Building Energy Management

Residential and non-residential
"Smart-building" connected to the "Smart-Grid"
Contribution to the ELECON Program

UFSC, July-August 2014, Elecon Program

Benoit DELINCHANT

Extracts and adaptation made at Elecon Meeting by F. Wurtz

Magdeburg 28 october 2014

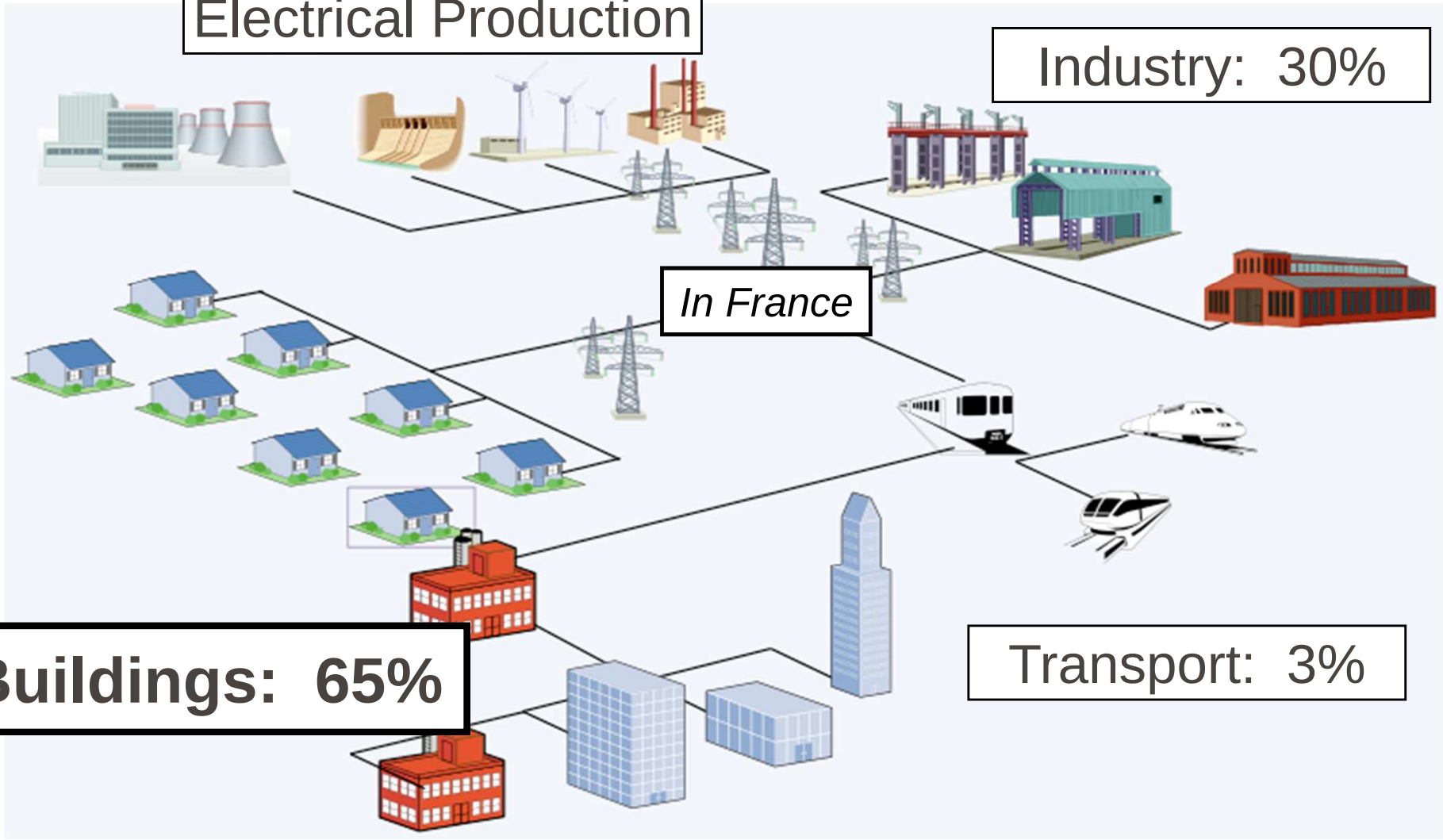
Outline

- **Electrical Energy for Buildings: why it is important to work on "smart buildings" integrated in "smart grids"**
  - Some key figures in France
  - In Brazil ?
- **How to manage consumption of buildings from the grid**
  - Dynamic pricing and smart meters !
- **Experimental platforms in Grenoble**
  - Smart building / Micro grid
- **Demand side management by using modelisation and optimisation**
- **Projects at the level of the city**
- **Perspectives and conclusions**
- **Contribution to the Elecon program**

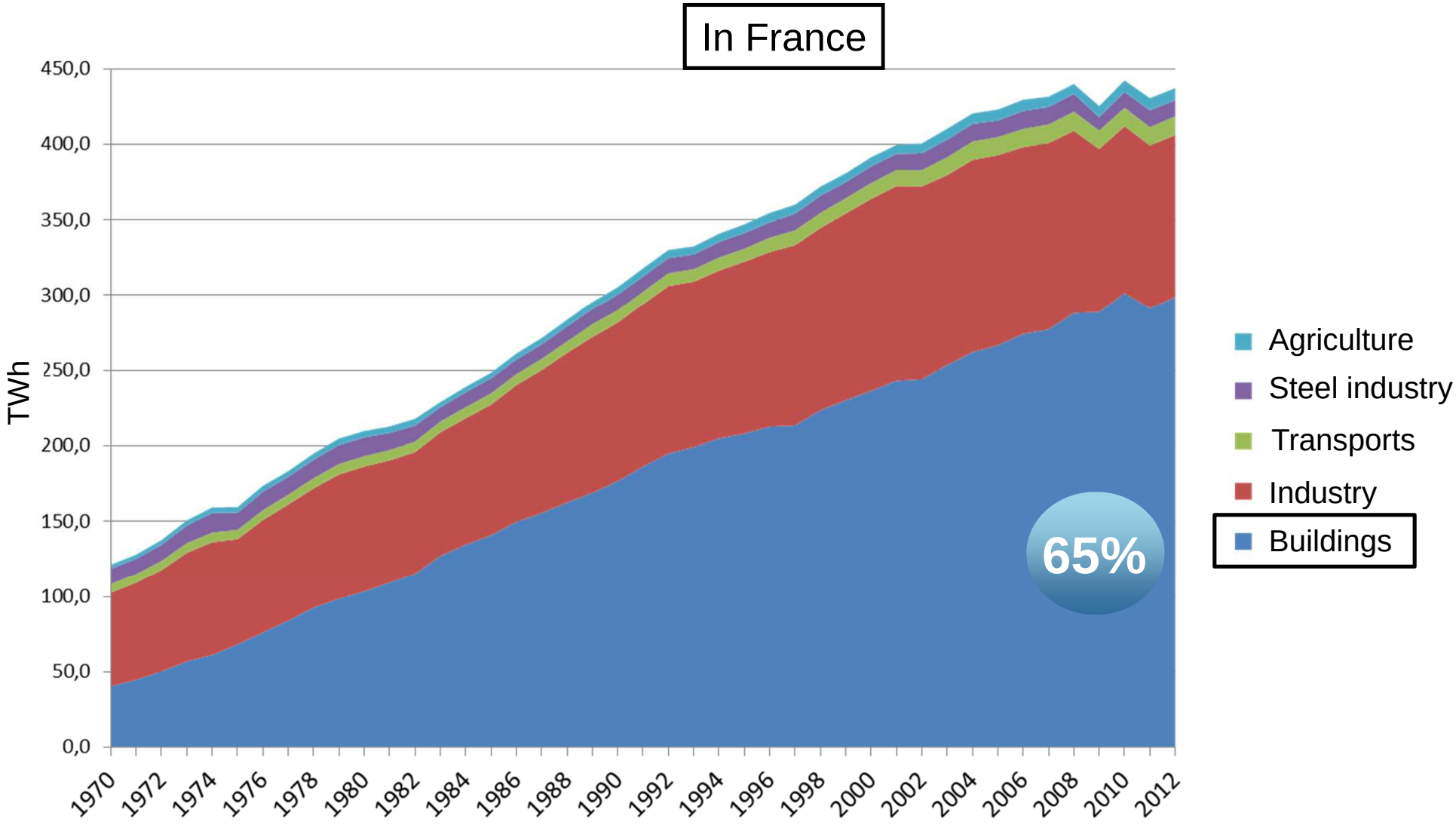
Electrical Energy Key Figures: why it is important to work on “smart buildings” integrated in “smart grids”

