



**UNIVERSITÀ
DEGLI STUDI
DI BERGAMO**

Department
of Engineering
and Applied Sciences

Ottimizzazione della filiera dell'idrogeno verde negli scenari ad alta penetrazione di rinnovabile

SPEAKER

Giovanni Brumana

LOCATION

Genova, Villa Giustiniani

DATE

25th Jan 2024

Gruppo di ricerca



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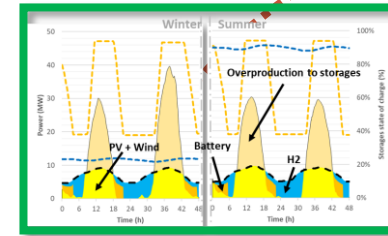


Elisa Ghirardi

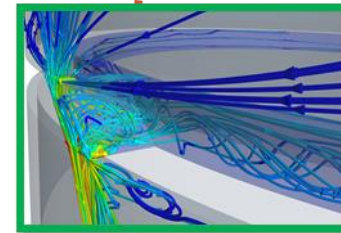


Otman Kouaissah

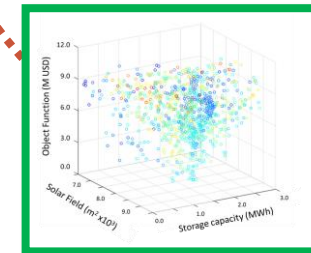
Simulation



Energy systems



CFD



Optimization



Banco prova disco freno



Galleria per schiera rotorica



Gallerie per schiera statica

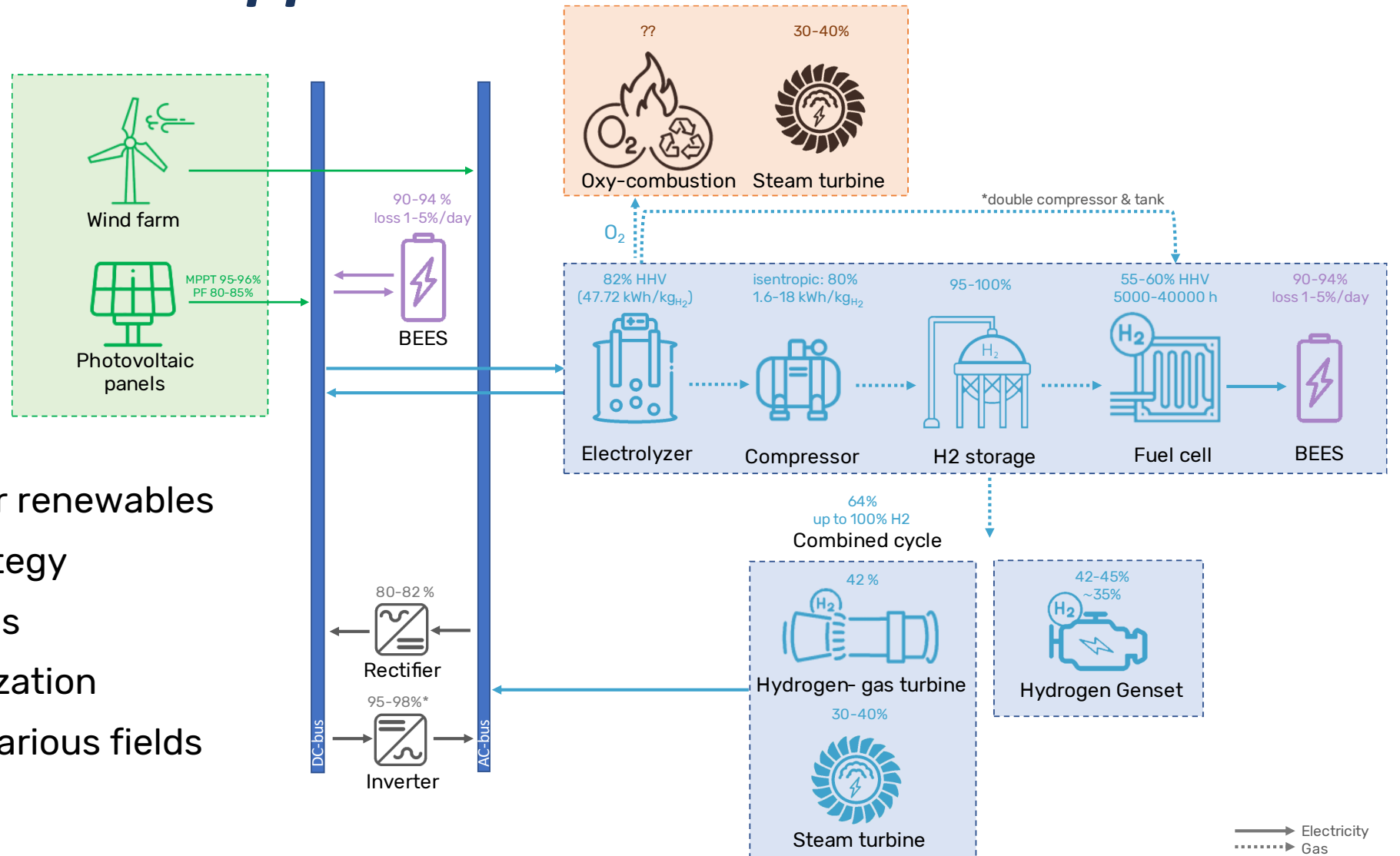
Experimental



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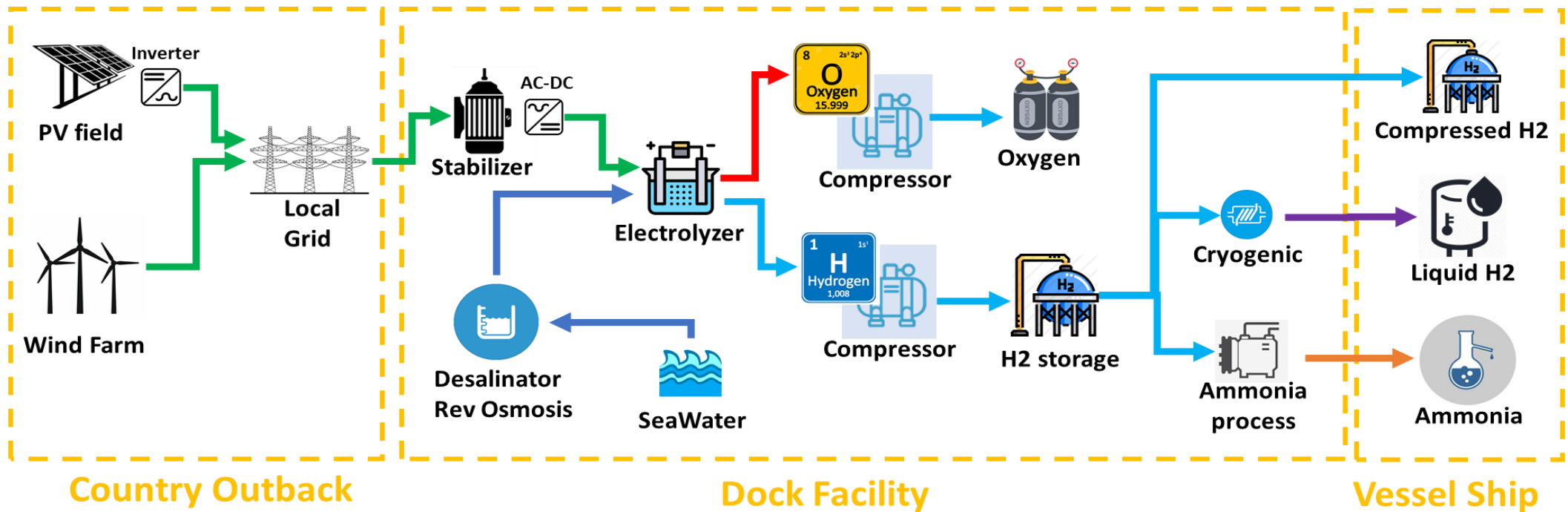
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1. Modelling - Grid approach



