Faroe Islands

Towards 100% Renewable Energy

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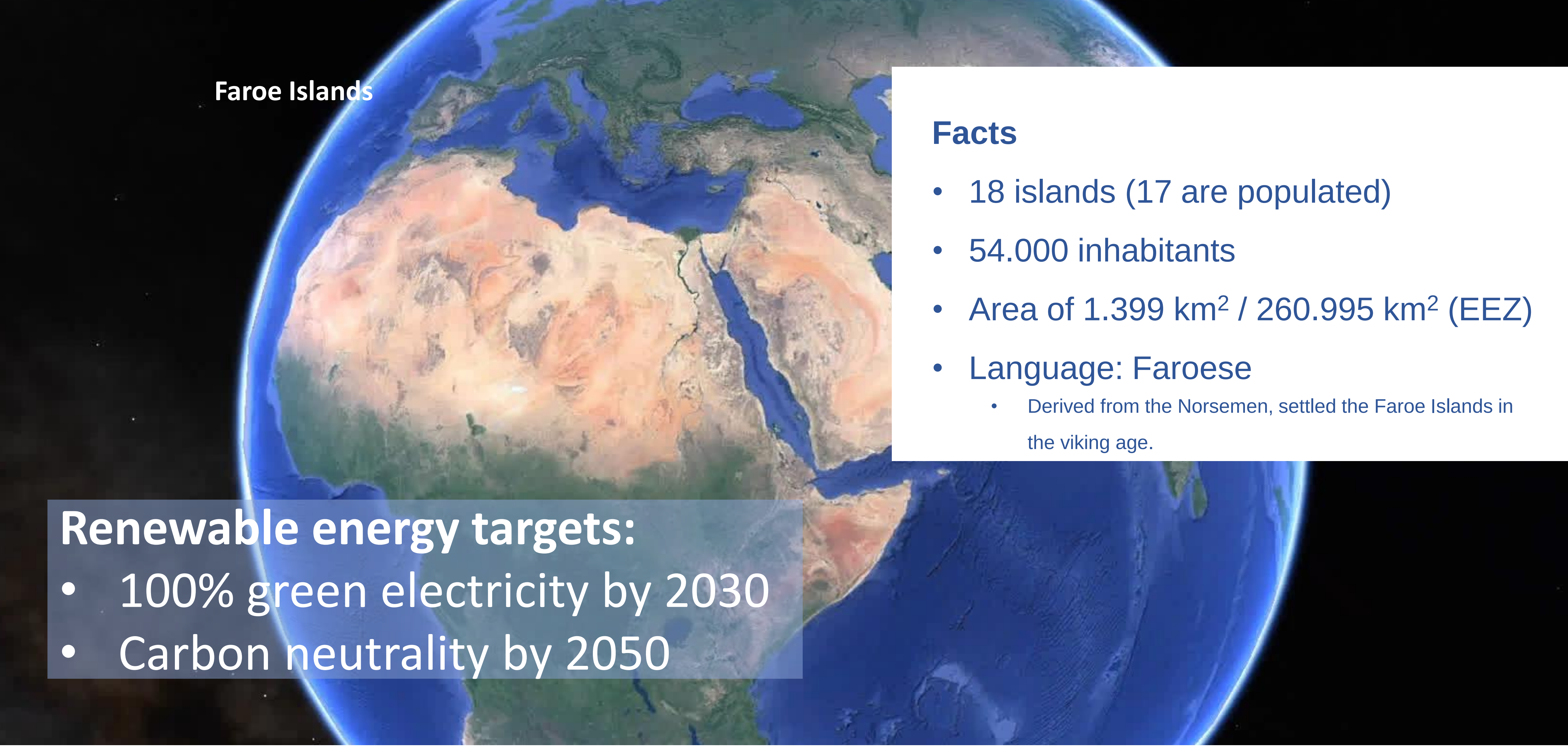
Agenda

- *Facts about Faroe Islands and the Faroese Power system*
- *Projected consumption and some renewable energy projects*
- *Tidal energy – a potential baseload generation*
- *Long- and short-term energy storage*

- *Developing a tangible 2030 RoadMap (PhD research project)*
- *Ensuring grid stability in a 100% inverter-based power system*



Facts

- 18 islands (17 are populated)
- 54.000 inhabitants
- Area of 1.399 km^2 / 260.995 km^2 (EEZ)
- Language: Faroese
    - Derived from the Norsemen, settled the Faroe Islands in the viking age.

Renewable energy targets:

- 100% green electricity by 2030
- Carbon neutrality by 2050

Faroe Islands

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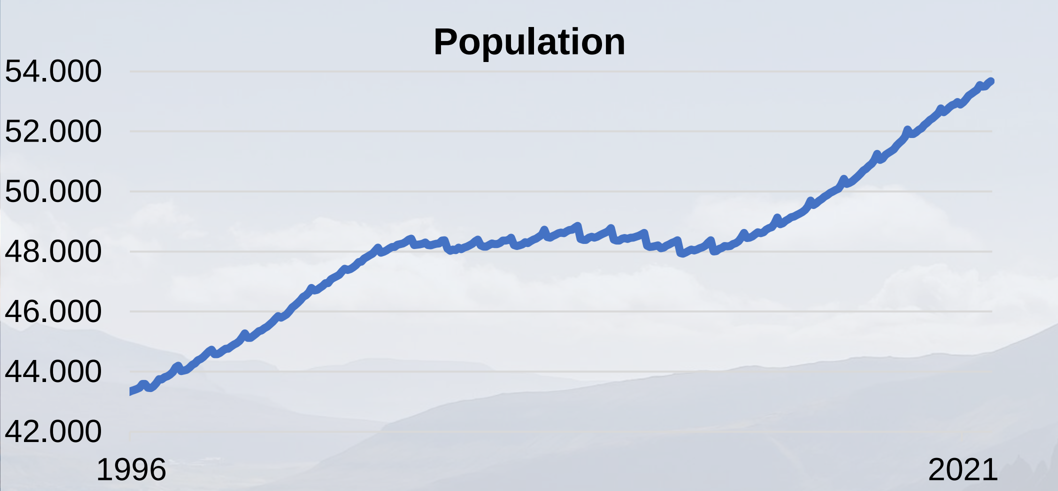
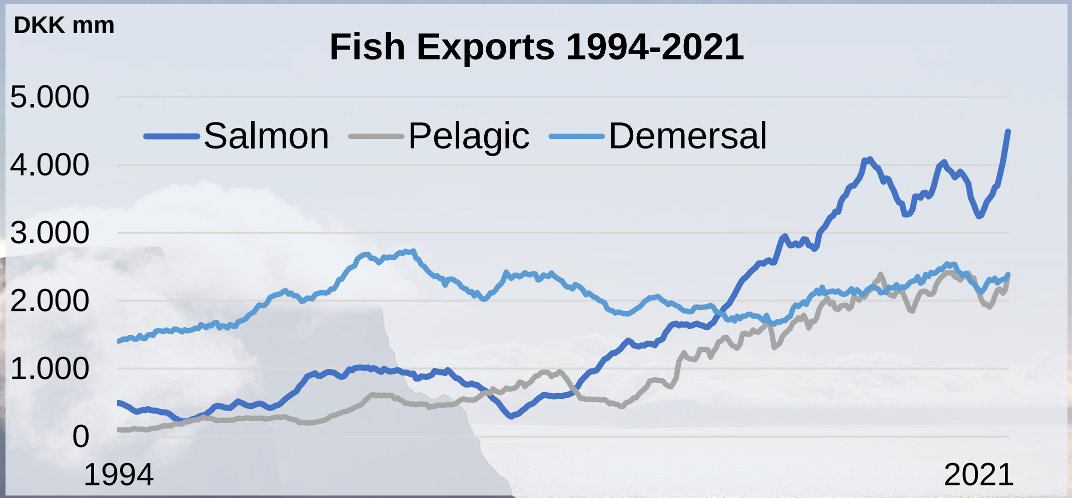
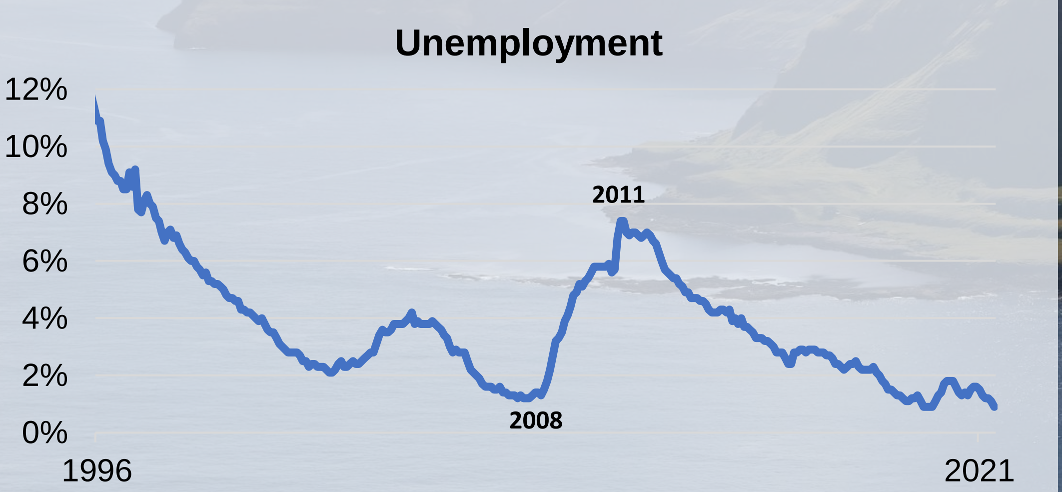
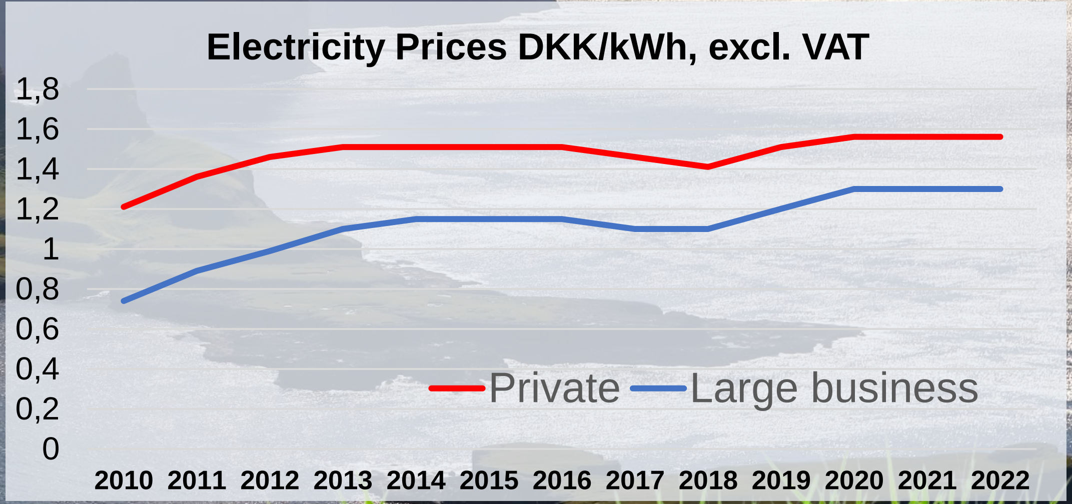