for Buildings in France

Final consumption of electricity by sector

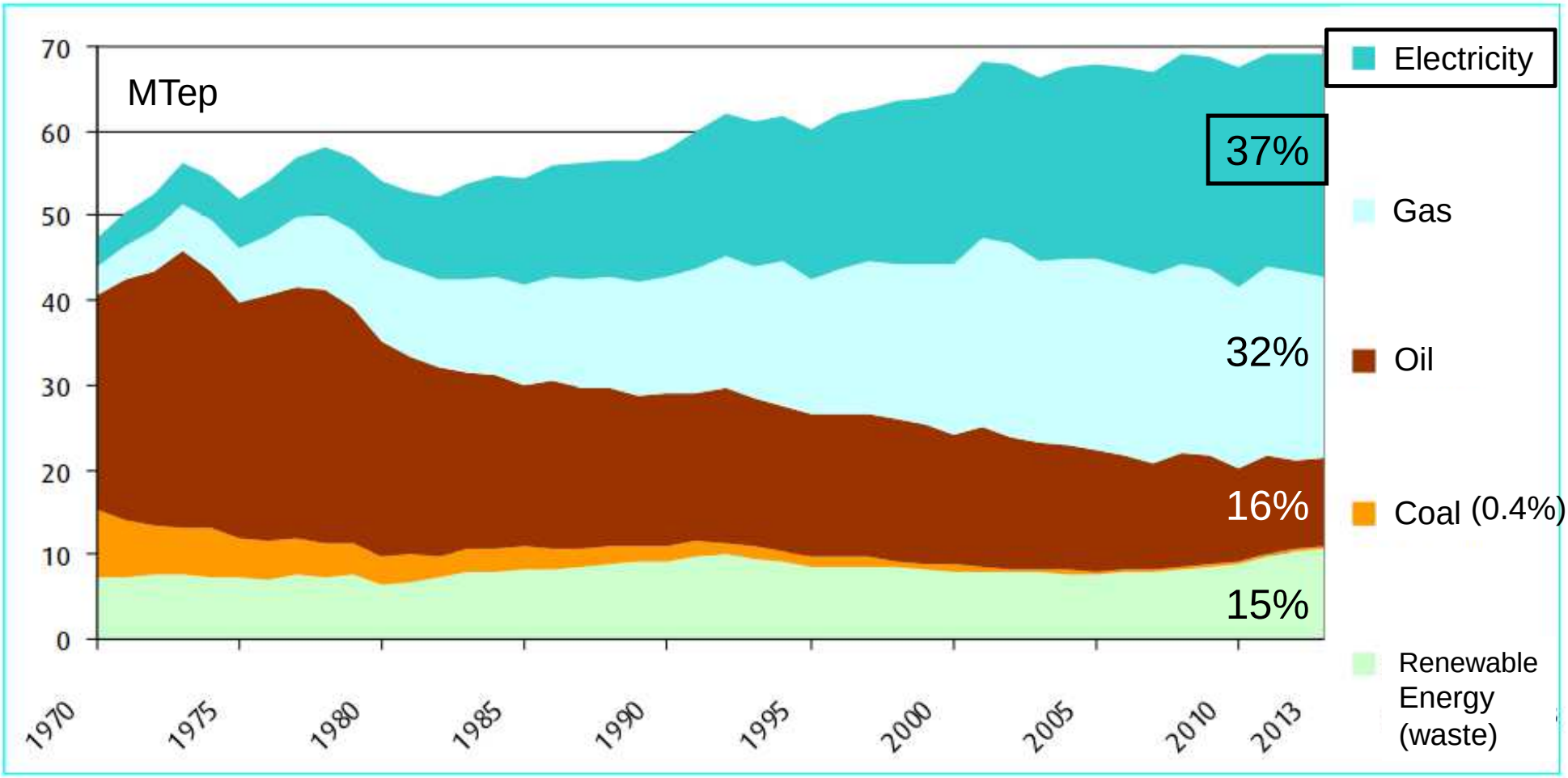


Evolution of final consumption of electricity by sector

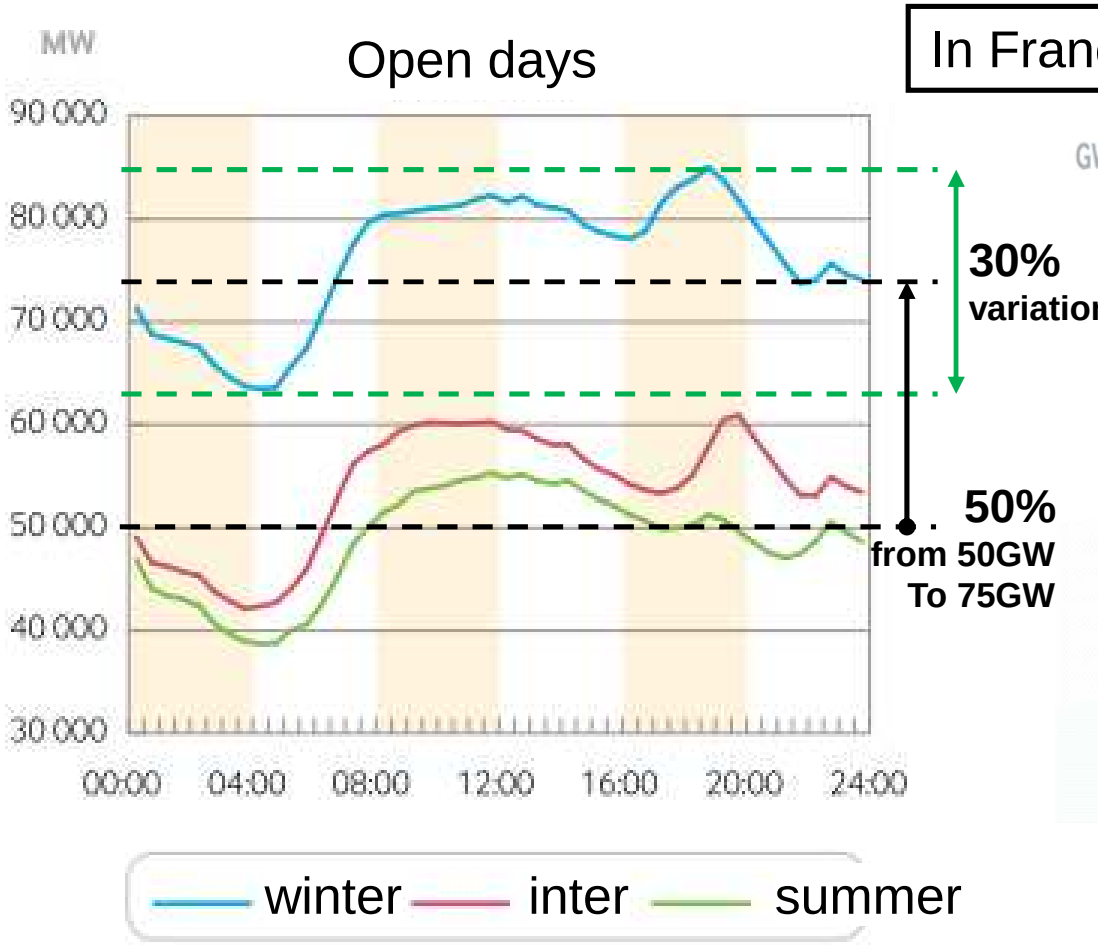


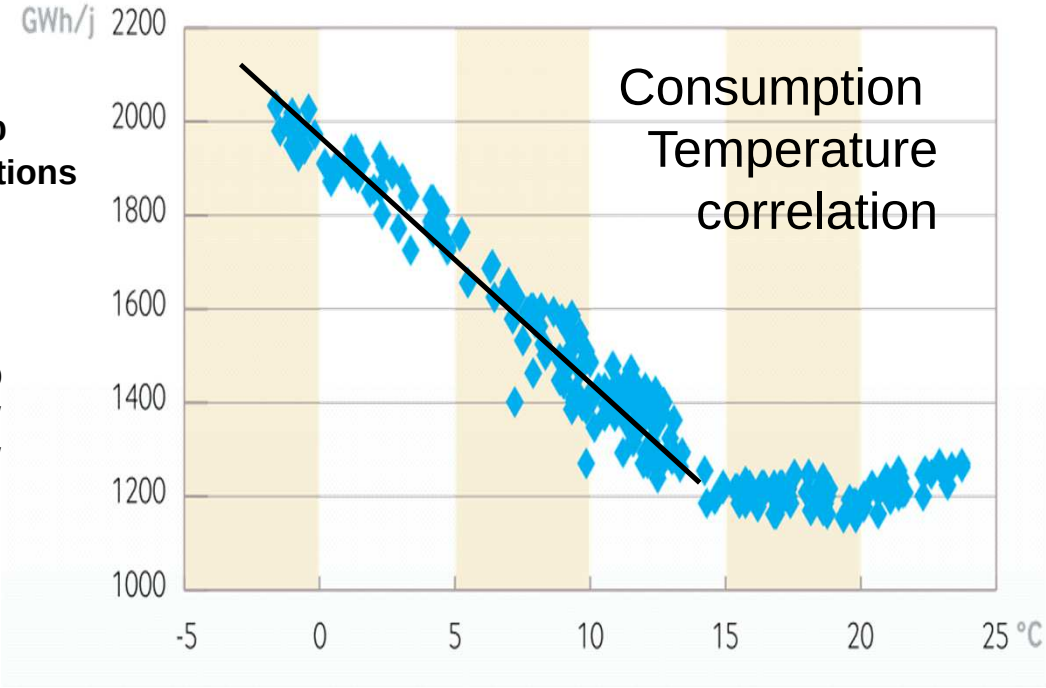