- Seasonal storage for renewables
- Load-following strategy
- Remote communities
- Components optimization
- Implementation in various fields

1. Modelling - Hydrogen supply chain



- Renewables optimization
- Hydrogen production

- Hydrogen compression and storage
- Hydrogen delivering

1. Modelling – Simulation approach

- Fast transient simulation
- All performance based on manufacturer characteristics



Li-ion batteries

Round trip efficiency 93%
 Rectifier efficiency 82%
 Inverter efficiency 98%

Meteo data

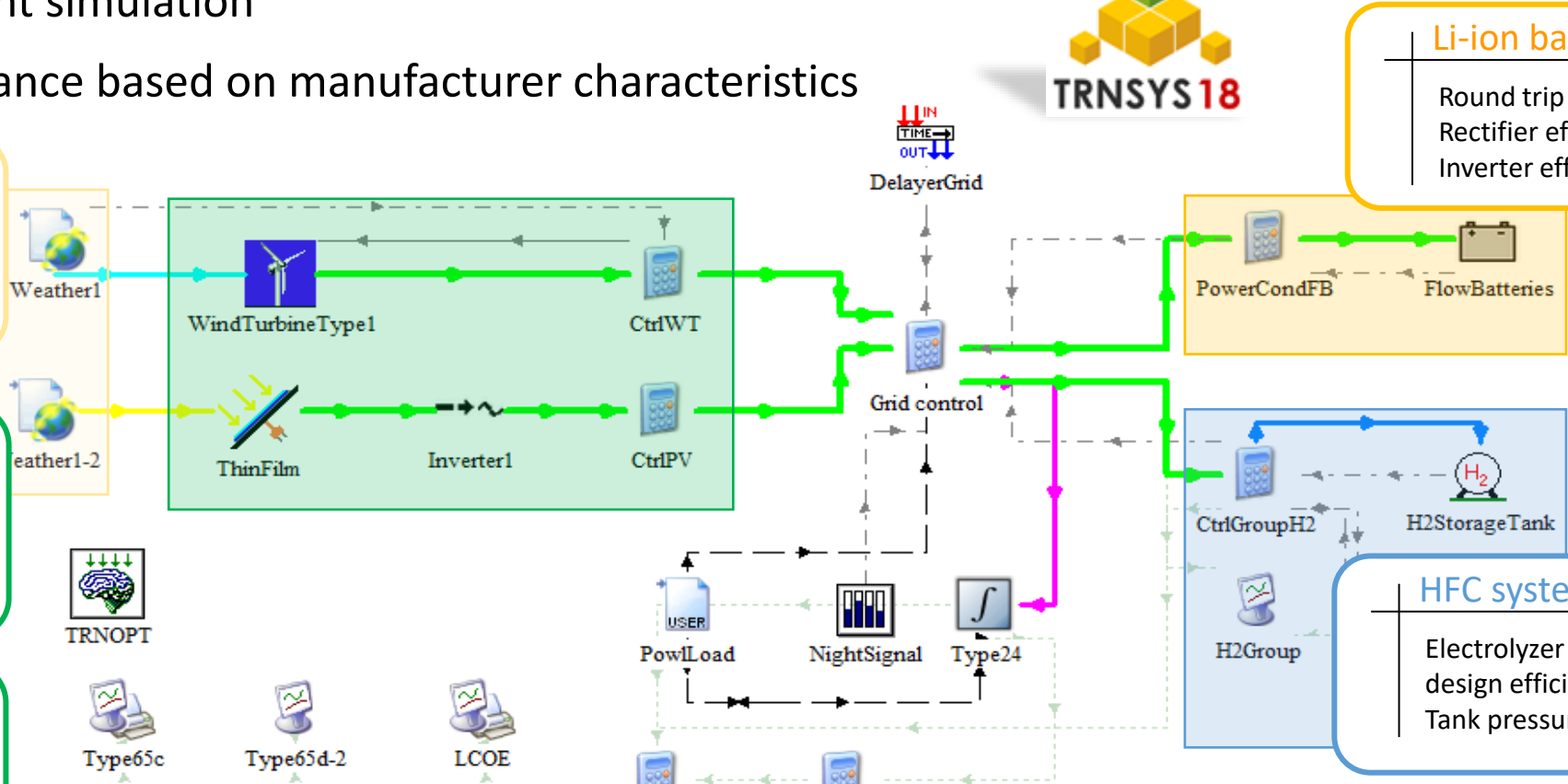
Solar radiation
 Ambient temperature
 Humidity

