Hydrogen Technology for Integration of Renewables

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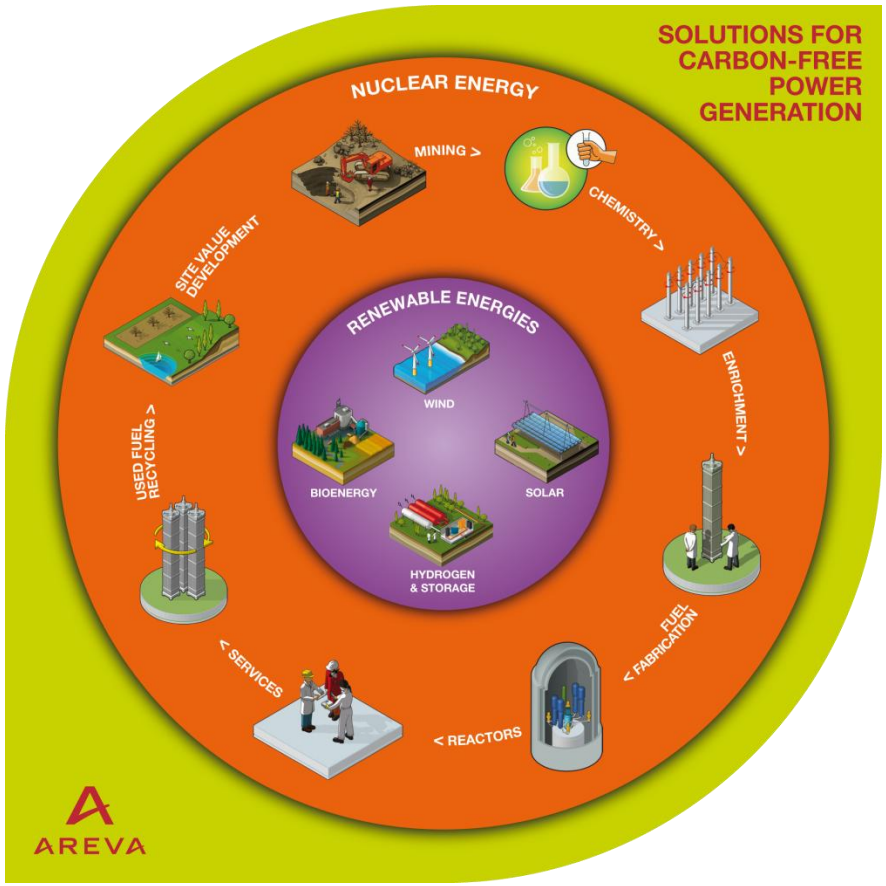
AREVA RENEWABLES

Outline

- **Introduction to AREVA and HELION**
- **The Green Energy Box - *The all in a box hydrogen Solution***
- **French Islands – *A case study for hydrogen storage***
- **Large scale integration of PV with H_2 storage - *A reality in MYRTE Platform***
- **Summary/Recommendations**

Introduction to HELION
The H_2 subsidiary of AREVA

HELION Hydrogen Power
an AREVA subsidiary



- ***Dedicated to hydrogen and energy storage***
  - ***Design, development and manufacturing of PEM H_2 / O_2 fuel cell and electrolyzer systems, producing hydrogen by water electrolysis and electricity with fuel cells***
  - ***Safe, reliable, clean and economical energy solutions for backup power and energy management applications in a power range from 5 kW*** *to 2 MW*

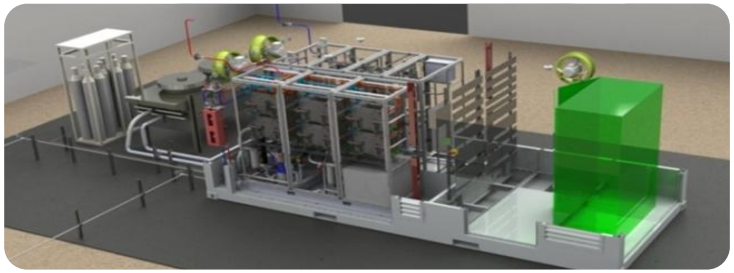
Creation	***March, 2001***
Headquarter	***Aix en Provence, France***
Headcount	***60 employees (75% as engineers)***
Shareholder	***100 % AREVA Renewables***
Certification	***ICPE – ISO 9001 – ISO 14001*** ***On the way to OHSAS 18001 certification***

The Green Energy Box

The all in a box hydrogen Solution

greenergy box, the *"all-in-a-box"* Energy Storage & Management System for decentralized applications

Greenergy Box: a solution for energy management and backup power without gas logistics



- ***Discharge power range:*** *20 to 100 kW*
  Scalable up 5 systems in parallel
- ***Gas storage:*** *Adjustable to customer needs*
- ***Footprint:*** *14,6 m^2 /160sf (excluding gas storage)*
- ***Weight:*** *~6t/13,227lbs (excluding gas storage)*
- ***Operating temperature:*** *-30°C to + 50°C / -22°F to 122°F*
- ***Voltage interface:*** *400 V 3-phase + N / 50 Hz*
  Other voltages and DC option also available

- ***Easy to install and low maintenance (No rotating components)***
- ***Quiet and clean solution, no greenhouse gas emission, no vibration***
- ***Outdoor installation***
- ***Safe and reliable system*** CE
- ***Rapid startup and islanding mode***
- ***Long term storage capacity***

The HELION innovative solution to support Renewable integration and grid stabilization