Final energy consumption in buildings

In France

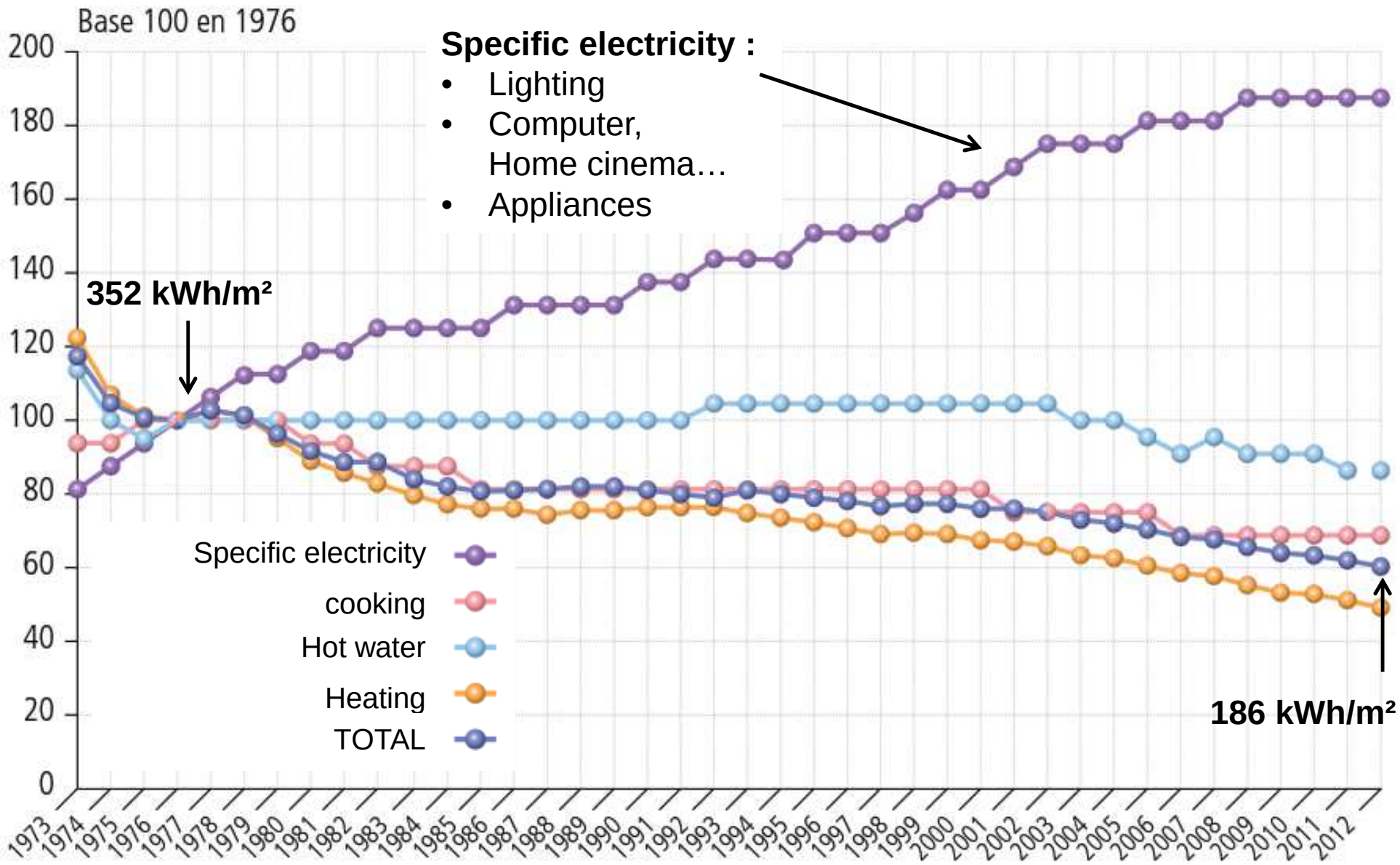


Typical daily electrical consumption





Evolution tendency of residential energy consumption /m²

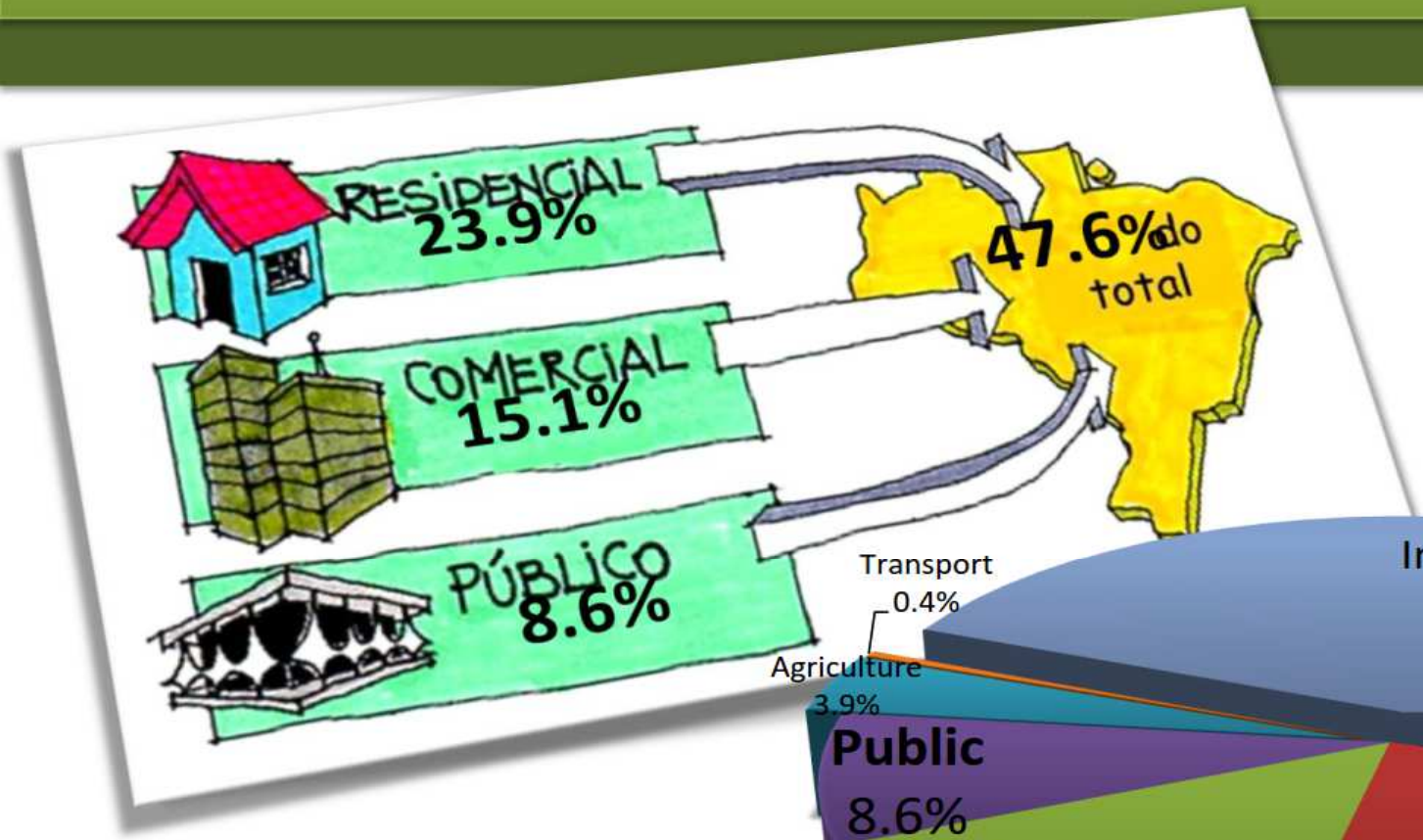


Electrical Energy Key Figures for

