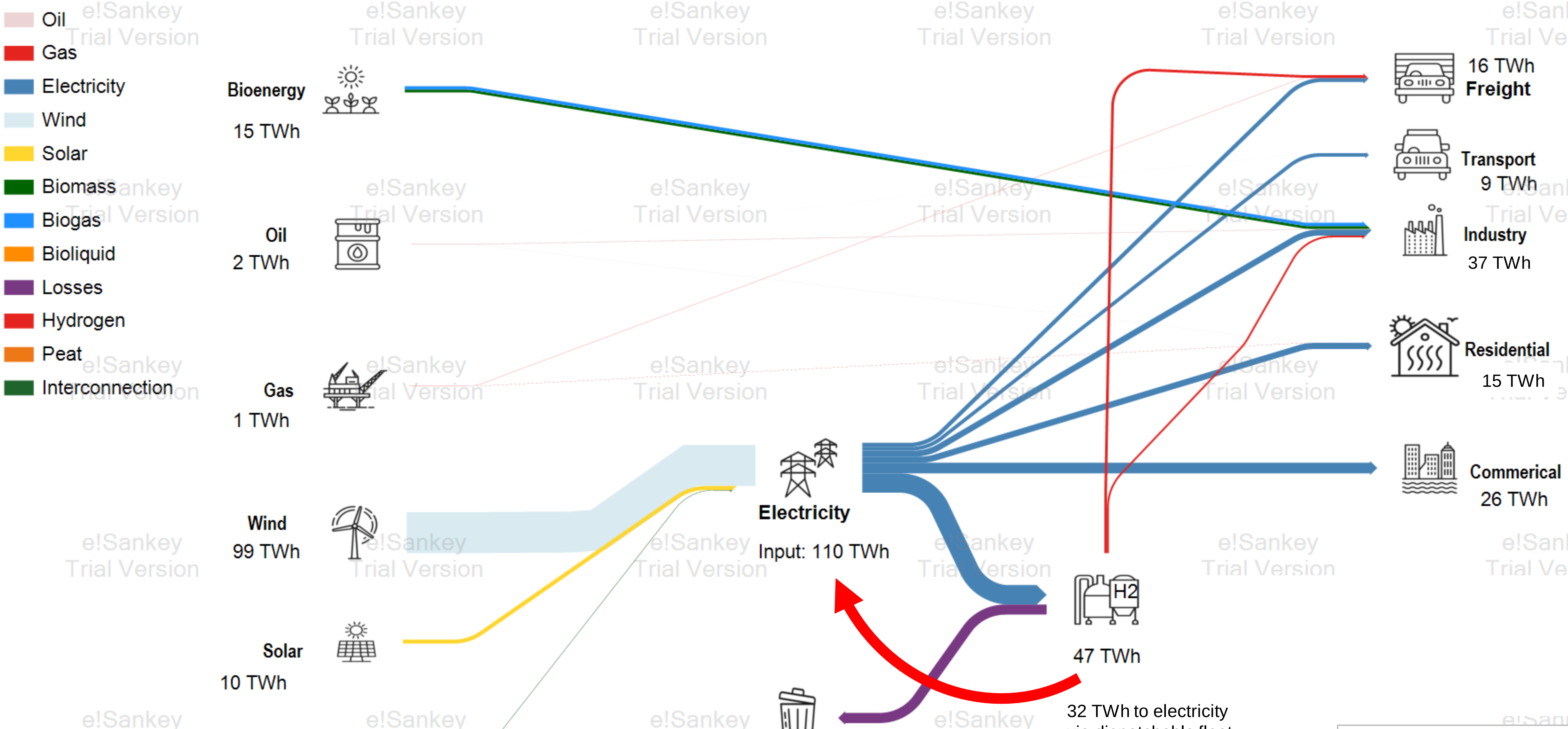
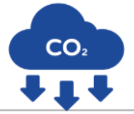
Methodology

Ireland’s Energy System 2050 – Average Wind Year



Negative Emissions Technologies are also required to remove 3Mt CO_2eq/yr in 2050



Irish Electricity System

	2021	2050
Electricity demand [TWh]	35	88
Energy demand [TWh]	162	
Population [mil]	5.0	6.2
Solar PV [GW]	0.2	9.8
Onshore wind [GW]	4.5	9.0
Offshore wind [GW]	0	?
RES generation [TWh]	11.5	?
H_2 storage [TWh]	0	?
Dispatchable fleet [GW]	6.8	?