CHARGE MODE

STANDBY MODE

DISCHARGE MODE

Electric Grid

Intermittent Renewables

Fuel production

Hydrogen (H_2) and Oxygen (O_2) storage

electricity

heat / cool

Electric Grid

Users

Industries

Villages/cities

Green cities

GB CHARGE

GB DISCHARGE

Main technical characteristics

- Built in **modular** system
- **Power: 20 to 100 kW** / module
- **Autonomy: adjustable to customer needs,** only limited by gas storage
- Potential **use** of **generated heat**
- **Higher lifetime and reliability thanks to HELION's proprietary air-independent technology**

Applications

Grid stabilization and backup

Solar or wind farm management

Remote sites

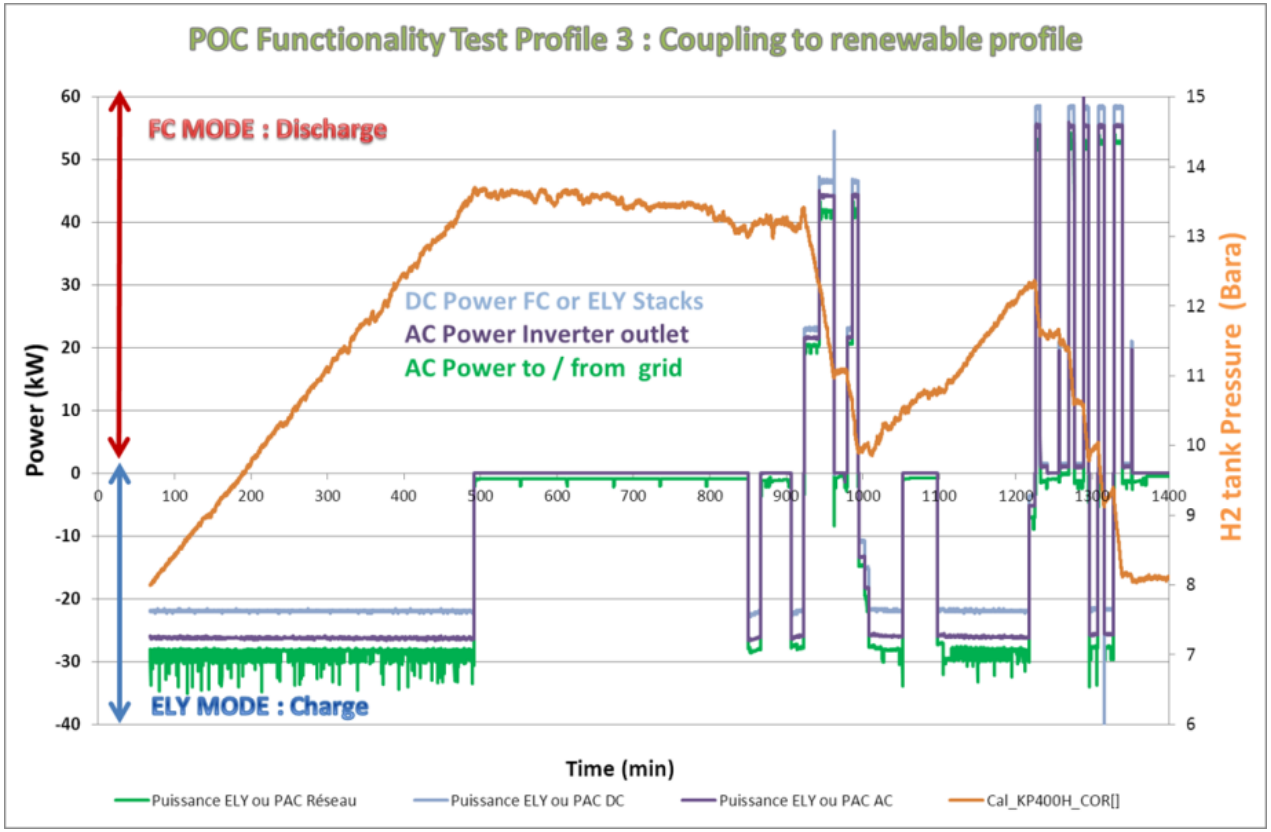
Micro-grid management

Greenergy Box Concept Proven in 2011

- ***GEB concept validation through functionality, performance, and reliability tests for different configurations***

- ***First tests dedicated to the GEB concept functionality in a grid connected configuration passed on June 22nd***