PV panels

Rated power 460W
 Module efficiency 18.3%
 Temperature derating -0.32%/°C

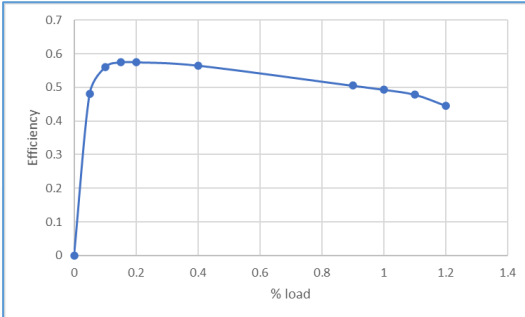
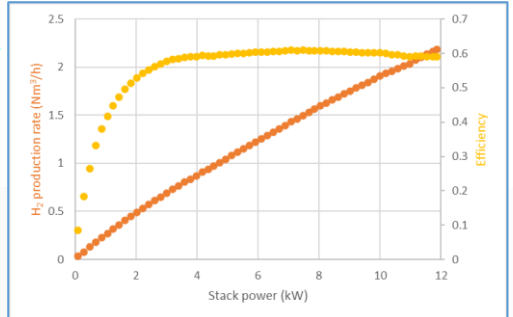
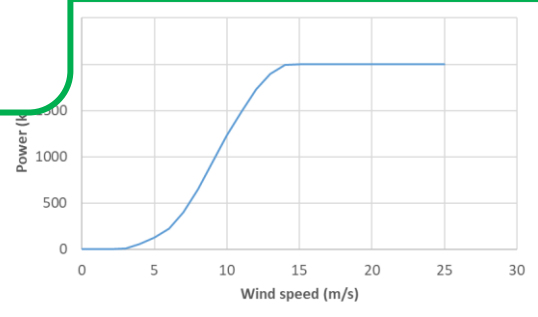
Wind Turbine

Single turbine rated power 2MW



HFC system

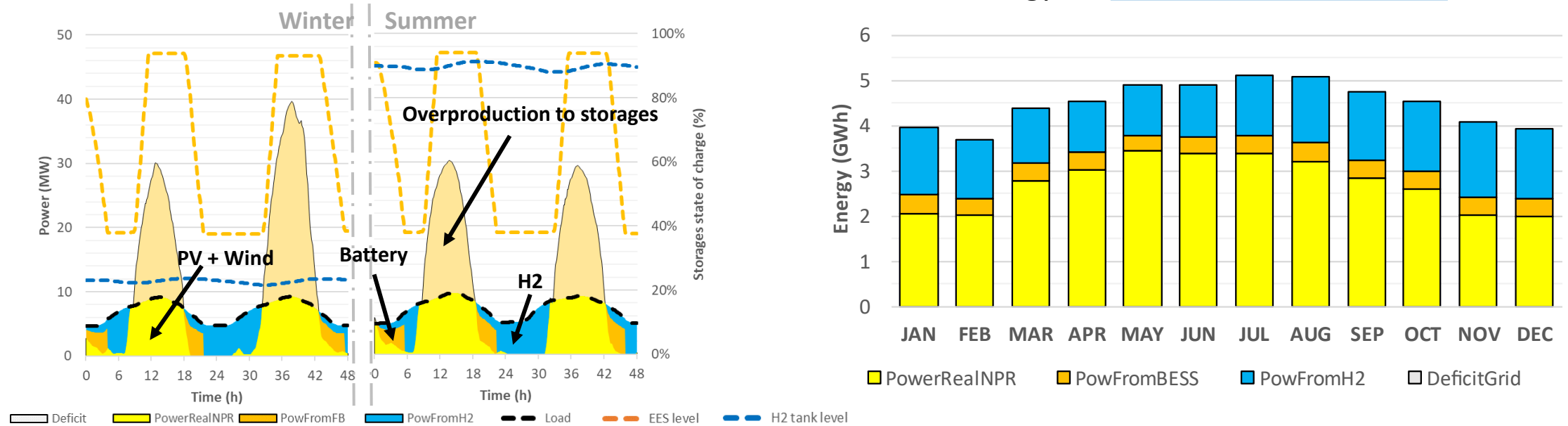
Electrolyzer and fuel cell off-design efficiency
 Tank pressure 450 bar