Assumptions

- 2050 system: highest electrification → hourly load profiles modelled by UCC/MaREI
- Generation: 100% renewable (onshore & offshore wind, solar PV)
- Storage: 100% green hydrogen
- System independence: no Interconnectors, no energy import/export

→ Model 16 consecutive years (2005-2016)

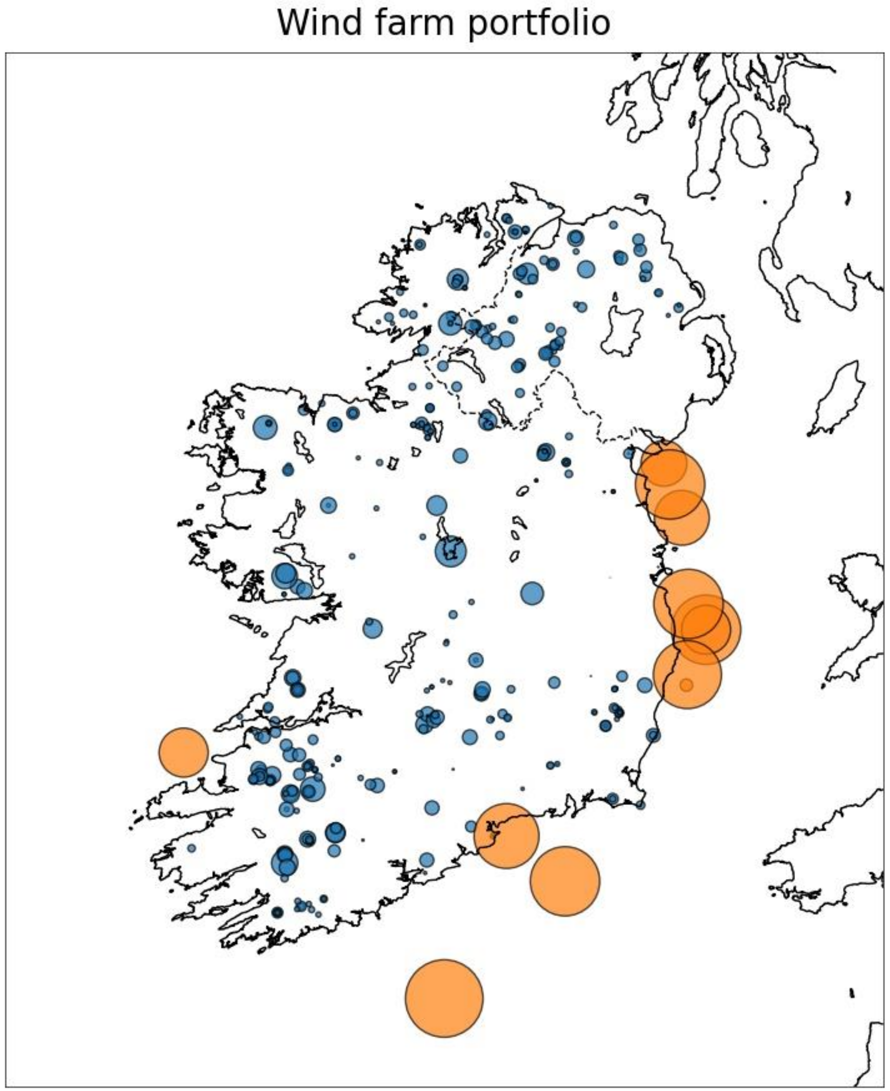
For each hour:

