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Grid Balancing with Electrolysers and Wind Power

FCR and aFRR participation in Norway, Spain, Italy and France

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Clean Hydrogen Partnership

Outline

Motivation: The Haeolus Project

Grid Services and Electrolysers

Results and Discussion

Conclusion

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Raggovidda Wind Park

Berlevåg municipality, **Varanger** peninsula, **Troms & Finnmark** county

- The Raggovidda wind park:
  - 45 MW built of 200 MW concession
  - Neighbour Hamnafjell: 50 MW / 120 MW
  - Bottleneck to main grid is 95 MW
  - Total Varanger resources about 2000 MW

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  - Total Varanger resources about 2000 MW
- Capacity factor 50 %
- Local consumption max. 60 MW
- Local economy based on fishing
- Partner operator of park & grid:

VARANGER KRAFT

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The Haeolus Project

- EU project, budget 7.6 M€
- Electrolyser beside Berlevåg harbour
- Capacity: 2.5 MW or 1 t/d @ 30 bar
- Production started in June 2021
- New 10 km power line from Raggovidda
- Virtually “inside the fence”
- Accessibility by road or sea
- Partner electrolyser manufacturer:

HYDROGENICS ⇒ Cummins ⇒ accelera by Cummins

The hydrogen tank
outside the containment building

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The electrolyser & rectifier containers within the containment building

Introducing Hydrogen to the Market

The technology is here, but there is some game theory in the way

We have:

- A solid, known, publicly-owned producer
- Interested public authorities
- Strong interest among local businesses

Hydrogen workshop in Vadsø

… so what are we missing to get started?

Hydrogen producers want:

- to sell hydrogen regularly
- to have a reliable income
- not to go broke in the “Valley of Death”

Hydrogen users want:

- to be sure hydrogen will stay available
- a predictable hydrogen cost
- reliable supply chain & maintenance

Breaking the Deadlock

Also known as the “chicken-and-egg” problem

- Hydrogen producers:
  - Energy companies
- Hydrogen users are more diverse:
  - Transport companies
  - Shipping companies
  - Public authorities
  - Industry
  - Private citizens
- “Is the other side going to deliver?”

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- Game theory: this is “prisoner’s dilemma”
  - not a “chicken”!
- We *must* start with infrastructure
- How do we make it viable?
  - Identify key niche
  - Find one big customer
  - Find a side revenue stream
- Authorities commit to buy back:
  - equipment if no hydrogen
  - hydrogen if no customers

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Grid Services

- Grid power must be synchronised with consumption
  - … but consumption is unplanned
- Production planned based on estimates (day-ahead)
- Must balance grid frequency at 50 Hz
- Real-time adjustments in multiple scales

Primary	automatic, seconds (FCR)
Secondary	automatic, minutes (aFRR)
Tertiary	manual, minutes–hours (mFRR)

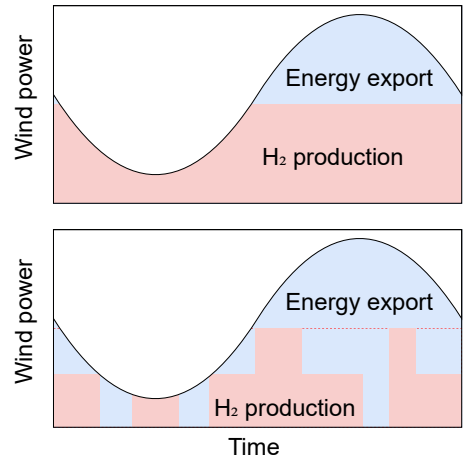
Framework for Grid Services

- Services can be:
  - Procured
  - Mandatory
- Remuneration based on:
  - Capacity
  - Activation
  - Both
- Minimum bid sizes:
  - 1 MW
  - 5 MW
  - Trend toward smaller sizes
- Direction:
  - Symmetric
  - Balanced to market
  - Up- or down-regulation
- Time slot size:
  - 1 hour
  - 30 minutes

…a very fragmented picture!