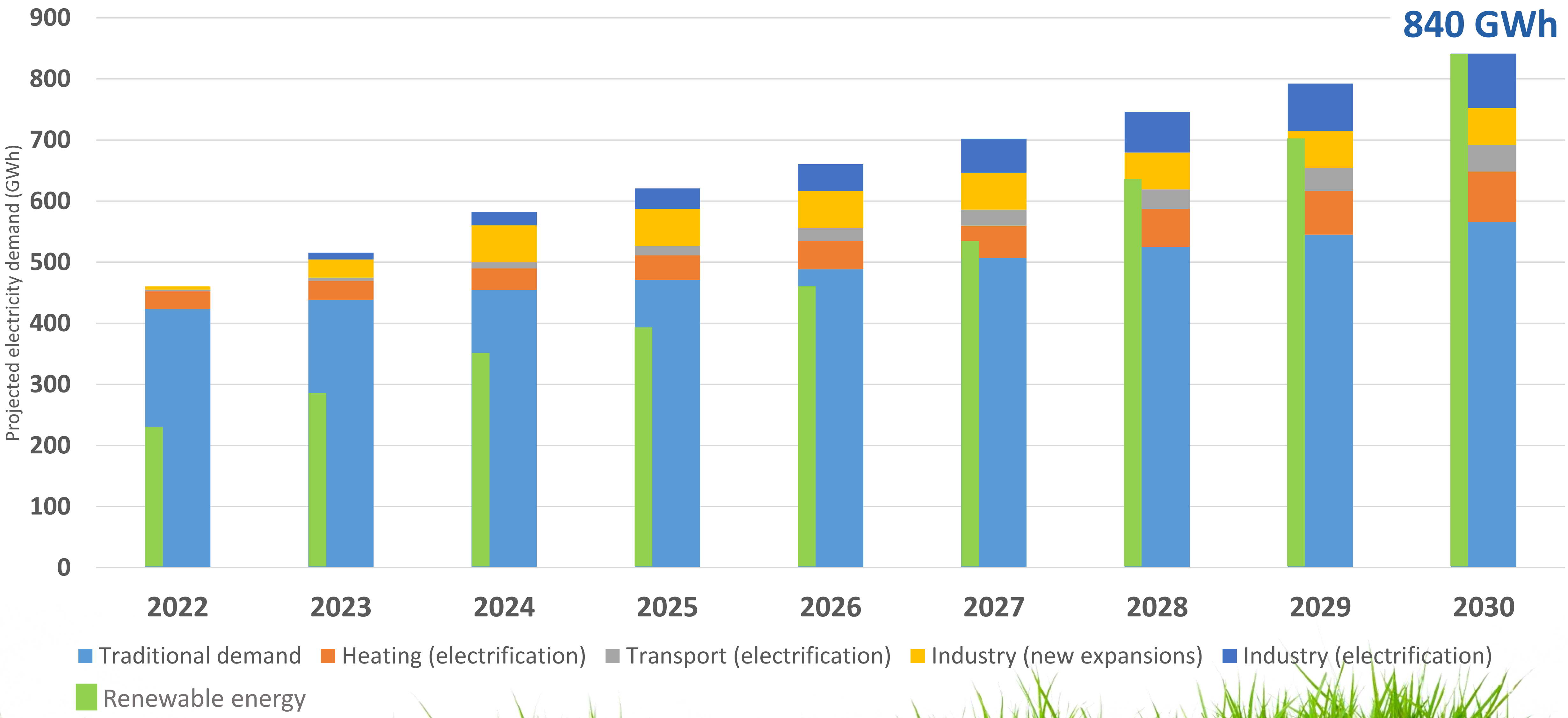




Faroe Islands - facts

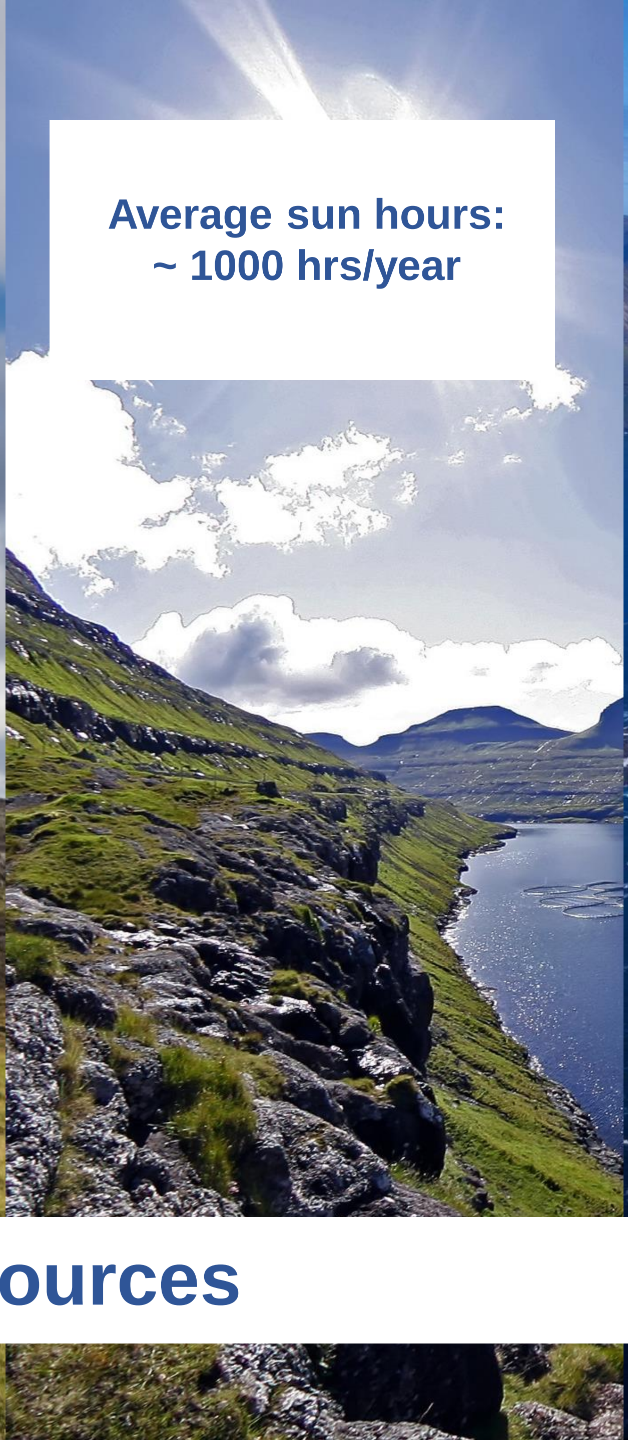
Total cost:
360 M€

Faroe Islands – subsea tunnels

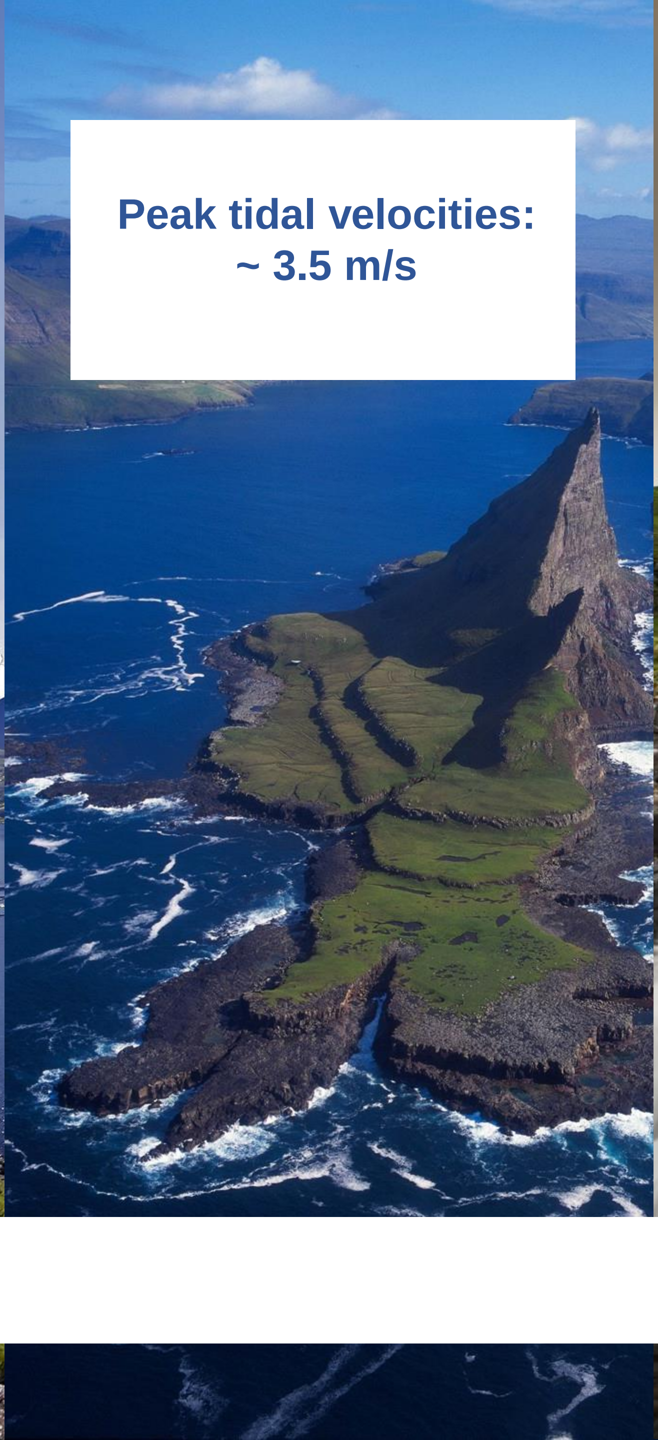


Projected electricity consumption 2022 - 2030

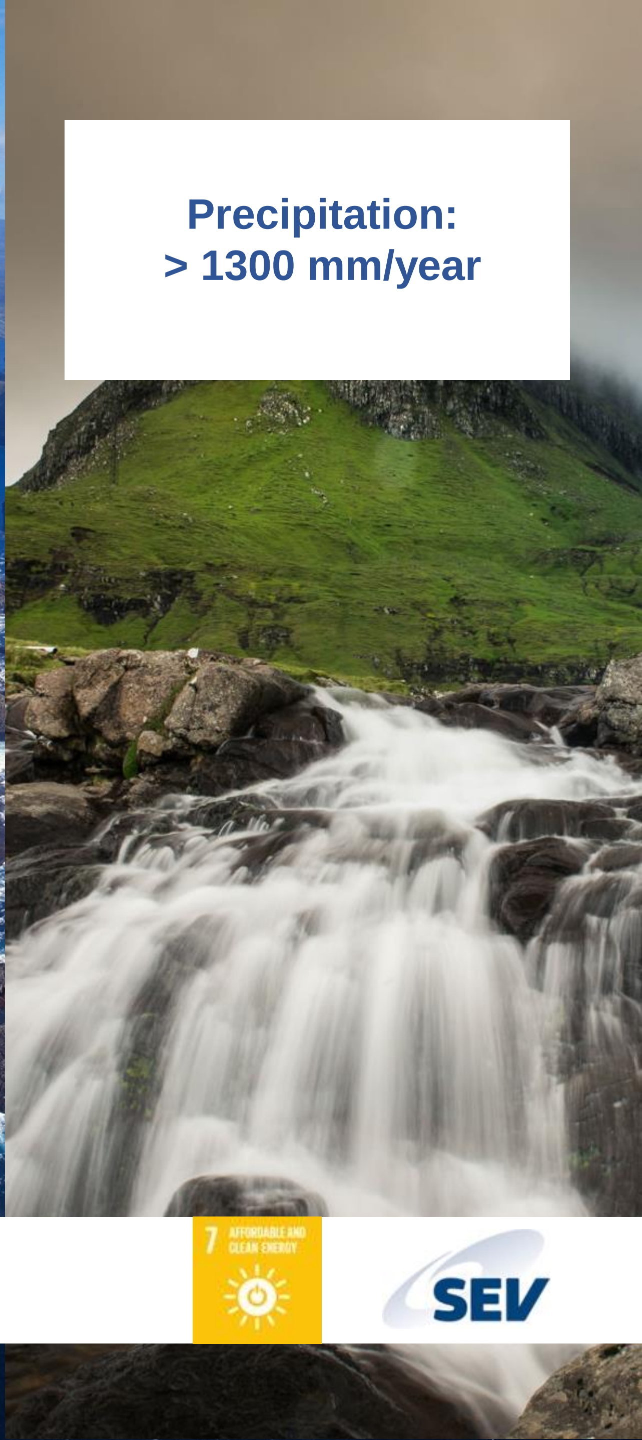
Average wind speed:
> 10m/s



Average sun hours:
~ 1000 hrs/year



Peak tidal velocities:
~ 3.5 m/s



Precipitation:
> 1300 mm/year

Renewable resources

7 AFFORDABLE AND CLEAN ENERGY

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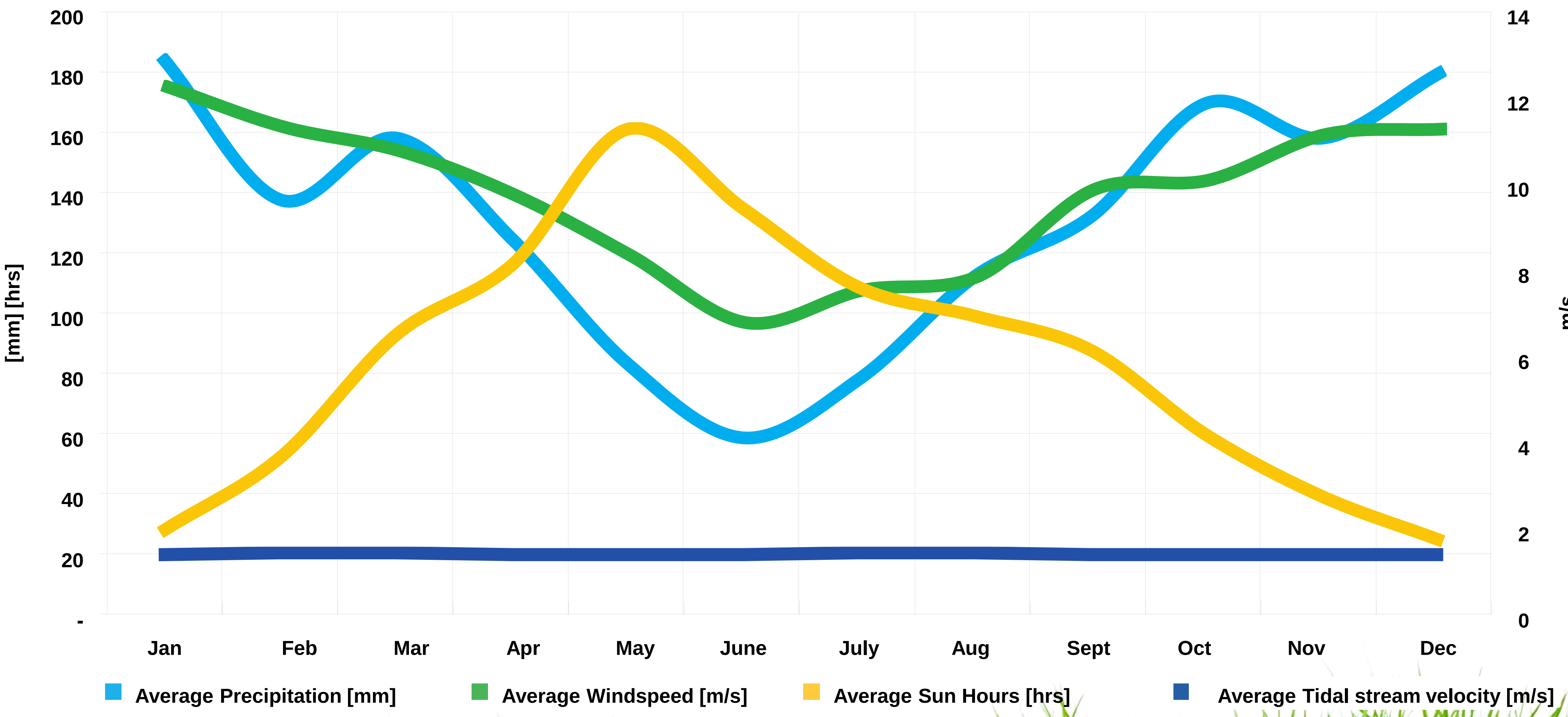