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

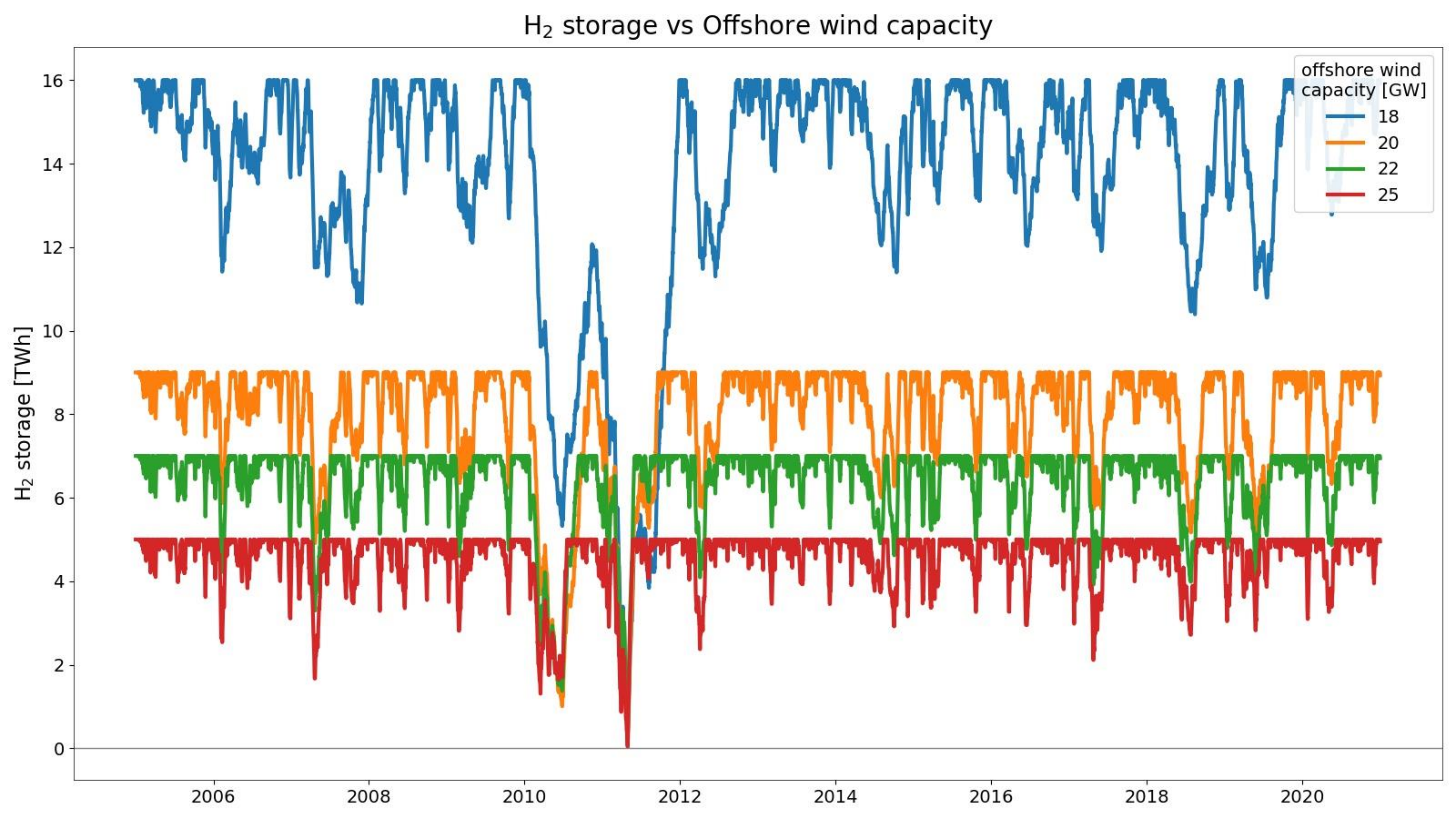
RES Generation

- Starting portfolio: ESB internal 2045 projections
- RES generation: ERA5 reanalysis data + PVGIS Tool + custom software

→ Trialed various extra offshore capacity & H_2 storage combinations

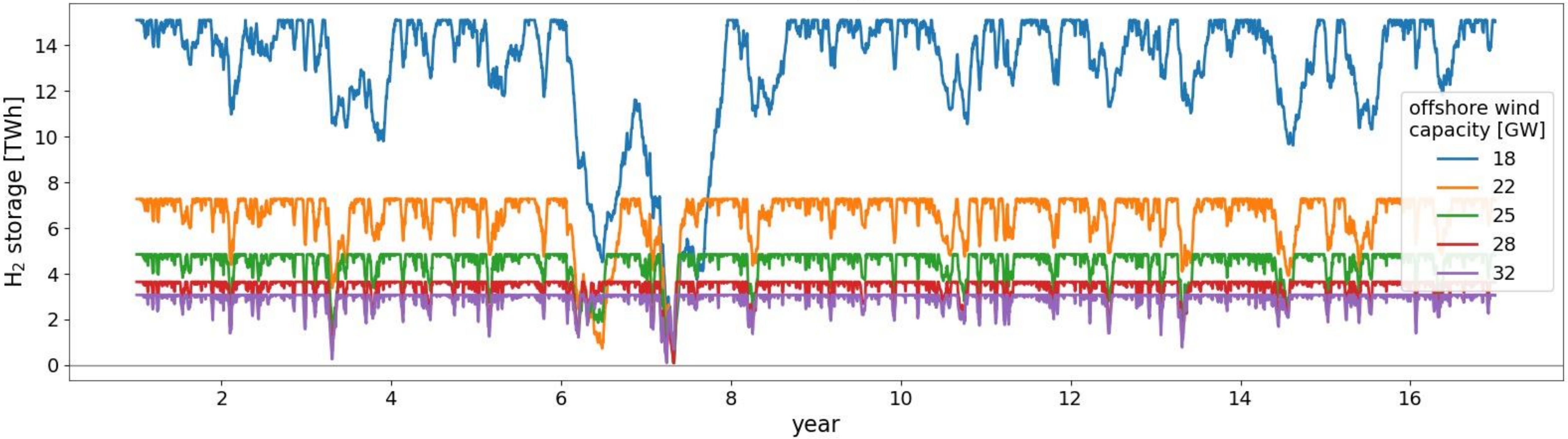


RES capacity v H_2 storage



H_2 storage vs Offshore wind capacity
H_2 storage [TWh]
0
2
4
6
8
10
12
14
16
2006
2008
2010
2012
2014
2016
2018
2020
offshore wind capacity [GW]
18
20
22
25

