Green Hydrogen for Heating and its Impact on the Power System

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Background

1. Climate Action Plan 2019:
   - Net-zero carbon target by 2050
   - 70% electricity needs from renewable sources by 2030
2. National Energy & Climate Plan 2021-2030:
   - green hydrogen an enabler of the transition to a low carbon economy
3. Massive electrification:
   - Transport
   - Heating
4. The predominant use of energy by households is for heating.
5. Space and water heating:
   - 78% of final energy usage [1].

Hydrogen for heating

1. Abundant
2. Can be extracted from several compounds and in different ways
   - Electrolysis
   - SMR
3. Different “colors”.
4. Can be mixed with methane (natural gas) in a process called blending without significant modifications to gas pipes and water heaters.
5. Hydrogen blending with methane
   - < 10% [2]

Objective

- Study the Impact of Electrolysers for producing H_2 for heating and the Renewable Target on the Power System and Emissions.

Methodology

- ENGINE model of the Power Flow Equations
- Electrolyser model adapted from El-Taweel et al. [3]

Case Study

- Irish Power System and two policy goals.
- Residential sector is the single largest consumer of heat in Ireland.
- 4 scenarios: BAU, ESR-Only, RET-Only, RET+ESR

Contributions

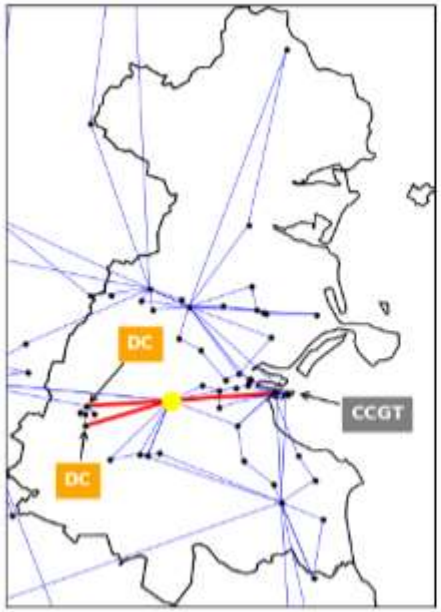
1. The additional infrastructure required, both generation capacity and transmission, to facilitate hydrogen electrolysis.

2. The location of electrolysers and new generation capacity.

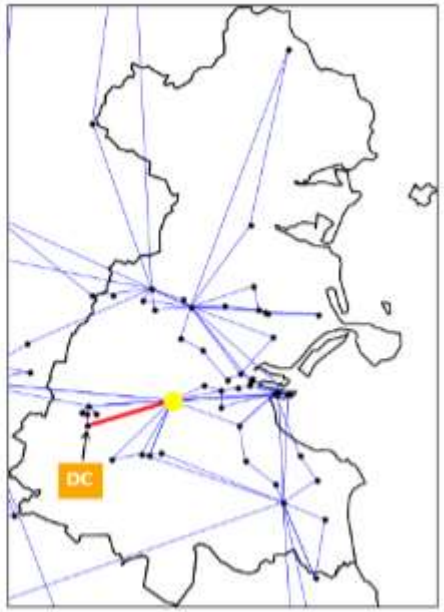
3. The effect on net emissions, electricity prices and wind power curtailment.

Transmission reinforcement

- No significant impact from the integration of electrolysers.
- All the lines and transformers reinforced are in the Dublin region.
- BAU: reinforcement of 3 power corridors. Panel (a).
- RET-only: reinforcement of 1 power corridor. Panel (b).



(a) BAU and ESR-only solutions.



(b) RET+ESR and RET-only solution.

Capacity Expansion

- RET+ESR and RET-only:
  - 7GW of onshore wind and 2GW of storage.
- ESR-only:
  - 16.5MW of renewable power and storage, and 155MW of CCGT.
- Almost 40% of the new PV capacity in both the RET+ESR and ESR-only cases is in Dublin.