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1. Example of simulation results

Detailed contribution of each technology for [Renewable fraction 80%](#)



- Batteries operation during fuel cell load ramps;
- Seasonal level variation of hydrogen storage;
- Hydrogen responsible for meeting the demand overnight;
- **50% of the energy** produced by renewable is cumulated into hydrogen system;
- Hydrogen demonstrates a higher capacity to increase the **renewable penetration**.

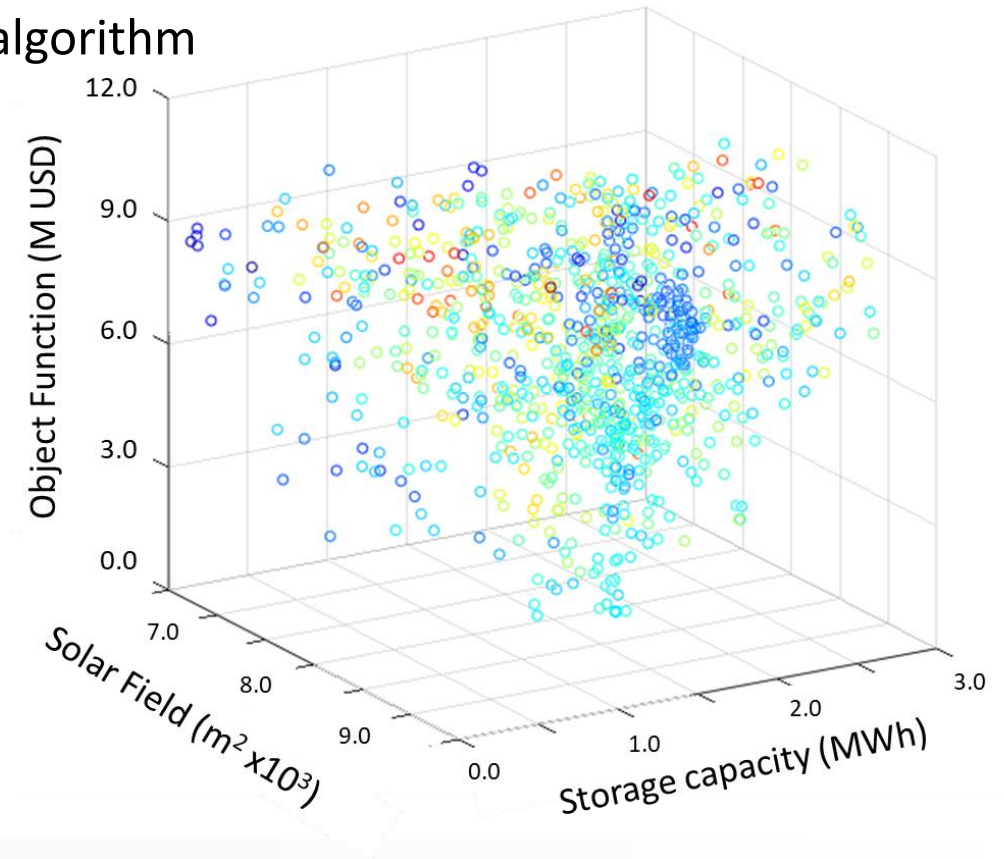
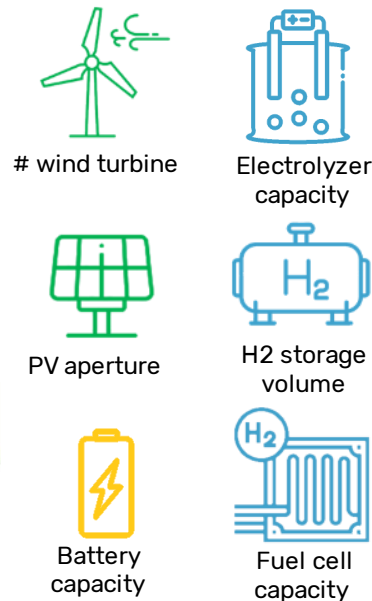
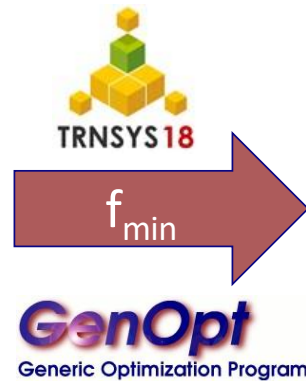
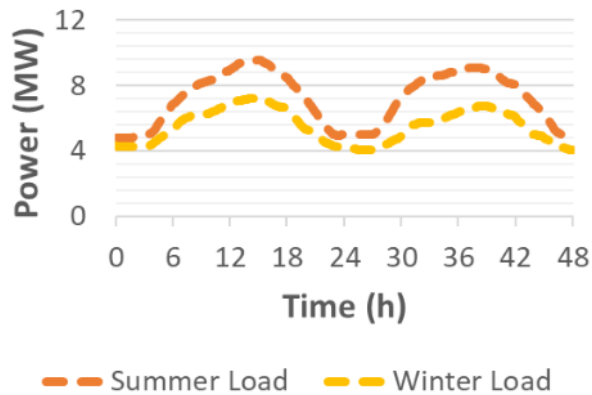
2. Optimization procedure