Hydrogen, Wind Parks and Grid Services

- Electrolyser within a wind park
- Exported power generates income
- Electrolyser are faster than wind dynamics
- Nominal operation
  - Electrolyser at maximum available power
- Grid-service operation
  - Throttle electrolyser as required
  - Extra income for grid services



Value of Curtailed Hydrogen

A metric to evaluate grid services on their own

- Price of sold hydrogen is unknown or volatile
  - Often agreed “politically” rather than set by market
  - Agreed-upon quantity may be limited
- There will always be some spare capacity
  - Ready for market expansion
  - Deployment of new electrolysers takes time
- Monetise this spare capacity
  - Operational income I
  - Hydrogen production H
  - H_0, I_0 for nominal case
  - H, I for grid-service case

$$v_{H_2} = \frac{I - I_0}{H_0 - H}$$

“Value of hydrogen we did not produce because of grid services”

- Same electrolyser
- Same OPEX/CAPEX
- Easily computable

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Data Sources

- Four countries: Norway, Spain, Italy, France
- Wind park data from each relevant grid, normalised to 45 MW
  - High confidentiality
- Two electrolyser sizes, 2.5 MW (Haeolus) and 45 MW (full size)
- Consider up, symmetric, and down-regulation
  - Even if not actually offered in relevant market
  - Keep electrolyser resp. at maximum, medium, or minimum power
  - Change set point when reserve activated
- All data for reference year 2017

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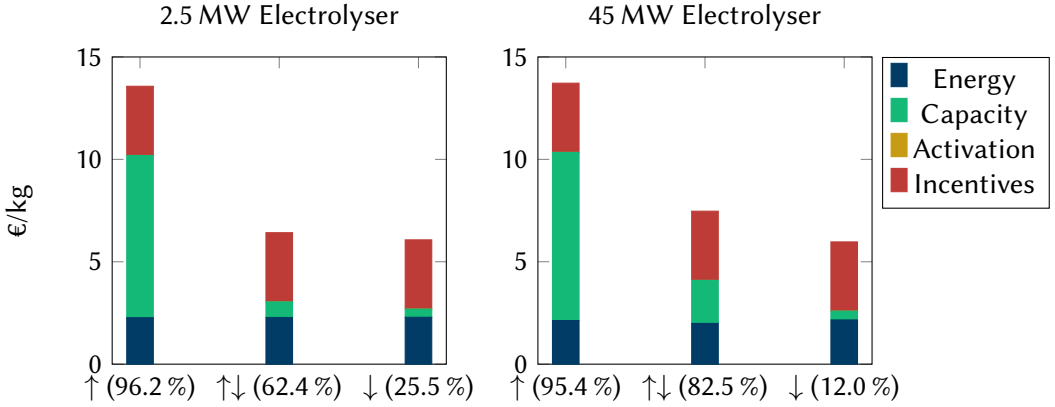
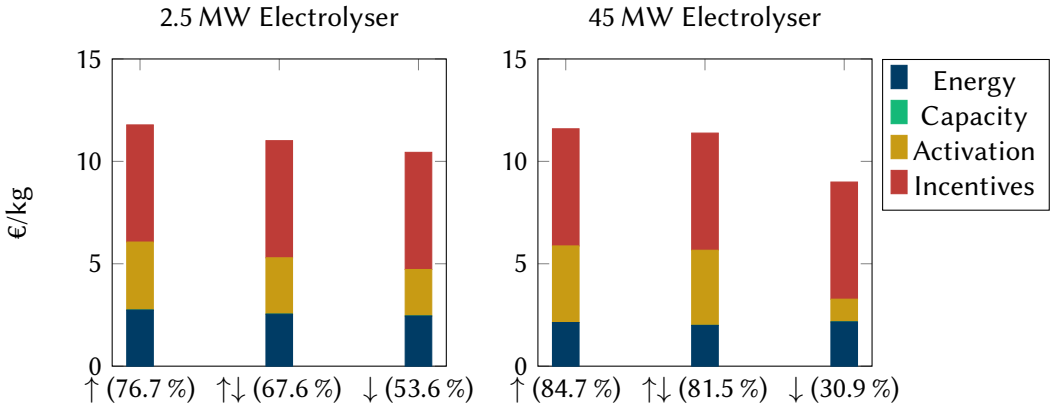
Results: France