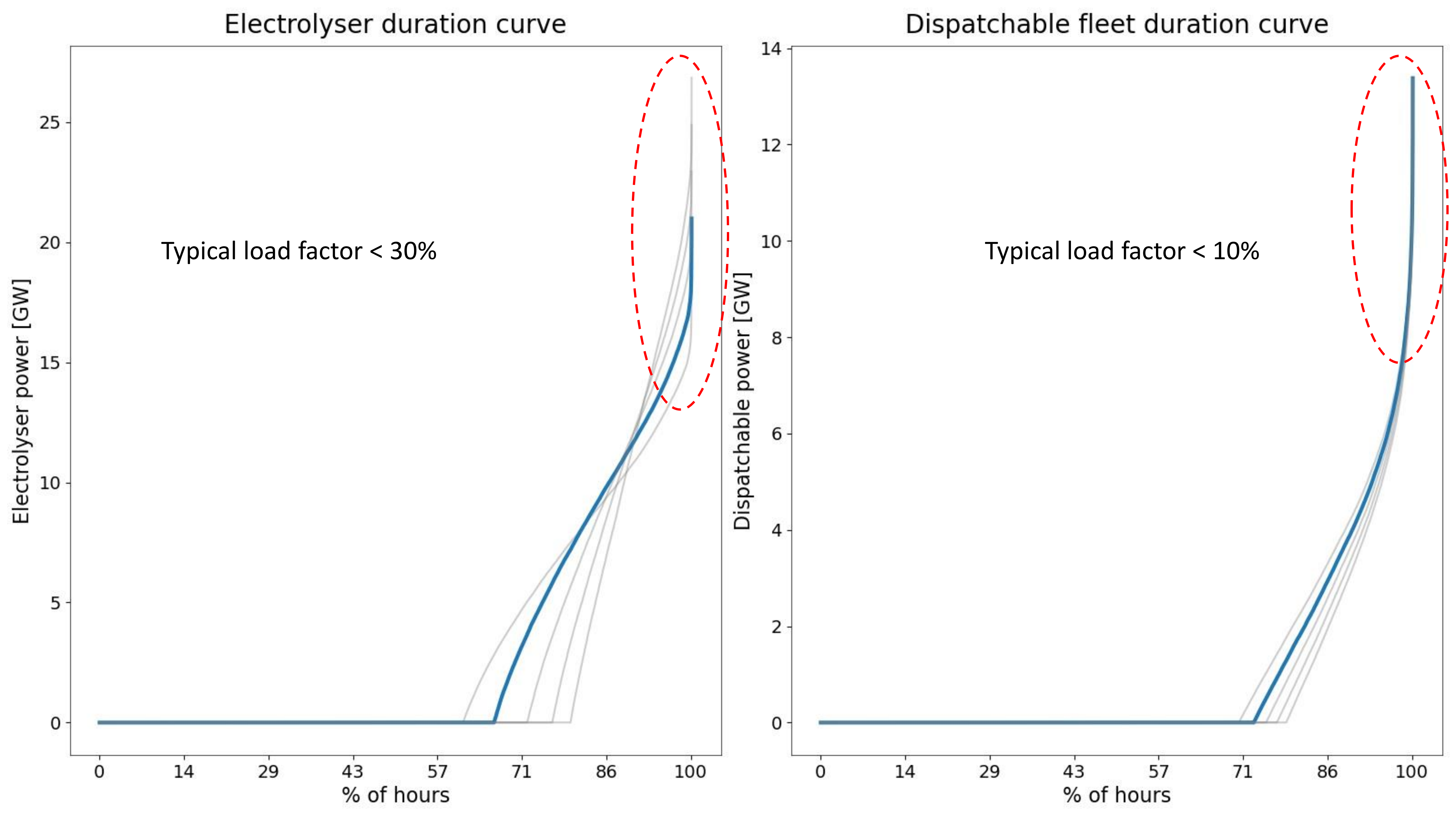
Trade-off between RES capacity & H_2 storage