Resource complementarity

- **General company facts**
  - **Non-profit, founded 1st October 1946**
  - **100 % owned by all Faroese municipalities**
  - **Vertically Integrated Company**
  - **Joint and several price structure**
  - **Monopoly on grid operation** *(transmission & distribution)*
  - **“*De facto*” monopoly on production (98%)**

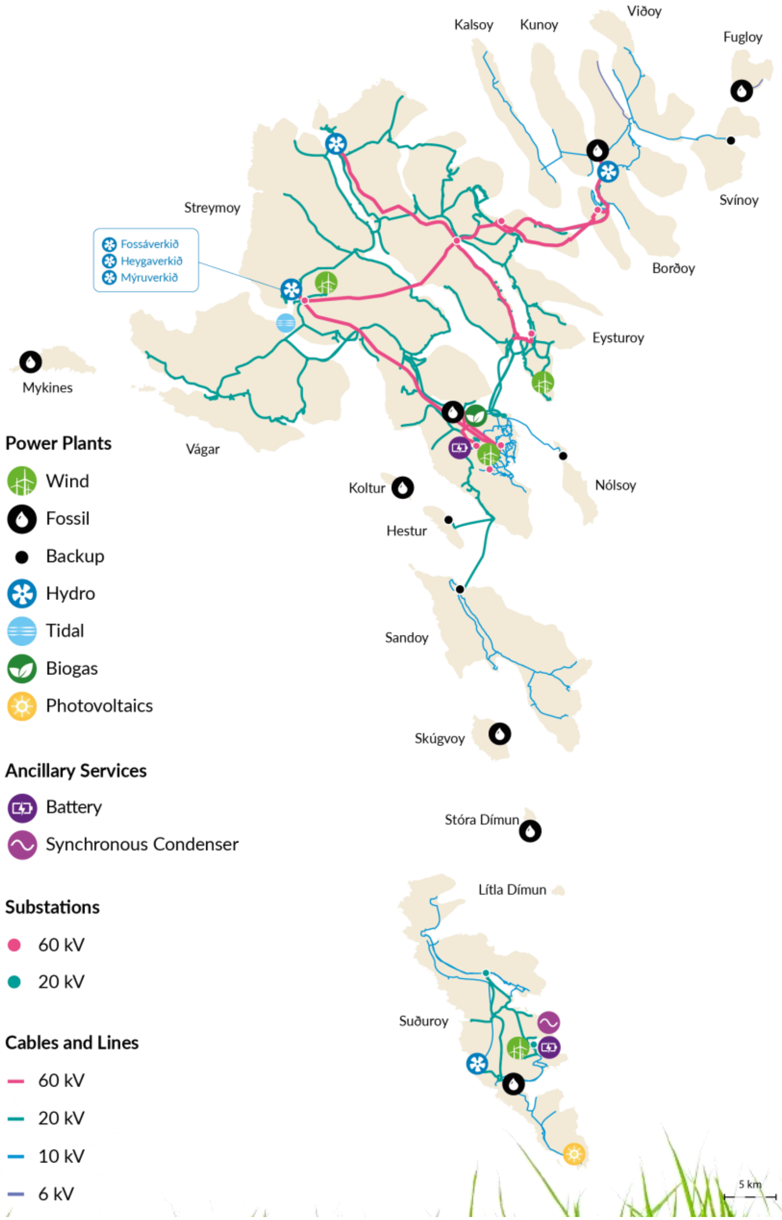
Electrical Power Company SEV

- **Key figures and characteristics**
  - **SEV is owner and TSO/DSO**
  - **Average/Peak demand 2021:** 42/62 MW
  - **Low load:** 25-30 MW
  - **Annual generation:** 424 GWh (2021)
  - **7 isolated grids**
  - **Electrically isolated from neighboring countries**

  - **Installed capacities:**
    - Fossil fueled power plants: 102 MW
    - Hydro power: 40 MW
    - Wind power:
      - Main area: 43 MW (+ additionally 18 MW in Q4/2022)
      - Suðuroy: 6.3 MW
    - PV: ~ 0,5 MW

The electrical grid

The electrical grid



Main drivers of grid investments

- Integration of RES
  - *Transmission lines, substations, ancillary services (synchronous compensators, batteries etc.)*
- Large industrial consumers
  - *Estimated increase in industrial loads 2022-2024: 26.5 MW*
- Continuous reinforcement due to increased load and electrification

Grid investments 2021 – 2030: 150 M£





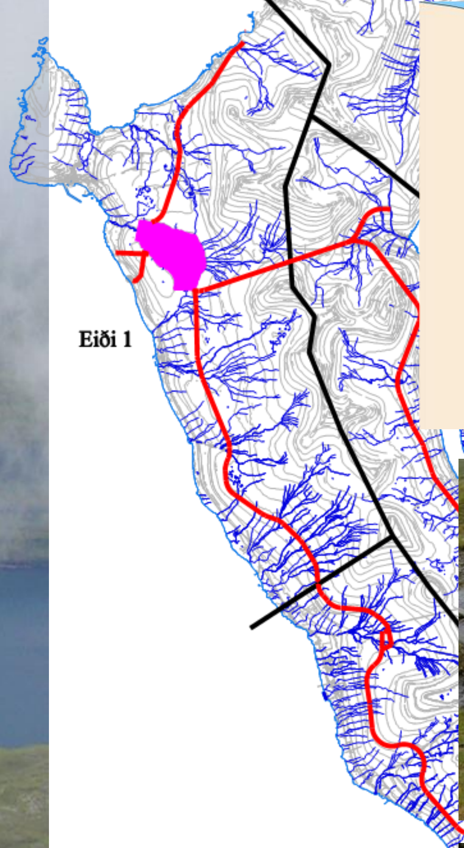
Renewable energy projects

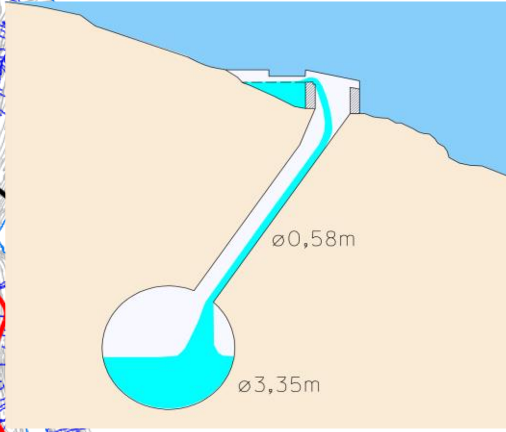

Hoyvíkshagi 2022 (25 MW)
Flatnahagi 2022 (18 MW)
Porkerishagi 2020 (6,3 MW)


Junkarahagi (18 MW)
Glyvrafjall (24 MW)
Klivaløkshagi (21 MW)
Vestfelli (2 x 18 MW)
Eiði (18 MW)