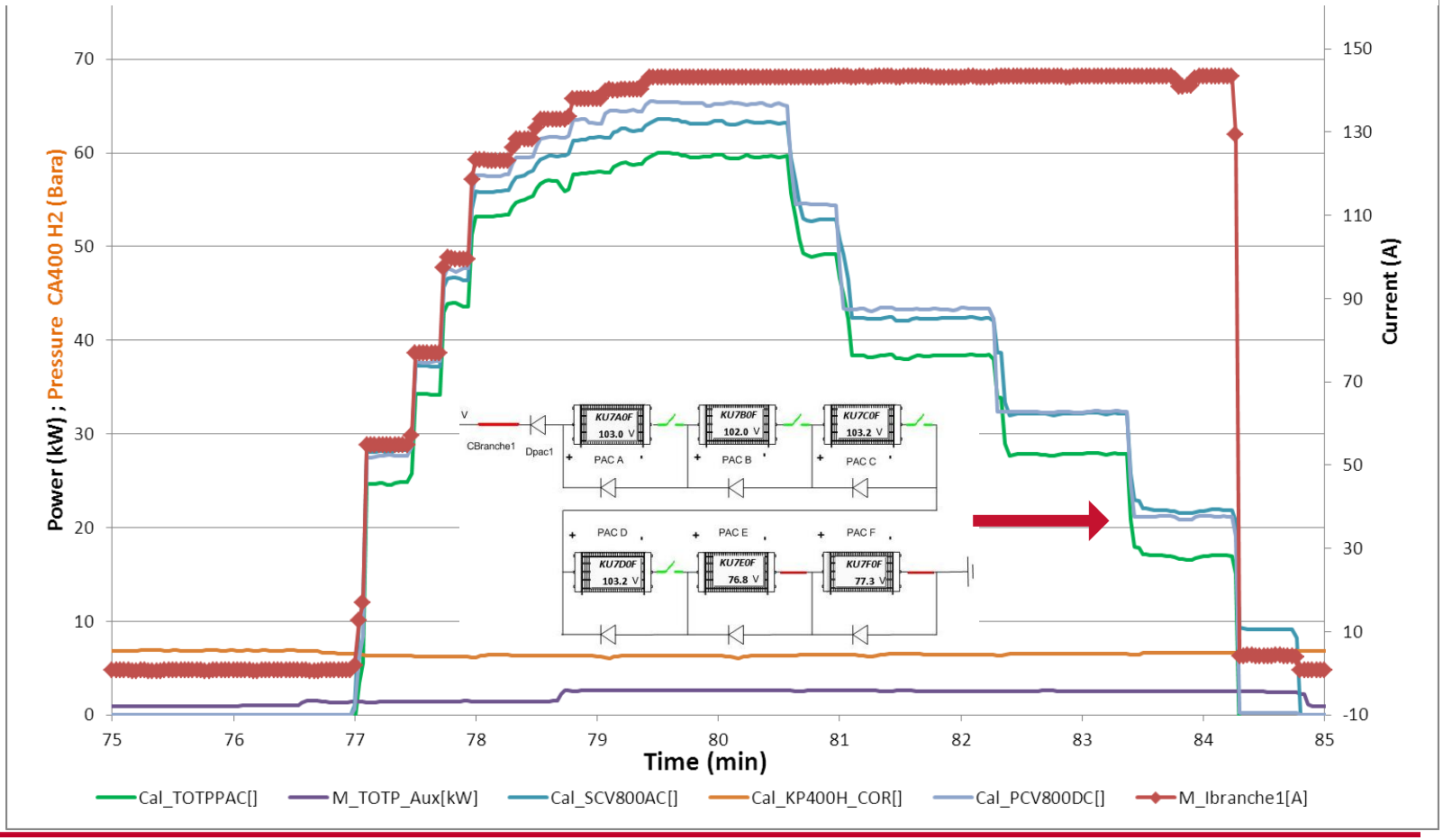
Renewable energies coupling tests



- ***Next steps***
  - ***From late 2011 on to late 2012: long-term testing***

Greenergy Box Concept Proven
Partial Load Service demonstrated

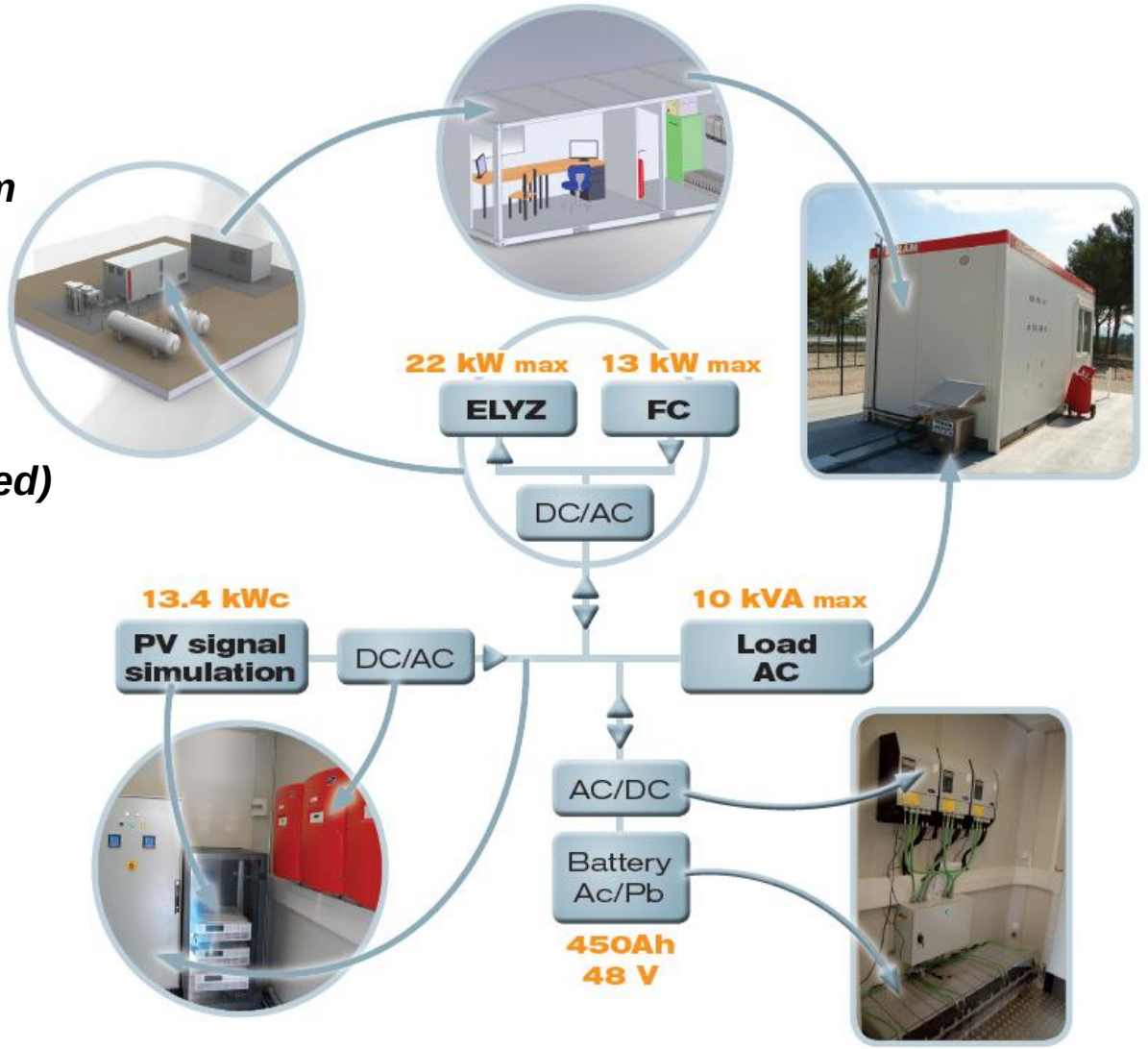
- ***In case of module failure, the system continues to operate with the remaining modules: while operating in degraded mode, performance is reduced but power is ensured to the load***



