LITEN

Institute for Innovation in New Energy Technologies and Nano materials

Li-ion Batteries: Solar Storage, Mobility & Second Life

Florence Fusalba
CEA Grenoble

Outline

- CEA Liten Introduction
- Batteries: Prototypes Manufacturing & Facilities
- INES: National Institute for Solar Energies; its Storage Platform
- Li ion cells, a technology integrated at the backside of PV panels
- Solar mobility
- Batteries Second Life, Eco conception & Recycling
- Life Cycle Assessment

Presentation of CEA and LITEN

French Atomic and Renewable Energy Commission

CEA : 9 R&D Centers in France

4 main research priorities

- Defense & Global Security
- Energy
- Health and Information Technology
- Fundamental Research

Key figures

- Staff : 15 618
- Budget : 3.5 b€
- 530 priority patents applications field

liten

« Laboratory for Innovation in New Energy Technologies and Nanomaterials »

- Staff : 900
- Budget : 120 M€ (90M€ turnover)
- 400 patents
- 150 p on batteries

R&D

⇒ Solar energy
⇒ Transport technologies
⇒ Energy sources for portable electronics
⇒ Nanomaterials
⇒ Extreme Materials
⇒ Hydrogen Technologies

energie atomique • energies alternatives

http://www.cea.fr/
http://www-liten.cea.fr

[1]**CEA** : **C**ommissariat à l'**E**nergie **A**tomique

An outstanding position : Between Research & Industry

1 Fundamental research

Publication

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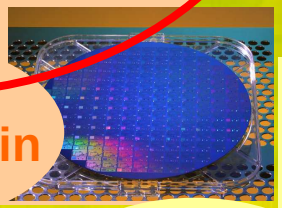
2 Applied Research

Research in partnership
Public - private

LITEN
900 p.
400 patents
(+160 in 2010)

Patent

3 Industrial Development



Prototyping

4

Product

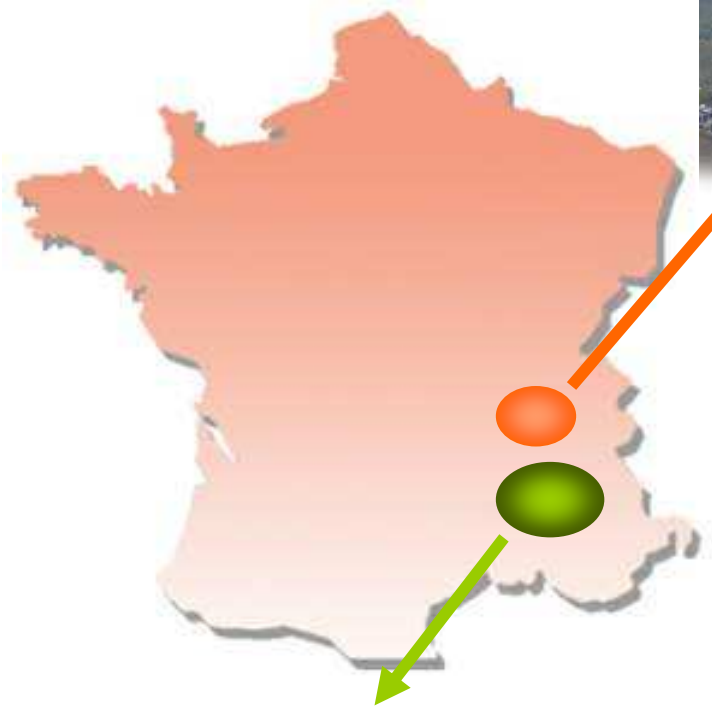
«4 P»

✓CEA is a French Public Company transferring technology to Industrial Partners
✓CEA is not a material nor a battery producer but may allocate platforms for Industrial Partners with confidentiality care

Developments at CEA-Liten

Automotive Market	Building Market	Nomad Market	New fuel Market
New Energy for Transportation	**New Energy for building**	**New Energy for nomad devices**	**New Energy from biomass**
Electrical Powered	**Solar Energies**	**Hybrid components**	**Novel fuel**
Hybridizing Fuel Cell / **Batteries**, storage and delivery Energy Saving / Storage Electrical Conversion / management	Thermal and Photovoltaic cells Electrical Systems Energetic efficiency Building integration	Micro-Power Sources Energy recovery Organic electronics Nano Technologies	Biomass to liquid, Massive hydrogen production Hydrogen storage
 	 	  	 

CEA-Liten Key points



Chambery : Solar Energy & Building integration
R&D
200 collaborators

ines
INSTITUT NATIONAL DE L'ENERGIE SOLAIRE

Grenoble : Electrical transports & Nano materials
700 collaborators

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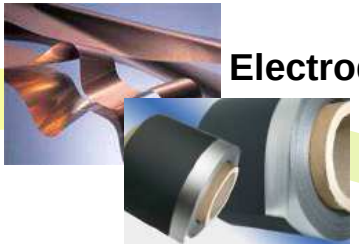
CEA Li-Ion batteries prototypes

TARGETS :
1 - SAFETY
2 - COST REDUCTION
3 - HIGH ENERGY
4 – HIGH POWER

From **Materials**



Electrodes

Cells

Modules

Packs

EV

PHEV**

Battery System*

(300kg, 160km, €265-€540/kW

Sensors
Calculator (BMS)
Junction box
Carter…

"Service plug"

*http://nissan-leaf.net/2010/05/27/nissan-leaf-battery-specifications/

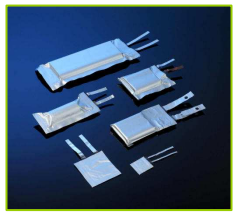
**http://www.a123systems.com/hymotion/

CEA Batteries: Li-Ion cells prototypes

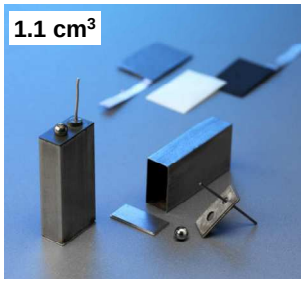
From 1mAh to 15Ah cells (100Ah in 2011)

"On-demand" Li-ion battery design






Various « fit & form » (Pr, Cy, soft packaging, hard casing…) & Specific architectures and design (bipolar cells, thin cells,...)



SAFT chemistry inside

Sensors

3.2V - 40 mAh
-0.01% / cycle
$LiFePO_4$-B/Graphite
Efficiency > 99%

Medical Implants

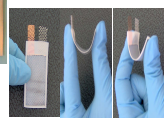
3.7V - 50 mAh - 2.45 g
10 years at 37°C
4000 cycles
Layered oxide/Graphite

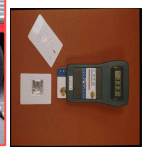

Safety tests performed successfully

Strong weldings
High tightness


After nail test

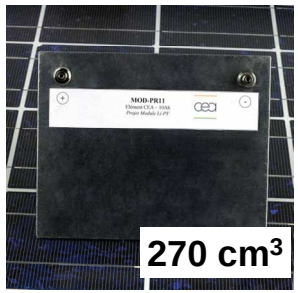

Overcharged cell



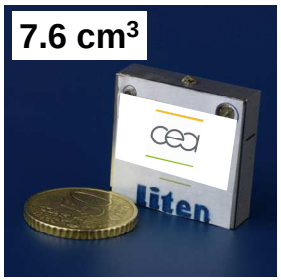
Smart-Cards, Intelligent Wears, secure personal devices, packaging, E-books, autonomous sensors...

few mAh to 800 mAh,
ultra-thin packaging (< 0.4 mm)
2.3 to 3.7 V; <1g to 45g
=> *Towards fully printed Li Batteries*



Photovoltaic

3.2V - 10 Ah
High cycle life
Operating up to +70°C



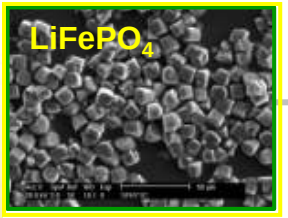
Spatial Sensor

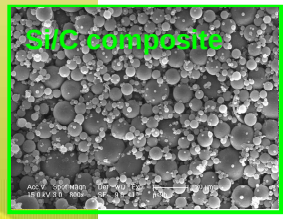
3.7V - 350 mAh
Cell for extreme conditions

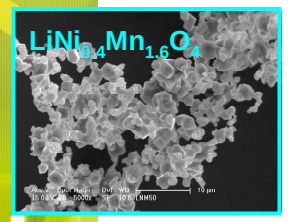

EVs

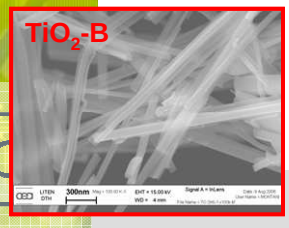
3.3V
-
15 Ah

Materials development from g to kg for Prototyping and Transfer









1) *Positive electrode:*

- *Safe Polyanionic materials* ***($LiFePO_4$...)***
- *High Voltage Spinel Oxides,*
- *High Capacity layered oxides.*