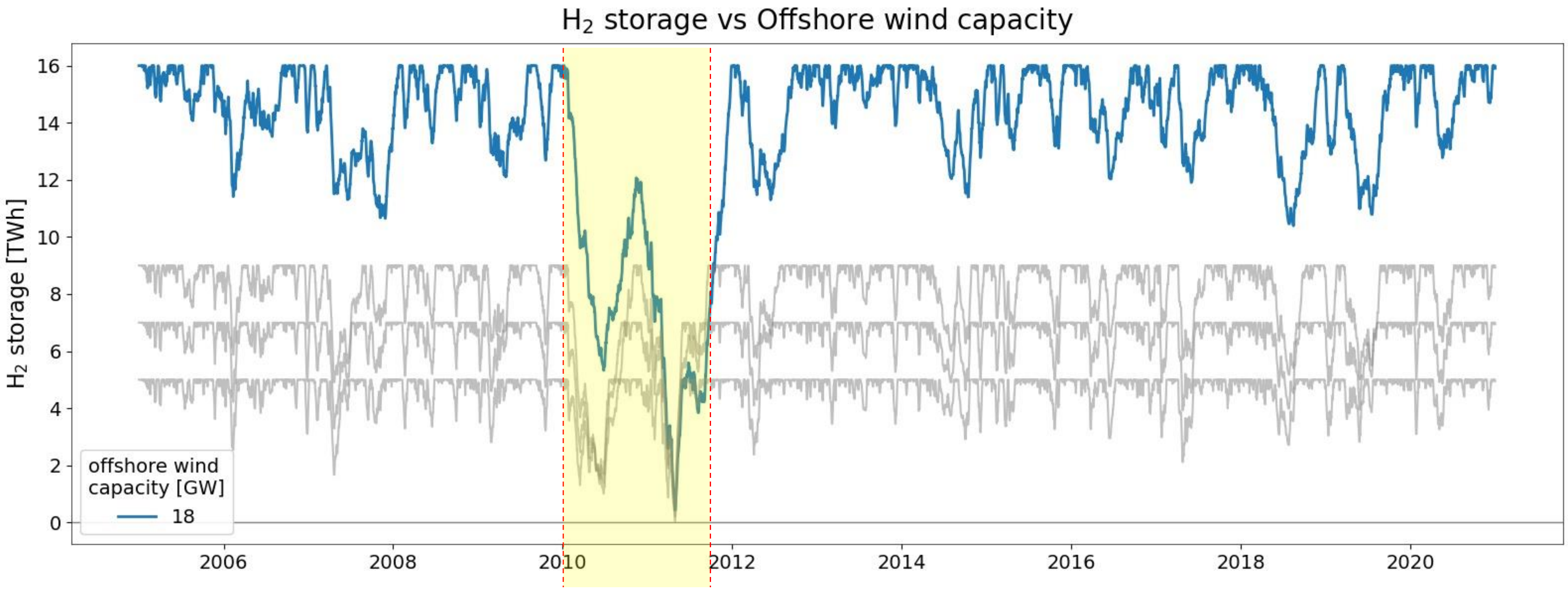
- All these options “technically” work
- Trade-off between RES capacity overbuild & H_2 storage size
- No optimisation performed in this study