Buildings in Brazil :

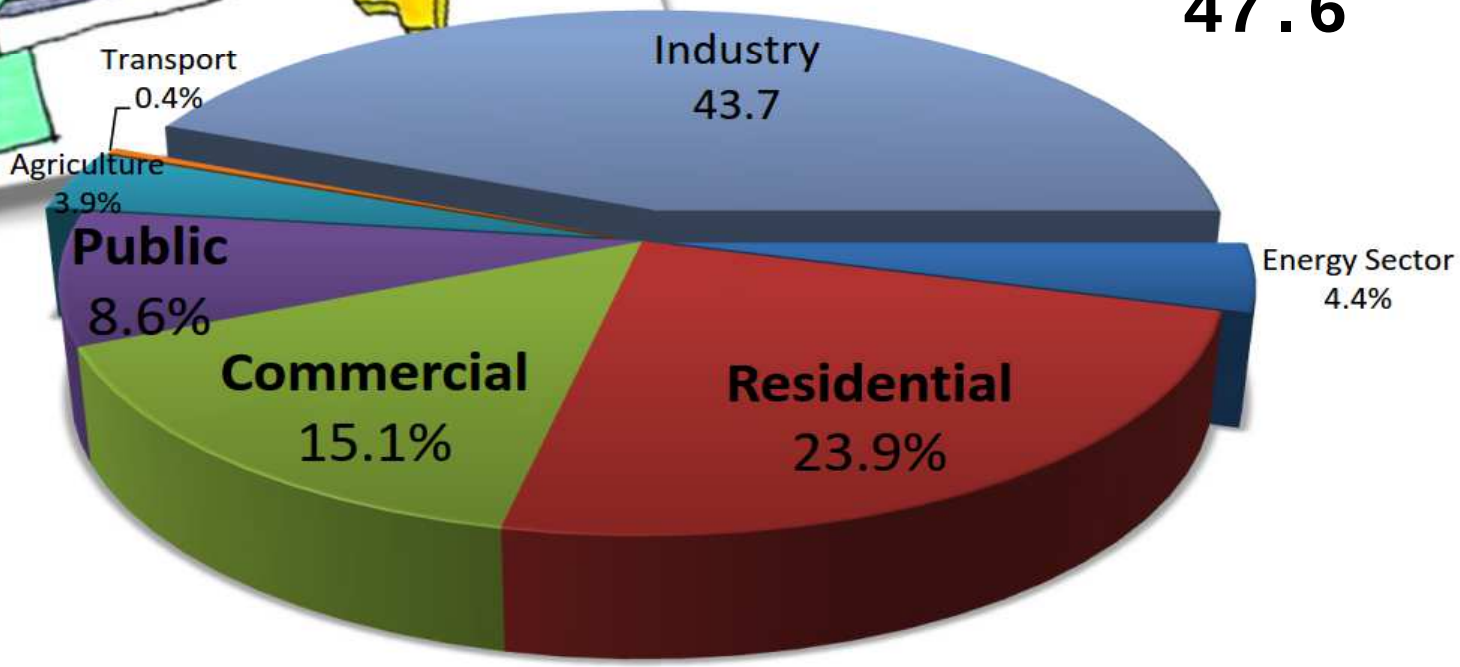
1. Electric consumption (%) ?
2. Electrical part in (%) :
    1. Public ?
    2. Commercial ?
    3. Residential ?
3. 3 most important consumers in residential building ?