Qualified for MicroGrid Management

The Experimental Layout

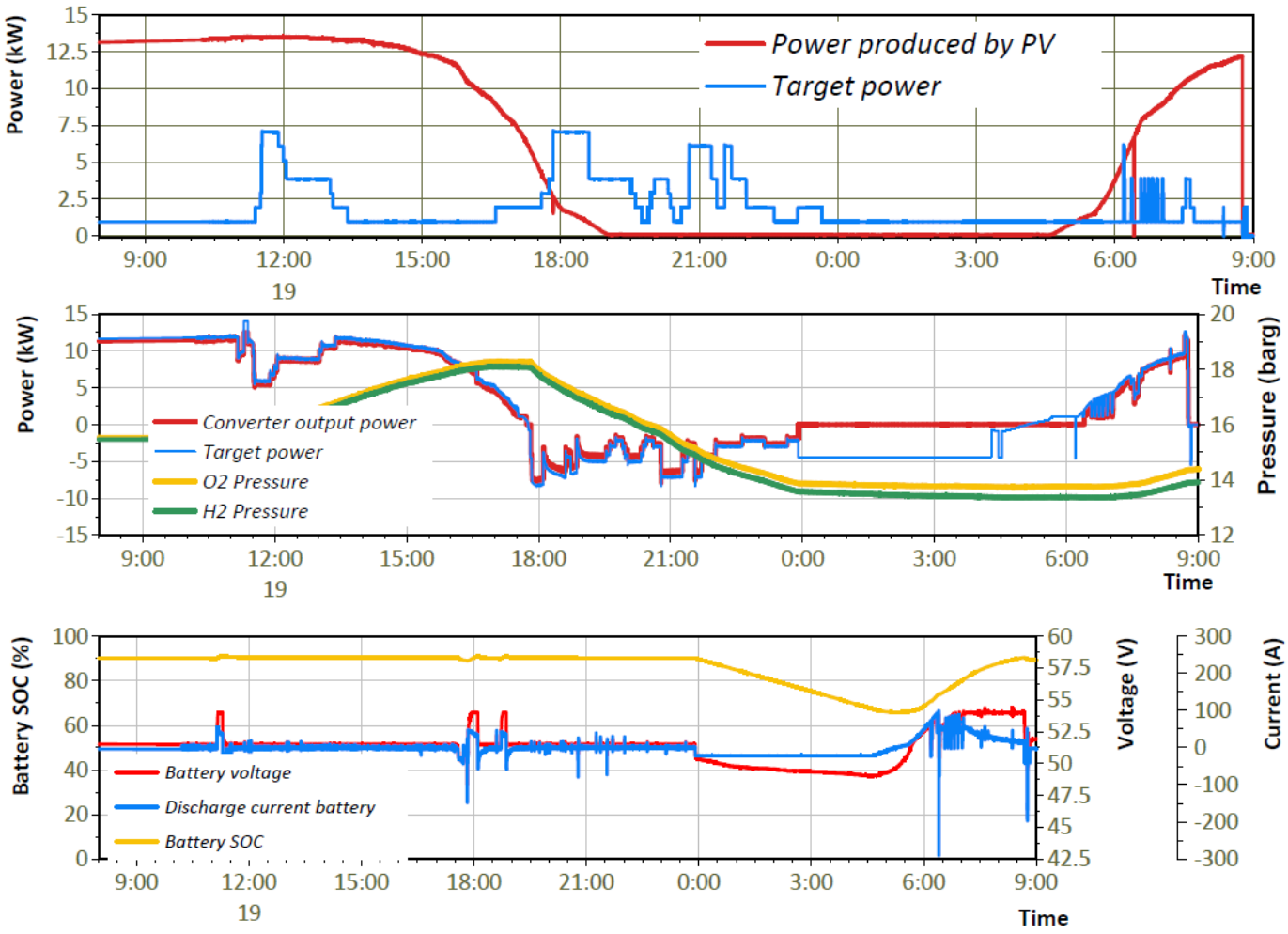
- ***3-component system***
  - ***PV (simulated)***
  - ***Battery***
  - ***Greenergy Box***
- ***10kVA load (simulated)***
- ***Monitor***
  - ***PV output***
  - ***Delivered load***
  - ***Battery current, voltage, SOC***
  - ***Gas pressure***