Solar photovoltaic

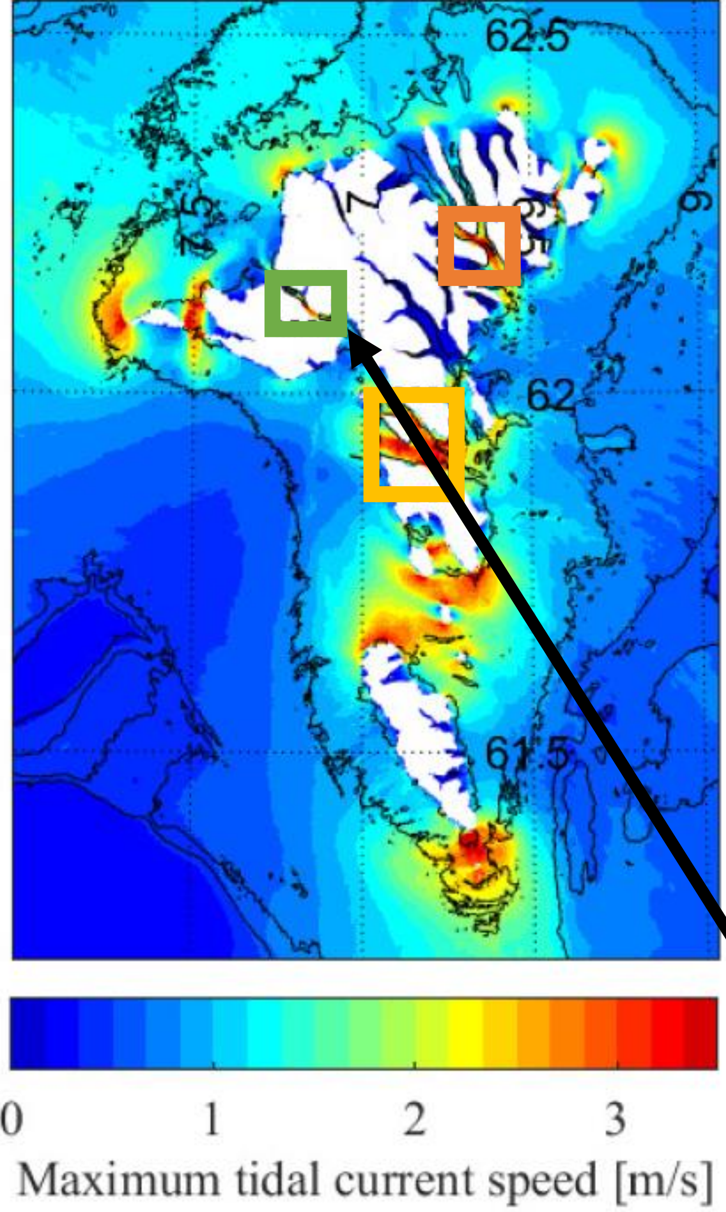


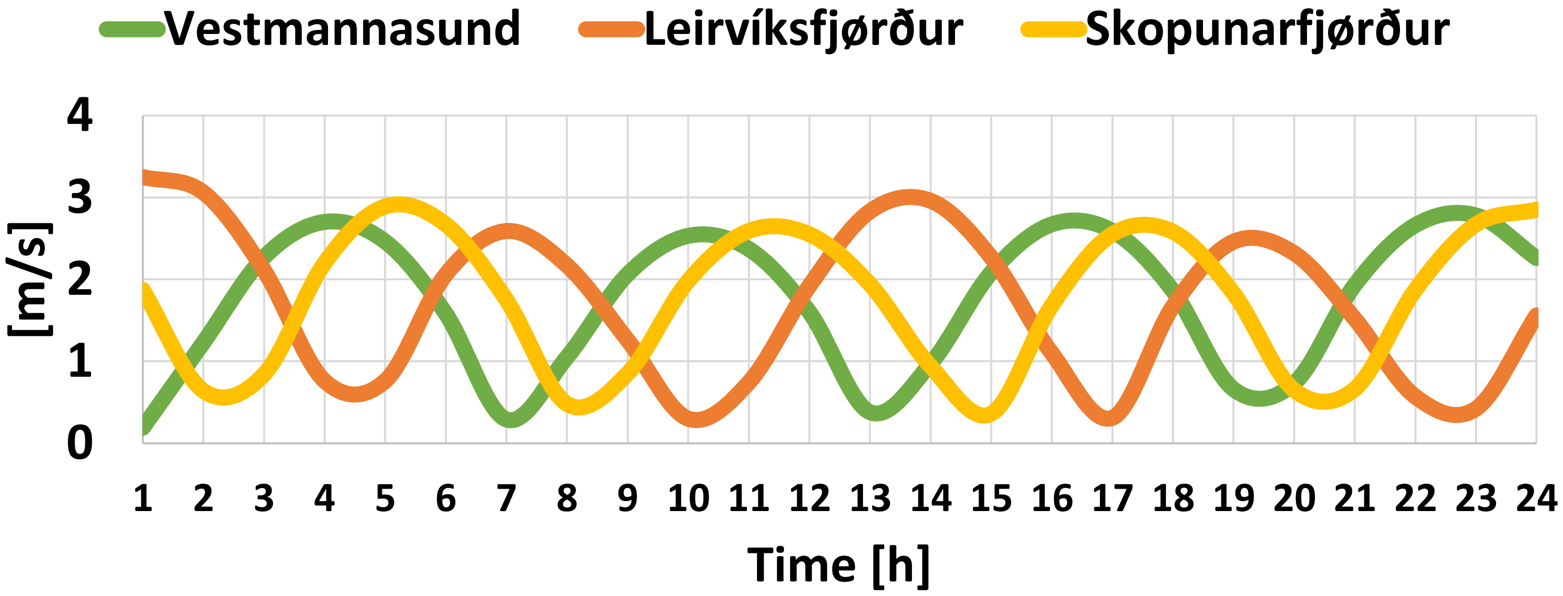


Hydro power

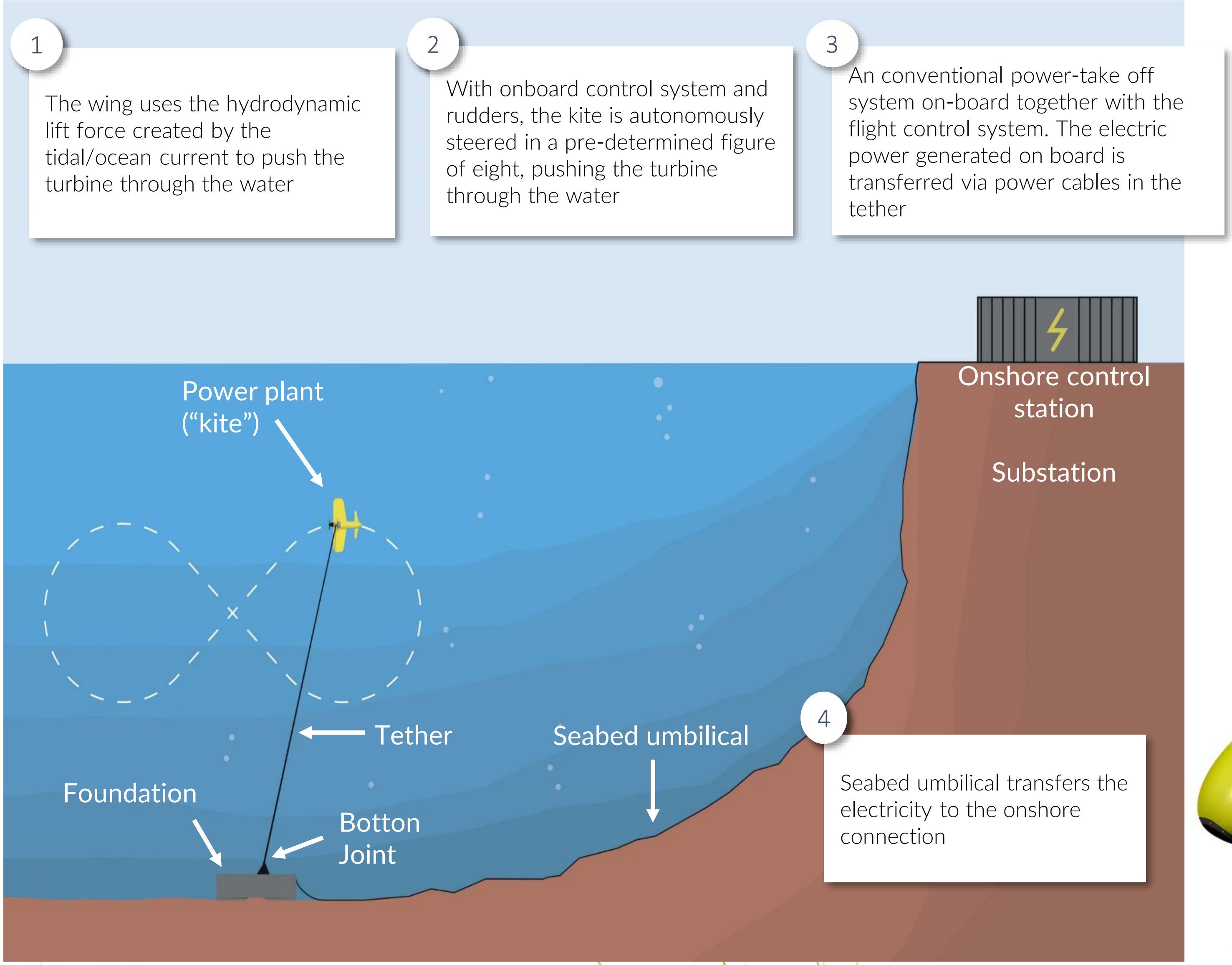
Tidal energy

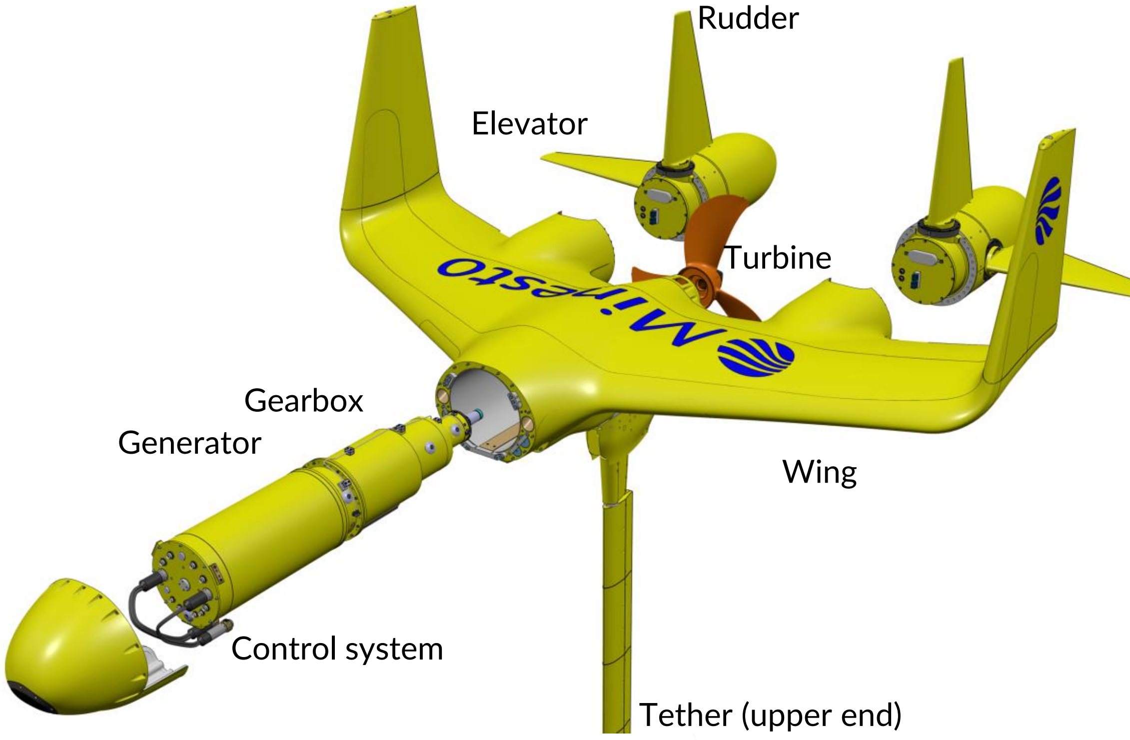
Potential base load generation





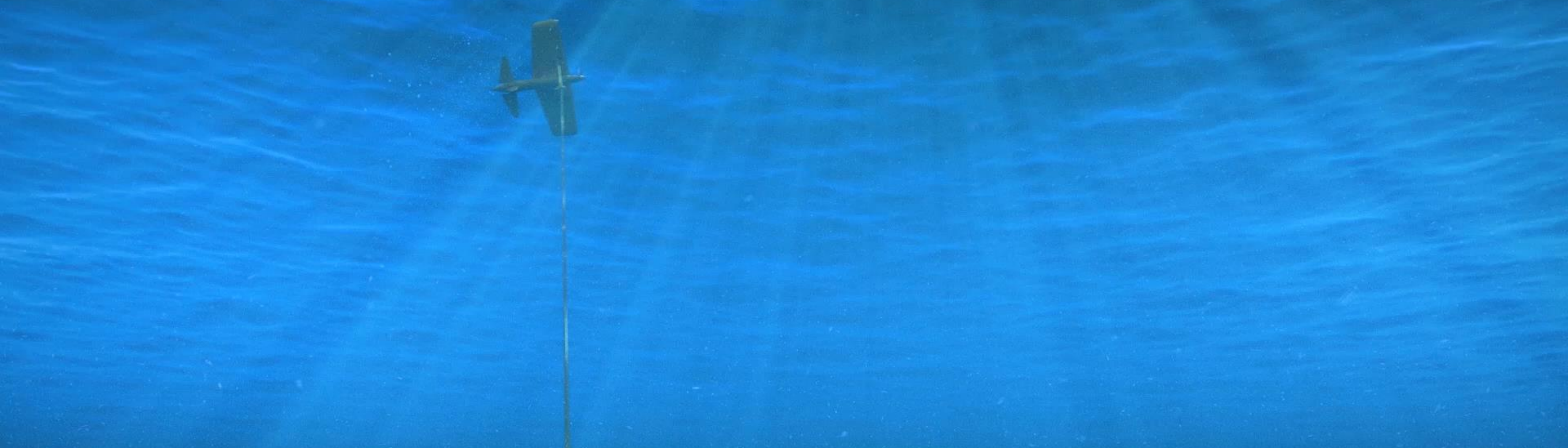
Tidal energy





From stream to grid

The power of speed in water



Sea water is 832 times heavier than air
Substantially higher kinetic energy content

+

Power is proportional to the speed cubed ($\mathbf{v}^3$)
The wing multiplies the stream flow through the turbine

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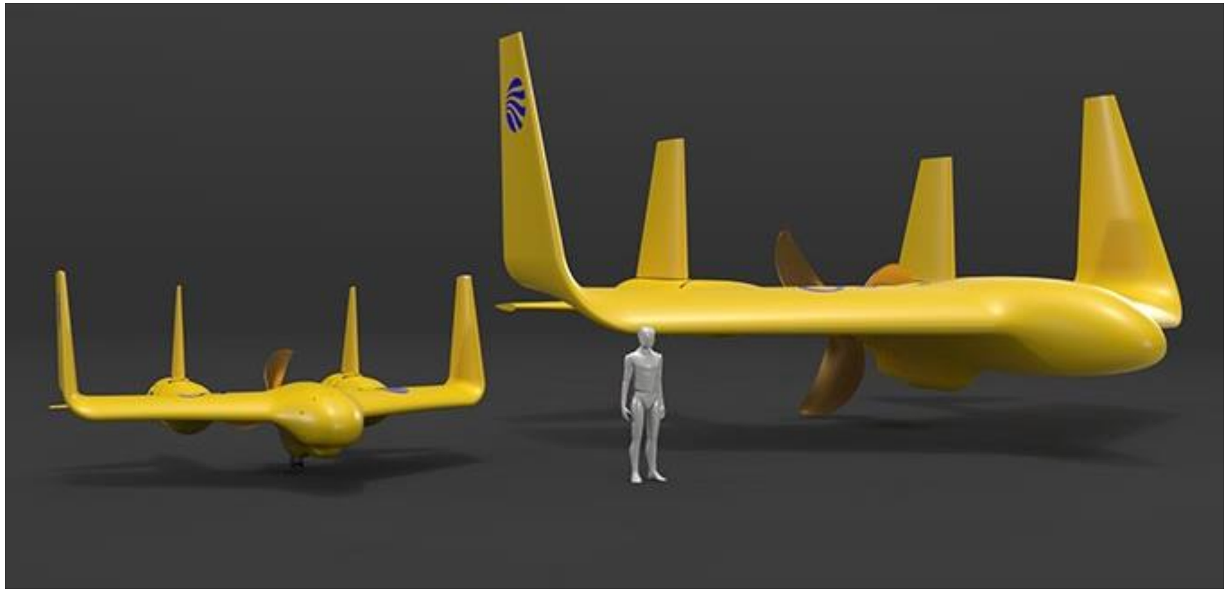
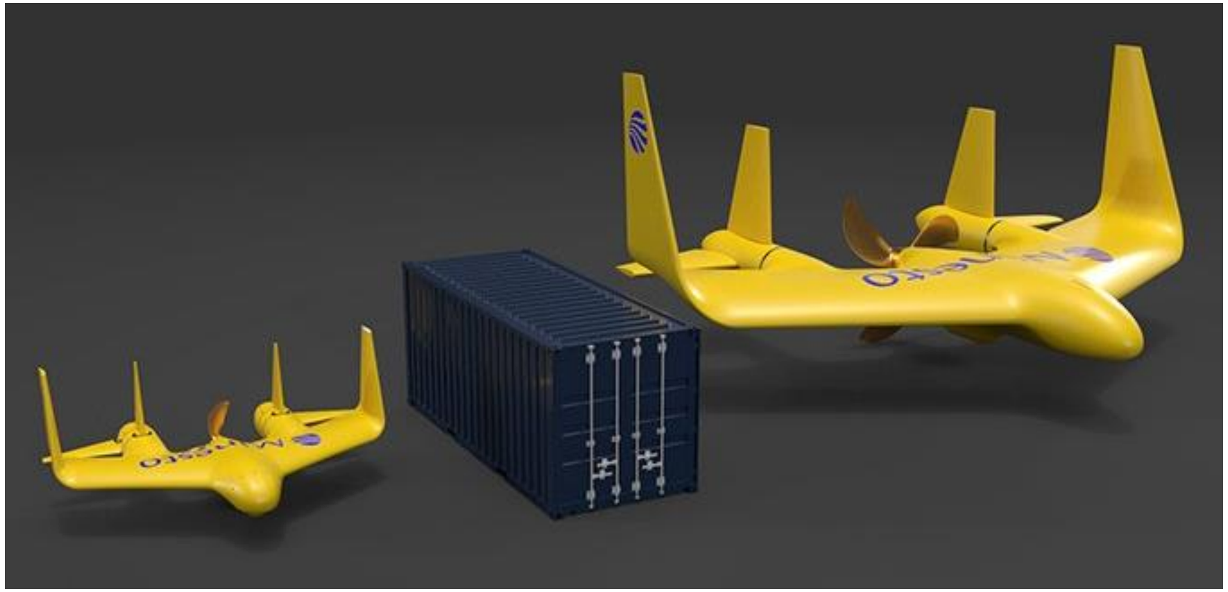
Cost-effective exploitation of a so far untapped energy source
Commercially viable electricity generation with small and lightweight systems


