FROM RESEARCH TO INDUSTRY

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New Energy World JU

fuel cells & hydrogen for sustainability

HYBRID PEMFC SYSTEM EXPERIMENTATION IN THE SAILBOAT ZERO CO_2

Fuel Cells and Hydrogen for Maritime and Harbour Applications

FCH Workshop, Venice, June 14th, 2013

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liten

OUTLINE

- Objectives
- System specification
- System overview
- Experimental feedback
  - Homologation process
  - Technical Assessment
  - Public acceptance
- Conclusions and future activities

General objectives (1/2)

- **Demonstrate the efficiency of combined clean energies** that power a commercial RM 1200 in place of petrol
- **raise awareness of climatic change, pollution and the importance of alternative energies** to the Mediterranean population and professional / amateur sailors
- **promote a culture based on respecting maritime environments** through the adoption of self-sustainable energies in harbors and coastal areas in place of traditional fossil fuels
- **analyse data obtained from the air**, sea and port sediments using the boats integrated onboard laboratory in order to evaluate pollution from the sea and coastline, especially pollution originating from fossil fuels

General objectives (2/2)

Why a sailboat?

- Sailing in Europe:

About

  - 1.4 yachting boats per 100 inhabitants in Italy
  - 0.3 in Spain
  - 2.2 in France

- Sailing in France: a dynamic market

  - Maritime territory: 11 million km² (20 times France area; 2nd after USA)
  - Estimation of 4 million sailors
  - 20 000 new boats registered every year
  - Boat fleet (sailboats 30% and yachts 70%) about 800 000 units
  - France is the 1st boat constructor in Europe and 2nd in the world
  - Market increase mainly through exports
  - 5,500 companies and 44,000 jobs involved in the nautical area for a turnover of € 4 billion *(source FIN -2006*)

System specification : Why a sailboat?

Electrification of a commercial RM 12m sailboat

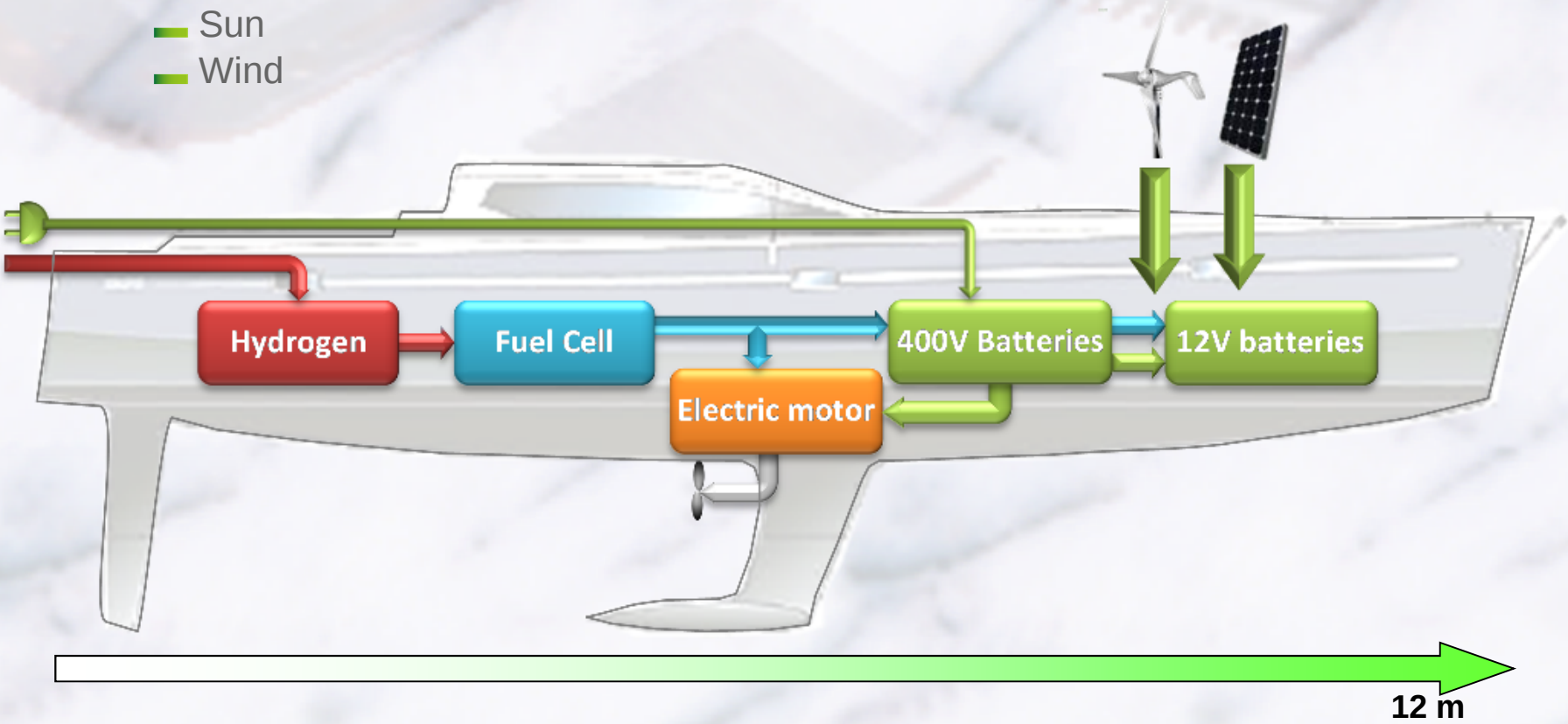
- Keeping the sailing comfort
  - Sailing category authorisation
  - Berthes for 8 people
  - Cogeneration for sanitary water
- Typical sailing cycle
  - Sailing ship propulsion (mandatory)
  - During harbour operations
  - Extra contribution during windless navigations
- Needs
  - Replace the internal combustion engine: 23 to 30 kW
  - Supply on-board ancillaries: (< 10 kW)
  - Autonomy: 5 hours