2) *Negative electrode:*

- *High Power Titanium Based Compounds* ***($Li_4Ti_5O_{12}$, TiO_2-B) → Power***
- *High Capacity Si/C composites →* ***Energy***

3) *Electrolytes (salts, solvents, additives, ionic liquids) and Membranes.*

PRAYON

Hydrothermal reactors

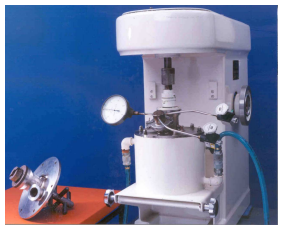
Spray dryers

Microwaves oven

Ball-millers

Furnaces

1 – 2 kg



200g

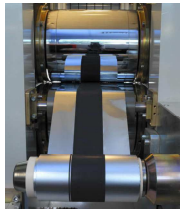
2x30g

30g

A R&D Prototyping Platform *

** In addition to our research laboratories (lab coaters, printing machines…) and testing facilities (450 channels)*

- A 130m² dry room with 3 areas
- Dew points: -20°C and -40°C
- Line capability from 5 to 15kWh/month



- Electrode formulation and rheological characterization, coating
- Electrode calendaring and slitting
- Cell winding, assembly
- Electrolyte filling, crimping, welding

Semi Industrial Line Extension– *2010-2011*

Li ion batteries Pilot Line

Semi Industrial Line – Mid 2011
Dry room extension > 300m²
New facilities (>1000m²)
Line capability up to 500kWh/month

Major Partnerships allowing CEA battery activity to ramp up steadily

RENAULT

COMMUNIQUE DE PRESSE

June 25, 2010

RENAULT AND THE CEA SIGN A STRATEGIC COOPERATION AGREEMENT IN THE FIELD OF TECHNOLOGICAL RESEARCH

On June 24, 2010, Renault and the CEA (French Alternative Energies and Atomic Energy Commission) signed a research and development agreement to work together in the field of clean vehicles and sustainable mobility for all: electric vehicles, new energies, and cleaner combustion engines.

Joint teams

Under the terms of this agreement, cooperation between Renault and the CEA will take the form of joint project teams working together at several sites. A Renault/CEA Strategic Steering Committee will be responsible for management. It will identify areas of synergy and the corresponding objectives, approve the three-year research and development program and ensure that a win-win balance is maintained for each party, particularly with respect to results and their use. The committee will be chaired jointly by the head of the DREAM (Research, Advanced Studies and Materials division) at Renault and the CEA technological research director.

Strategic programs

Following the detailed studies conducted by Renault and the CEA in 2009 to identify possible synergies, four main areas of research have been set out:

- new energies in transport;
- upgrades in electrical and electronic architecture;
- improvements in the competitiveness of combustion engines;
- communicating vehicles.

Partnership / Industrials

End-users**:**

- **Automotive**: RENAULT, NISSAN, PSA, FIAT, Daimler-Chrysler, Volkswagen, Valeo, Aixam, Michelin, Irisbus
- **Aeronautics**: ESA, Eurocopter, Dassault, EADS
- **Medical**: Cochlear, Finetech, Sophysa
- **Smart-Tags and Sensors**: confidential partners
- EDF, INERIS, DGA,…
- Other actors in NTIC and Textile domains,…

Material/Battery manufacturers**:**

- Prayon, Solvay, Merck, Timcal, Umicore, Solv
- Saft, Varta µBatteries (Printed), Prollion (Niche Markets), Batsca Cegasa,…

PROLLiON

Li-ions cells and batteries systems

Company

PROLLiON develops and manufactures custom-designed cells and battery systems, from the most innovative Li-ion technologies to meet high demanding customer needs

- Breakthrough performances: autonomy, power, energy
- Severe environments: thermal, mechanical
- Volume constraints
- Reliability, safety, …

Applications

- Stationary systems: renewable energies, grid support, …
- Electric vehicles: buses, light electric trams, light vehicle fleet, …
- Defense: soldier of the future, radio communication, unmanned vehicles (UAVs, UUVs, …
- Aeronautics and Space (autonomous sensors, ...)
- Sea and Underwater applications
- Medical: implantable medical devices, …
- Distress beacons, seismic sensors
- …

prollion@prollion.com

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INES Facilities dedicated to storage

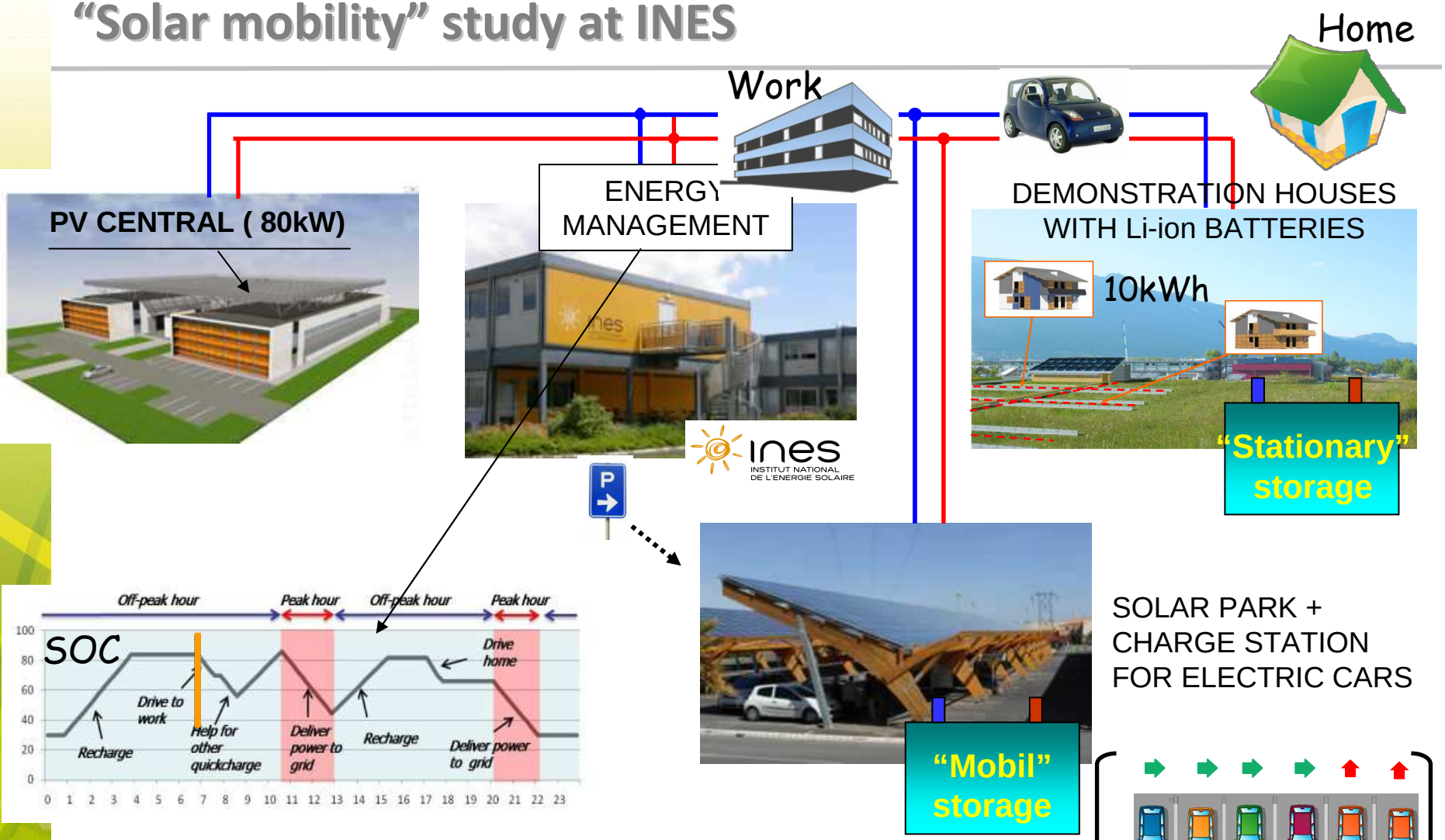
- **The STORE Platform: an outstanding test facility in Europe**
  - ♦ More than 100 cycling channels (up to 200 V, 500 A)
  - ♦ Thermo regulated baths, climatic chambers (-40℃, + 60℃)
  - ♦ Two laboratories for physical-chemical analyses, safety tests
  - ♦ For all storage systems investigation (simulation, emulation, profile of use testing, ageing…)