Minesto
Minesto

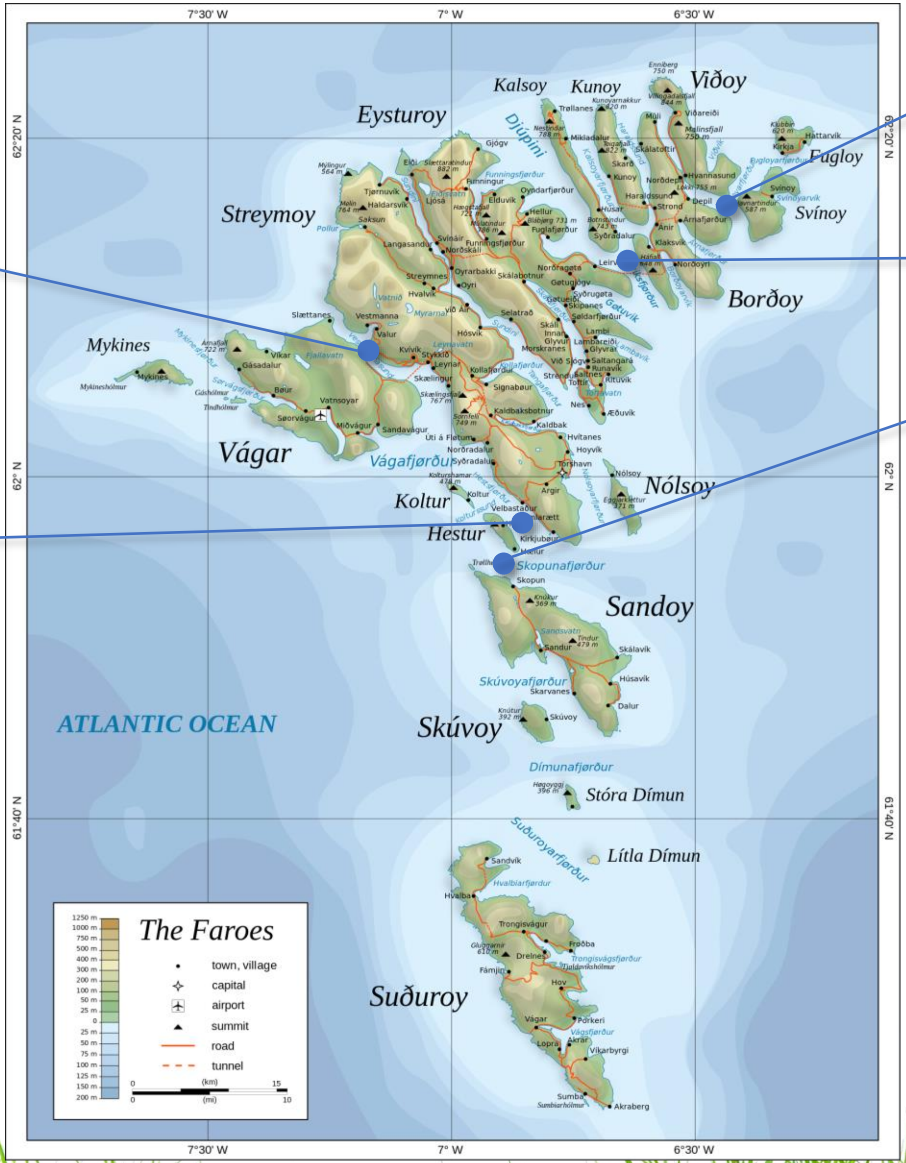
Minesto



Potential for Tidal energy build out in Faroe Islands

Vestmannasund
- Demo. installation: 2x100kW
- Demo. installation: 1x1.2MW

Hestfjord
- Array installation: 30MW
  - Phase 1a: 5MW
  - Phase 1b:5MW
  - Phase 2: 20MW

Non grid connected islands
- Mykines
- Fugloy
- Skúvoy



Svinoyarfjord
- Array Installation: 18MW

Leirviksfjord
- Array installation: 36MW

Skopunafjord
- Array Installation: 40MW

5 identified sites with a capacity of 125 MW

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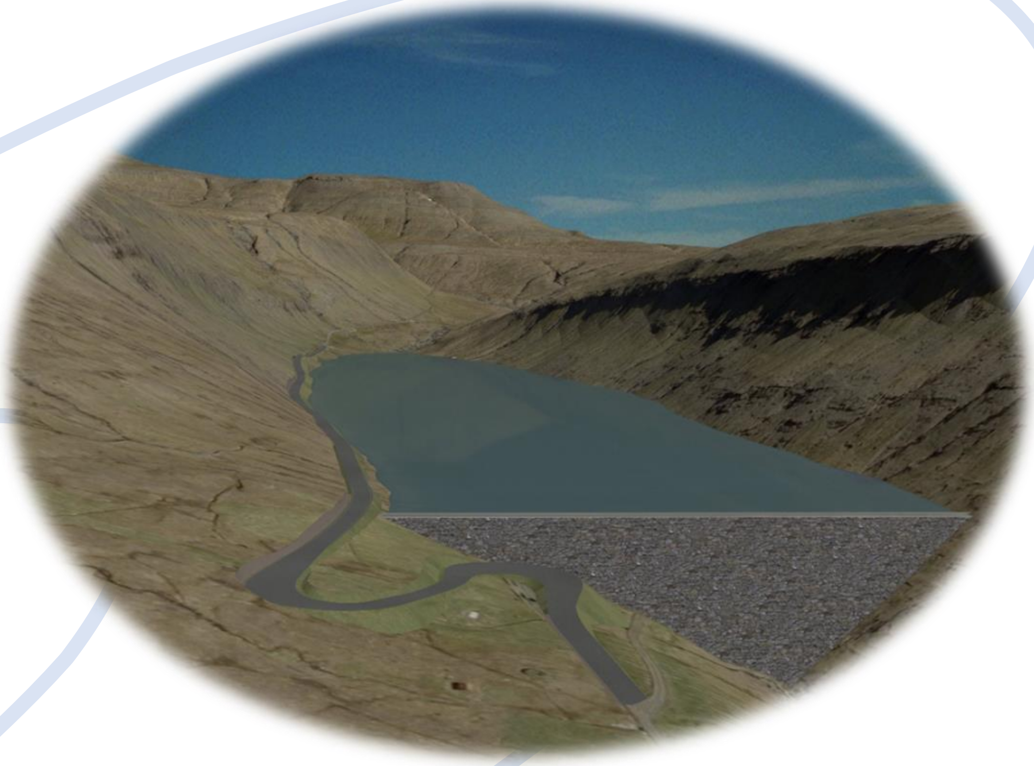
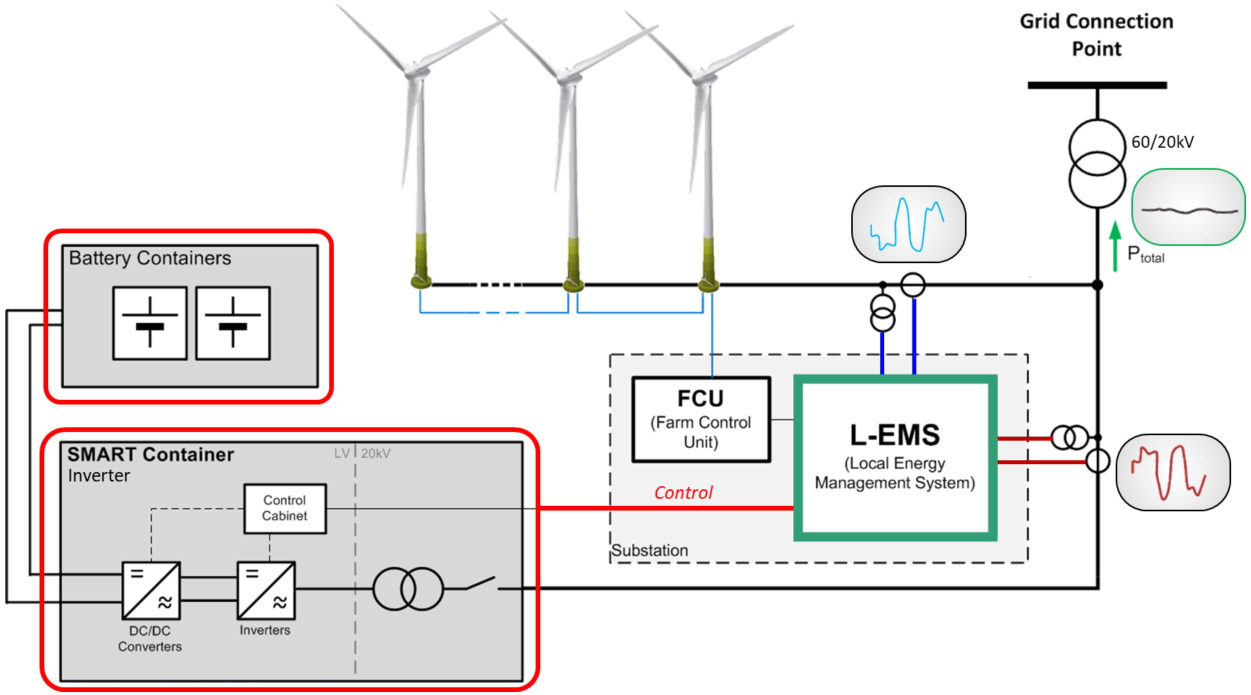


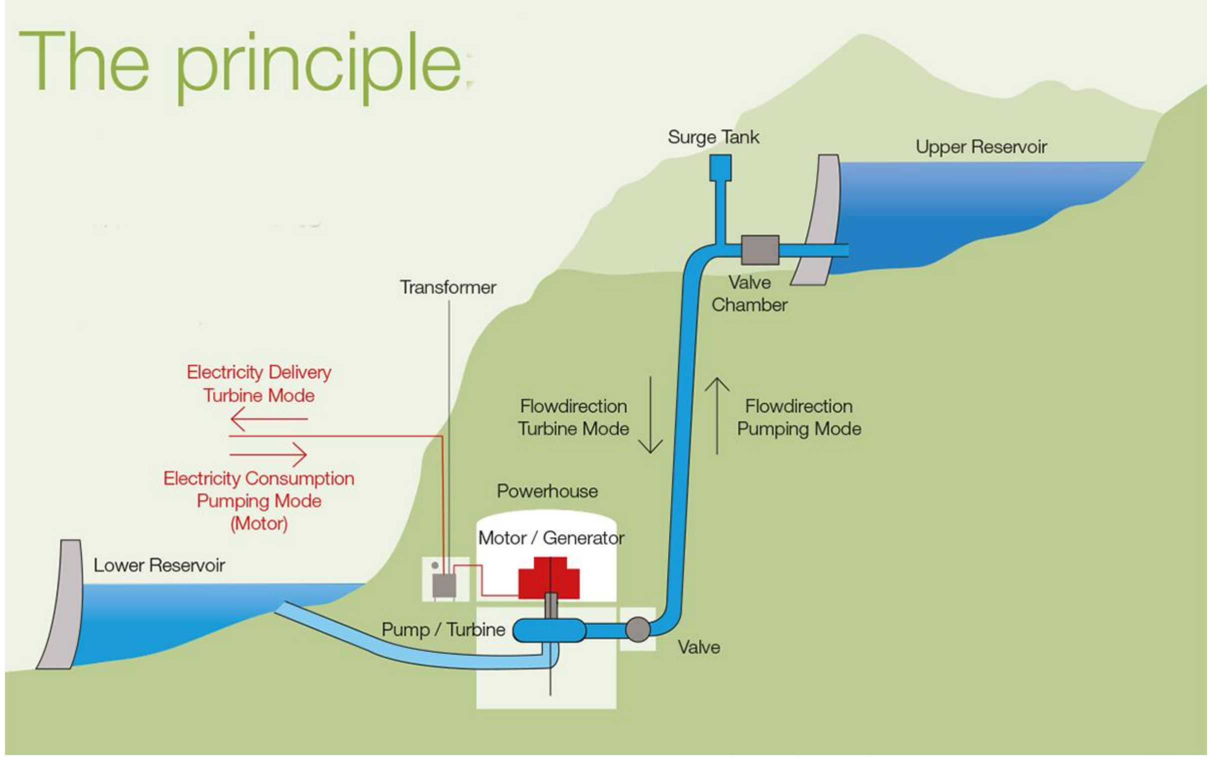
Energy storage

For balancing the power system

- **Batteries** for short-term storage
  - *Seconds, minutes, hours*



- **Pumped hydro** for long-term storage
  - *Hours, days, weeks*



Short- and long term storage

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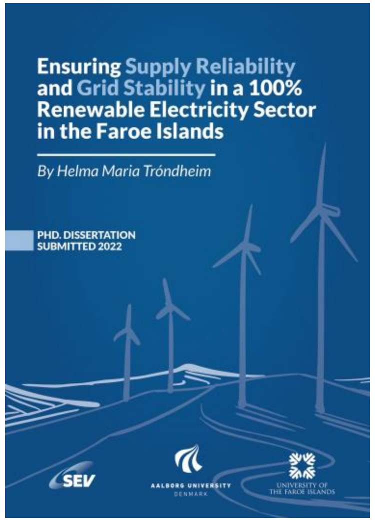
Pumped storage project in Vestmanna

