Federico Zenith

Large-scale hydrogen production from wind power in Arctic conditions
The HÆOLUS project

SINTEF Mathematics & Cybernetics

Nordic Hydrogen & Fuel Cell Conference
October 9, 2018
Reykjavík, Iceland
Outline

Motivation

The Project

Future Perspective
Outline

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Future Perspective
Motivation

- EU 2030 target: 27% renewable energy consumption
  - In 2015 it was 13%
  - *Production* is already 26.2% (2015)
  - No renewables in energy imports
- Most renewables produce electricity
- Several are not controllable
- Some are unpredictable
Constraints of Wind Power

- Hard to predict production
- Capacity factor about 33\%
- Need reserve capacity
- Often, good wind power is found where:
  - there is little hydro potential
  - few people live
  - the grid is weak
  - accessibility is difficult
- All this even more true for offshore wind!
The Connection between Hydrogen and Wind

- Beyond 20% wind share, value plummets
  - Gonzalez et al., Ren. Ener., 29.4 (2003), 471–489
- Hydro is rarely possible
- Batteries are too expensive
- Hydrogen has lower efficiency
- IEA’s HIA task 24 identified 3 main cases:
  - Energy storage
  - Mini-grid (e.g. islands)
  - Fuel production
- Grid services, reserves, target matching...

The Utsira, Norway, 50 kW / 215 kg\textsubscript{H\textsubscript{2}} system (2004)
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The HAEOLUS Project
http://haeolus.eu - @HaeolusProject

• A FCH2 JU Innovation Action
• Objectives:
  – Enable more wind power
  – Test multiple use cases
  – Demonstrate a 2.5 MW system
  – Demonstrate remote operation
  – Report & disseminate
• Key figures:
  – Budget: 6.9 M€ (5 M€ from EU)
  – Time frame 2018–2021
  – Capacity 1 t/d
  – Production start: late summer 2019

Kick-off in Oslo, January 2018
The Wind Park

Raggovidda wind park, Berlevåg municipality, Varanger peninsula, 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
The Wind Park
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  - 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
- Capacity factor 50 %
- Local consumption max. 60 MW
- Local economy based on fishing
- Partner operator of park & grid:
  VARANGER KRAFT
The Electrolyser System’s Site
Raggovidda wind park, Berlevåg municipality, Varanger peninsula, Finnmark county

- Located beside Berlevåg harbour
- Compact 2.5 MW PEM electrolyser
- 100 kW fuel cell for re-electrification
- New 10 km power line from Raggovidda
- Virtually “inside the fence”
- Accessibility by road or sea
- At least 120 t over 2.5 year
- Partner electrolyser manufacturer:

View of Berlevåg, site highlighted
Grid Services

- Wind energy production target match
  - Currently: prediction outsourced
  - 3rd party paid in % of production
  - Easily quantifiable potential
  - Adjust electrolyser to fulfil target
- Primary, secondary & tertiary reserves
  - Electrolysers are easily ramped
  - Can acquire slots in all reserves
- Project partner:

<table>
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<th>Hour</th>
<th>Price NOK/MW</th>
<th>Volume MW</th>
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<td>33</td>
</tr>
<tr>
<td>2</td>
<td>139</td>
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</table>

Price for primary reserves on October 3, northern Norway.
Other Activities

- Remote operation
  - Relevant for many wind parks
  - Run demonstration from Italy

- Partner software developer:

- System prognostics
  - Reduce on-site inspections
  - Optimise maintenance
  - Avoid unscheduled stops

- Partner university:

- Dynamic modelling
  - Process model & optimisation
  - Control synthesis

- Partner university:

- Control implementation
- Integration with smart grids
- \( \text{H}_2 \) valorisation plan

- Coordinator:
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Future Perspective
Expected Impact
From Short to Long Term

- Convince Varanger Kraft to expand hydrogen production
- Export model to other sites in Europe (other EU projects?)
- Allow deployment of wind power beyond 20 %
- Push hydrogen utilisation in the area
  - Mobility, industry, etc.
- Contribute to EU renewable targets & energy independence
Public Deliverables

Reports (18):

- Raggovidda energy analysis
- Dynamic model & control
- Impact on energy systems, RCS
- Valorisation plan
- Business case analysis
- Road to MAWP 2023 targets
- Techno-economic analysis
- Environmental performance
- Demonstration protocols & data

Other (15):

- Workshop at ECC2019 Naples
- Real-time demo on website
- Plant visit
- Academic seminars
- Student internship
- Presence at industrial fair
What to Do with the Hydrogen?
Valorisation Plan: Identified Opportunities

<table>
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<tr>
<th>Action</th>
<th>Realism</th>
<th>Size</th>
<th>Gimmick</th>
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<tbody>
<tr>
<td>Svalbard energy supply</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Coastal ships</td>
<td>(✓)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Fishing boats</td>
<td>✓</td>
<td>✓</td>
<td></td>
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<tr>
<td>Ammonia production</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Aquaculture</td>
<td>(✓)</td>
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<tr>
<td>Fast passenger boats</td>
<td>(✓)</td>
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<td></td>
</tr>
<tr>
<td>Cars</td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>Regional mini-buses</td>
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<tr>
<td>Waste collection trucks</td>
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<td>Backup generators</td>
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<tr>
<td>Snowmobiles</td>
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<tr>
<td>Regional planes</td>
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<tr>
<td>ZE steel production</td>
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<tr>
<td>Mining and ore processing</td>
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Conclusion

- Hydrogen can boost wind power
- HAEOLUS will test relevant cases for Europe and beyond
- Many possibilities for hydrogen use—the most promising still to develop, though
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Thank you for your attention!
Hydrogen-Aeolic Energy with Optimised eLectrolysers Upstream of Substation

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