  (1 hour daily cycle at maximum power)
- System architecture choice
  - Hybrid system
    - Battery propulsion for short cycles or in default case (1 hour autonomy at full power)
  - On board compressed Hydrogen storage at 35 MPa
    - Best compromise between storage space, autonomy and cylinders availability

GENERAL OVERVIEW (1/2): GLOBAL STRATEGY

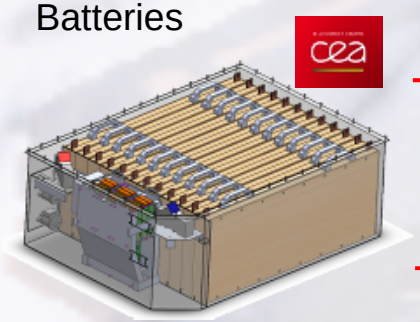
"Zero CO2" is a Plug-In Hybrid Electric Sailboat

- Energy sources
  - Hydrogen
  - Grid
  - Sun
  - Wind
- Energy converters
  - PEM Fuel Cell system
  - Li-ion Batteries

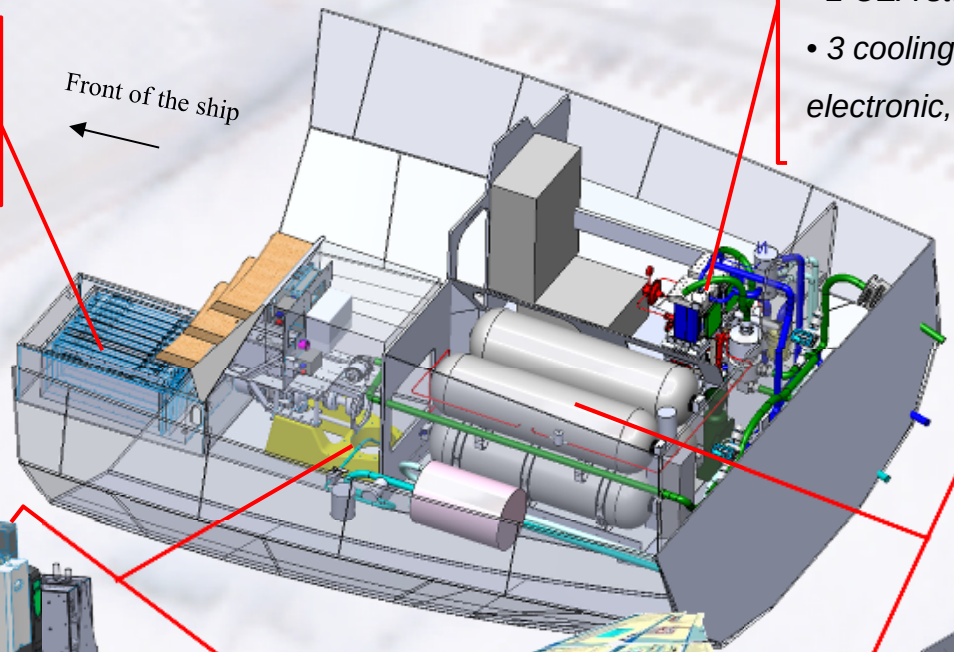


GENERAL OVERVIEW (2/2)

