BUSINESS CASES FOR REMOTE MICRO-GRIDS AND OFF-GRIDS WITH HYDROGEN-BASED TECHNOLOGIES
EURO 2019 – 25.06.2019

Miguel Muñoz Ortiz, V. Nørstebø, A. Werner, K. Sundseth

"This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779541. This Joint undertaking receives support from the European Union's Horizon 2020 research and innovation programme"

Agenda

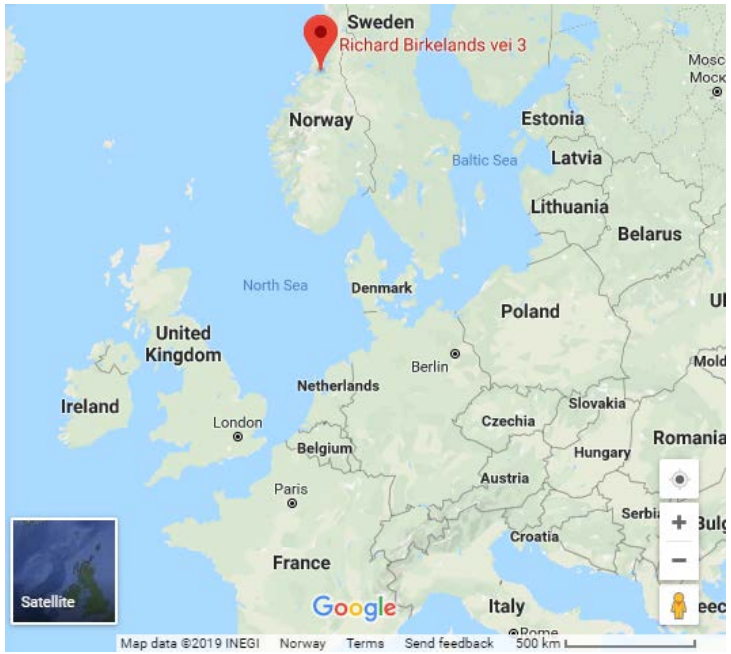
- Introduction
- Methodology
- Application in EU project REMOTE
- Results
- Conclusions
- Future work

Disclaimer: *"Any contents herein reflect solely the authors' view. The FCH 2 JU and the European Commission are not responsible for any use that may be made of the information herein contained."*

Introduction

- Sintef Industry
  - Department: Sustainable Energy
    - Group: **Operation Research and Economics**

- We develop and provide actors in the private and public sectors with tools and methods to take rational and sustainable decisions.



Source: Google maps

Richard Birkelands vei 3
7034 Trondheim, Norway

SINTEF

Introduction

- EU requires a **Resilient Energy Solution**
- Increase of Renewable Generation (**PV** and **Wind**)
- Intermittency demands **bulk energy storage solutions**
- **Batteries not viable** in storing energy for more than one day
- **No network** in **isolated** micro-grids and **off-grid** remote areas
- **Hydrogen-based P2P storage** viable solution compared to diesel generators

Methodology

- Model **HyOpt** (hydrogen-energy system optimisation model)
- Programmed in **Mosel** language
- **Xpress** solver
- **Optimisation model** for a given case or load
- MILP including **strategic** and **operational** decisions
- Flexible **time resolutions**
- Used in a number of **industry and research projects.**

Methodology

- Nodes: building block
  - Production plants
  - Markets
  - Storage
  - Transport
- Decision variables: strategic & operation variables
- Technical constraints depending on node
- Objective function: **minimise NPV** of the energy system

Methodology

INPUTS:

- **Load profile** during operation period (e.g. yearly profile with hourly resolution)
- **Technology costs:** CAPEX, OPEX, regeneration costs
- **Renewable production profiles** (wind, PV etc.)
- Other **techno-economical** inputs (production functions, efficiency, discount rate).