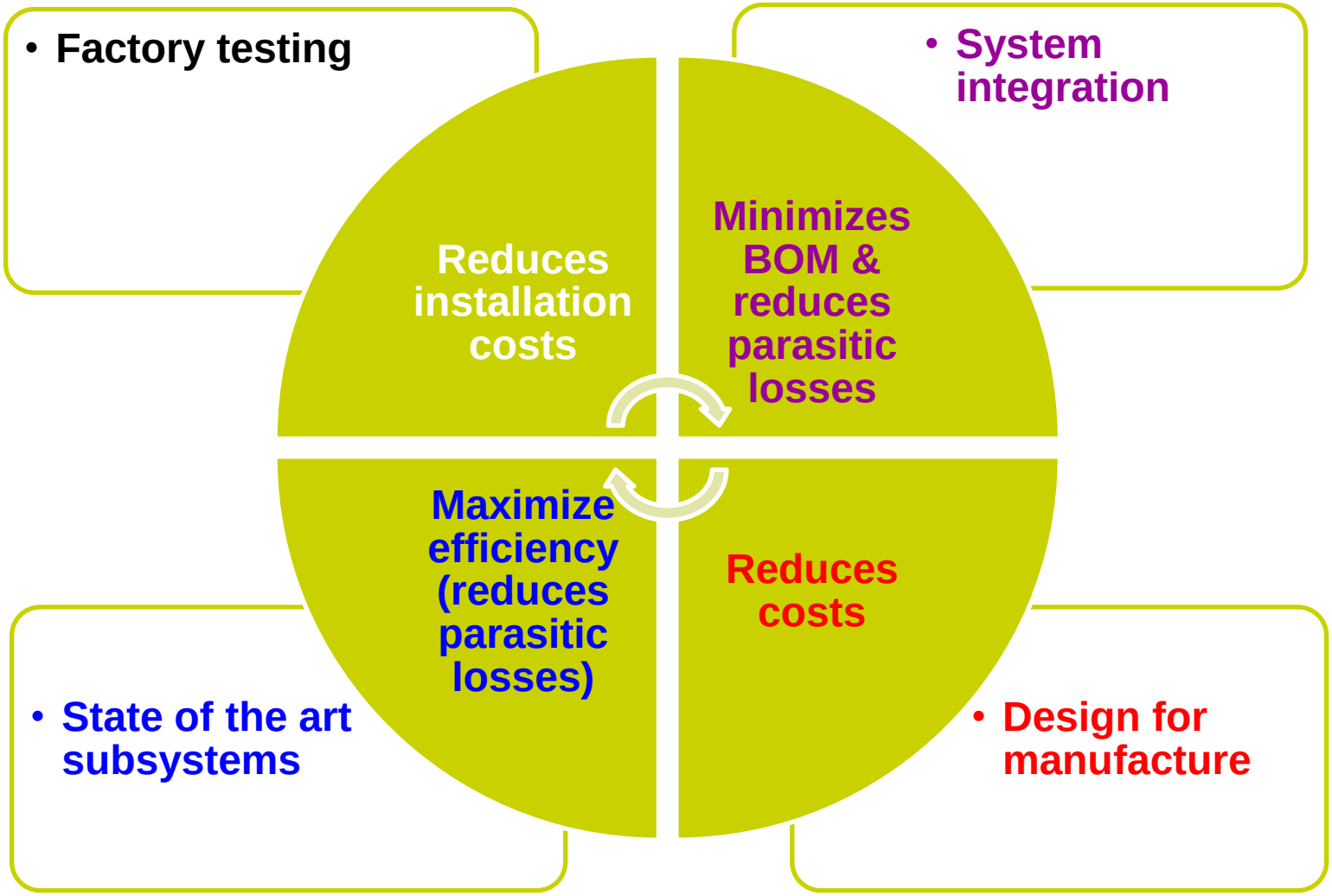
Greenergy Box Concept Proven

Microgrid Capability Demonstrated

Tests dated July 19 & 20, 2011



greenergy box optimises the economics of H_2 systems for integration of renewables



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French Islands

A model for hydrogen storage

Islands have a unique driver:
to meet the demand for electricity while reducing their dependence on fossil fuels

An increasing level of imported fossil fuels

Strong drivers for increased production

- Population growth
- Increase demand
- Saturated natural resources (hydropower) or seasonal fluctuations (biomass)