Aggregated New Power Capacity and Storage [MW] by Technology

	RET+ESR	RET-only	ESR-only	BAU
Onshore Wind	7098.0	6850.8	6.22	-
Offshore Wind	0.03	-	0.02	-
Solar PV	0.05	-	0.04	-
CCGT	-	-	155.2	44.26
COAL with CCS	-	-	-	-
CCGT with CCS	-	-	-	-
ESS	2313.6	2230.8	10.3	10.0

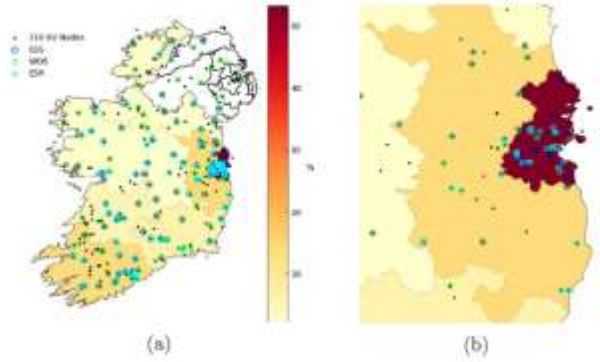
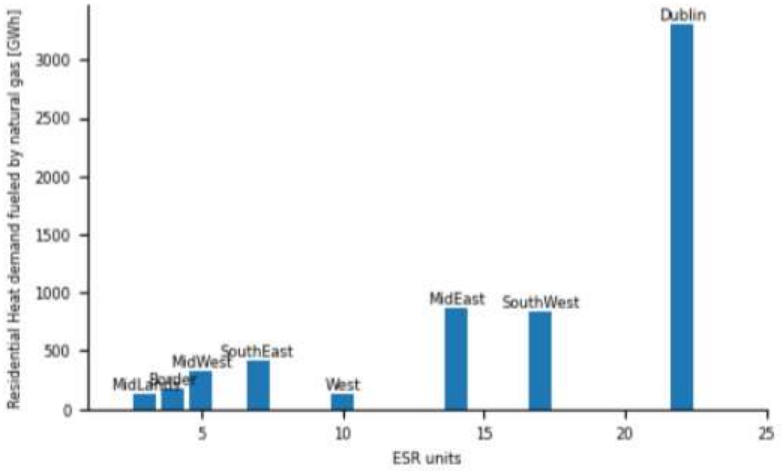


Fig. 2 – Heat demand by region with respect to total heat demand and transmission nodes aggregated at 110 KV. Fig. 2a shows the resulting locations of new energy storage (ESS), onshore wind (WOS) and electrolysers (ESR) for the RET + ESR case, while Fig. 2b focuses on the Dublin and MidEast Regions.

Electrolysers 1/2

- 82 locations out of 205.
- Distribution is not monotonically increasing with total heat demand:
  - heat demand in the West region is less than 50% of that in the Midwest and Southeast but the number of electrolysers is up to 100% higher.
  - similar heat demand in the Mid-lands, Border and West regions, but the West region has 2–3 times the number of electrolysers.



Number of electrolysers against yearly heat demand in the ROI.