Massive infrastructural investments for Net-Zero

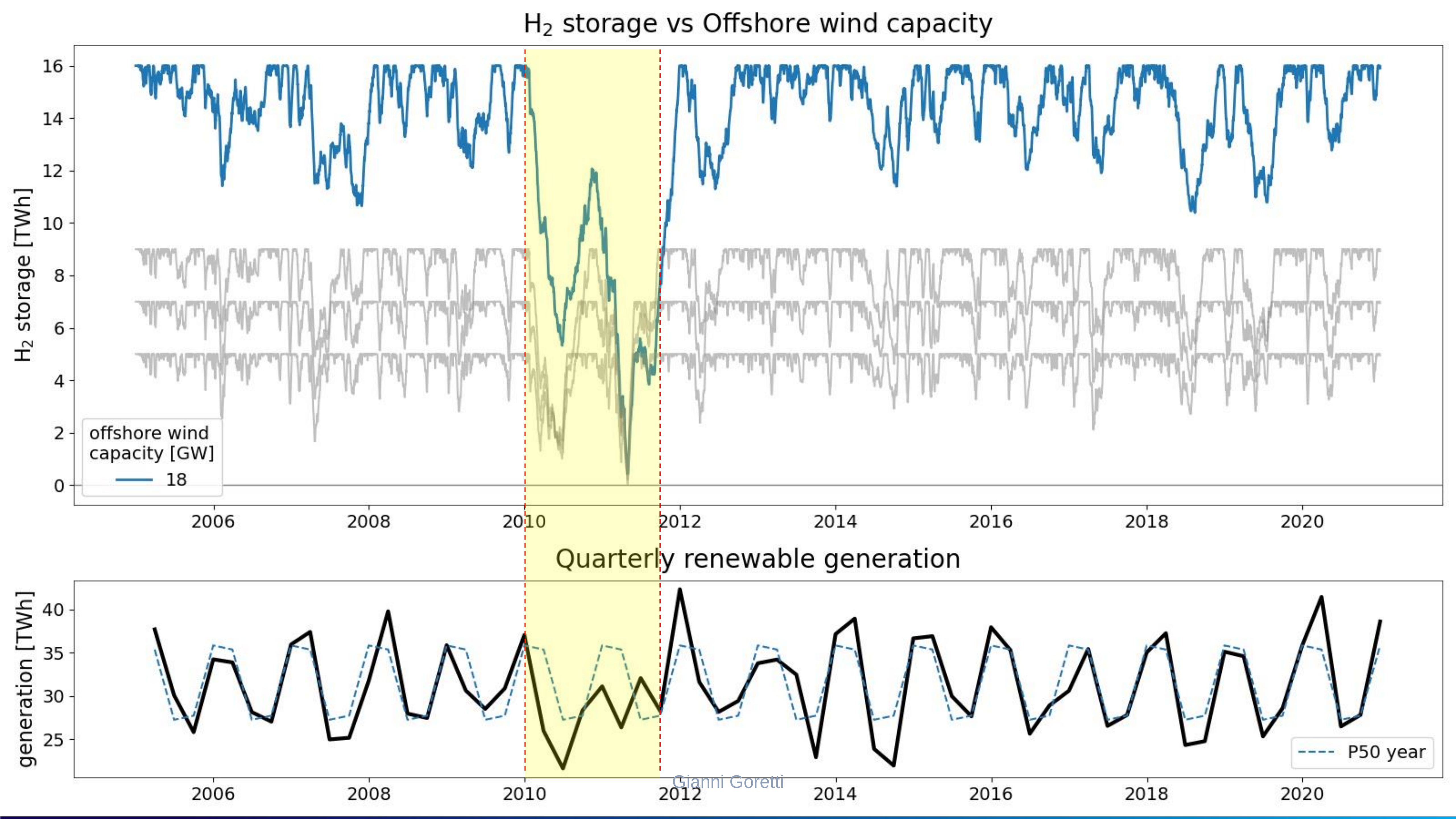
	2021	2050 (resilient)
Electricity demand [TWh]	35	88
Energy demand [TWh]	162	
Solar PV [GW]	0.2	9.8
Onshore wind [GW]	4.5	9.0
Offshore wind [GW]	0	18 – 28 ↑
RES generation [TWh/year]	12	102 – 148 ↑
H_2 storage [TWh]	0	16.0 – 3.6 ↓
Dispatchable fleet [GW]	6.8	12.9*
Electrolysers [GW]	0	29*


Electrolyser duration curve
Electrolyser power [GW]
25
20
15
10
5
0
Typical load factor < 30%
0
14
29
43
57
71
86
100
% of hours
Dispatchable fleet duration curve
Dispatchable power [GW]
14
12
10
8
6
4
2
0
Typical load factor < 10%
0
14
29
43
57
71
86
100
% of hours

Wind Droughts



H$_2$ storage vs Offshore wind capacity
H$_2$ storage [TWh]
0
2
4
6
8
10
12
14
16
2006
2008
2010
2012
2014
2016
2018
2020
offshore wind capacity [GW]
18