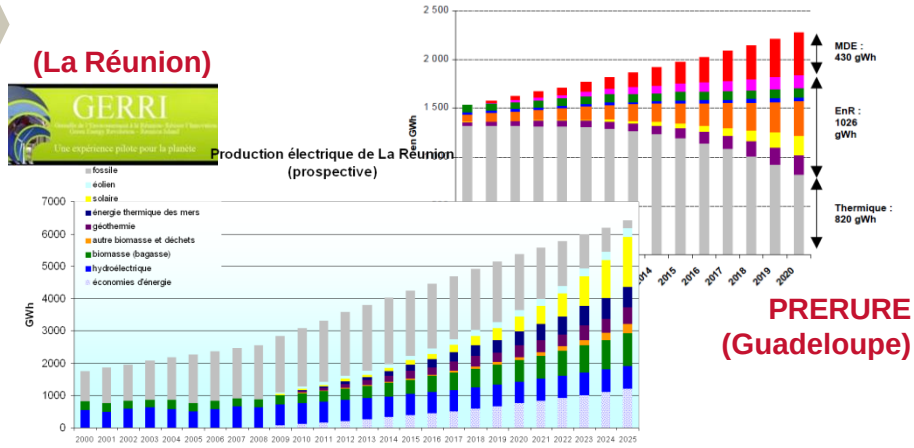
Inherent energy vulnerability

92%	Average energy dependence compared with 49% on continent
760 tCO_2/MWh	Carbon footprint of electricity generation compared with 90 tCO_2/MWh on continent
22%	Average unemployment rate compared with 9% on continent

All Islands have ambitious energy plans

> ***To make overseas territories energy independent within 20 years***
> *(Etats Généraux de l'Outre-Mer, résolution III-3, 2009)*

(La Réunion)



PRERURE (Guadeloupe)

- **Towards new resources that are**
  - **Non-polluting; and**
  - **Plentiful and affordable on islands**

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The challenges for renewables on islands

High level of imported fossil fuels
Social and economic risks

- *Sensitivity to severe weather*
- *Risk for the development of tourism*
- *Local economy is sensitive to the volatile costs of imported materials*

2008 Guyana
2009 Guadeloupe
2012 La Réunion

The challenge of integrating renewables on islands

- **Imbalance between generation and demand**
  - Intermittency (wind)
  - Difficulty in regulating or controlling their production (geothermal)
  - Lack of coincidence between peak production and peak load (solar)
  - Still not economically viable I (marine energy)

Integration of renewables has an upper limit

Above a certain threshold, the network manager is unable to manage the instability generated by intermittent renewables

- **Island grids cannot benefit from regional balancing between neighboring grids or networks**
  - **Thermal power plants** are used to balance production and stabilize the grid
  - Certain customers have **emergency diesel generators** to mitigate possible grid failure

Storage has a pivotal role

- **Provide power reserves**
  - **Realistically, this must be approx. 10 to 15% of nameplate capacity**
  - **Sited (located) near renewable generation assets (to minimise losses)**

» **Small, decentralized units from100kW to 2-3 MW**

- **Provide energy reserves**
  - **On the order of 1% of annual production *(e.g., . La Réunion : 35 to 40 GWh)***
  - **Stable storage for long periods (hurricanes, seasonal)**
  - **Transportable fuel for clean vehicles**

» **Long term chemical storage**

- **Low environmental impact**

Energy storage is both a solution to real problems and an opportunity for the sustainable development of islands

But not all technologies meet the particular needs of islands

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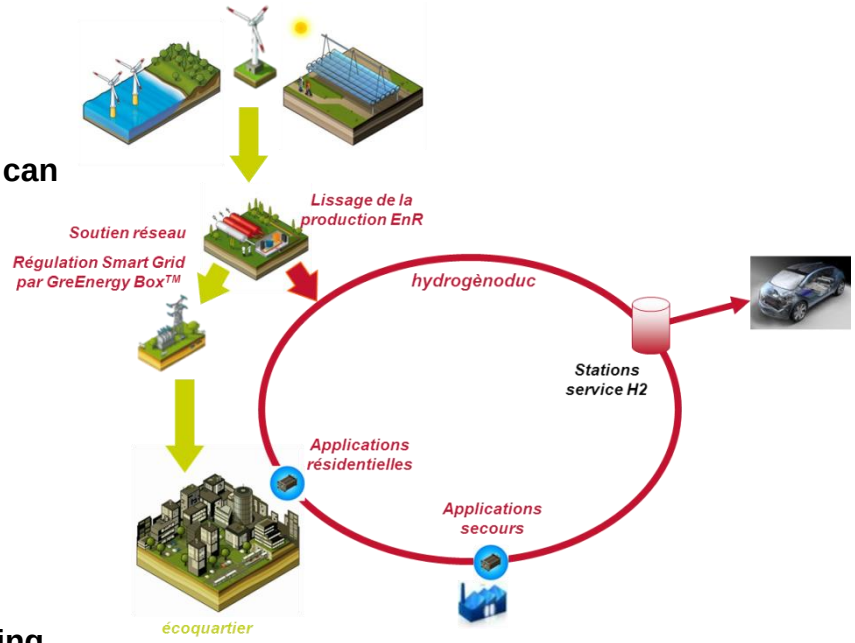
Hydrogen
A unique storage technology for islands

- **Consider the evolution of the grid and transportation networks simultaneously**
  - An energy storage system would have greater value if it can contribute to both
- **Produce and store hydrogen locally**
  - Easily transportable to the center of an island
  - For use in vehicles
  - Spread investments over both vehicle and grid infrastructures
- **Allow ports to focus on commerce and development of tourism**
  - Reduce the amount of port resources needed for importing hydrocarbons
  - Reduce the inherent risks of transporting hydrocarbons
  - Reduce the risk of spills from tankers
- **Energy storage systems that preserve the fragile environment of islands**
  - Neither hydrogen nor oxygen harm the environment



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Large scale integration of PV with H_2 storage A reality