- **Investire Thematic Network : 2001-2004**
- **REX DER-LAB : 2005-2011**
- **Infrastructure DERRI**

“Solar mobility” study at INES

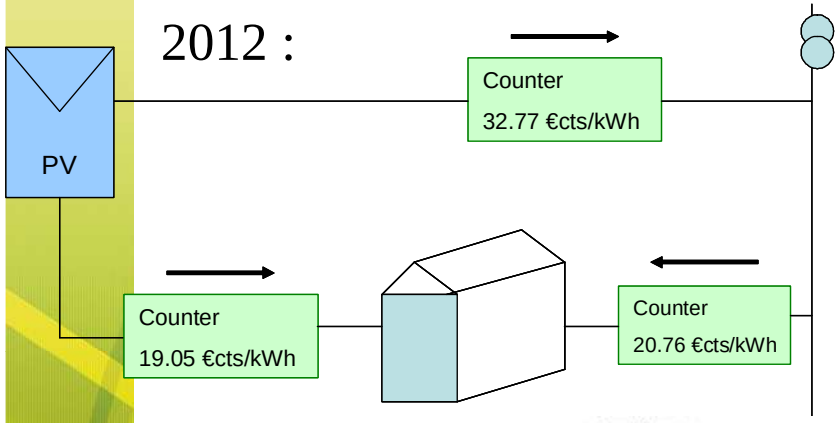


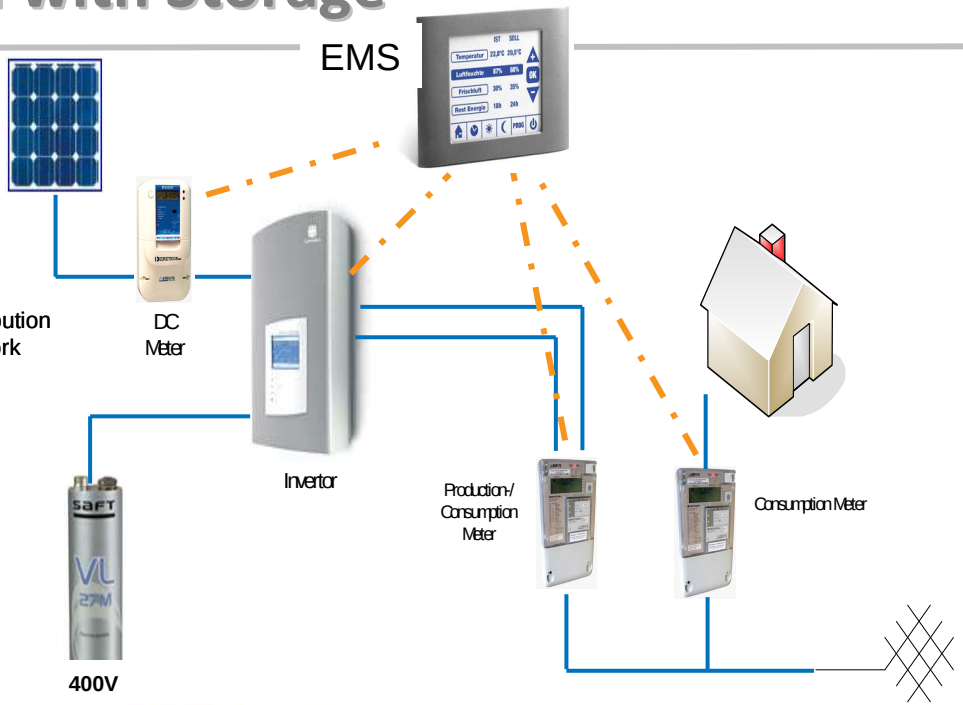
- Development of energy simulation tools
- Development of energy management strategies

Sol-ion Project : PV system with Storage

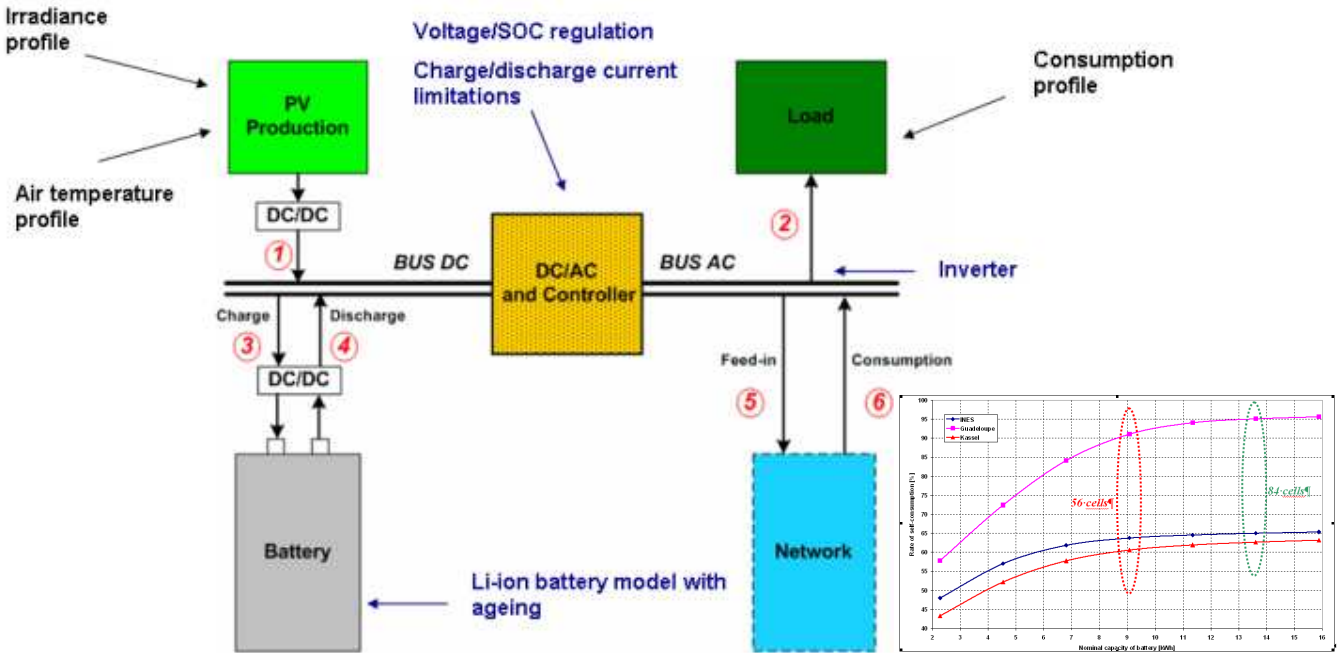
- **Following German Law on Self Consumption**
- **Low interconnected PV networks Optimization**

2012 :

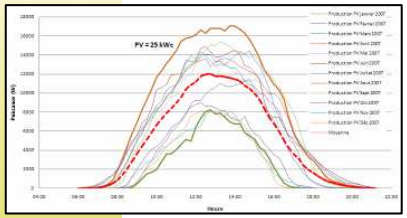




- **System Simulation**



Future smart recharging station



Weather station (real time, forecast)

Distribution Grid

Lead Acid

SC

Lithium-ion

Stationary storage system

NiMH/NiCd

Redox Batteries

...