Methodology

OUTPUTS:

- **Investment decisions** (technology capacity and its costs)
- **System operation** (hourly and yearly energy production, flows)
- Levelised cost of energy (**LCOE**) of the system
- **CO_2 emissions**

Application in EU project REMOTE

- *"**R**emote area **E**nergy supply with **M**ultiple **O**ptions for integrated hydrogen-based **TE**chnologies"*
- **Island operation of renewable energy systems**
- Duration: **4 years**
- Project start: January 2018
- Sintef's role: local coordination, data analysis, business models and LCA

Application in EU project REMOTE

Four demos:

- Demo 1 **Ginostra** (IT): diesel generators
- Demo 2 **Agkistro** (GR): connection to grid
- Demo 3 **Ambornetti** (IT): invasive grid connection or diesel generators
- Demo 4 **Froan** (NO): Replacement of sea cable

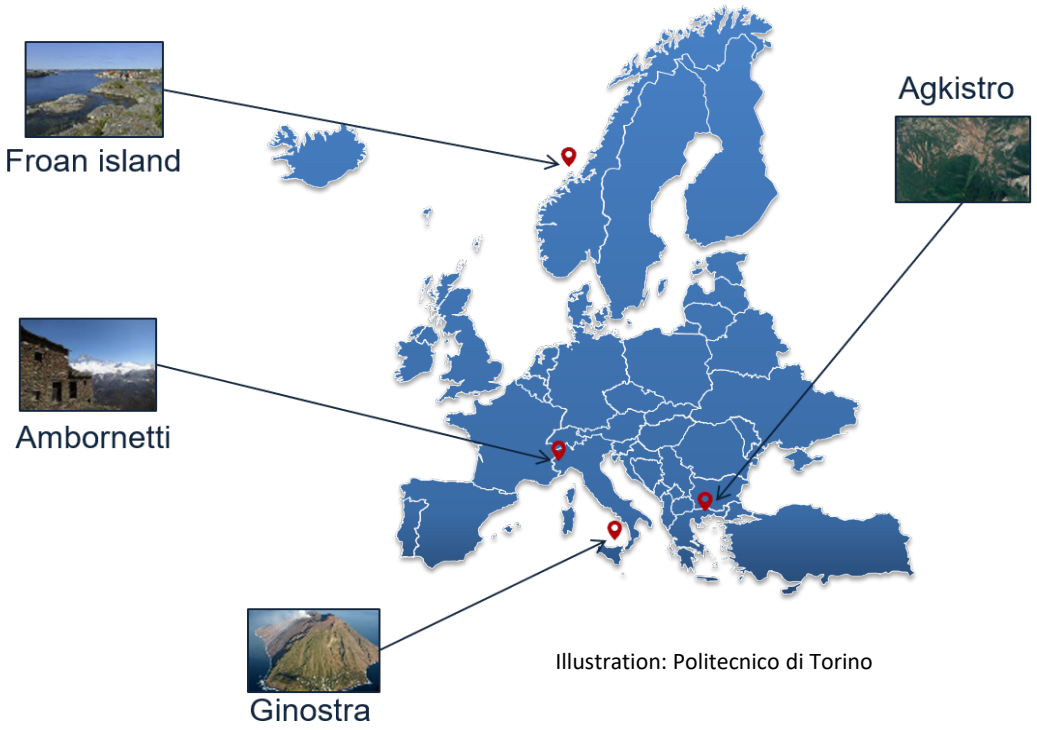


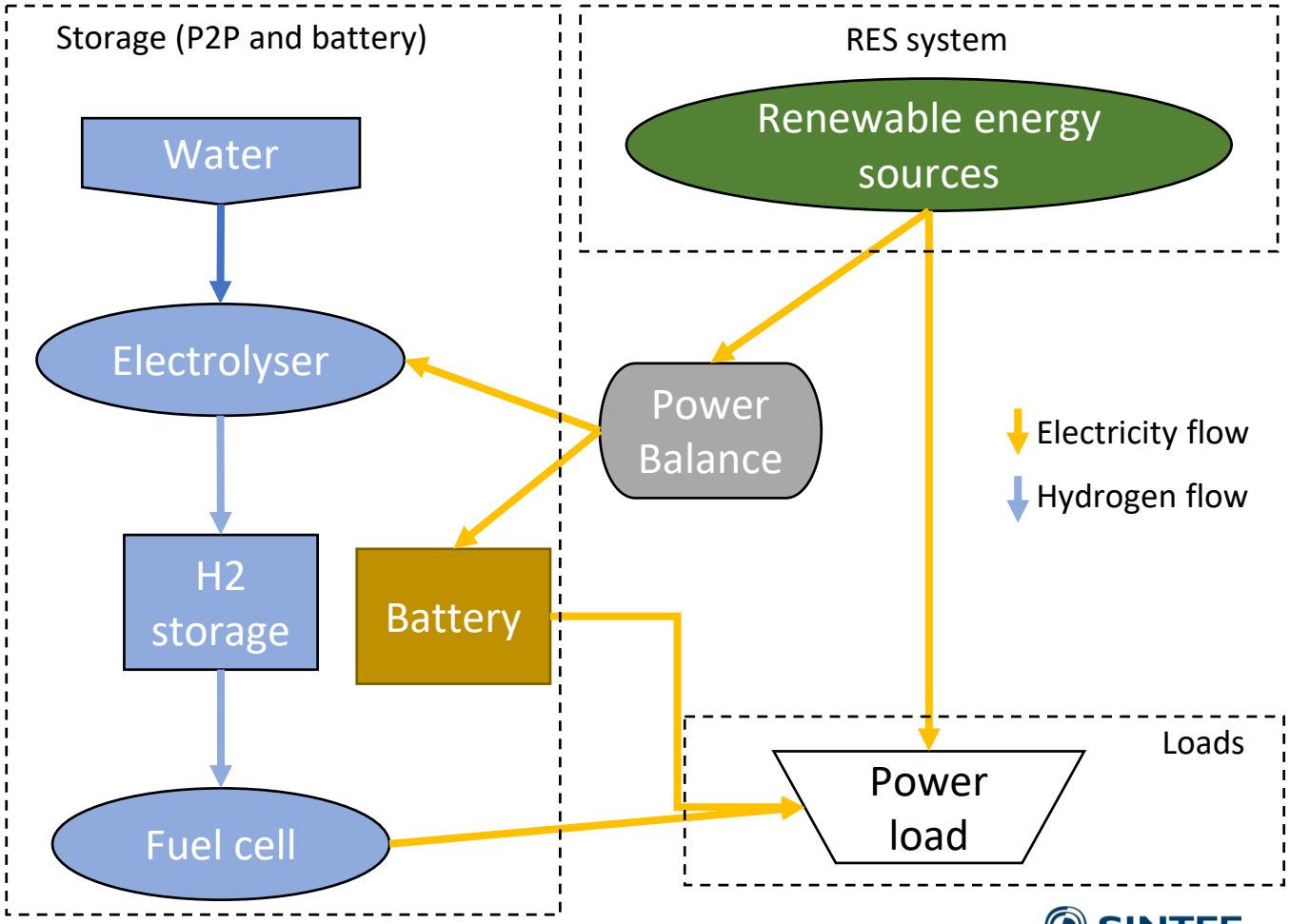
Illustration: Politecnico di Torino

SINTEF

Application in EU project REMOTE

Generic RES solution:

- Renewable sources: PV, Wind turbines, hydropower and biomass CHP generator.
- Li-ion battery
- P2P hydrogen storage