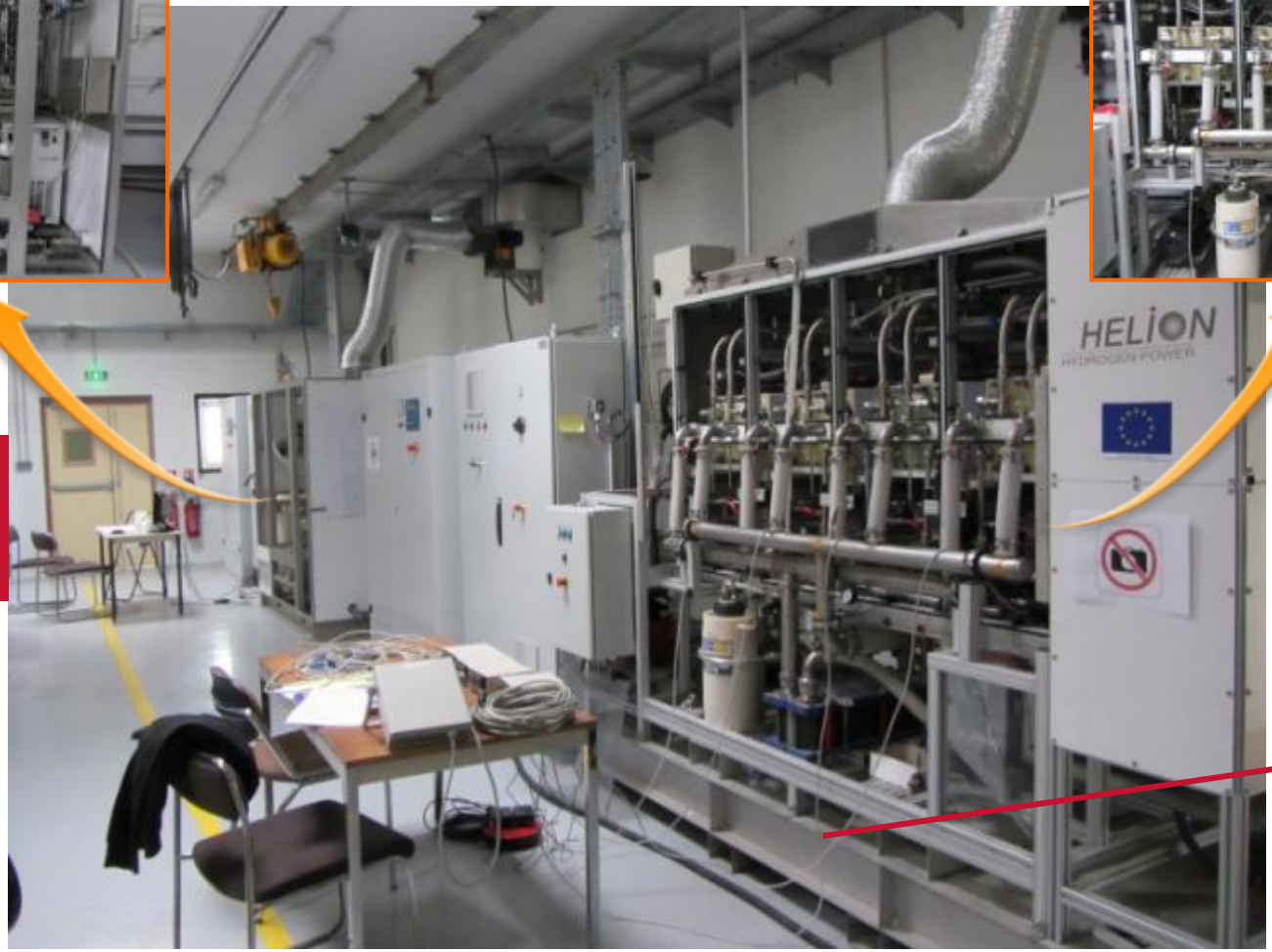
Island of Corsica - MYRTE Platform

MYRTE
General view

MYRTE
Hydrogen center

► *Electrolyser*
10 Nm^3/h H_2

► *FC*
100kVA



Phase 1: 100 kW / 1,75 MWh
Phase 2: 200 kW / 3,5 MWh

Water storage: Water circulates in a closed circuit

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MYRTE
Hydrogen storage

H_2 & O_2 tanks@ 35barg
1400 Nm^3 H_2
700 Nm^3 O_2

Taking into account constraints imposed by the local terrain

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MYRTE
Very limited impact

The MYRTE project was developed with awareness of both:

social acceptance

protection of the environment (landscape and wildlife)

*On the verge of extinction in France, a population of **Hermann's Tortoise** was found on the project site and had to be accommodated*

MYRTE
In the press

PennEnergy

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Renewable energies: AREVA inaugurates innovative energy storage platform in Corsica

January 16, 2012

Source: Areva

In partnership with the University of Corsica and the French Nuclear and Alternative Energies Commission, the Hydrogen & Energy Storage unit of AREVA inaugurated the MYRTE platform at the University of Corsica site in Vignola, close to Ajaccio.

MYRTE platform aims to demonstrate the feasibility of a solar energy storage solution using hydrogen technologies to mitigate the fluctuations of solar power generation, and contribute to securing Corsica's power grid.

After more than two and a half years of work, the 560 kWc photovoltaic power plant was connected to an innovative energy storage system developed by AREVA, made of an electrolyzer, hydrogen and oxygen reserves, and a fuel cell.