Sodium-beta

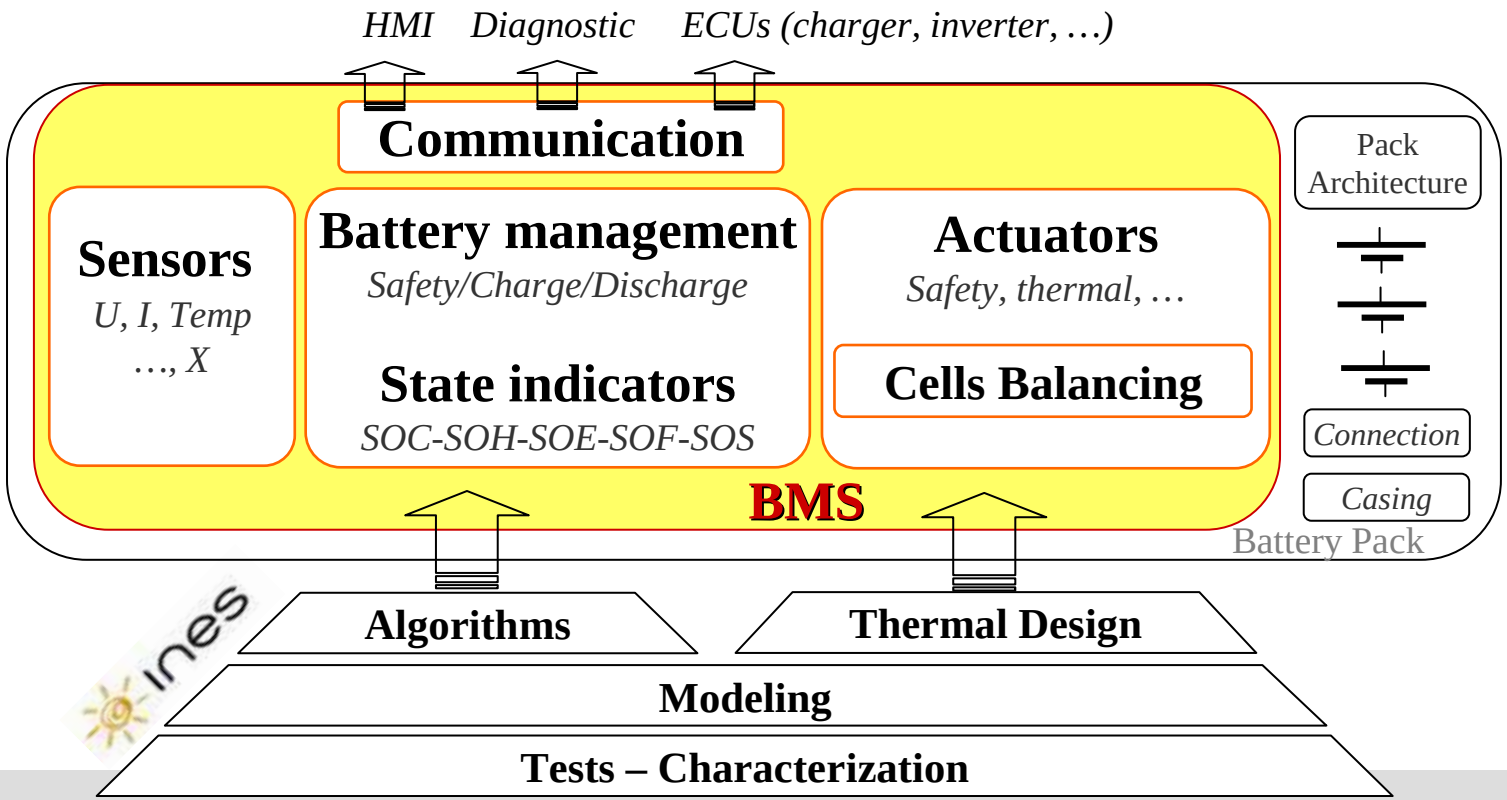
PV production (home, work, garage)

Electrical or Plug-In vehicles

Battery Management System

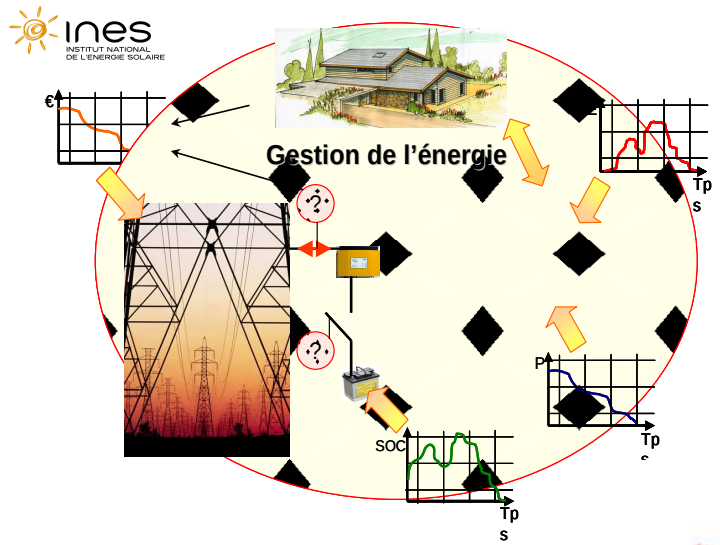
Goal

- Ensure ***safety***
- Improve ***performances***: Life Cycle **Cost** *(€/kWh, €/km)*
- Improve ***service***
- Improve ***information***: *Driver information, Diagnostic*

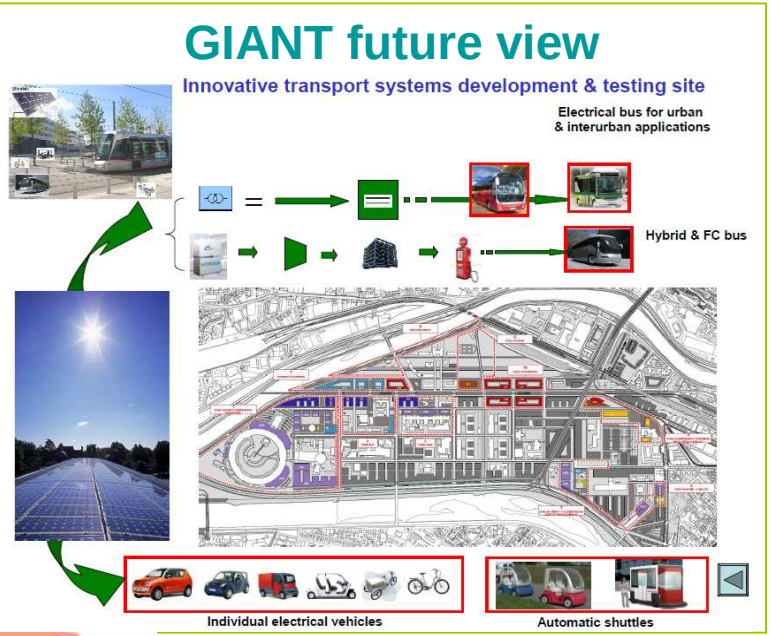


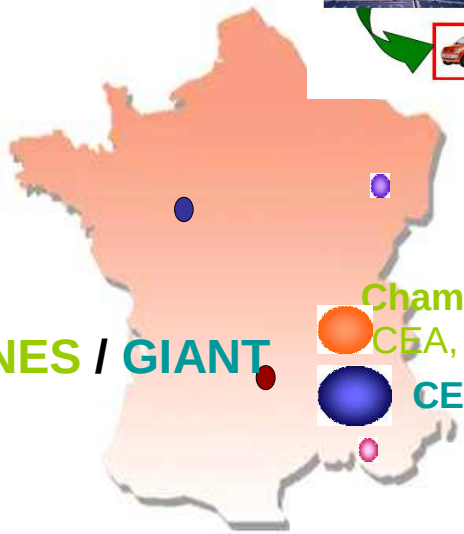
Two mobility projects for public demonstration

INES « Green mobility »



GIANT future view





Two major data sources : INES / GIANT

Chambery Solar Institute (INES)
CEA, CNRS, CSTB, Savoie Univ.

CEA Grenoble (GIANT)

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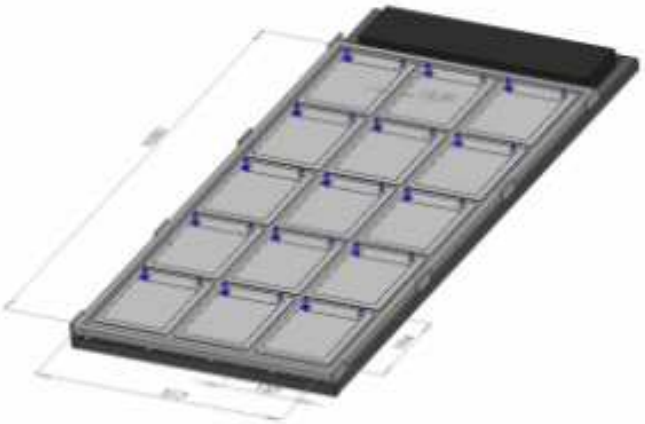
Design of the cells:

Example of battery cells integrated at the back side of a photovoltaic panel

- To ensure the battery energy aimed and the working voltage focused → association in series and/or in parallel
- to allow thermal integrity of the PV panel → covering the whole surface of the PV panel back integrating an air layer
- to ensure long life time → encapsulation in rigid can
- to make the module handling → flat format and light metallic can



Battery specification

- ***Energy*** : 360Wh, 15 years
- ***Operational voltage*** : 25 to 80V
- ***Max current :*** ~ 4A
- ***Weight*** :