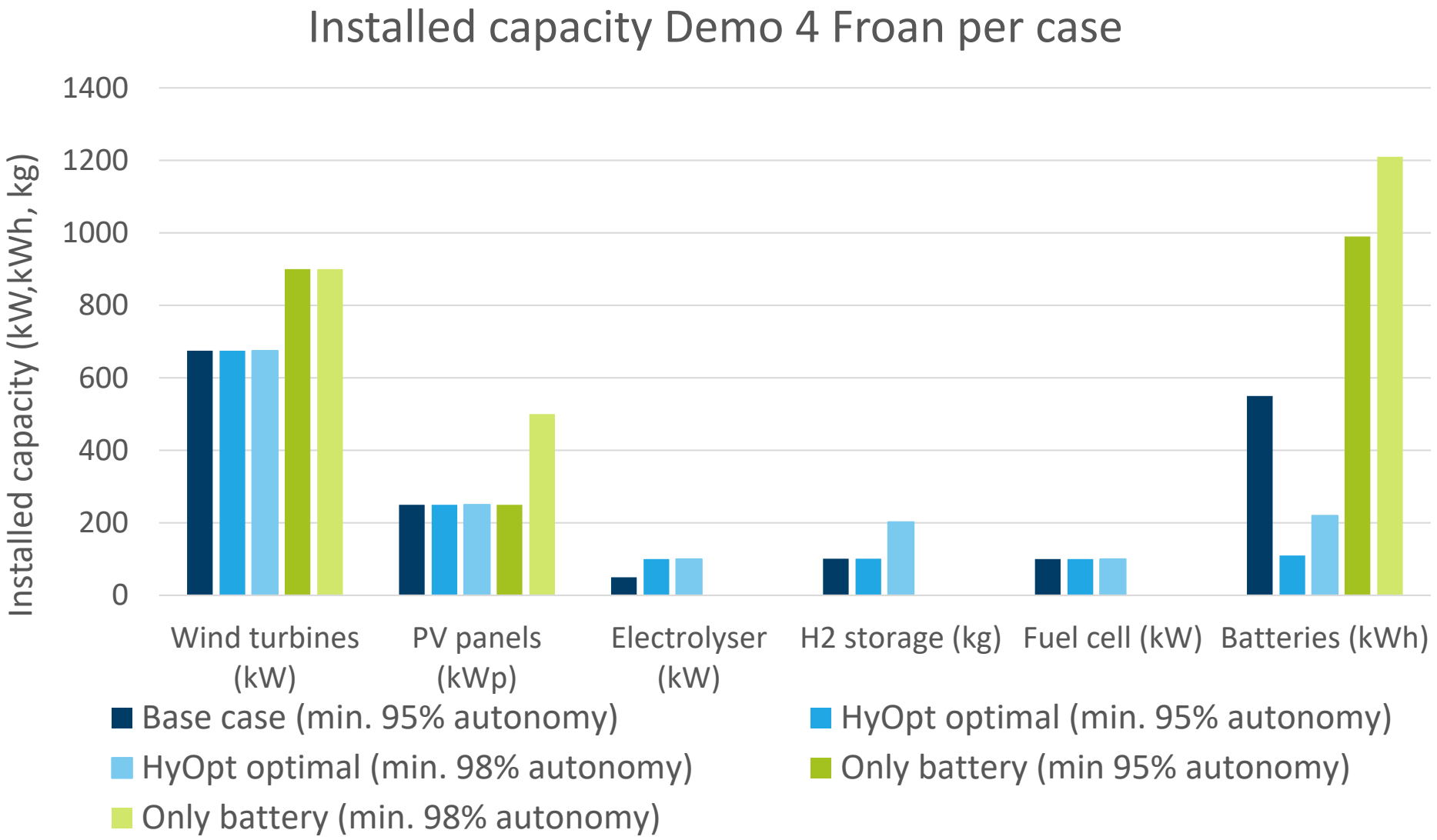
SINTEF

Application in EU project REMOTE

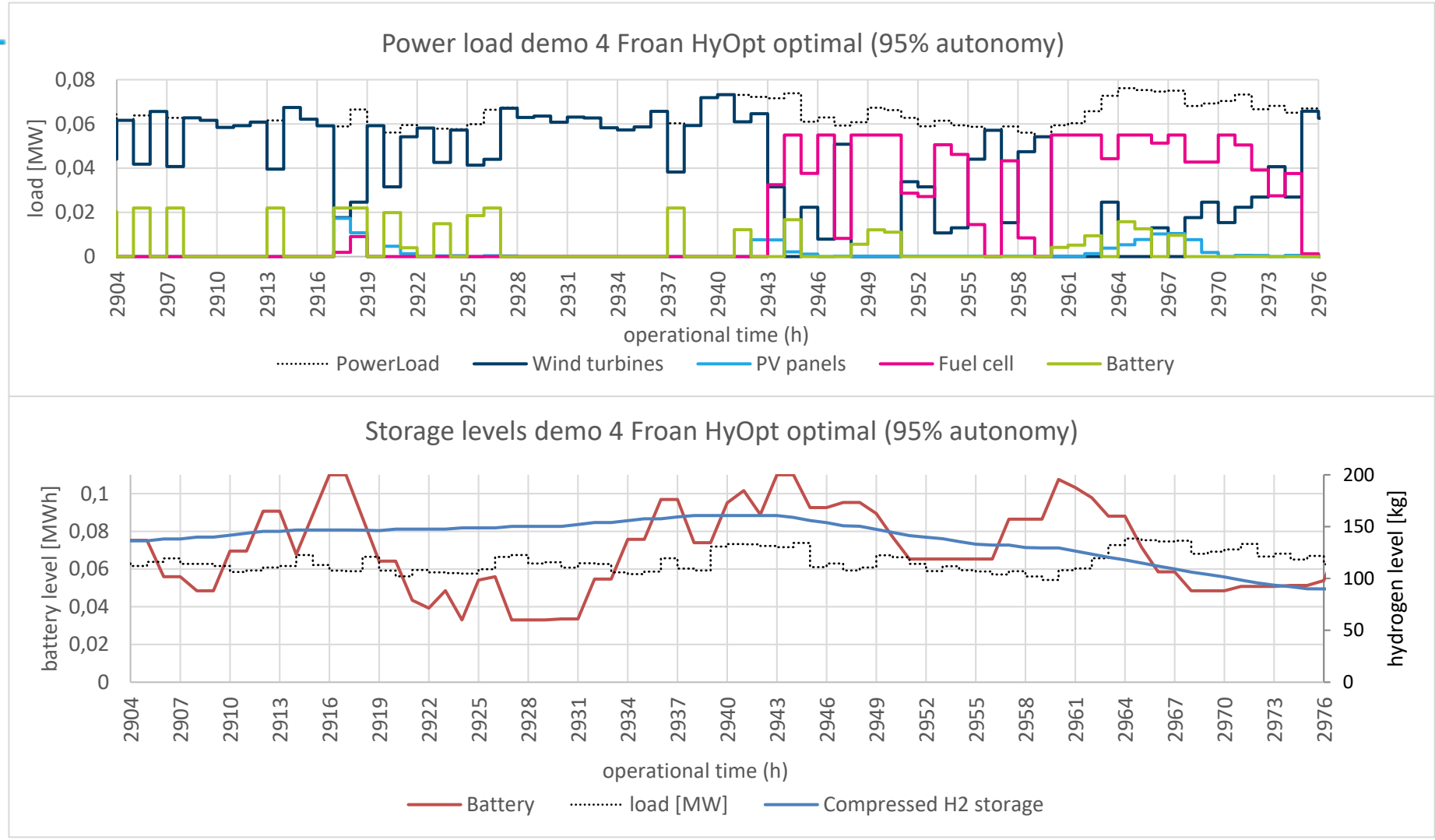
Different cases:

- **Base case** with sizing from previous deliverables
- **HyOpt optimal** solution with flexibility in chosing storage and renewable production capacity
- Optimal solution with **only battery** as storage