MYRTE has been running connected to the Corsican electrical grid since December 16, 2011: a first in Europe and worldwide in this power range.

"The MYRTE platform allows us to get out of the laboratory and test our technology in a real environment. It is our first installation at this maturity level, connected to the electricity network. This day is the beginning of a new chapter for the BU: we will now on be in operational exploitation of such systems." says Jérôme Gosset, Vice President of the H&ES BU, "

The H&ES BU objective is now to work out progressively the most successful operation modes to integrate decentralized renewable electricity into insular grids, while contributing to secure them.

AREVA will continue investing in MYRTE: The Hydrogen & Energy Storage activity will install by 2013, within the framework of MYRTE phase 2, the next generation of hydrogen systems to increase the current platform hydrogen system power: the Greenergy Box a containerized integrated hydrogen system, based on hydrogen technologies currently implemented in MYRTE.

The MYRTE platform based on hydrogen technologies fits perfectly with the group strategy which is to provide electrical production technologies, nuclear and renewables, with extremely low CO2 emissions.

Stockage de l'énergie solaire : la Corse innove

L'électricité est conservée sous forme d'hydrogène afin de resservir à la demande quand le soleil ne brille plus.

CYRILLE VANLERBERGHE
ENVOYÉ SPÉCIAL À AJACCIO

ÉNERGIE À quelques kilomètres d'Ajaccio, dans le maquis, au pied de collines sauvages et face à la Méditerranée, se cache une installation de stockage de l'énergie solaire unique en Europe.

Après un peu plus de deux années et demie de travail, un large champ de panneaux photovoltaïques a été couplé à un système innovant de production et de stockage d'hydrogène qui permet de compenser l'intermittence inévitable liée à la production d'électricité à partir du soleil à une échelle préindustrielle.

3700 mètres carrés de panneaux solaires pour une puissance maximale de 560 kW

Intermittence de la production

Cette plate-forme appelée Myrte a été inaugurée hier par l'Université de Corse et ses partenaires, l'industriel Hellon, filiale d'Areva spécialisée dans les technologies de l'hydrogène, et le Commissariat à l'énergie atomique (CEA). Elle est dotée d'un budget de 21 millions d'euros, avec des financements régionaux, nationaux et européens.

Pour des régions insulaires non raccordées aux grands réseaux électriques comme la Corse, l'intermittence de la production d'électricité fournie par les énergies renouvelables, que ce soit le solaire ou l'éolien, est l'un des principaux freins à leur implantation à grande échelle.

« Contrairement à ce qui se passe sur le continent, où les énergies renouvelables sont envoyées directement sur le réseau d'électricité, qui est assez dimensionné pour amortir en partie les fortes variations de production, sur les îles, les réseaux électriques sont trop petits pour supporter les à-coups brutaux d'une production irrégulière, explique Philippe Poggi, chercheur de l'Université de Corse, qui est à l'origine du programme. *Notre plate-forme est conçue pour limiter les variations du courant que nous renvoyons vers le réseau EDF. »*

Les 3 700 m² de panneaux solaires im-

AREVA launches energy storage platform in France

CTBR Staff Writer

Published 18 January 2012

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FULL TEXT NEWS STORIES

Bloomberg

AREVA OPENS HYDROGEN-BASED SOLAR POWER STORAGE SYSTEM IN CORSICA

17 Jan 2012 / Solar / PRODUCTS & TECHNOLOGY / France / Alert: organisation - Areva SA

Areva SA, the world's largest producer of nuclear equipment, commissioned an energy storage system bas photovoltaic plant on the French Mediterranean island of Corsica.

The company, in partnership with the University of Corsica and France's Nuclear and Alternative Energies Commission kilowatt solar plant to the regional electricity grid in December, it said in a statement.

The project will be one of the world's first to hold electricity in reserve from a utility-scale solar plant, according to Blo reduces the peak load that must go onto the transmission grid and eases the management of intermittent output from

The MYRTE project aims to demonstrate the feasibility of storing solar energy using hydrogen and its integration to an The connection to the grid of a project of this size was a world first, it said.

The system, which took more than 2 1/2 years to develop, consists of an electrolyser that splits hydrogen from water to install a second generation of hydrogen systems there by 2013, it said yesterday.

Summary/Recommendations

- **In the United States there are many locations that share common features with islands**
  - **National parks where environment is sensitive, of high value and to be actively protected**
  - **Small cities or remote areas where grid may be weak**
  - **Large cities and non-attainment zones**
  - **Military installations & Critical infrastructure like FAA, emergency response centers, …**
- **Policy suggestions**
  - **Maintaining hydrogen technologies' eligibility for ITC**
  - **A national "SGIP" program that includes hydrogen as an eligible storage medium**
  - **An investment/reward policy/fund for early stage deployment**
    - A useful model could be France's "*Horizon Hydrogene Energie*" (H2E)
- **What would help focus to facilitate technology acceleration and acceptance?**
  - **Help offer meet demand or vice versa: help the industry promote the existence of such solution**
  - **Help us dig into business cases in specific locations or projects**

MYRTE
Today and tomorrow

Our accomplishments

- **Deployment of innovative, clean technologies for energy storage on islands is possible today.**
- **Demonstration that safety and regulatory issues can be managed**

Our perspectives

- **Accumulate lessons learned on deployed systems**
  - **Life expectancy**
  - **Level and costs of long-term maintenance**
  - **Optimization and long-term evolution of the performance**
- **Deploy the first integrated demonstrator: " MYRTE in a box “**