– Module < 30 kg

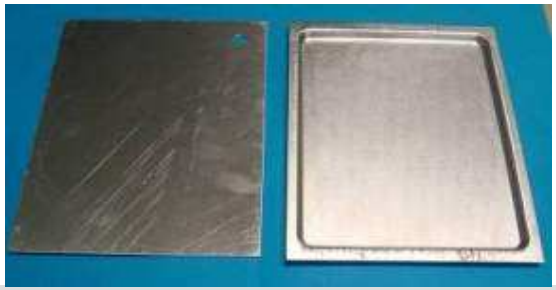
– PV panel, 75 W ~8 kg

Max battery weight < **7 kg**

- ***Integrated at the back side of the PV panel***
- ***Thickness :*** 50 mm

Li ion Cell characteristics
LFP Technology

- Technology **$LiFePO_4$**/Graphite – 3.2V [2.6 V – 3.7] , 10Ah
- Overall dimensions : 194 mm x 157 mm x 9 mm
- Electrochemical core:
  - ✓ thickness ~6mm
  - ✓ Snap contact in Cu and Al sealed to the connections
- Can in Al
- Stable electrical behavior & good behavior during abusive tests
- The high degree of integration of these cells exhibiting new designs & reliable technologies is applicable, for instance, to lighting where inserted components are required



Batterie Li ion pour stockage PV - Comportement

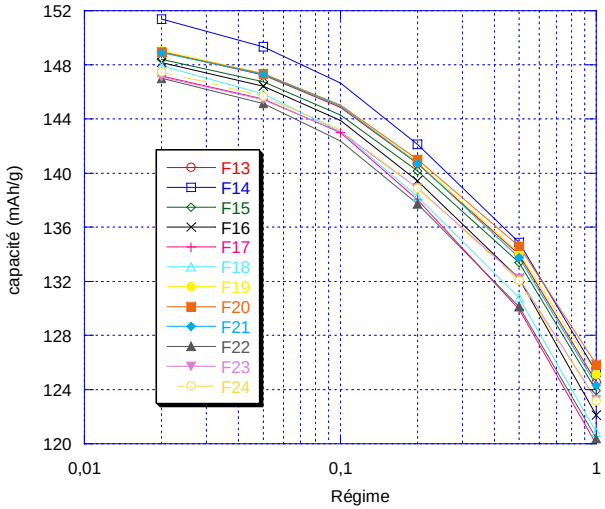
Comportement en cyclage des éléments:

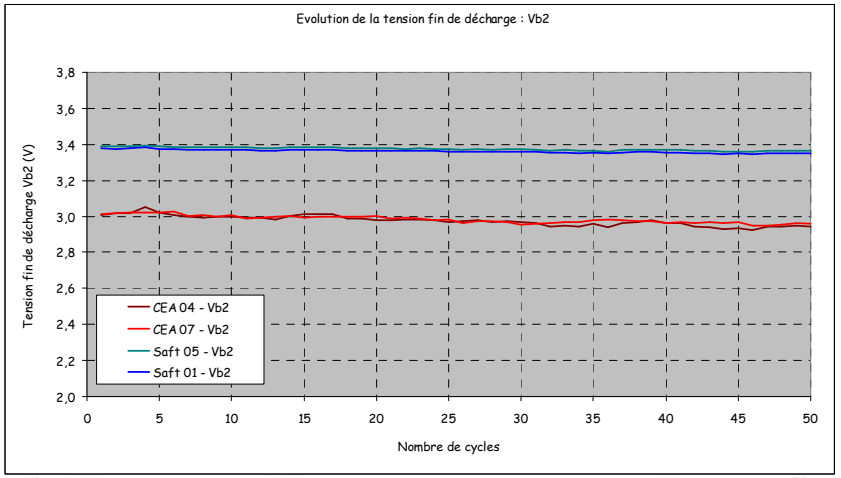
- Détermination d'un protocole de test accéléré à partir d'un profil d'utilisation

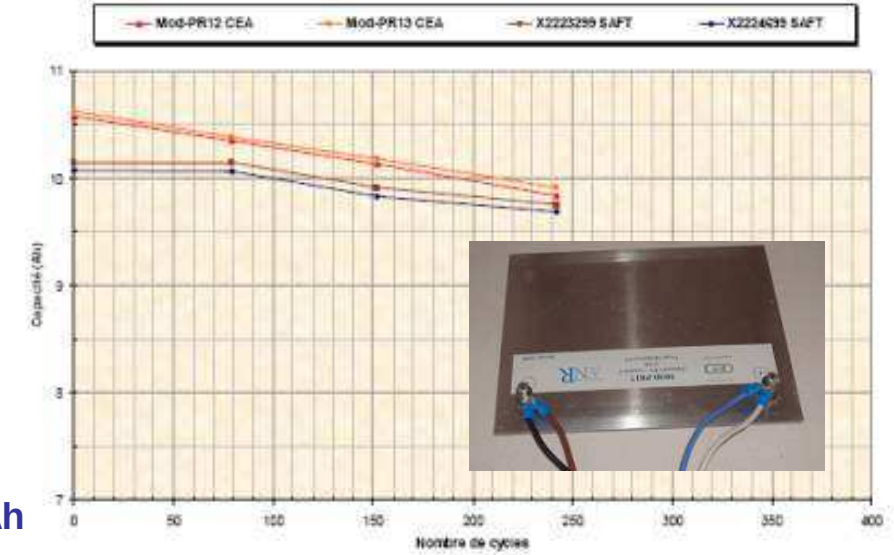
- Cyclage des éléments CEA suivant le profil accéléré

→ Tensions de fin de décharge stables

- Mesure des énergies de décharge







- **Capacité nominale (C/10 et 20℃) : 10,5Ah ± 0,5Ah**
- **Résistance interne : 10mΩ ± 3m Ω**
- **40 éléments fabriqués**

Design de la batterie: - constituée de 15 éléments 10 Ah mis en série

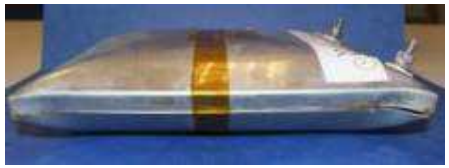
Batterie Li ion pour stockage PV - Sécurité

Comportement des éléments CEA 10Ah pour modules PV lors des essais abusifs

Type d'essai abusif	Techno CEA LFP/G
Test de court-circuit externe	**Fusion des joints aux bornes → remplacés depuis sur version 2**
Test du clou	**Pas de dégagement de fumée, pas de flamme → Bon comportement de la technologie.**
Test de surcharge	**Gonflement de l'élément jusqu'à rupture des soudures après plusieurs heures de surcharge.**

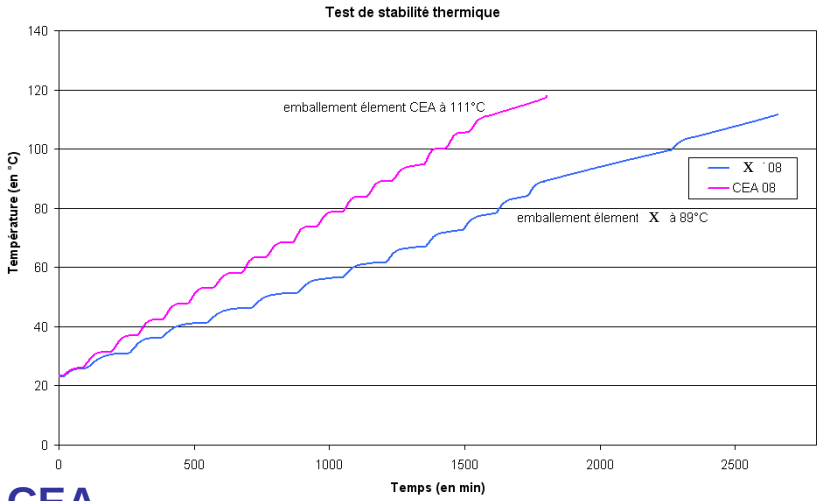
Test de court-circuit

Test du clou



Test de surcharge

- **Technologie LFP très sûre**
- **Elément plat plus facilement intégrable dans un panneau PV**



Bonne tenue à la température des éléments CEA

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LFP/G Li ion techno.