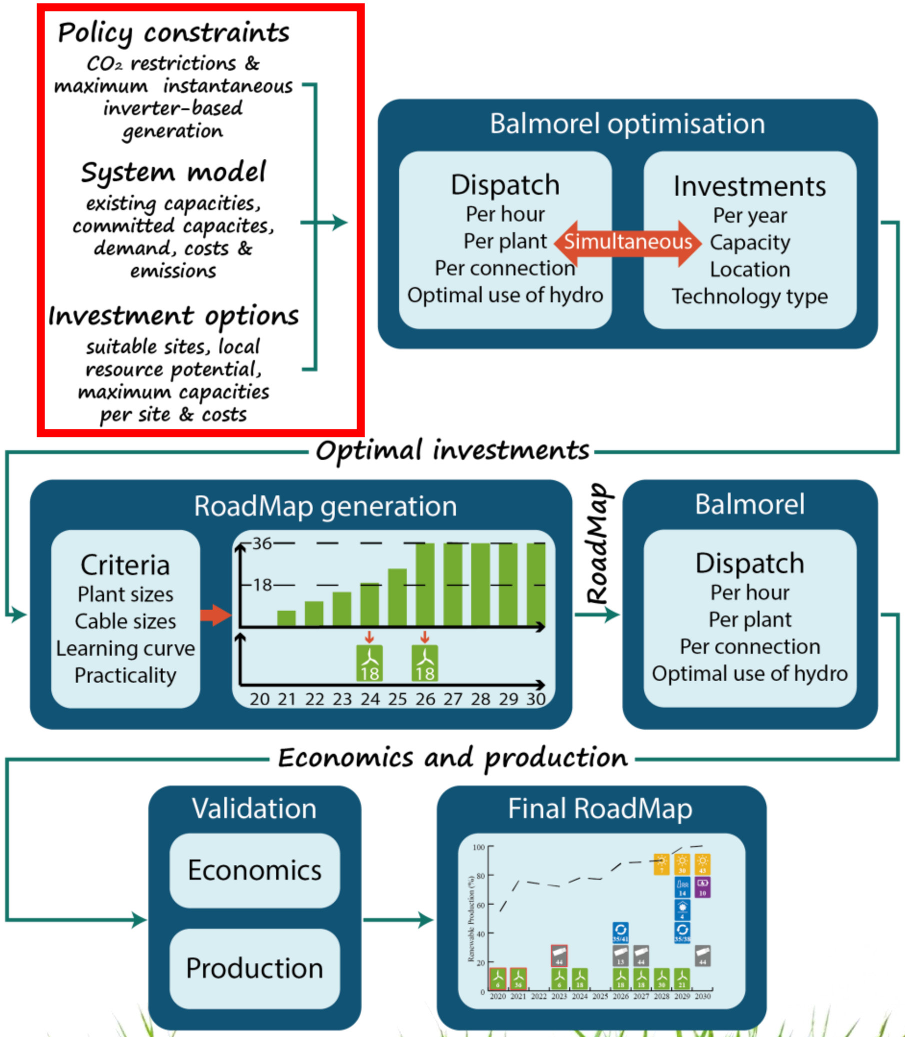


Developing a RoadMap

According to PhD research project

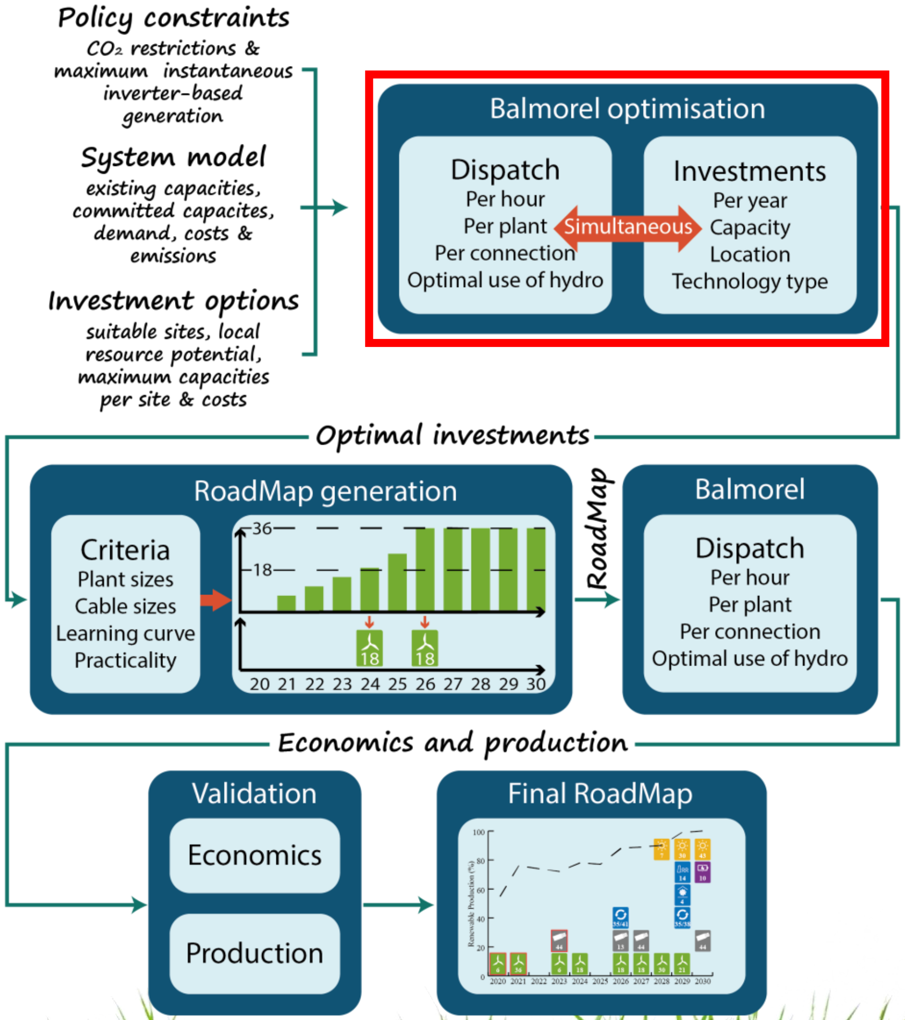
Helma Maria Tróndheim, PhD

- Policy constraints:
  - Linear decrease in CO_2 emissions to ensure 100% renewables in 2030
- System model:
  - Existing and committed capacities have been defined
  - Demand projection includes electrification of heating and transport
  - Costs are based on the O&M of the system, and fuel cost projection is from the Danish Energy Agency
- Investment options:
  - Energy potential based on local resources
  - Maximum capacities at locations have been defined
  - Costs are based on previous projects and catalogues (Danish Energy Agency)



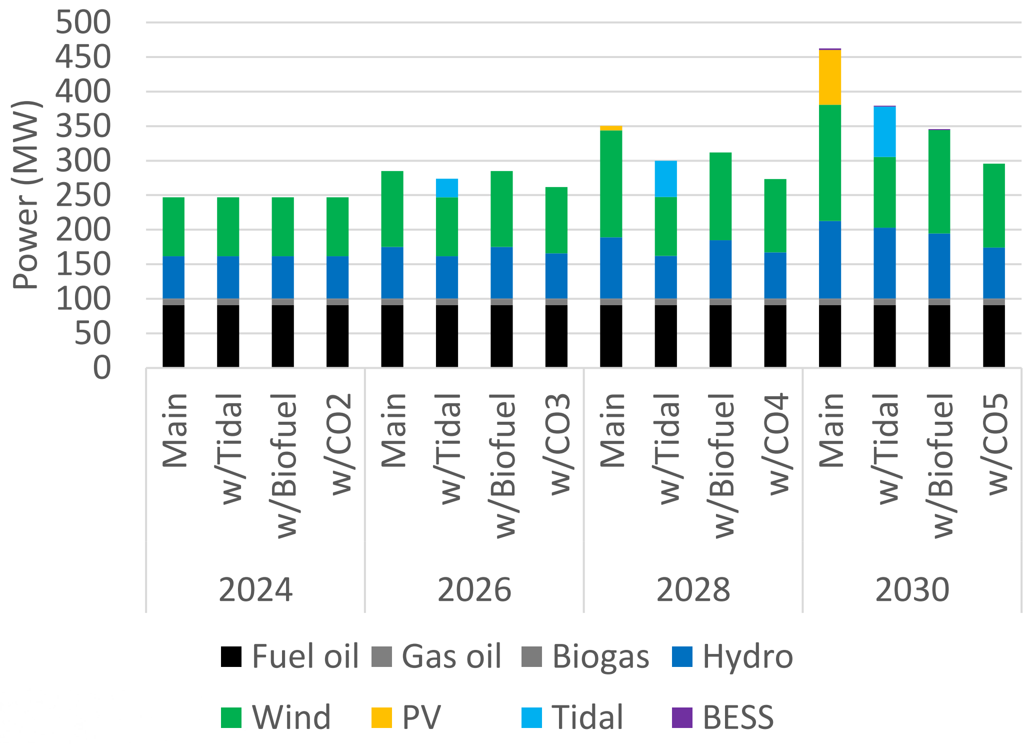
Inputs to Balmorel

- Dispatch and investments are optimised simultaneously
- The dispatch is optimised per hour, plant and connection
- Investments are optimised annually for each location and technology type
- Multiple scenarios and sensitivity analysis



Optimisation

Generation capacities



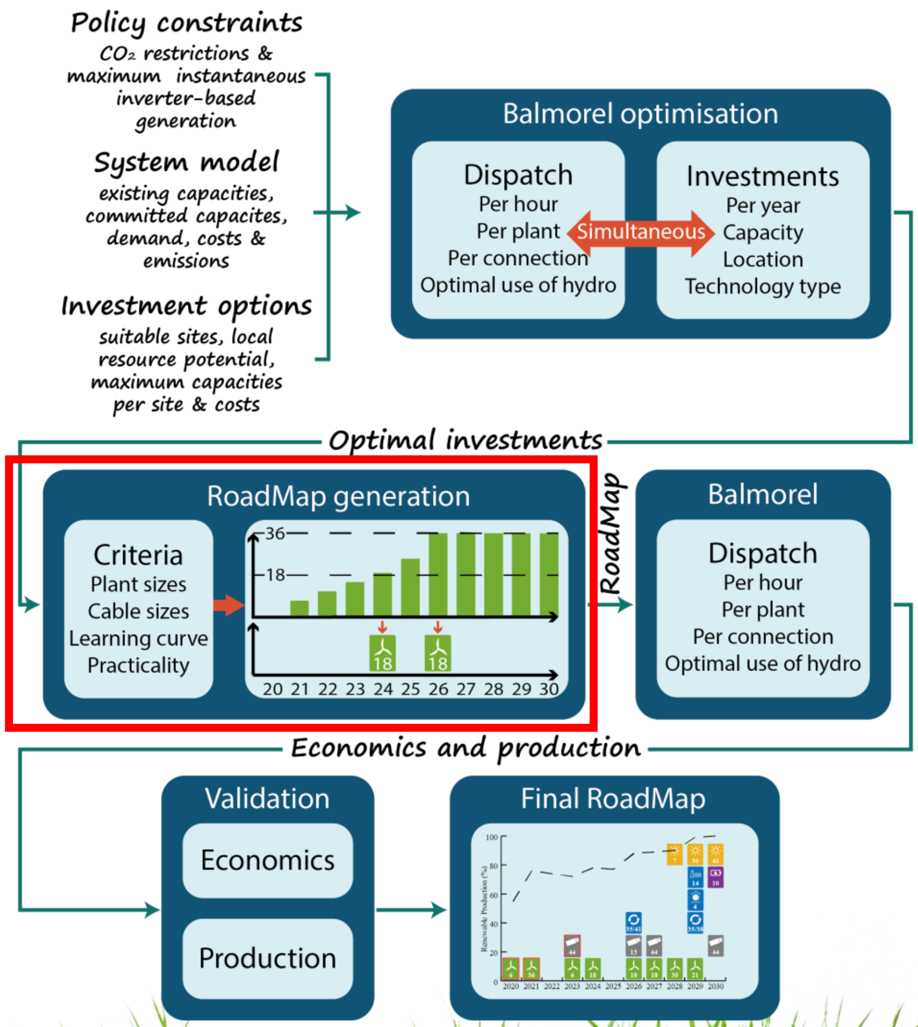
Noteworthy optimisation results

- Renewables are economically favourable up to 86-87%
- Going from 96% in 2028 to 100% in 2030 doubles the need for storage
- The results are not highly sensitive to the investment and fuel costs
- Tidal energy can have a major impact on the future power system, reducing the generation and storage capacities by 18% and 75% respectively