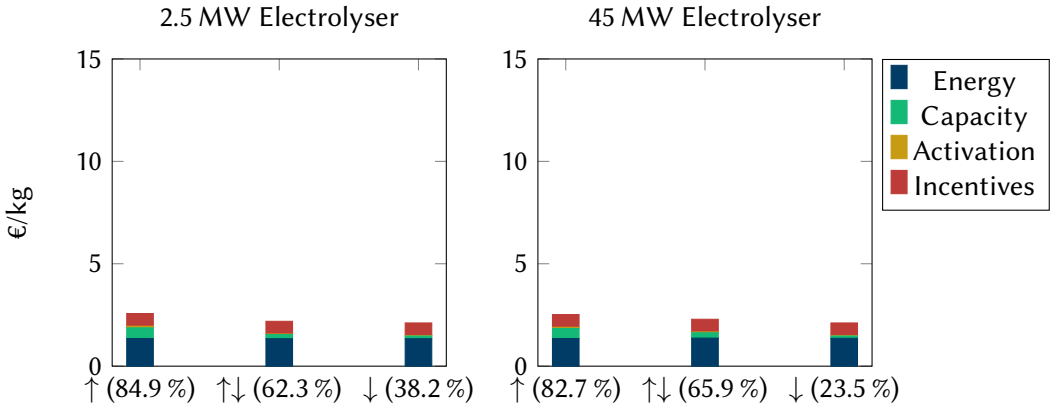
(Percentages are production when delivering grid services compared to nominal case)

Results: Italy



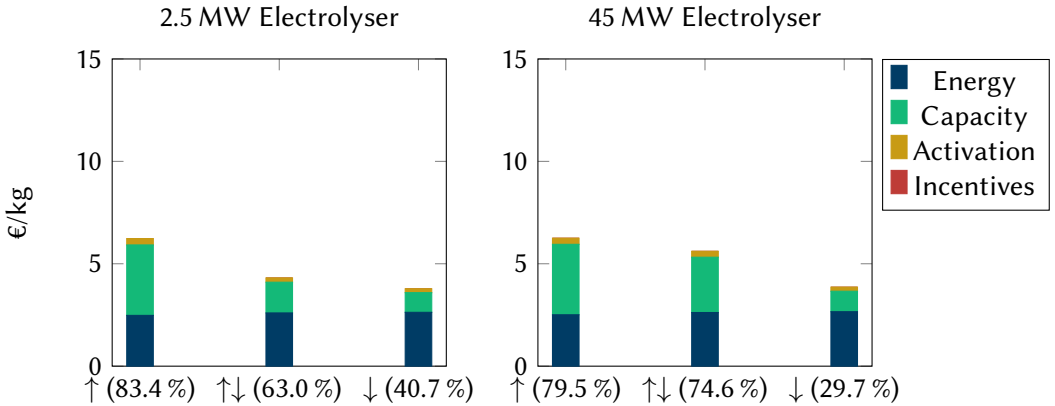
(Percentages are production when delivering grid services compared to nominal case)

Results: Norway



(Percentages are production when delivering grid services compared to nominal case)

Results: Spain



(Percentages are production when delivering grid services compared to nominal case)

Discussion

- Strong differences among countries:
  - France: Good up-regulation, but rarely activated
  - Italy: Good contribution of activation part
  - Norway: Hydro is dominant, little FCR demand
  - Spain: Good contribution of capacity part
- Hardly any impact of electrolyser size from 5 % to 100 % of wind park
- Up-regulation has highest value for curtailed hydrogen, minimum production reduction; conversely down-regulation.
- Good agreement with previously published literature (Chardonnet et al.)

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- Defined value of curtailed hydrogen to measure income from grid services
- Results depend very much on country, somewhat on regulation mode, not much on size
- Presence of cheap, flexible power generation reduces demand for grid services
- Often, grid service income is higher than hydrogen production cost targets
  - EU 2030: 1.8 €/kg (green); US “Hydrogen Shot”: 1 $/kg in 2031
- As more wind/solar enters the market, grid service demand will rise

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Thank you for your attention!

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Hydrogen-**A**eolic **E**nergy with **O**ptimised e**L**ectrolysers **U**pstream of **S**ubstation

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