Le double contexte: Photovoltaïque / Véhicule électrique

« Entre 2 et 4 millions de véhicules électriques devraient être mis en circulation en France d'ici à 2020, soit environ 5%-10% du parc national »

5-10 TWh/an*

12 m² / place de parking

1600 Wc / place de PV

25 km /jour /place

« Entre 5 et 10 GWc de systèmes PV seront installés en France d'ici à 2020, soit 1% à 2% de la production d'énergie nationale »

5-10 TWh/an**

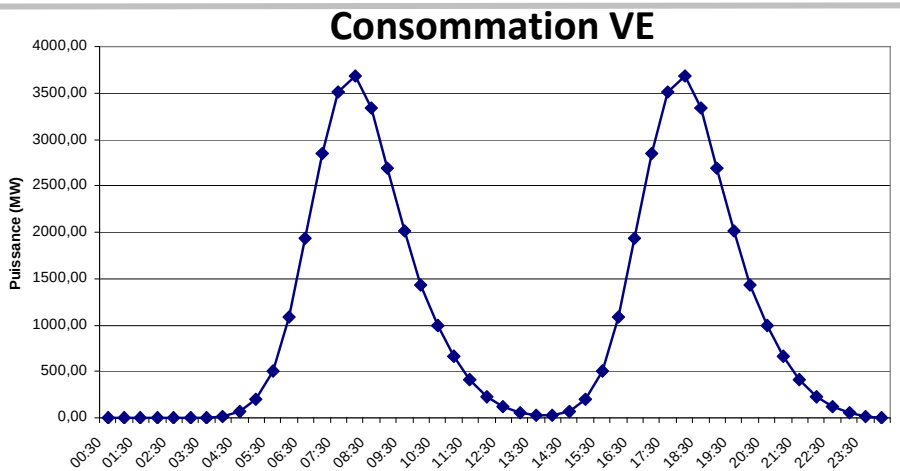
3000 Wc / habitat

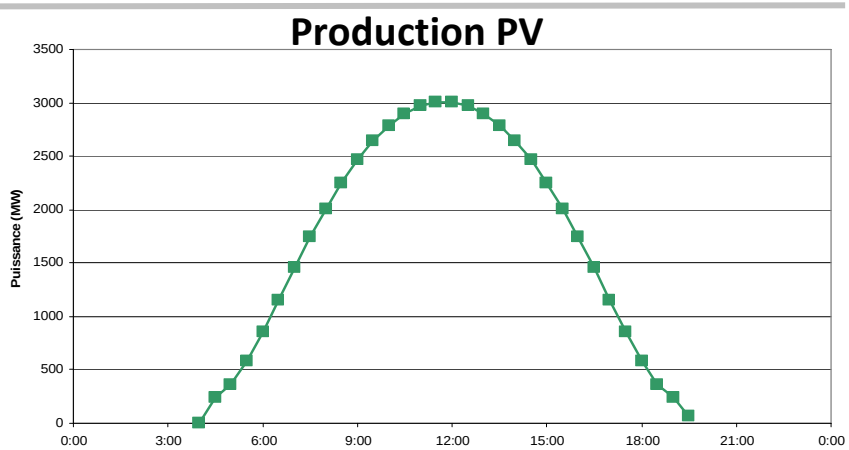
50 km /jour

* *Hypothèses : 15000 km/an; 180 Wh/km*

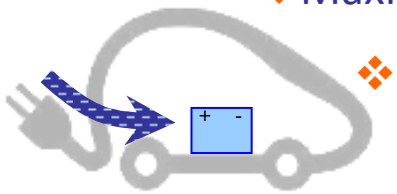
** *Hypothèse : 1000 Wh/Wc/an*

Les contraintes - Les objectifs - Les Outils

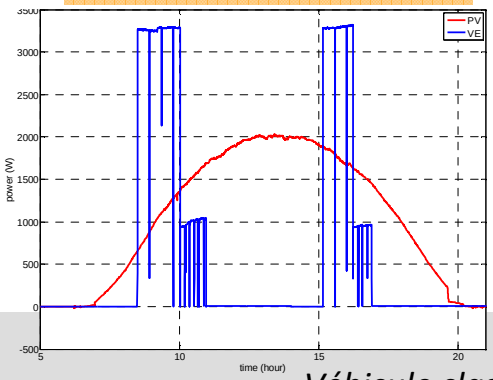




- Maximiser l'adéquation **Production PV-Consommation** localement
- Minimiser **l'impact sur le réseau** de distribution et les infrastructures
- Minimiser **l'impact chez le particulier**



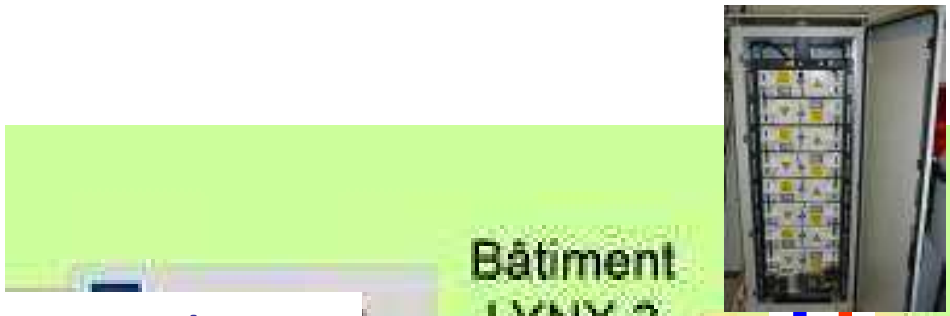
Modélisation-Simulation → **Prototypage sur banc** → **Validation sur système réel**



Véhicule classique

CEA Property

Plate-forme Micro-réseau PRISMES



Stockage stationnaire

Bâtiment LYNX 3 2010

Maisons INCAS

Centrale PV 80kW

Supervision et interconnexion

Garage solaire 12 places

Réseau AC

Réseau DC

Les démonstrateurs en cours d'opération

- 21 kWc
- 12 places de parking

- 12,5 kWc
- 6 places de parking à Grenoble

- 2 x 5,5 kWc
- 2 places de parking

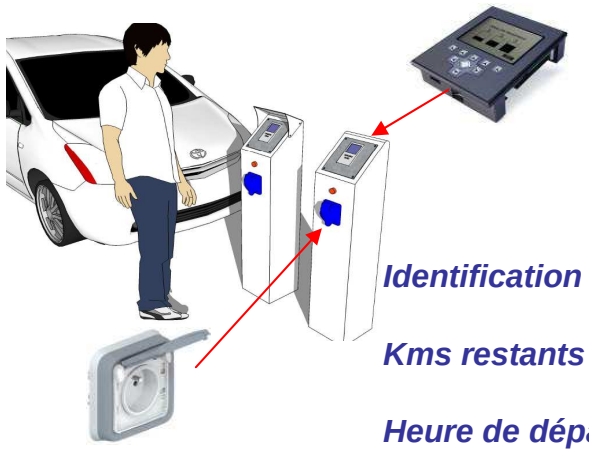
Thèmes de recherche

- Système véhicule/réseau/bâtiment: Optimisation énergétique, communication, gestion prévisionnelle de l'énergie
- Nouvelles architectures électriques (ex.: courant continu)
- Intervention sur véhicules
- Intégration du véhicule dans un réseau iloté
- Smart GRID
- Borne de recharge
- Systèmes de stockage

Les projets en cours et à venir

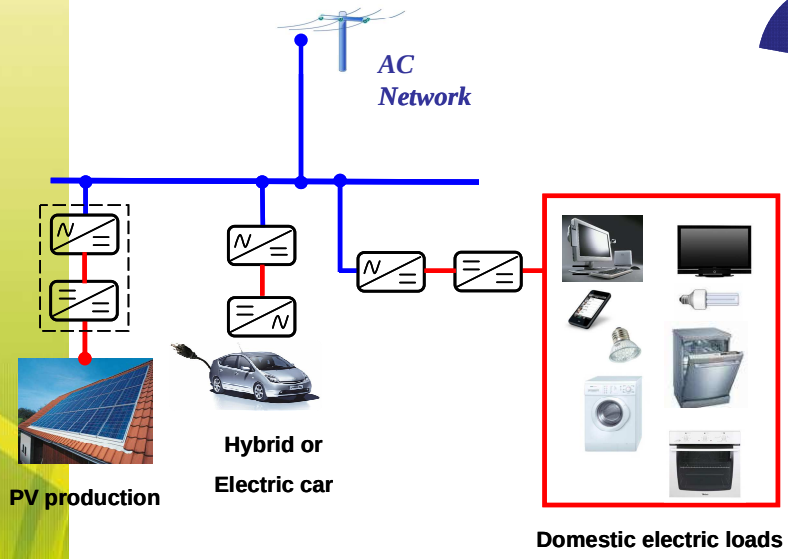
- DHRT2 (Toyota-EDF) AMI ADEME
  - Maximiser la couverture solaire de PHVR
- VELCRI (Renault, Schneider, EDF…) AMI ADEME
  - Valoriser l'énergie stockée dans un VE
- RéactivHome (Orange, Schneider…)
  - Gestion de l'énergie dans l'habitat
- ZENdrive (Courb, Heuliez) AMI ADEME
  - Quadricycles légers
- GREENLYS (ErDF, GEG, GDF-SUEZ…) AMI ADEME
  - Compteur intelligent, délestage des stations de recharge (pour le CEA)