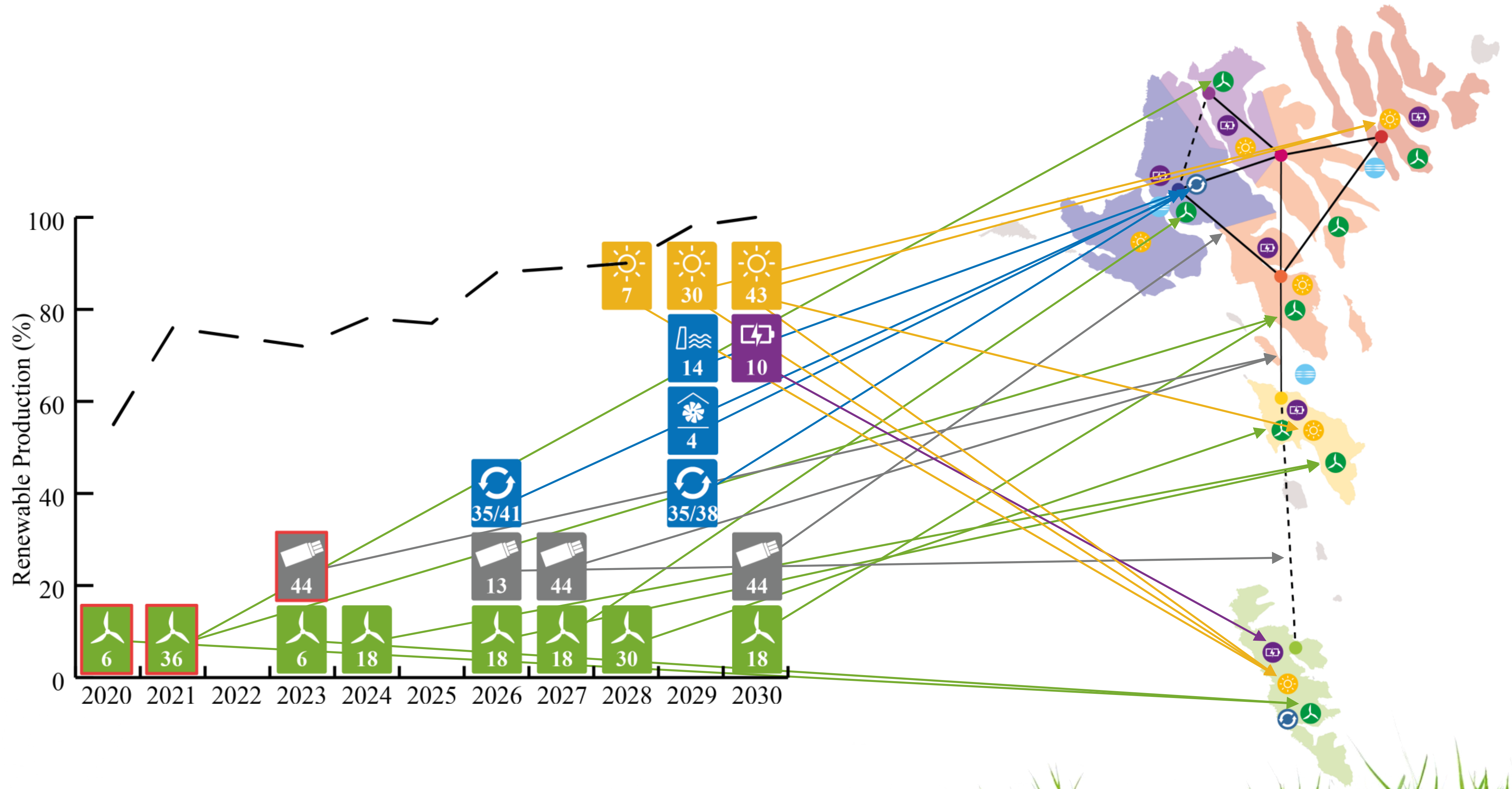
Optimisation results

SEV

- Based on main scenario
- Investments should be made in realistic project sizes
- The learning curve of the operators is considered
- Practicality has been considered
- Wind farm example



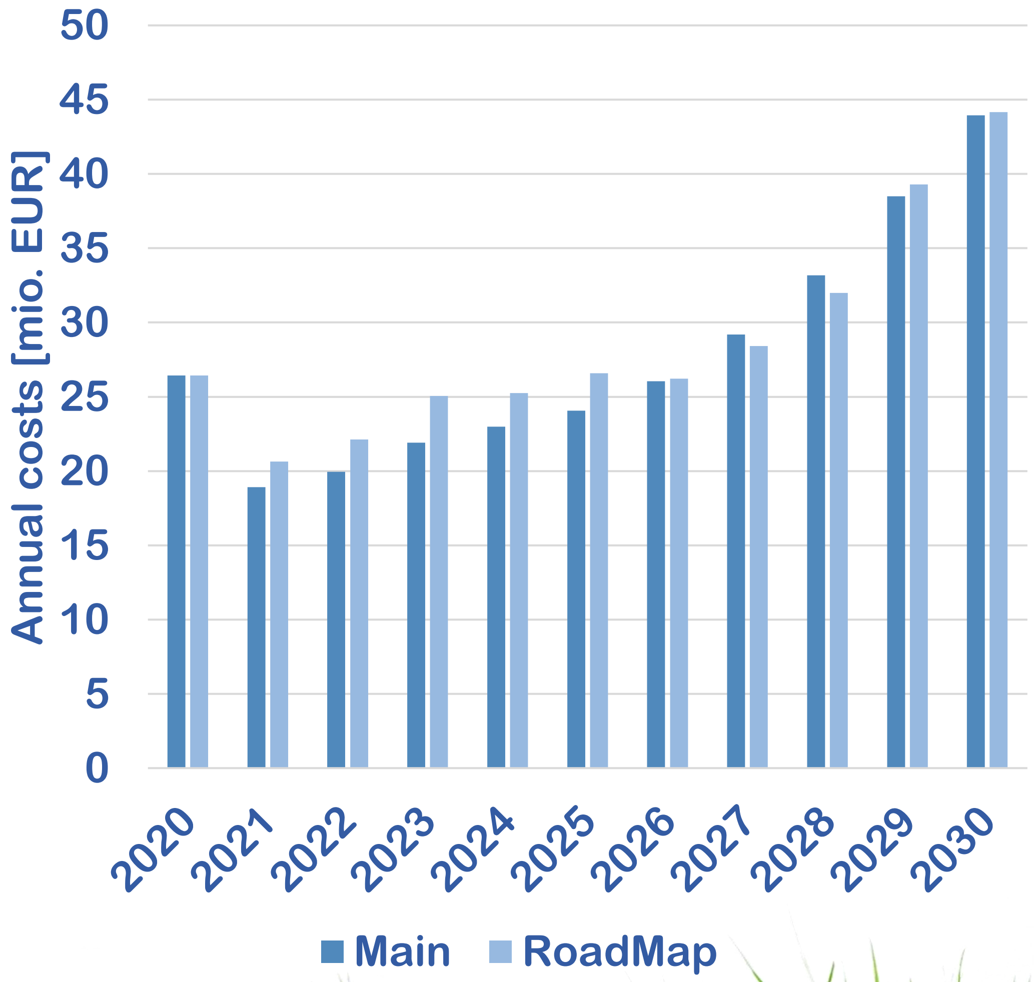
RoadMap Generation



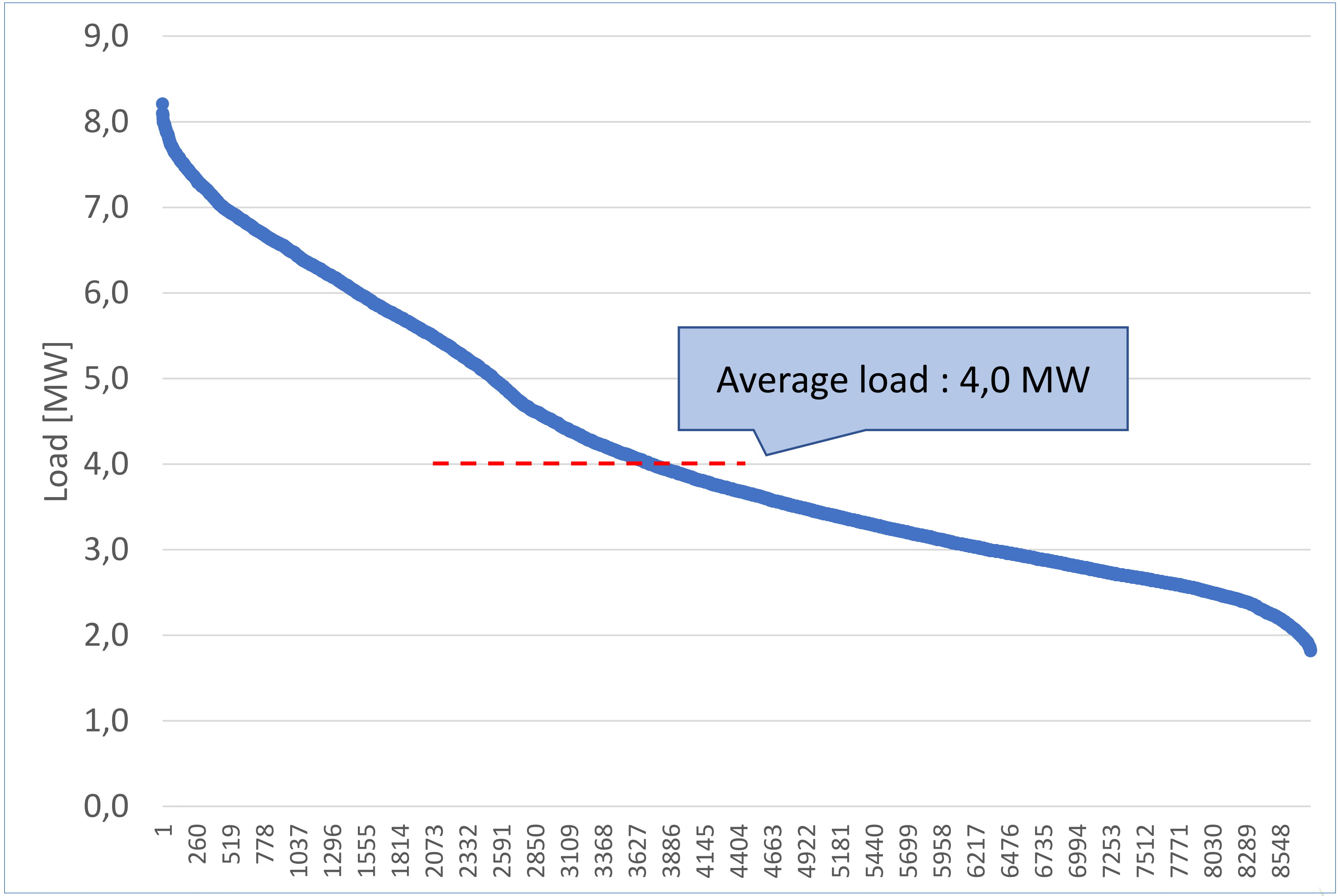
100by2030 RoadMap

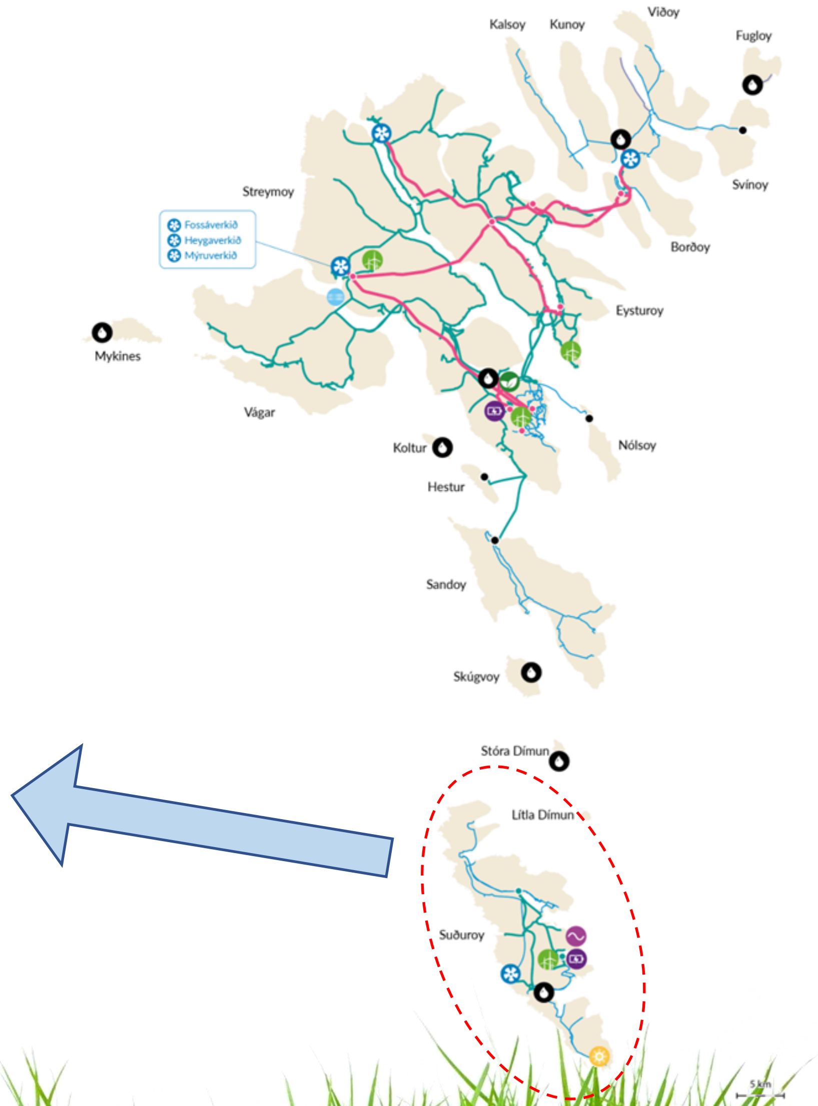
Validation of RoadMap

- The RoadMap is simulated in Balmorel as committed capacities
- The production in 2030 should be 100% renewable
- The economics of the RoadMap should be similar to the main optimised scenario