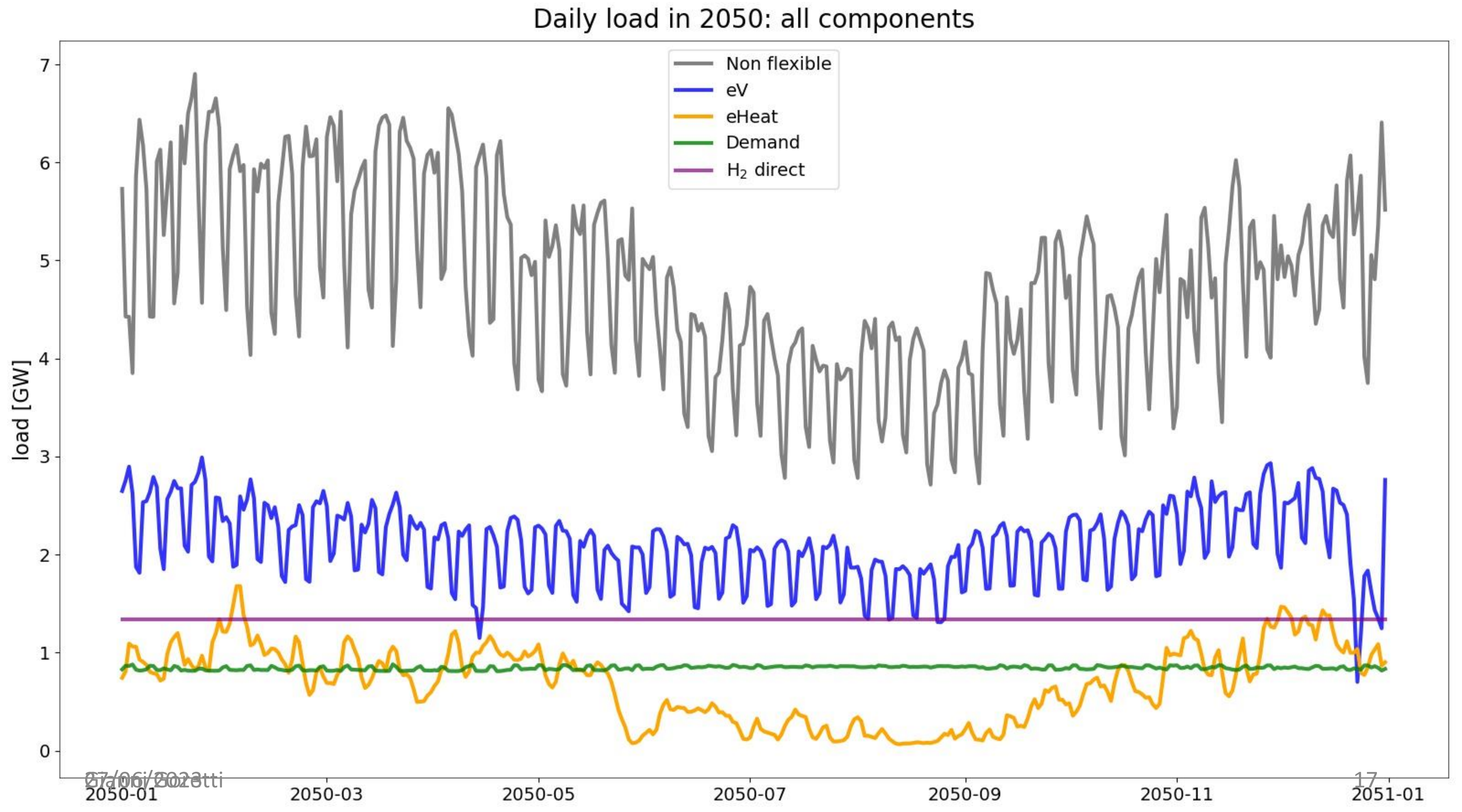


H2 storage vs Offshore wind capacity
H2 storage [TWh]
offshore wind capacity [GW]
18
16
14
12
10
8
6
4
2
0
2006
2008
2010
2012
2014
2016
2018
2020
Quarterly renewable generation
generation [TWh]
40
35
30
25
P50 year
2006
2008
2010
2012
2014
2016
2018
2020
Gianni Goretti

Cost of resilience (UCC/MaREI study)

	2050 – Typical year	2050 – Resilient
Electricity demand [TWh]	88	88
Solar PV [GW]	9.8	9.8
Onshore wind [GW]	9.0	9.0
Offshore wind [GW]	17.0	21.7
RES generation [TWh/year]	110	148
H_2 storage [TWh]	2.0	5.7
Curtailed electricity [TWh/year]	10	26