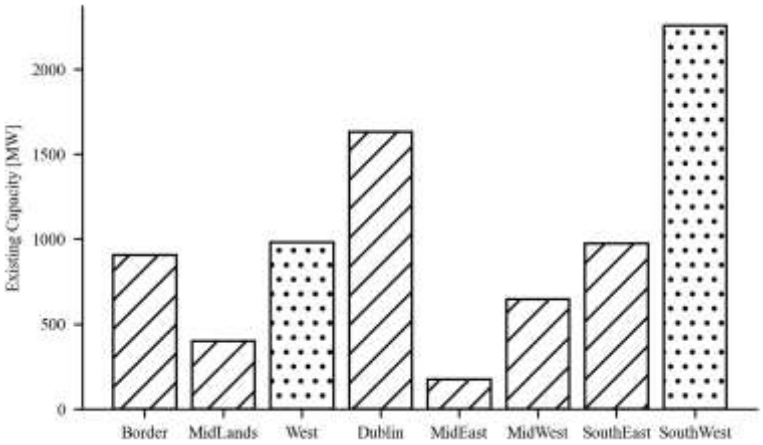
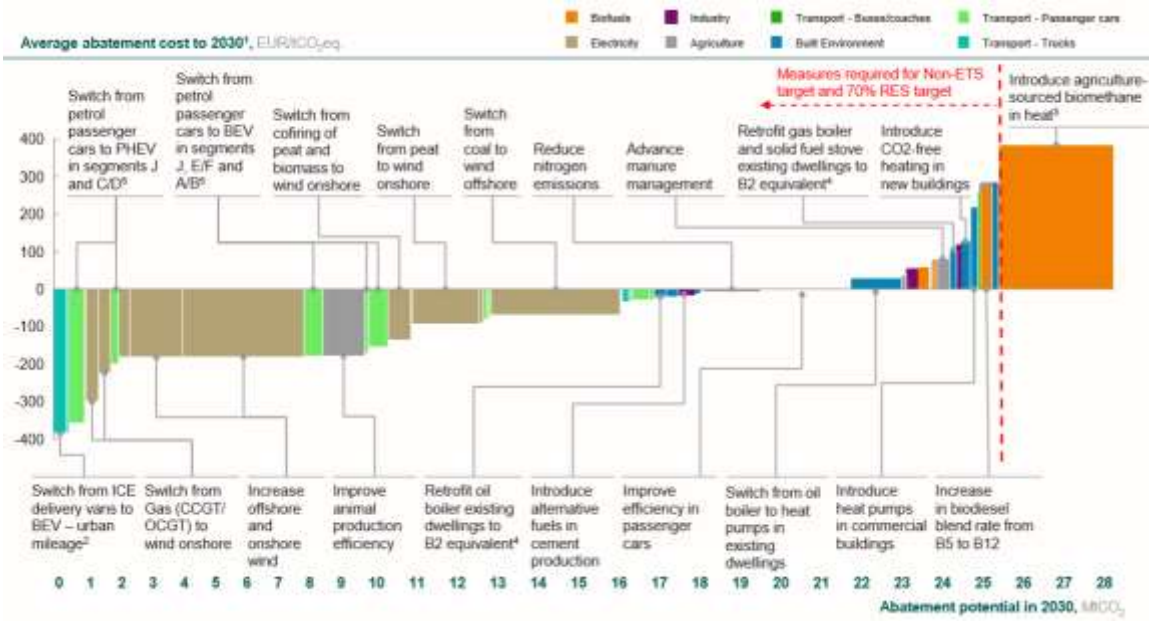


Figure 8: Available existing capacity per region. The existing capacity in the West region is 8%, 146%, 52% and 1% more than the Border, MidLands, MidWest and SouthEast regions respectively. The existing capacity in the SouthWest is 459% more than in the MidEast.

Electrolysers 2/2

- MAC:
  - €114.3/tCO_2
- Between:
  - retrofitting existing dwellings with either gas or solid fuel stoves to a high standard (i.e. a B2 rating) and
  - using CO_2 free heating in new buildings.



Marginal Abatement cost Curve for Ireland 2030 [4]

CO_2 emissions

- Two main factors:
  1) Emissions from producing electricity.
  2) the carbon emissions avoided with blending.

- RET-only and RET+ESR: 30% reduction.
- Savings from residential heating: 0.11 MtCO2 per year.
- ESR-only: 3% increase.

Aggregated CO_2 emissions [$MtCO_2$] of existing and new capacity.