Batteries

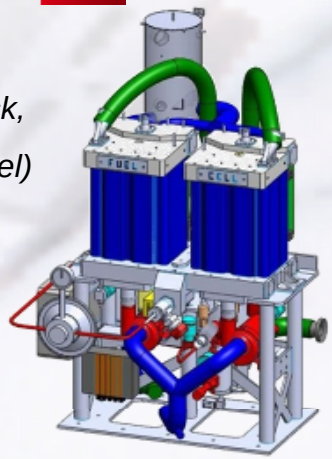


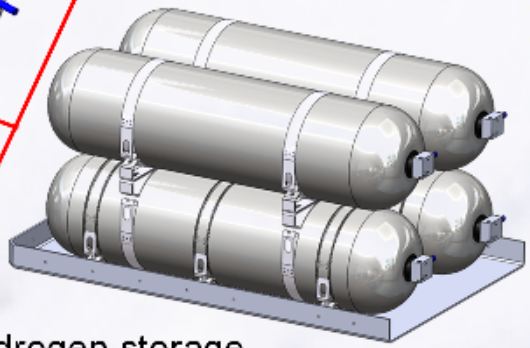
- *CEA design*
- *$LiFePO_4$*
- *40 Ah and 400 V*
- *Energy storage: 14.8 kWh*



Fuel cell system

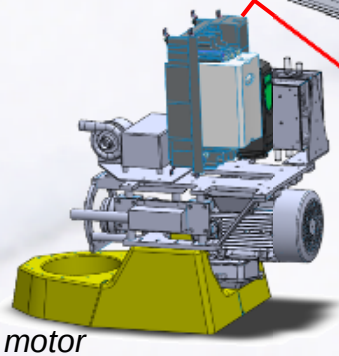
- *CEA design (25 kW)*
- *2 CEA stacks*
- *3 cooling loops (stack, electronic, water vessel)*





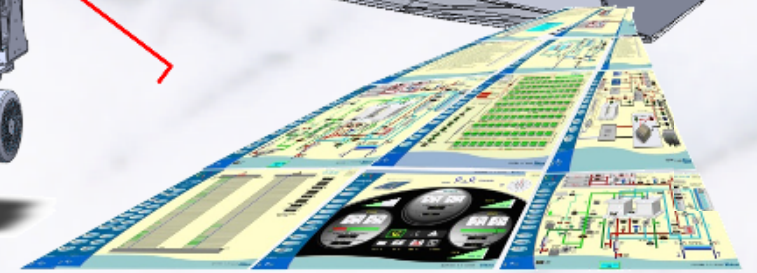
Hydrogen storage

- *4 cylinders of 150 L, Type III*
- *Service pressure: 35 MPa*
- *Hydrogen mass stored: 14 kg*
- *Total energy stored (LHV): 500 kWh*