ELECTRIC ENERGY CONSUMPTION IN BRAZIL



23.9
+15.1
+ 8.6

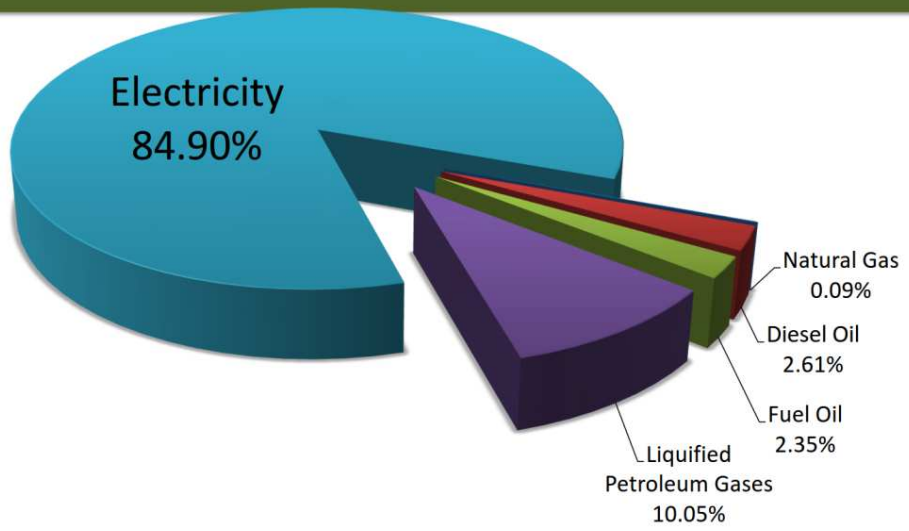
47.6



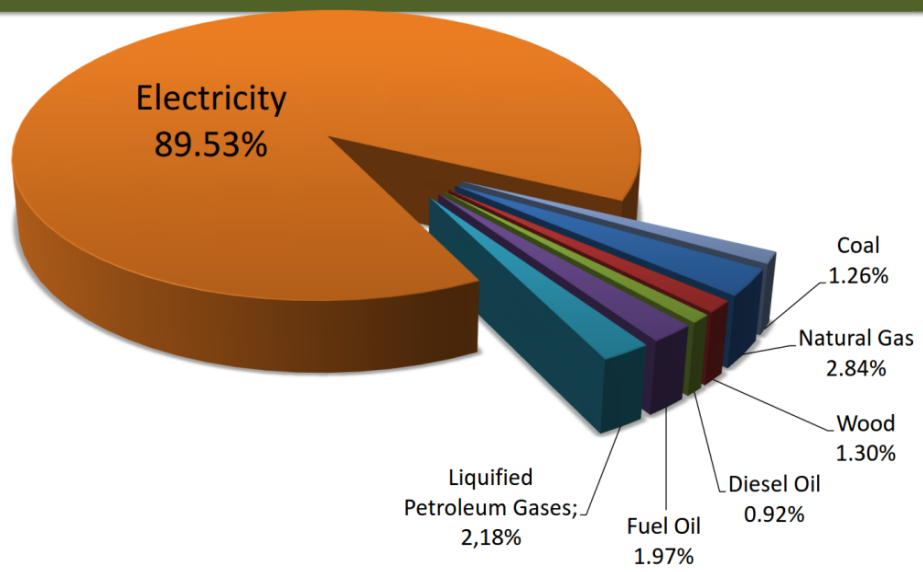
From Prof. Roberto Lamberts, LabEEE

Source: BEN- 2010 / year 2009

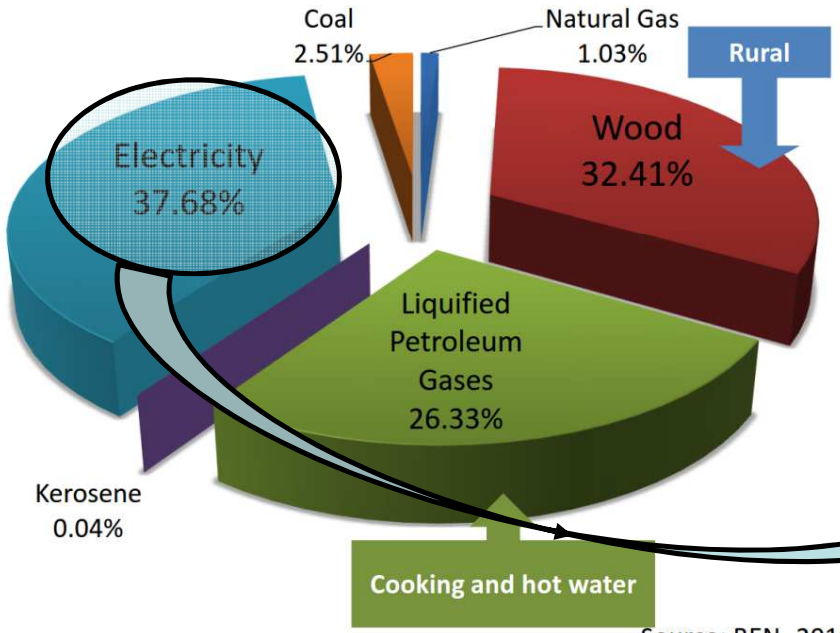
SOURCES CONSUMPTION - PUBLIC SECTOR



SOURCES CONSUMPTION - COMMERCIAL SECTOR

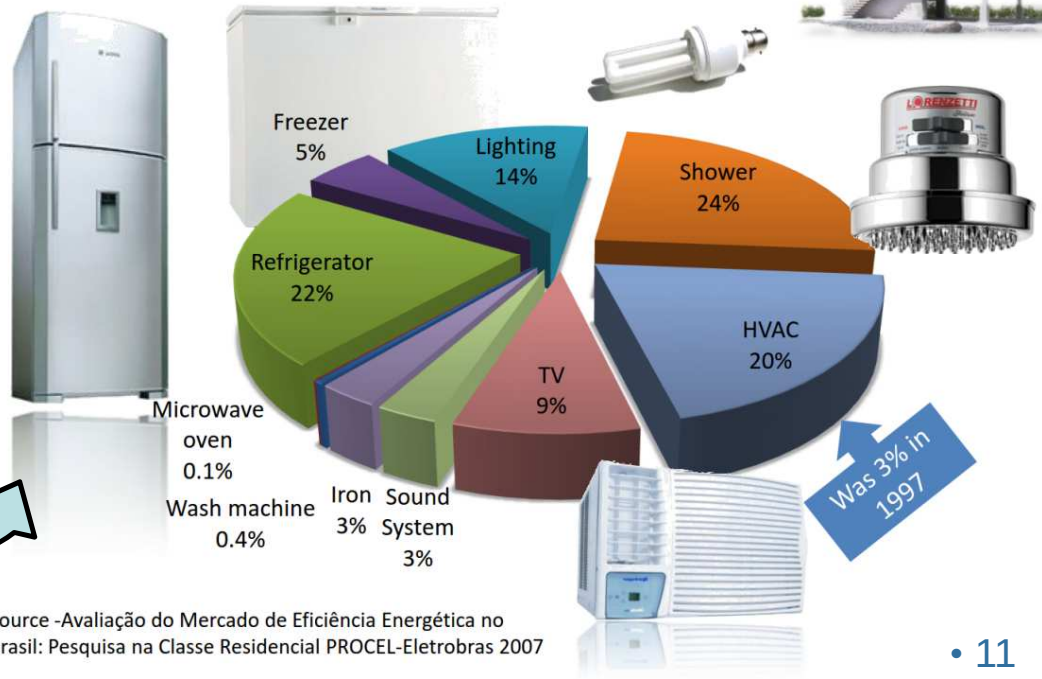


CONSUMPTION IN RESIDENTIAL SECTOR



Source: BEN- 2010 / year 2009

RESIDENTIAL ELECTRIC END USE



Source -Avaliação do Mercado de Eficiência Energética no Brasil: Pesquisa na Classe Residencial PROCEL-Eletrobras 2007