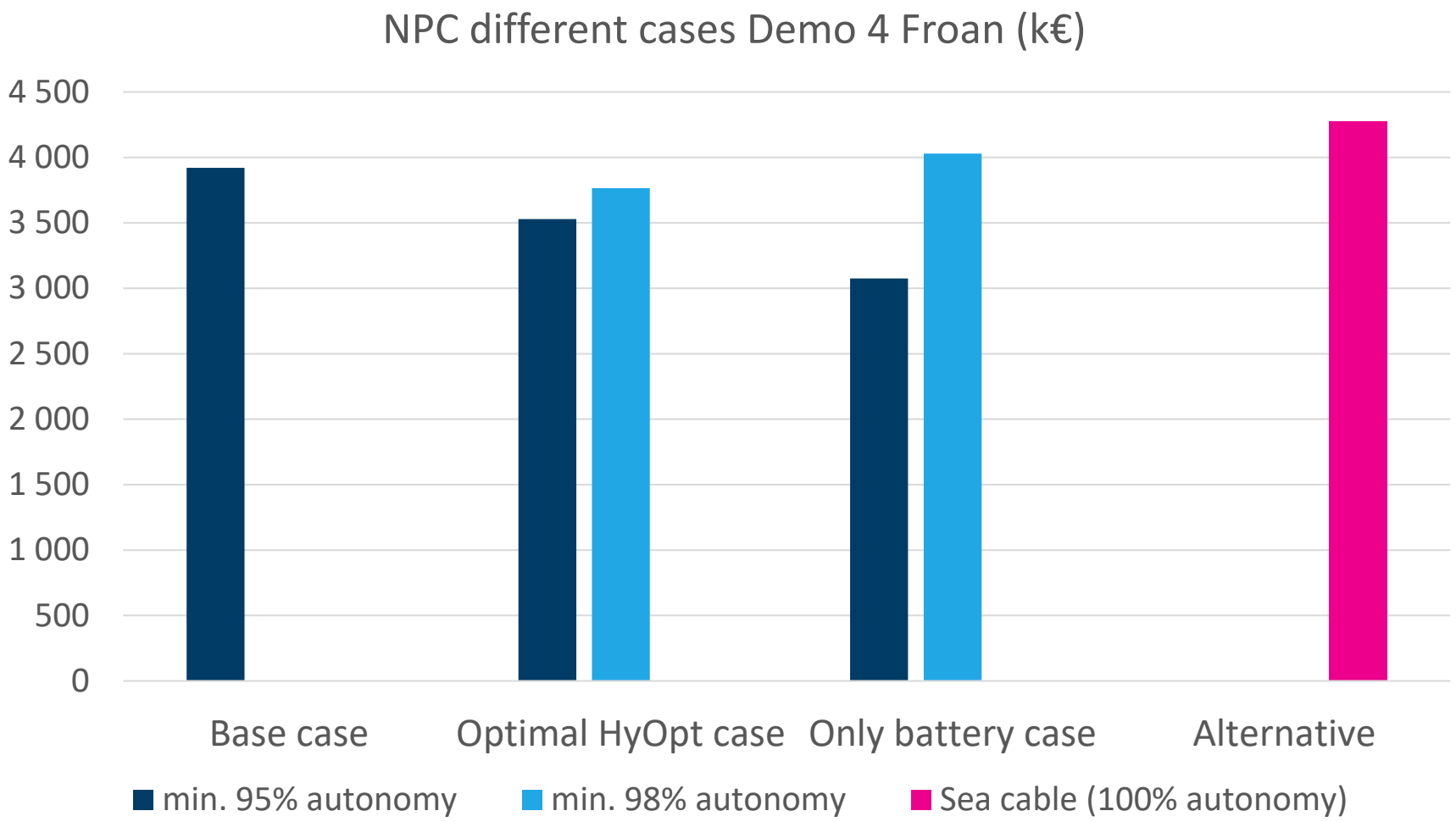
Results


Installed capacity Demo 4 Froan per case
Installed capacity (kW,kWh, kg)
1400
1200
1000
800
600
400
200
0
Wind turbines (kW)
PV panels (kWp)
Electrolyser (kW)
H2 storage (kg)
Fuel cell (kW)
Batteries (kWh)
Base case (min. 95% autonomy)
HyOpt optimal (min. 95% autonomy)
HyOpt optimal (min. 98% autonomy)
Only battery (min 95% autonomy)
Only battery (min. 98% autonomy)