Multi variable Optimization based on annual simulation results

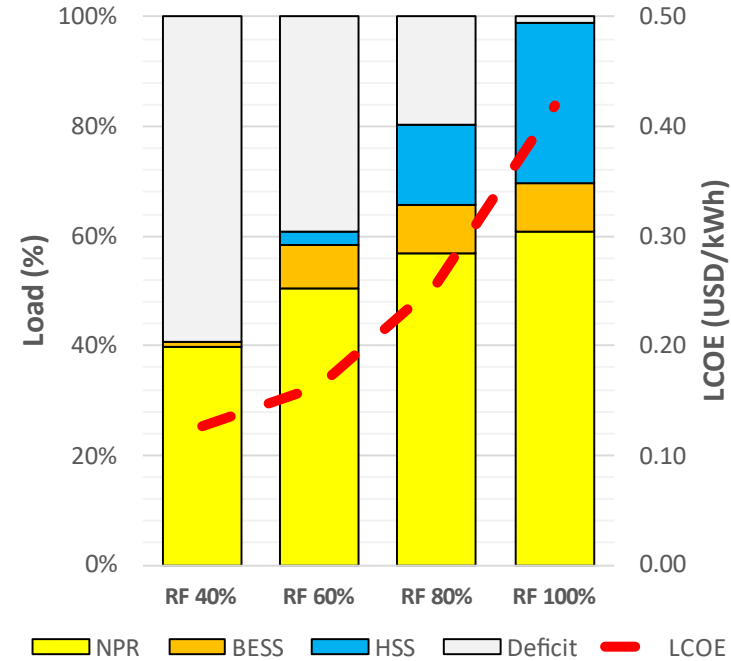
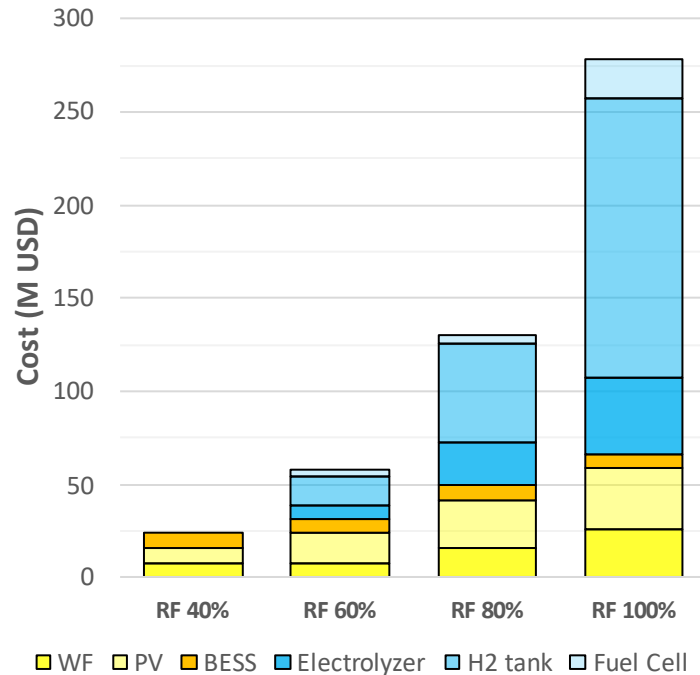
assuring an annual imposed renewable fraction and minimizing the LCOE/LCOH2