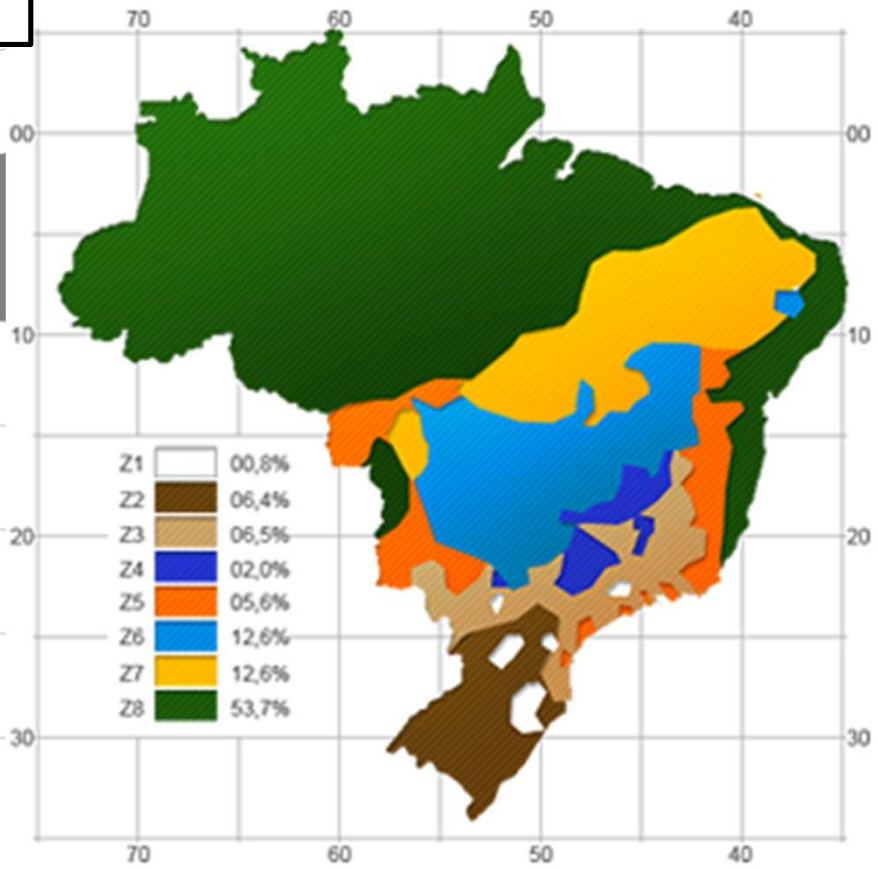
From Prof. Roberto Lamberts, LabEEE

RESIDENTIAL ENERGY CONSUMPTION

Description	Unit	2010	2030
Total Residential	TWh/year	**105.35**	**284.65**
Mean consumption per dwelling	kWh/month	**178**	**331**

Bioclimatic zones:

Z1: 21,5ºC, Z2: 16,9ºC, Z3: 23,1ºC,
Z4: 21,6ºC, Z5: 22ºC, Z6: 24,1ºC,
Z7: 26.1ºC, Z8: 26.9ºC



Consumption estimative 2 bedrooms with HVAC

City	Unidade	HVAC	Total
Curitiba - ZB1	kWh/month	**45**	**223**
Florianópolis - ZB3	kWh/month	**50**	**228**
São Luís – ZB8	kWh/month	**240**	**418**

85% of residential sector are houses

Consequences ?

For Electrical Engineers

Working on the “smart building” integrated in the “smart grid”

Electricity consumption will still increase

- **What can be the consequences :**
  - Non renewable energy / CO2 production
  - Lake of energy, Increase of peak demand, Grid instability…
- **What can we do ?**
  - Improve efficiency of lighting, appliances, fans and pumps.
  - Help the grid with local production : PV on the roof to supply HVAC
  - Improve the usage of energy :
    - **Awareness** of people when using energy
    - **Automation / Regulation** : automatic sun shading, cooling using fresh air during nights, controlling HVAC according to meteorological forecast…

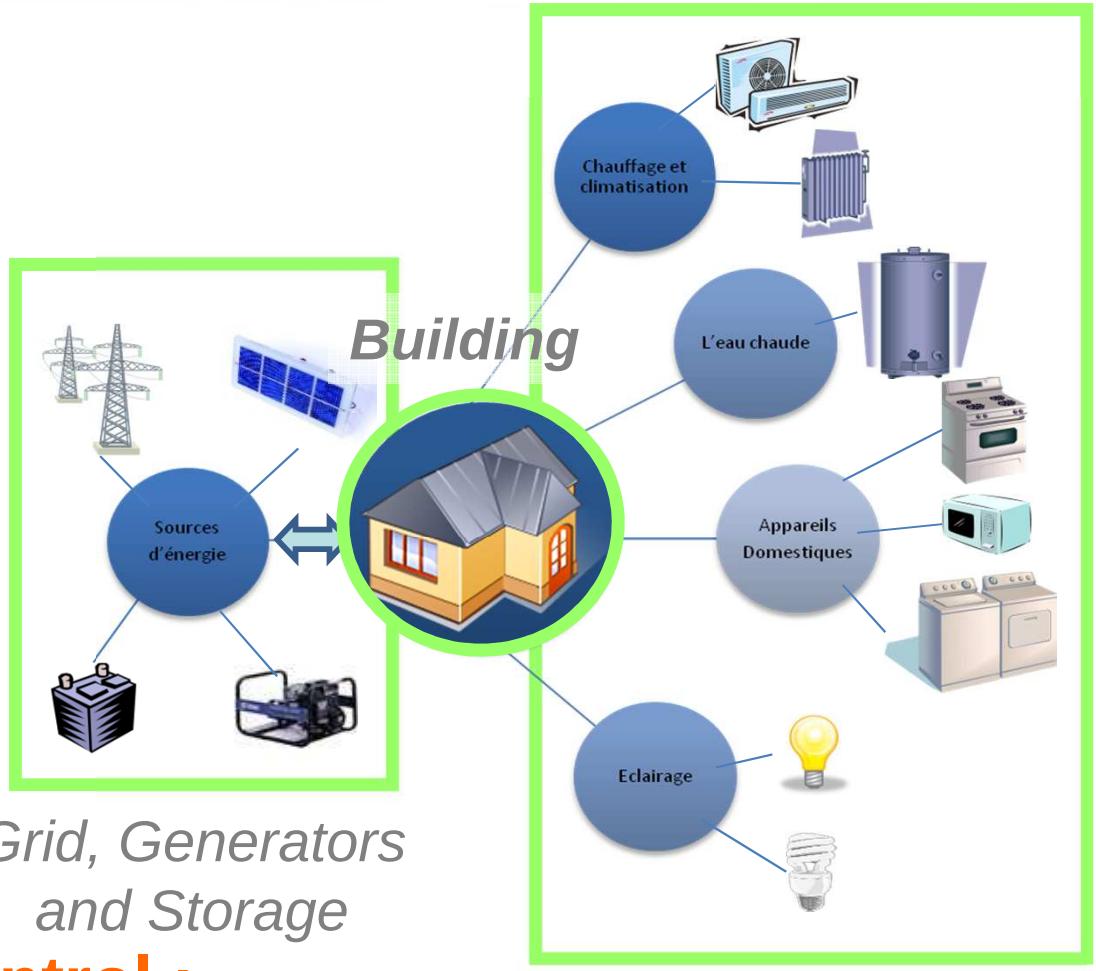
=> Improve interaction between grid and buildings:

- Optimal power flow including buildings :
  - Production : disturbed energy resources management
  - Consumption : demand side management
- For the whole grid / for micro-grids (autonomy)
- Building active solution for Demand Response

The "building" system

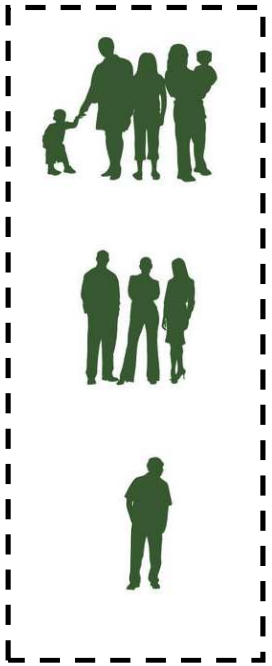
Uncertainties :

- renewable sources
- heating/cooling needs



Grid, Generators and Storage

Loads



Uncertainties :

- equip. usage
- comfort req.

Multi sources control :

- arbitration between generators
- scheduling production / storage
- uncertainties on availability

Load management :

- uncontrolled load prediction
- scheduling / adjusting / shedding

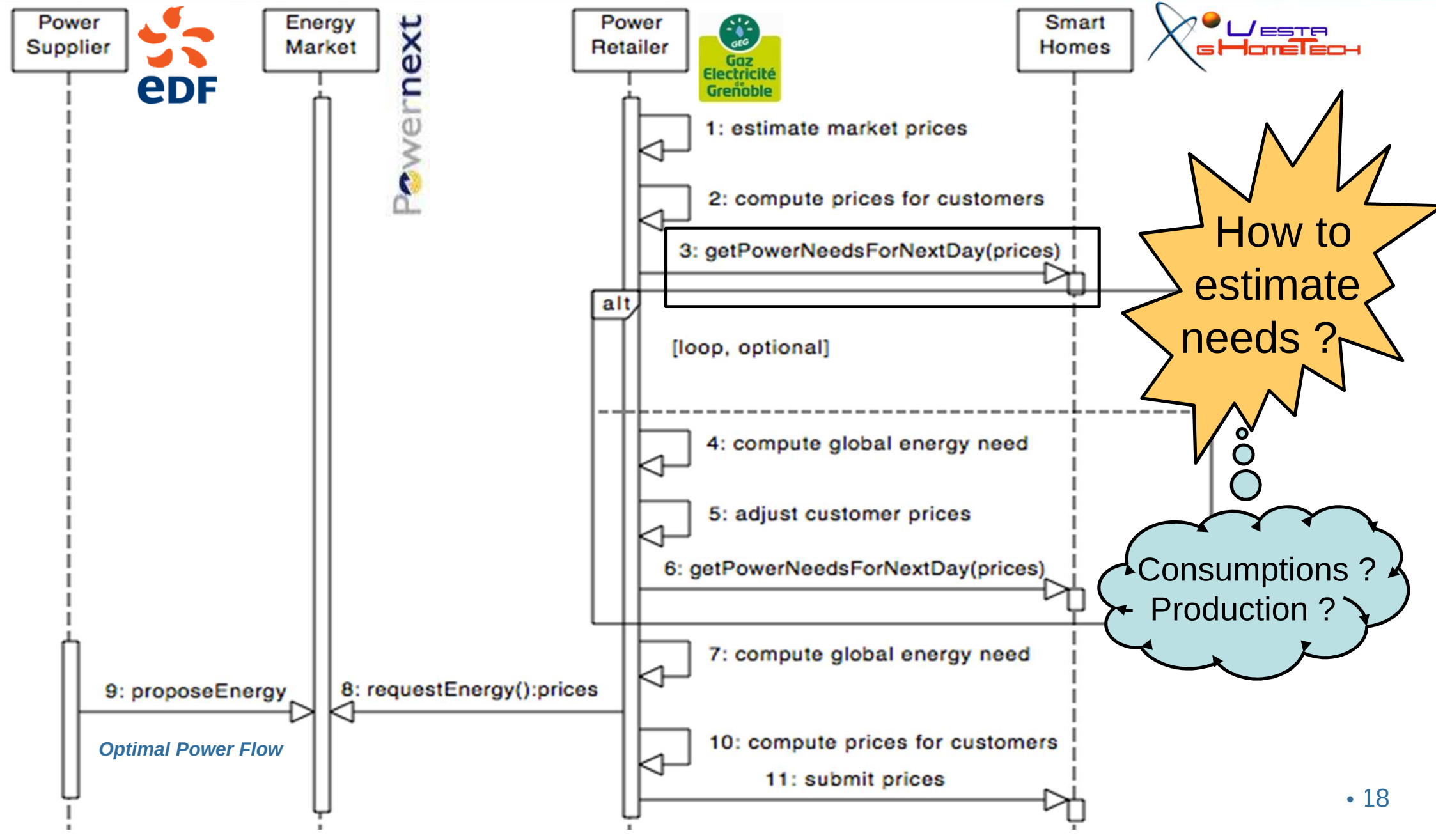
How to manage consumption of buildings from the grid ?

Dynamic pricing and smart meters

New “smart” meter: Linky (ERDF)

- **Number of installed Linky**
  - Now : more than 100 000,
    - 3 000 000 in 2016
      - **35 000 000 planned for 2020**
- **Functionalities :**
  - Measuring the consumption and, if existing, distributed generation, with remote access
    - **Remote management :**
      - **8 controllable switches**
      - Turn off and on electricity
  - **Transfer messages** from market to the customer (consumer / producer)
    - **pricing signals.**
    - **power reduction demand**
  - A main communication port for transferring information via GPRS, GSM or CPL
  - Quality measurements *(including the continuity of supply and voltage quality).*
- Remote management of meter settings such as tariff structures, the contractual power, intervals reading the meter by suppliers

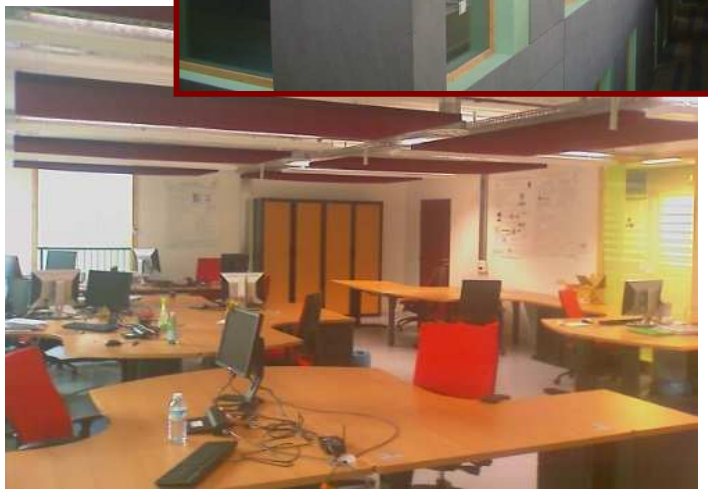
Demand Side Management :
Anticipating day ahead