Renewable and Stable Grid





Suðuroy - Load duration curve

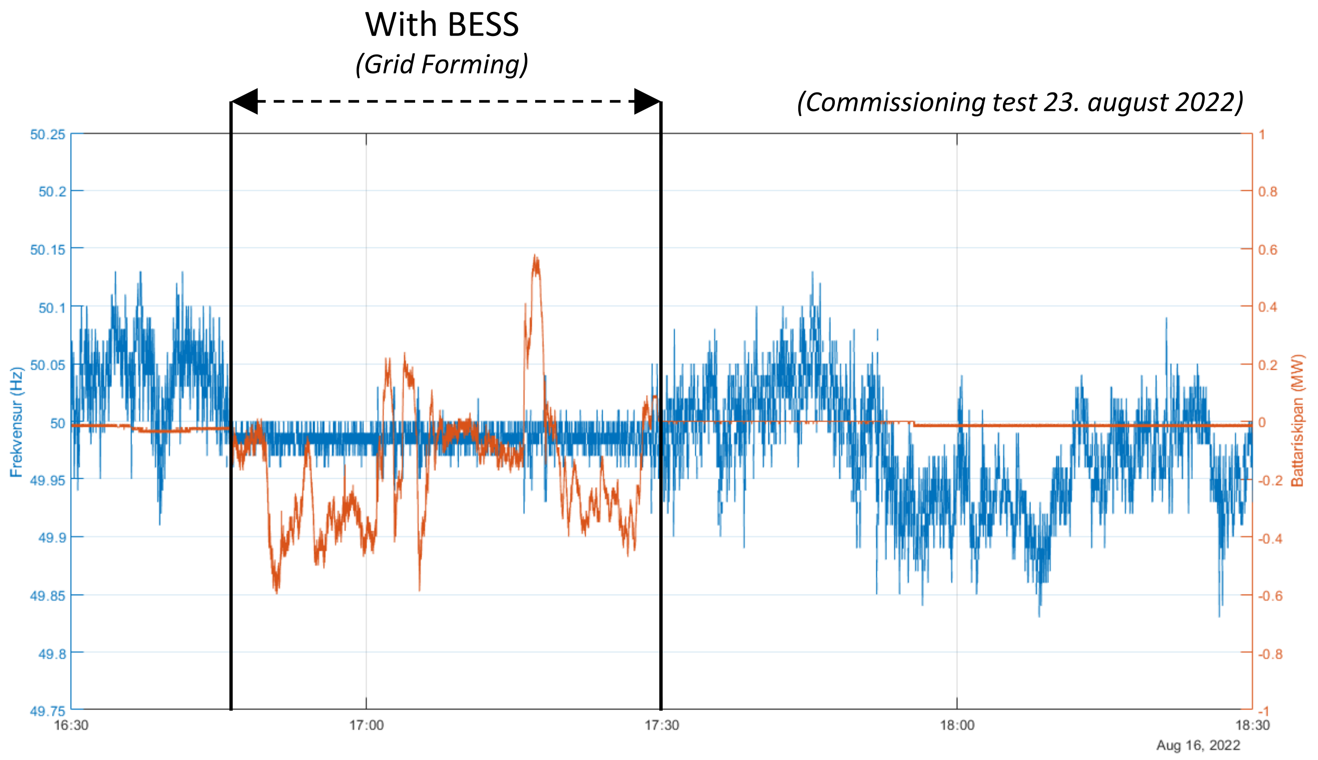
Botn Hydro Power
3 MW

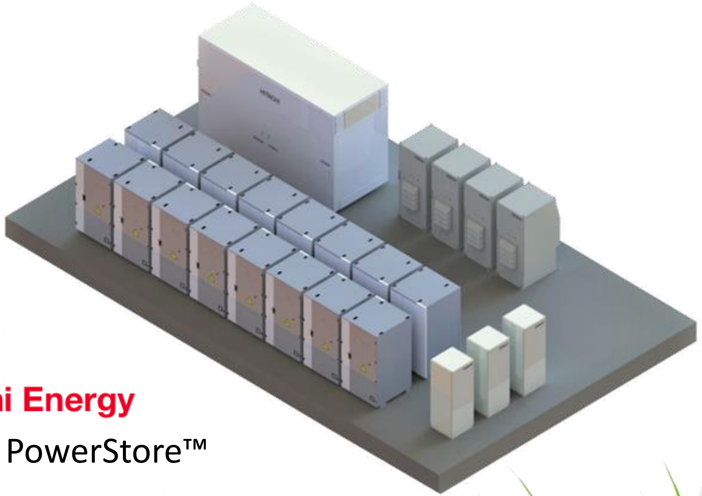
Porkeri WPP
6,3 MW

Vágur PP
14 MW

Sumba PV
0,3 MW

Grid Stability



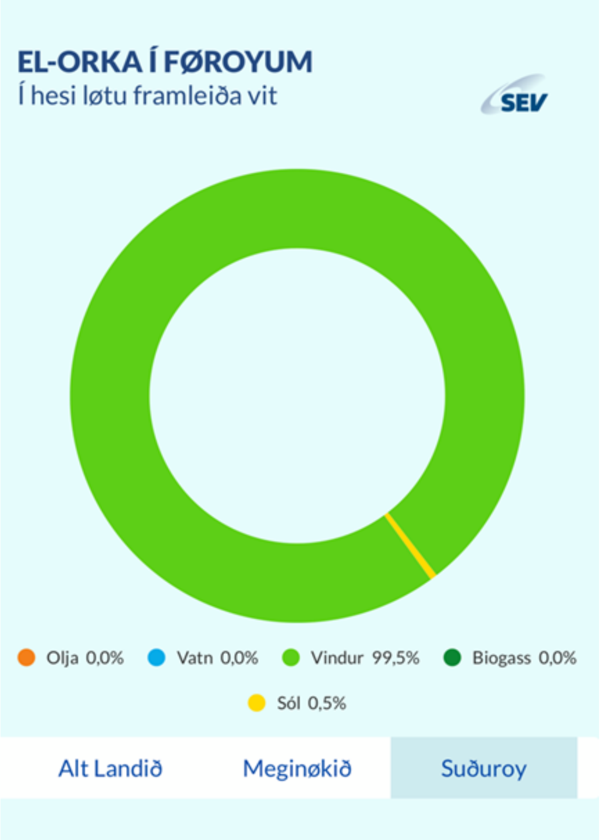


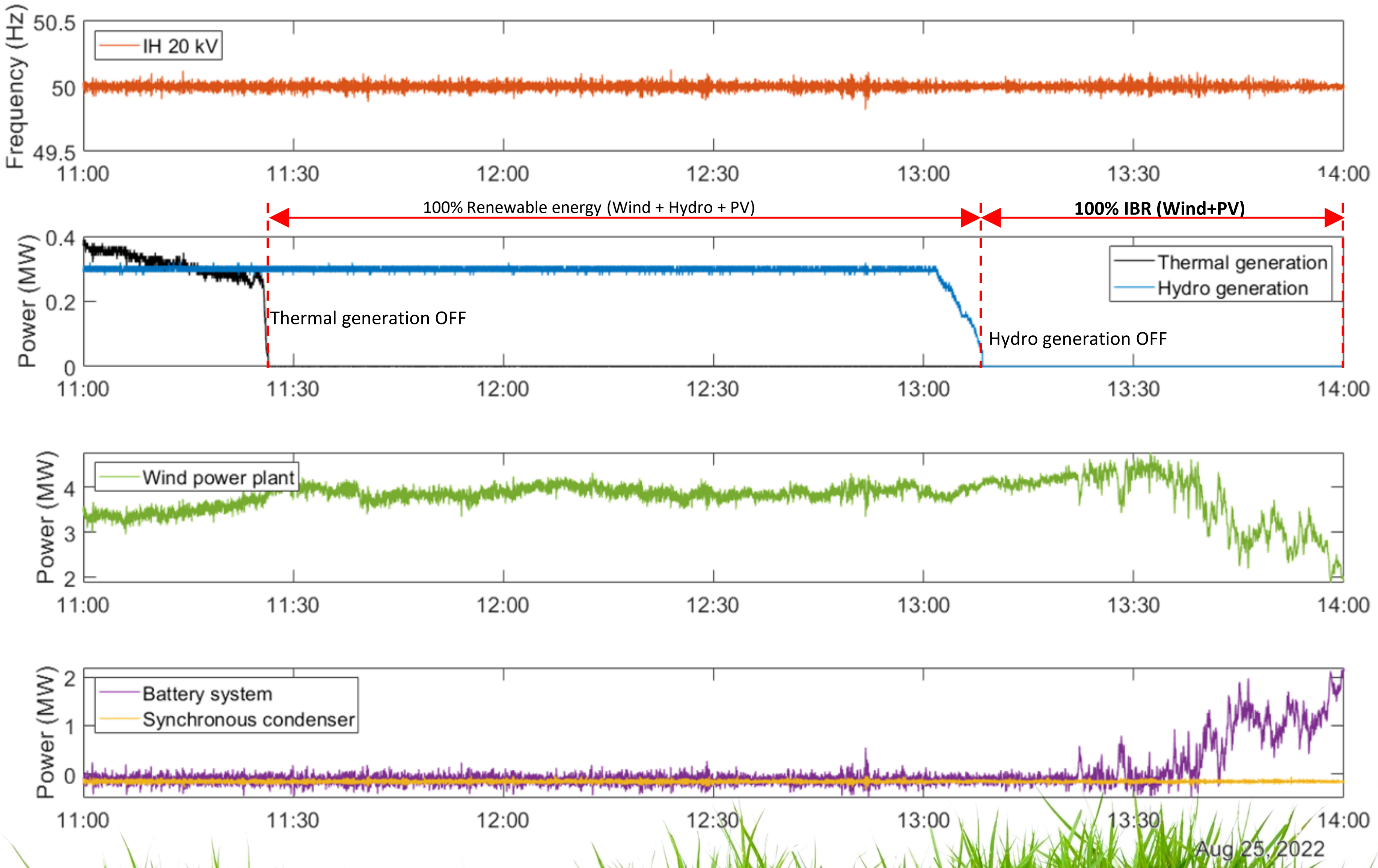
Hitachi Energy

e-mesh™ PowerStore™

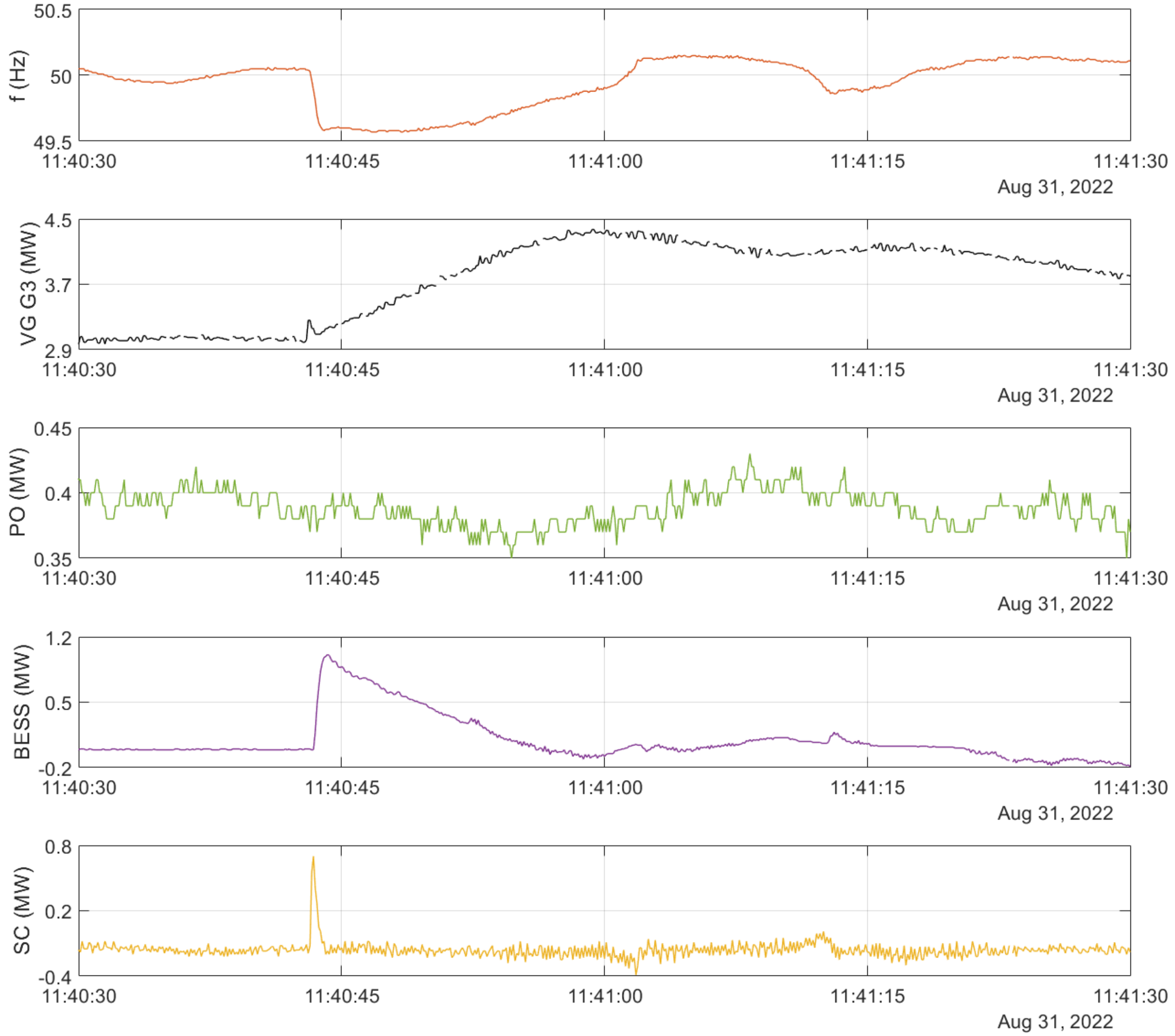
Batteries for fast frequency response in Suðuroy

SEV





100% inverter-based generation



Example of Grid Disturbance (outage of hydro turbine)

Thank you

Helma Maria Tróndheim,
R&D department, PhD