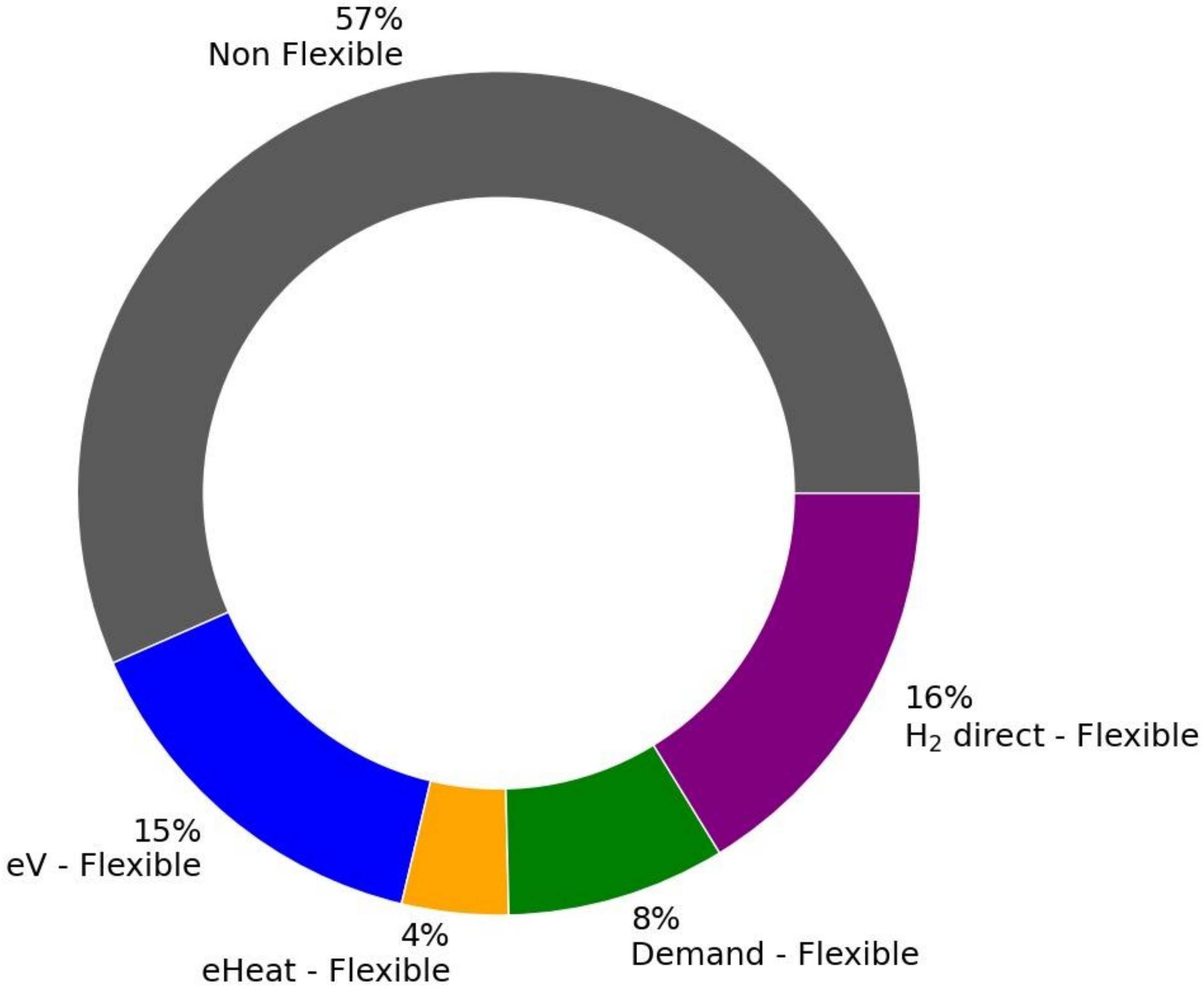
Load Flexibility


Daily load in 2050: all components
Non flexible
eV
eHeat
Demand
H_2 direct
load [GW]
0
1
2
3
4
5
6
7
2050-01
2050-03
2050-05
2050-07
2050-09
2050-11
2051-01

Flexibility scenarios

1. Non-flexible: 100% of load non flexible
2. Flexible:
    - eV: 70% flexible within 24-h window
    - eHeat: 60% flexible within 24-h window
    - Demand (15% of plug loads): flexible within 24-h window
    - H2 for transport & industry: flexible within 30-day window

Flexible scenario



	TWh	Flexibility
Non flexible	49.9	
Flexible	41.9	
eV	13.0	24 h
eHeat	3.6	24 h
Demand	7.4	24 h
H_2 direct	14.3	30 days

Results: Infrastructure Requirements for Minimum RES Capacity

Component	Non-flexible	Flexible
Onshore wind [GW]	9	9
Solar PV [GW]	10	10
Offshore wind [GW]	20	18
RES generation [TWh/year]	119	107
H_2 storage size [TWh]	20	15
Electrolyser [GW]	23	21
Dispatchable fleet [GW]	17	13

The value of expected flexibility is:

- greater than 2 GW of offshore wind capacity, and
- ~5 TWh of H_2 storage.

Conclusions

1. Net-Zero world is electric: electricity demand is huge → more of “everything” is required
2. Cost/feasibility trade-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 → Dispatchable fleet & Electrolysers vs Interconnection.
3. The **value** of expectedl load **flexibility** is:
   - > 2 GW of offshore wind capacity
   - ~5 TWh of H_2 storage.
4. In a wind-dominated system, resilience is a **multi-seasonal** issue: ~1.5-year wind drought
5. Cost of resilience:
   - ~5 GW of offshore wind
   - ~4 TWh of H_2 storage
6. Long-term storage is beyond utility-scale, it’s **economy-wide-scale**!

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gianni.goretti@tudublin.ie