La borne de recharge, un élément clé

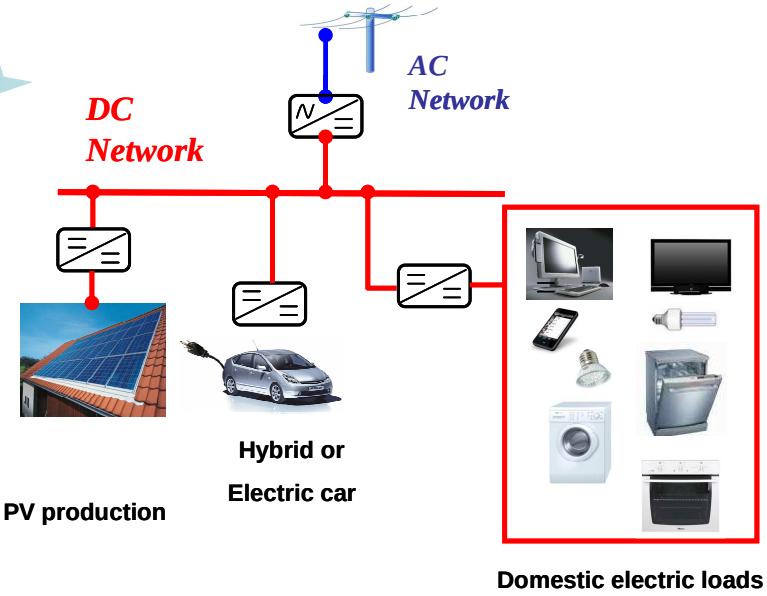


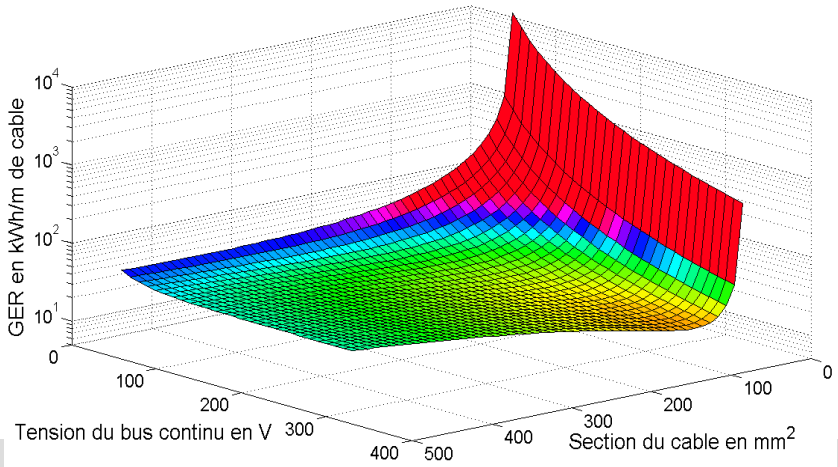
Approche efficacité énergétique et ACV

Distribution AC classique



Distribution DC ou Hybride



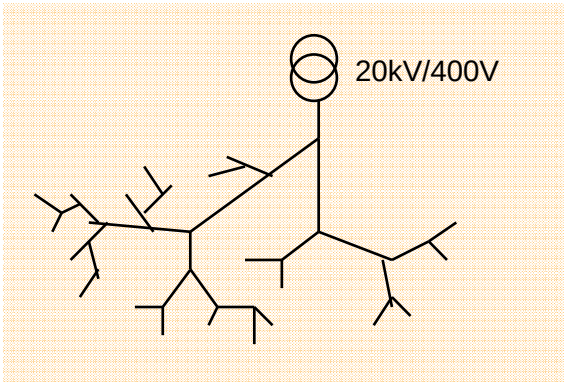


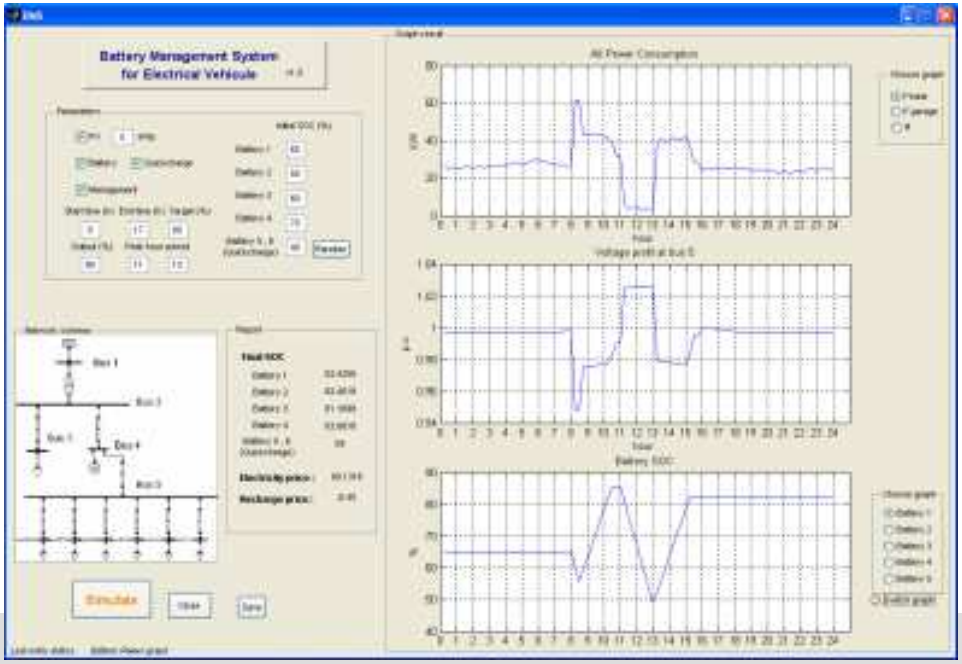
Etudier l'intérêt des réseaux continus localement sur des critères d'analyse de cycle de vie

Système de gestion de batteries pour véhicules électriques

Besoin des VEs

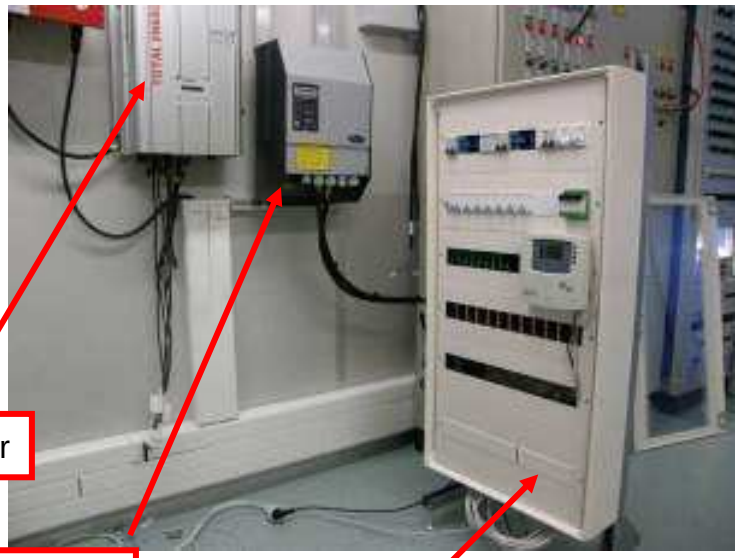
Architecture électrique



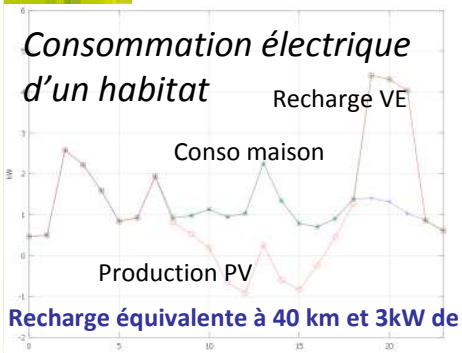


- Plan de tension-puissance
- Etat de charge des batteries
- Planification

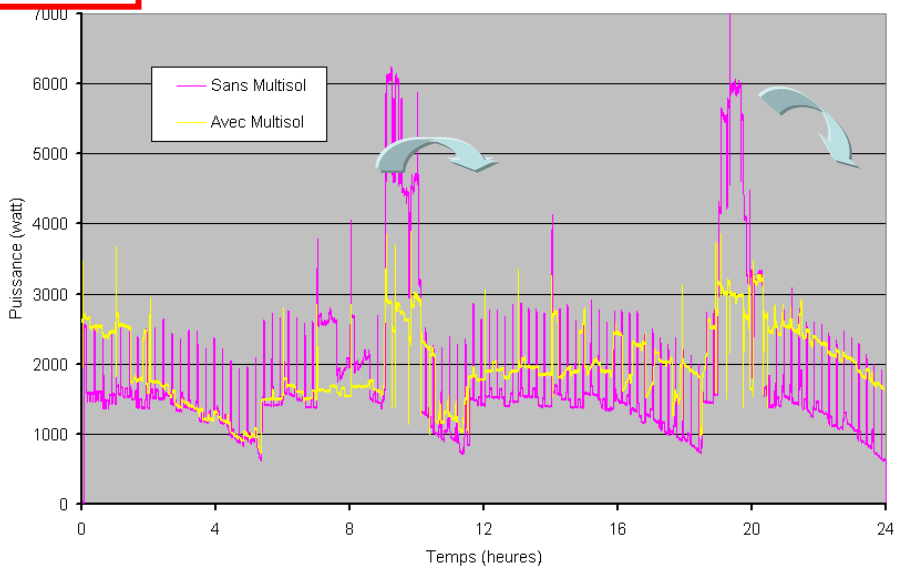
Prototypage de la gestion électrique d'une maison