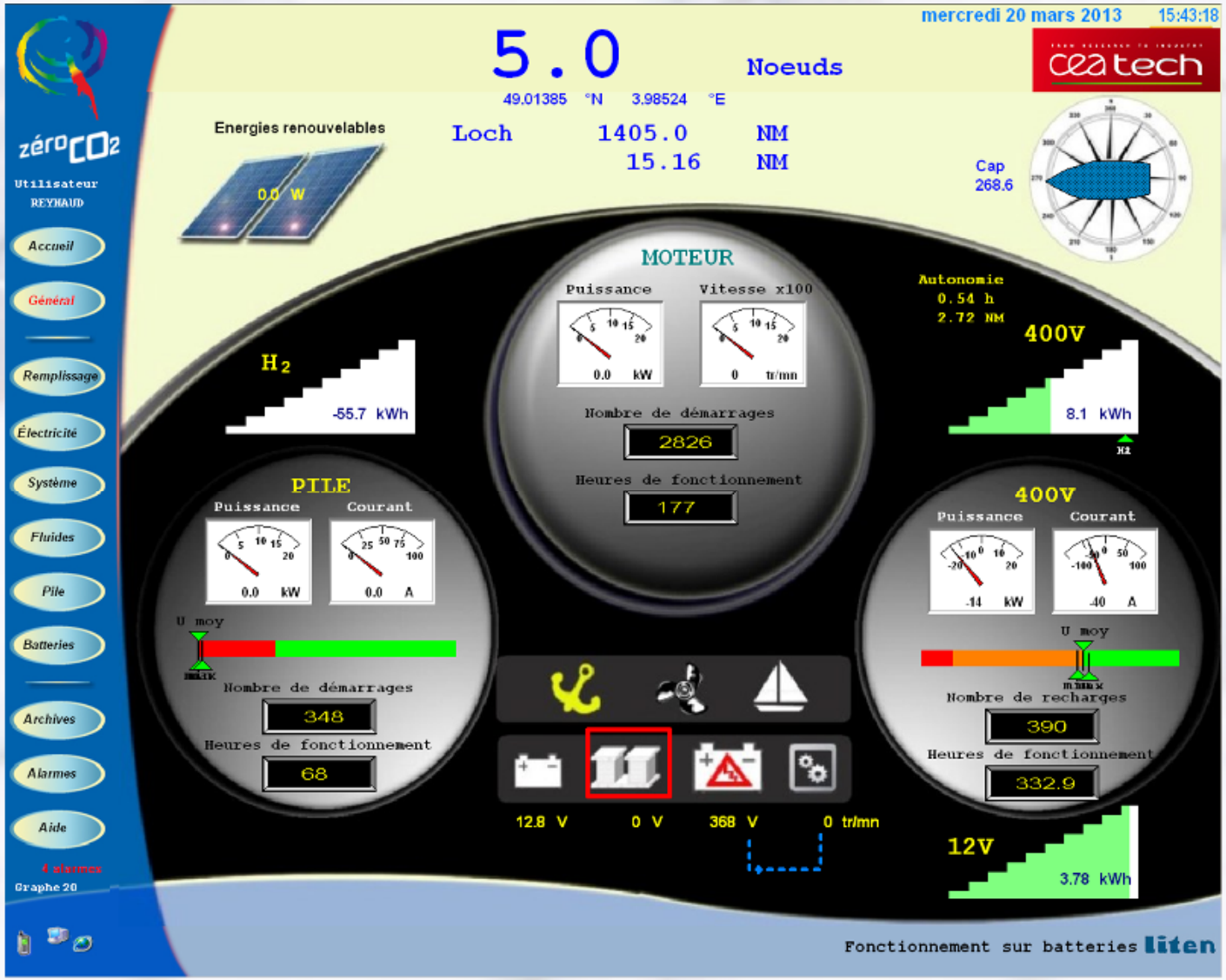
Motor

- *Synchron motor*
- *Permanent magnets*
- *23 kW (1800 r/min – 110 N.m)*
- *Frequency variator*



835 sensors | **550 safety thresholds** | **Monitoring**

SYSTEM OVERVIEW: CONTROL/HANDLING (1/3)



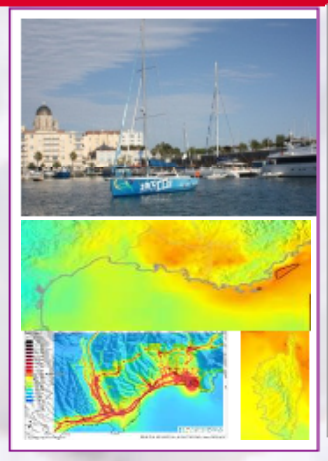
SYSTEM OVERVIEW: CONTROL/HANDLING (3/3)

Not needed to be a FC specialist, just a good sailor!

Engine control

Start key - Batteries/FC buttons

EXPERIMENTAL FEEDBACK: KEY DATES



June – August 2011 / 2012 ... 2013

November 10

July-
September 10

April 09

zéroCO2
Alternative énergétique

June 10

April 10

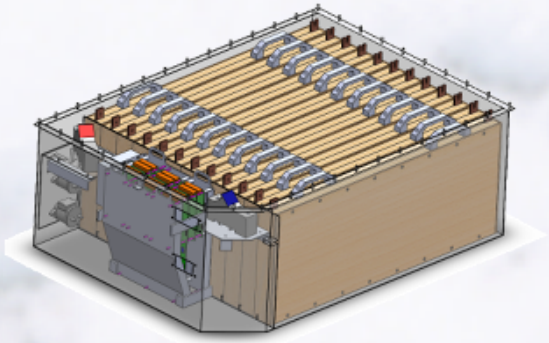
December 09

September 09

HYBRIDIZATION (1/2)