Two Step optimization procedure :

Particle Swarm algorithm coupled with the **Hooke and Jeeves** algorithm



2. Example of optimization results



- **Budget cost index** increases with **RF**:
 - **H2 tank** is the component with greater influence
 - Higher RF greater the economic clout of storage
- The **oversizing of generators** and storages to achieve **RF 100** is reflected into the global cost

- **LCOE** of generators increases with the **RF**
- Contribution of each technology to the achieved RF:
 - Direct contribution of renewable generation increase
 - RF 40 battery provides only 0.6% of the load



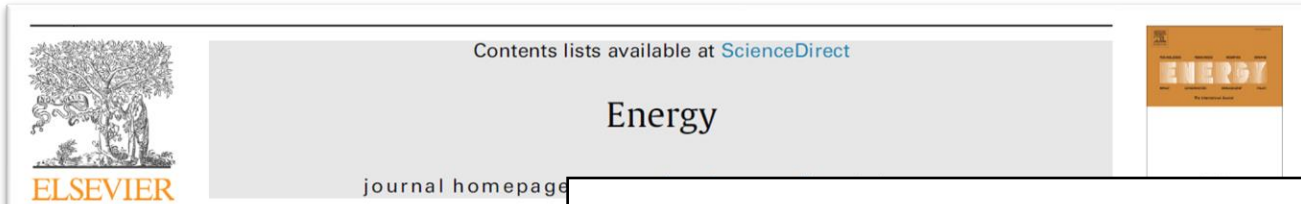
3. Computational fluid dynamics modeling

CFD simulations of filling and emptying of hydrogen tanks

- Conjugate heat transfer model (CHT) vs simplified strategies [$<$ CPU cost]
- Residual convergence criterion for RMS $10e-5$
- Redlich-Kwong equation of state
- Turbulence: K-w SST, K-w SST SAS , K- ϵ
- Buoyancy effect
- The material properties
- Whole 3D geometry and only half of the geometry were performed.



Publications



Techno-economic optimization of H₂ renewables community case study

Giovanni Brumana*, Giuseppe Franchini, Elisa Ghirardi
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H₂ Contribution to Power Grid Stability in High Renewable Penetration Scenarios

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Experimental and numerical investigation on the sealing capability of a high pressure, dry running, hydrogen reciprocating compressor



Experimental and numerical investigation on the sealing capability of a high pressure, dry running, hydrogen reciprocating compressor



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H₂ contribution to power grid stability in high renewable penetration scenarios

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