(Multisol)



Recharge équivalente à 40 km et 3kW de PV

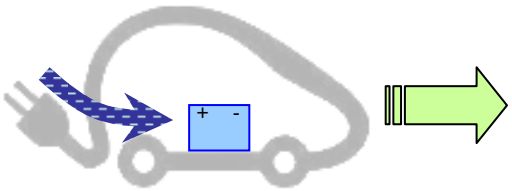


Outline

- CEA Liten Introduction
- Batteries: Prototypes Manufacturing & Facilities
- INES: National Institute for Solar Energies; its Storage Platform
- Li ion cells, a technology integrated at the backside of PV panels
- Solar mobility
- Batteries Second Life, Eco conception & Recycling
- Life Cycle Assessment

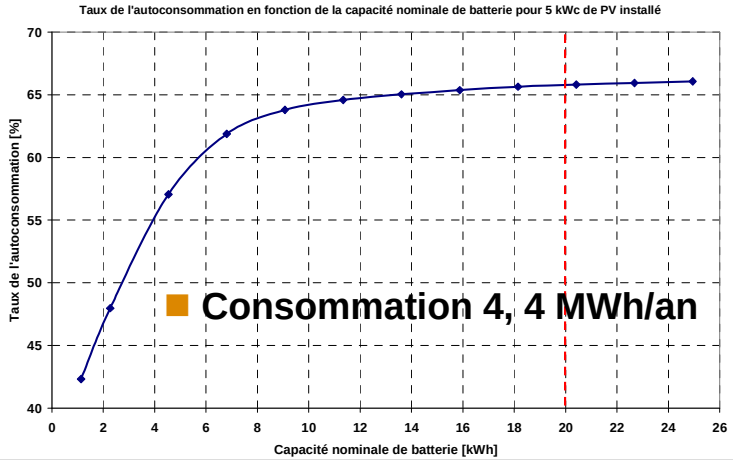
Seconde Vie des batteries: Applications envisagées

- Stockage stationnaire de systèmes isolés
- Couplage à la maison PV
  - ►Autoconsommation à l'issue du tarif d'achat
  - ►Autoconsommation par tarif incitatif
- Sécurisation



Calcul économique en prenant en compte les coûts diagnostiques et reconditionnement… : comparaison des technologies…

Taille de batterie pour 5kWc PV et maison 4 pers.



	Li-ion neuf	Li-ion reconditionné	Pb PV neuf
Electronic €/kWh	300	50	150
Diagnostic reconditionnement	0	300	0
BMS	500	500	200
Câblage connectique	200	200	
Contacteurs sécurité	200	200	
Coffre	100	100	
Prix système 10kWh	4 000	1 800	1 700
% capacité nominale utilisée	90%	90%	60%
Rendement énergétique	95%	95%	80%
Capacité restituée par cycle en kWh	8,55	8,55	4,8
Durée de vie en années	15	8	7
Cycles à 50% DOD	13950	5840	5110
kWh restitués (0,5 cyclo*)	23 406	12 483	6 132
Coût kWh restitué	0,171 €	0,144 €	0,277 €

Seconde Vie des batteries et Eco-conception

Concevoir des modules permettant des assemblages pour divers applications avec des éléments facilement accessibles pour être inter changés ou pour faciliter le recyclage (le démantèlement)

Batterie dans un véhicule électrique

Batterie dans un cabinet pour stockage stationnaire

+ health and safety aspects of critical materials

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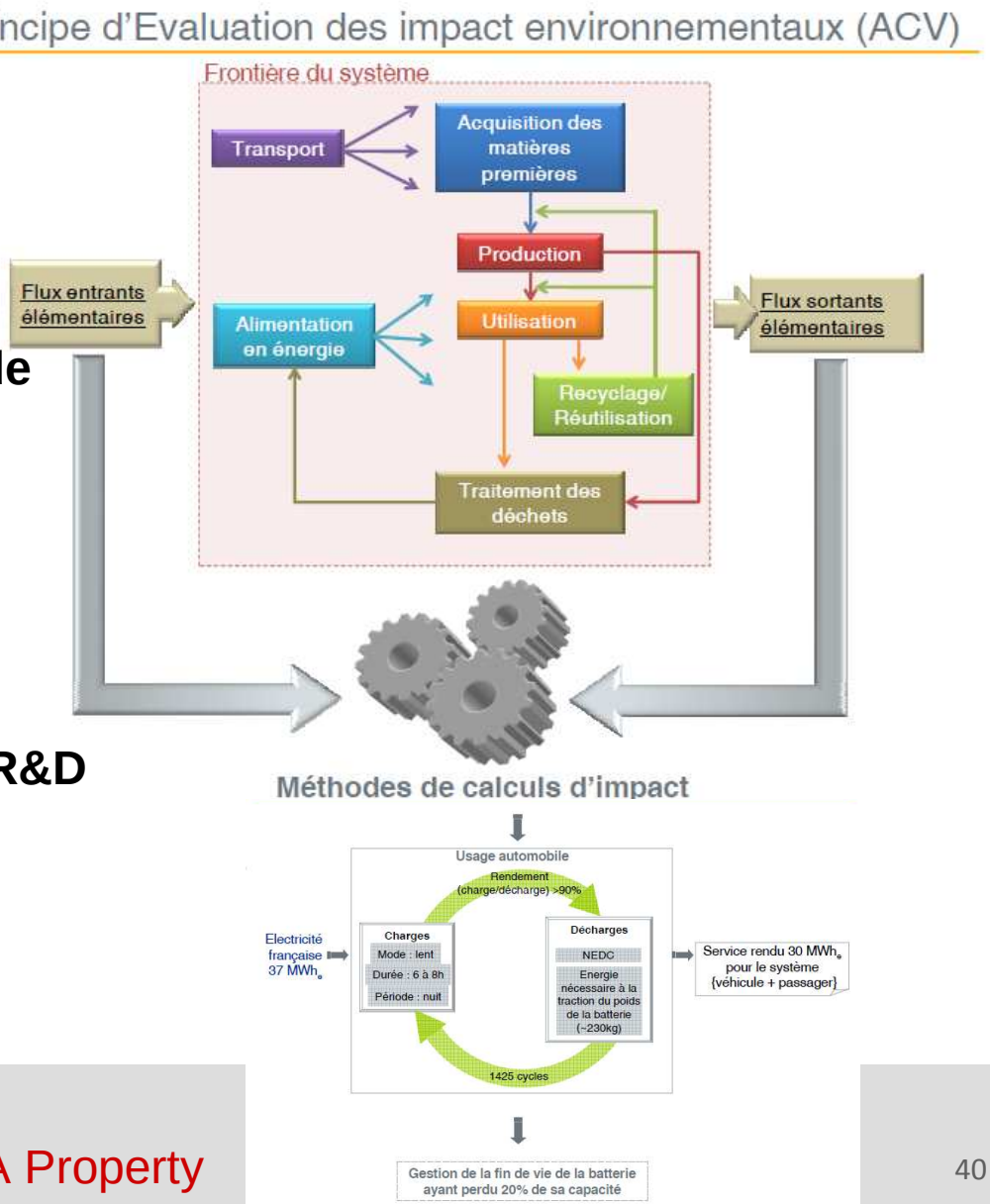
Analyse du Cycle de Vie (ACV)

- **Une meilleure maîtrise du cycle de vie des batteries Li-ion à application automobile**
  - ✓**Exhaustivité**
  - ✓**Vision globale**

- **Une évaluation par des critères environnementaux**
  - ✓**Comparaison de technologies de batteries**

- **Une prise de conscience des bénéfices et dommages environnementaux significatifs**

- **Une orientation des travaux de R&D à venir**
  - ✓**Optimisation**
  - ✓**Éco-innovations**



Thank you / Contacts at CEA

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