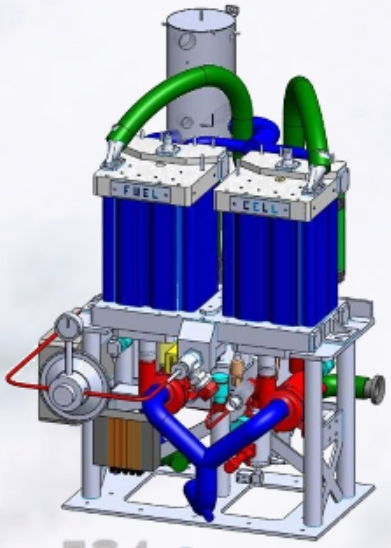
Focus on batteries

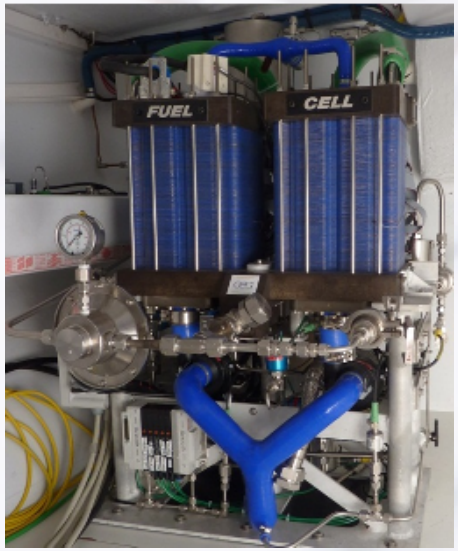
- Main functions:
  - Ensure power transients
    - Avoid delays some auxiliaries (eg air compressor)
    - Limit damage to the battery
  - Increase efficiency at low power
    - Power the motor for less than 5 kW (compare to auxiliaries power)
    - Limit cycling on / off battery
- Characteristics:
  - Lithium Iron Phosphate batteries
  - 14,8 kWh (Energy densities: 100Wh/L – 77Wh/kg)

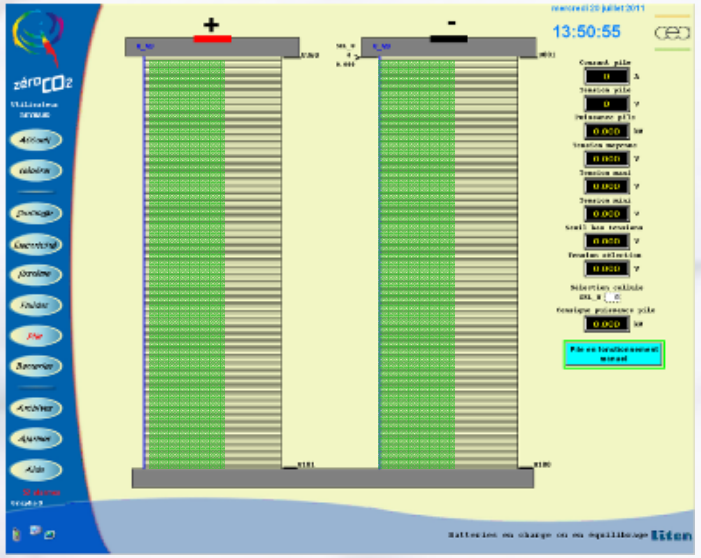


EXPERIMENTAL FEEDBACK: TECHNICAL ASSESSMENT (1)