Results

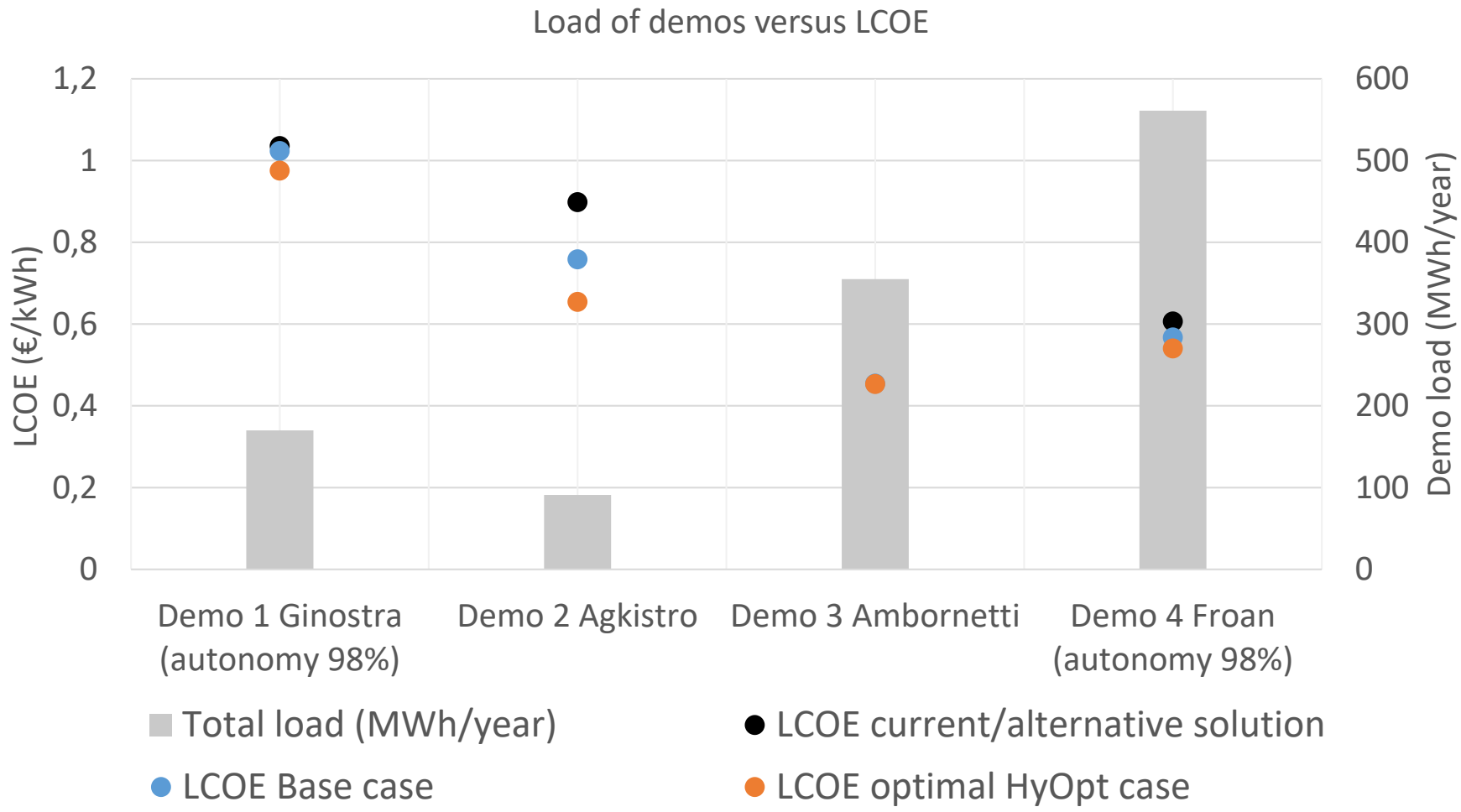

Power load demo 4 Froan HyOpt optimal (95% autonomy)
load [MW]
0,08
0,06
0,04
0,02
0
2904 2907 2910 2913 2916 2919 2922 2925 2928 2931 2934 2937 2940 2943 2946 2949 2952 2955 2958 2961 2964 2967 2970 2973 2976
operational time (h)
PowerLoad
Wind turbines
PV panels
Fuel cell
Battery
Storage levels demo 4 Froan HyOpt optimal (95% autonomy)
battery level [MWh]
0,1
0,08
0,06
0,04
0,02
0
hydrogen level [kg]
200
150
100
50
0
2904 2907 2910 2913 2916 2919 2922 2925 2928 2931 2934 2937 2940 2943 2946 2949 2952 2955 2958 2961 2964 2967 2970 2973 2976
operational time (h)
Battery
load [MW]
Compressed H2 storage

Results



SINTEF

Results


Load of demos versus LCOE
1,2
1
0,8
0,6
0,4
0,2
0
LCOE (€/kWh)
600
500
400
300
200
100
0
Demo load (MWh/year)
Demo 1 Ginostra (autonomy 98%)
Demo 2 Agkistro
Demo 3 Ambornetti
Demo 4 Froan (autonomy 98%)
Total load (MWh/year)
LCOE current/alternative solution
LCOE Base case
LCOE optimal HyOpt case

Conclusions

- Renewable solution with **hydrogen and batteries appropriate solution**
- **Hydrogen storage** still expensive, but **necessary** in remote areas
- Solutions with **larger loads** (350-600MWh/year) present **lower LCOE**
- **Fuel cell** not used actively, but **vital**
- Only **battery solutions larger LCOE** (if large autonomy is expected)
- **Alternative solutions larger LCOE**
- **Increase income** by **selling hydrogen** and **by-products**

Future work

- Model used in other projects
- Model documentation
- Scientific publication on HyOpt with application on REMOTE
- Life Cycle Analysis in REMOTE

Contact

- Miguel **Muñoz Ortiz**
- e-mail: **miguel.ortiz@sintef.no**
- Phone: **+47 413 75 237**
- Address: *Richard Birkelands vei 3, 7034 Trondheim, Norway*

Thank you for your attention!

Questions?

SINTEF

SINTEF

Teknologi for et bedre samfunn