Policy	Existing	New	Total
BAU	12.59	0.115	12.7
ESR-only	12.62	0.408	13.0
RET-only	8.596	0.273	8.87
RET+ESR	8.630	0.284	8.91

Wind curtailment and CF

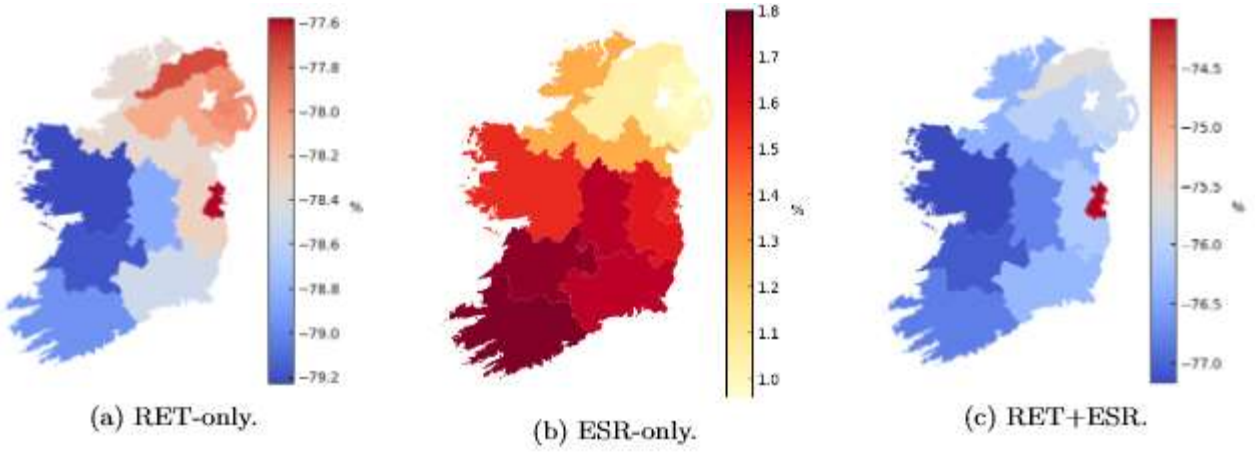
- ESR-only: 13% reduction.
- RET-only: 726% increase.
- RET+ESR: 740% increase.

Wind energy curtailment and Capacity factor.

Policy	Wind Curtailment [TWh]	Capacity Factor [%]
BAU	0.721	35
ESR-only	0.625	36
RET-only	5.957	30
RET+ESR	6.059	30

Electricity zonal prices

- Adding hydrogen for heating leads to an increase in price across all regions by between 1-2%
- Expansion in renewables generation leads to price falling in all regions by 77-79%
- RET-only: SD of prices decreases 59%
- RET+ESR: SD of prices decreases 45%.



(a) RET-only. (b) ESR-only. (c) RET+ESR.

Conclusions

- ESR-only:
  - The least cost option is dominated by new thermal capacity.
  - Negative net emissions savings.
  - 155 MW of new CCGT capacity.
  - Wind curtailment reduces by 13%.
  - Wind CF increases to 36%.
- Transmission infrastructure reinforcement is 76% lower in the RET-only and RET+ESR scenarios.
- Heat demand is not the only factor driving electrolyser location.
- Market challenges: In the RET scenarios, electricity prices decline by more than 75% and wind capacity factors decline by 5 percentage points.

References

[1] Eurostat (2020) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_consumption_in_households

[2] K. Alteld, D. Pinchbeck, Admissible hydrogen concentrations in natural gas pipelines, 2013.

[3] N. A. El-Taweel, H. Khani, H. E. Z. Farag, Hydrogen storage optimal scheduling for fuel supply and capacity-based demand response program under dynamic hydrogen pricing, IEEE Transactions on Smart Grid 10 (2019) 4531-4542.

[4] DCCAE, Climate action plan 2019 - to tackle climate breakdown, Gov. of Ireland, 2019.

Thanks

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