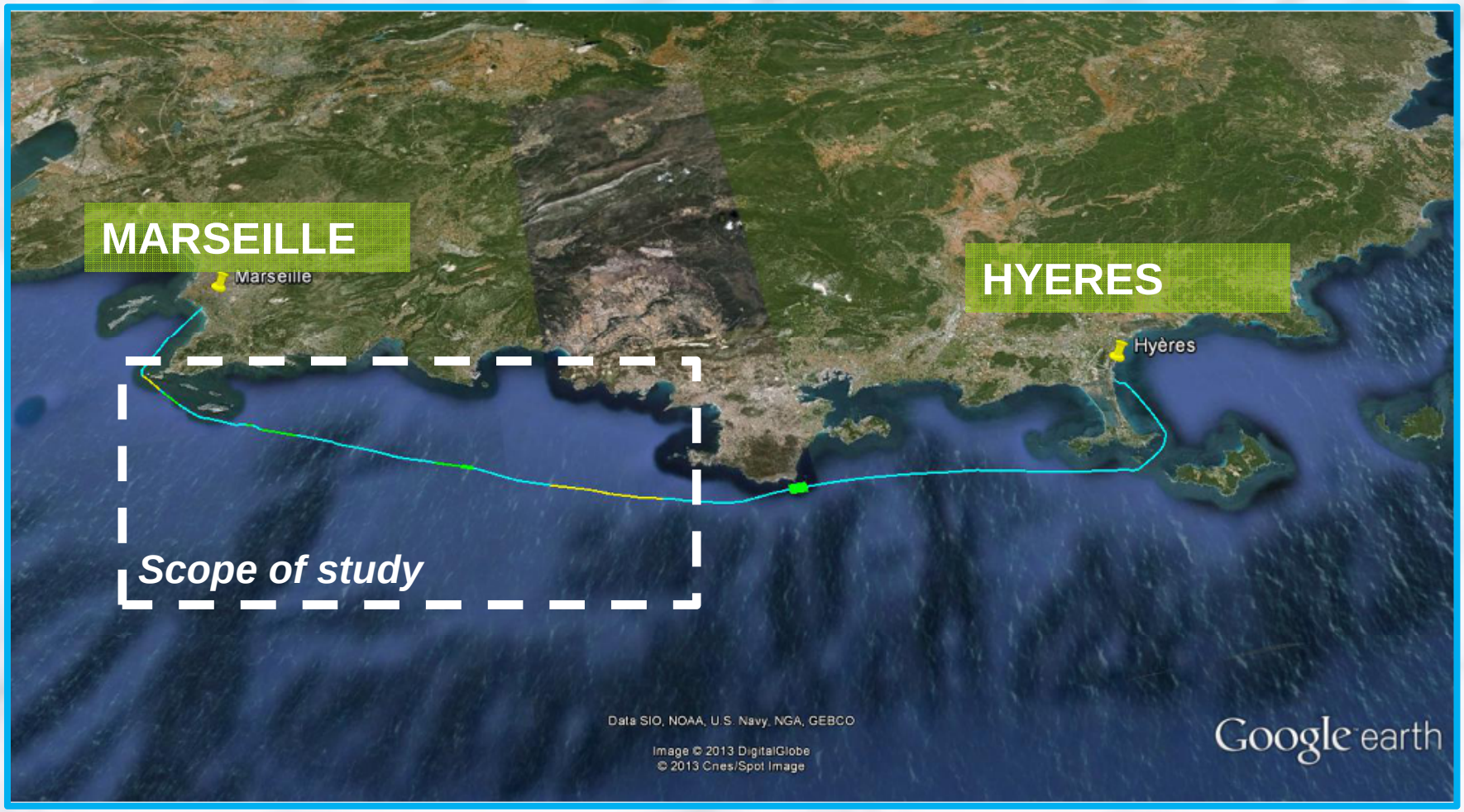
- Characteristics:
  - Maximum power 30 kW (density power: 0,5kW/L – 0,8kW/kg)
  - « Dead End » mode
  - Technology: GENEPAC
  - Architecture: 2 stacks of 180 cellules in serial



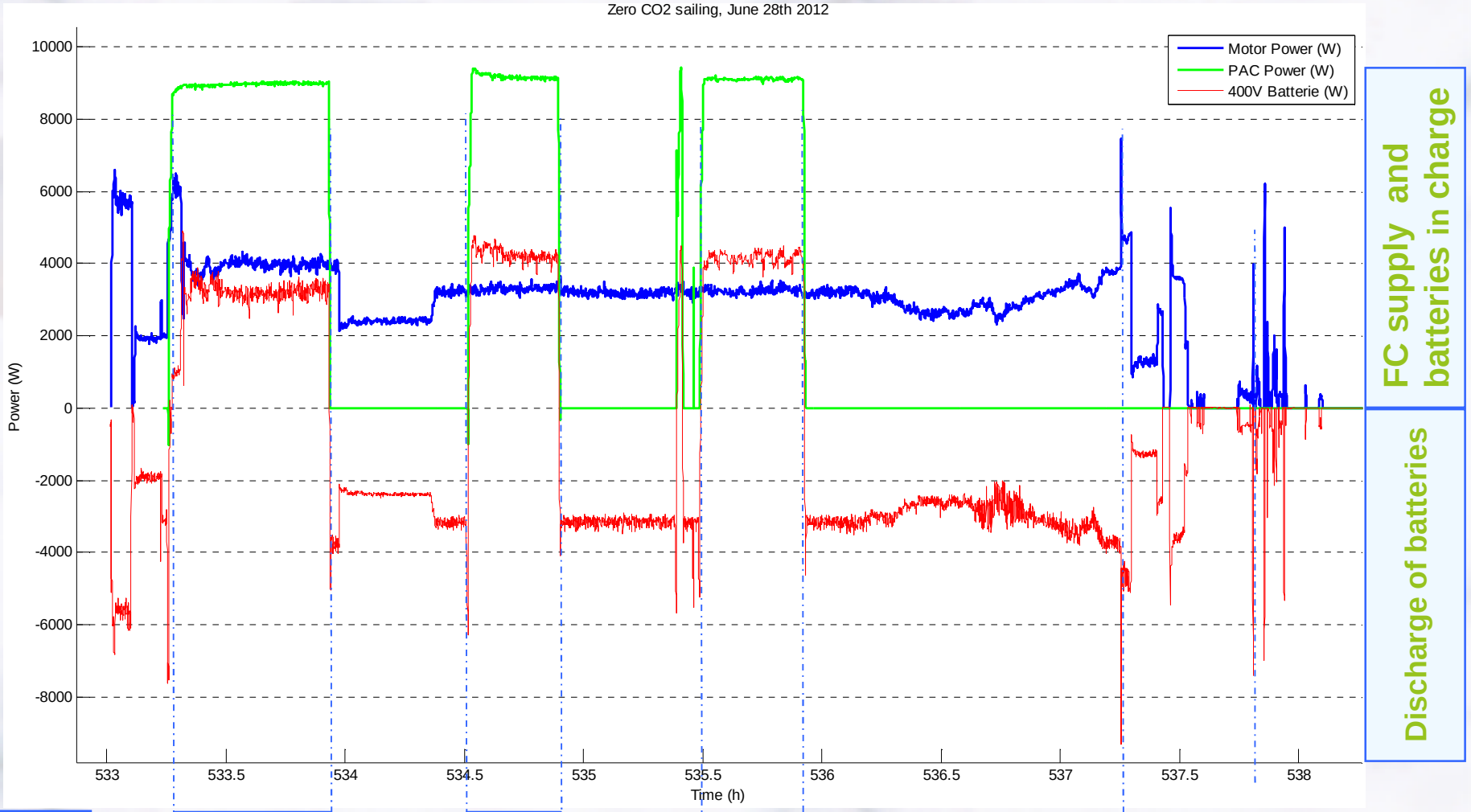




EXPERIMENTAL FEEDBACK: TECHNICAL ASSESSMENT (3)

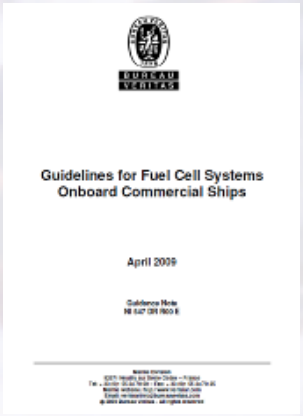


EXPERIMENTAL FEEDBACK: TECHNICAL ASSESSMENT (4)



EXPERIMENTAL FEEDBACK: TECHNICAL ASSESSMENT (2)

Registration of the sailboat



safety document

Insurance of the sailboat

- not a usual case in France
- many meetings and discussions
- visit on board

CONCLUSION AND FUTURE WORK

Zero CO_2: a demonstration model and an experimental platform

- **Fuel Cells can be part of the electric power train of boats** in maritime or inland water environments (roll, pitch, saline conditions…)
- "Zero CO2" sailboat allows to:
  - **optimizing the on board sailing ship energy**
    - Specify the real « on-board facilities » needs
    - Characterize the renewable energies coupling
    - Specify the real needs for propulsion energy
  - **getting an experimental hybrid system feedback**
    - Develop new hybrid strategies
    - Life time system feedback
  - being an actor in standards & regulation and education
  - following up environmental analysis
  - Atmospheric analysis along Mediterranean coast
- **Extend to local "green" Hydrogen production and refilling stations**
- **Open to any other proposals or collaborations!**

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THANK YOU
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