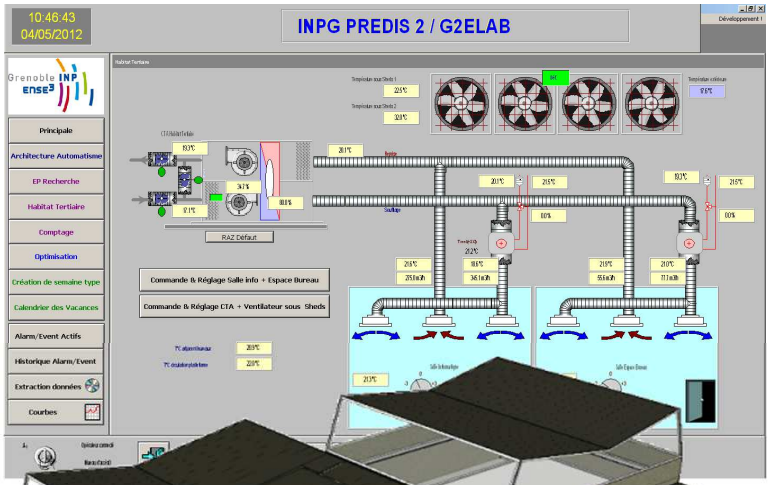


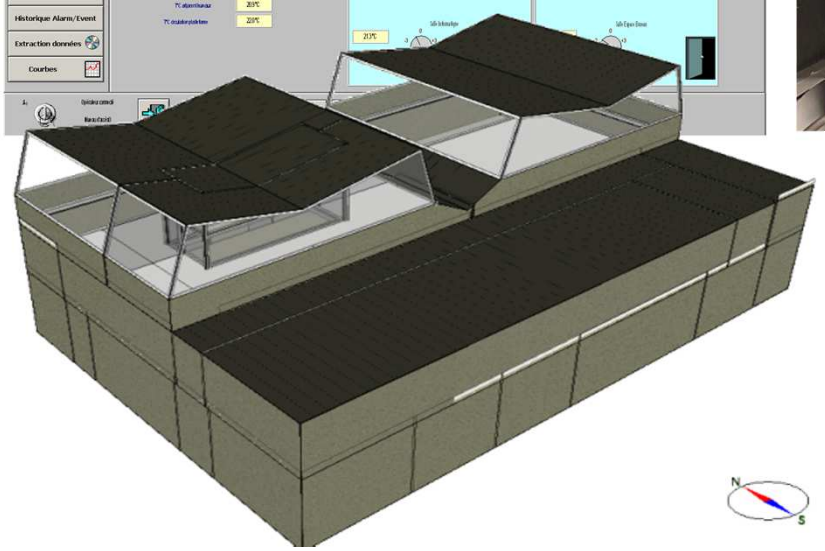
Experimental platforms

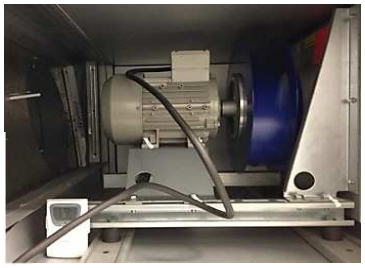
G2Elab – Predis
Grenoble, FRANCE

Smart Building Platform









Motor / Speed driver

Wireless sensors

Wattmeter Power Switch

- Measures and characterization
- Design and Operation of buildings
- User behavior

Plug & Play communication architecture

Monitored and controlled Equipments:

- HVAC double flow with heater and heat recovery
- Reversible heat pump
- Dimmable lighting
- Laptops…

Building Management System

- PLC TAC / Xenta
- Fieldbus : Lonworks / Dali / Modbus
- SCADA : InTouch OPC

Advanced monitoring in :

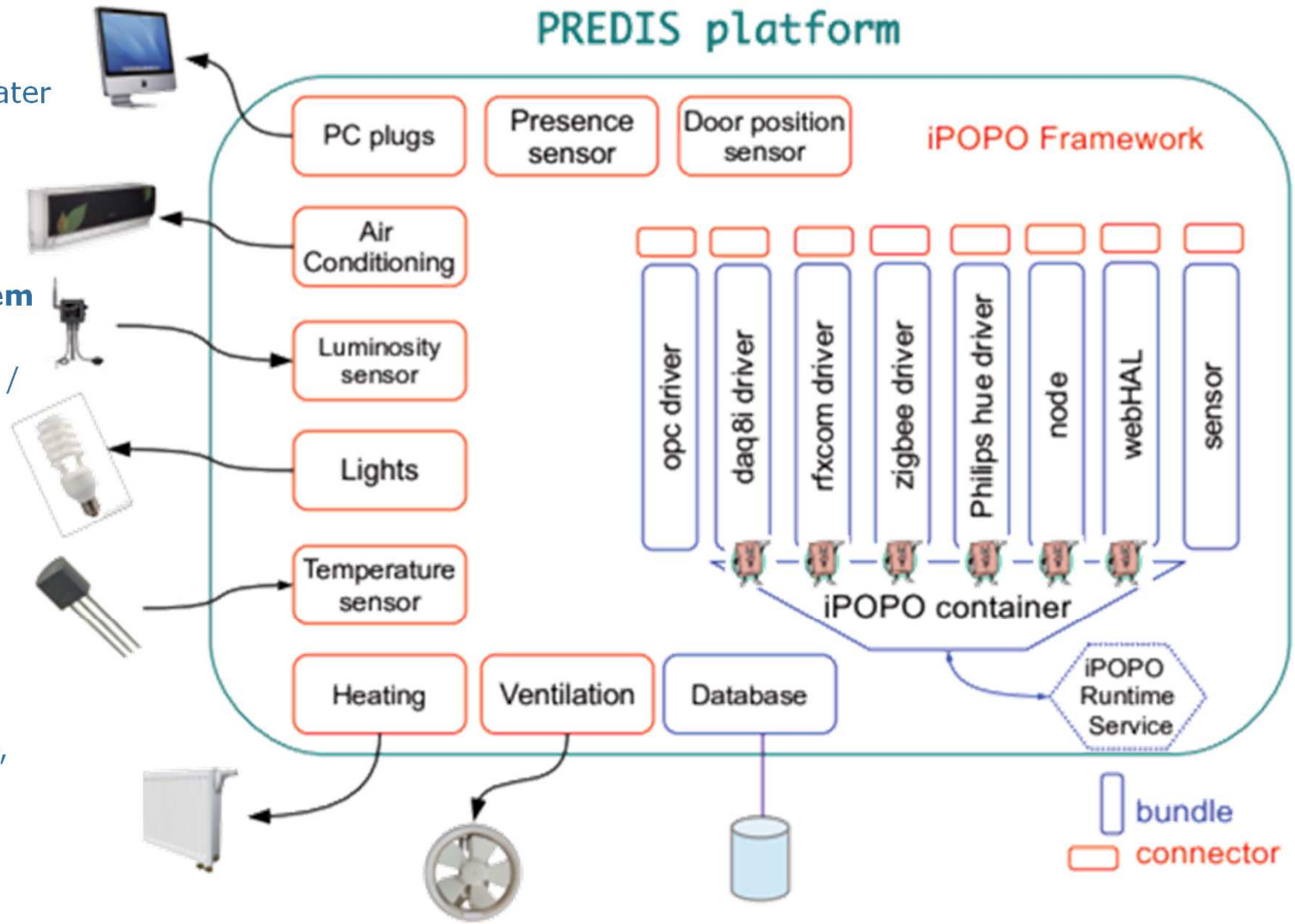
- electricity consumption
- controlled outlets
- temperature, CO2…

Communication supports

- Ethernet
- Wireless (433MHz, ZigBee, EnOcean, DeltaDore)
- Powerline : X10

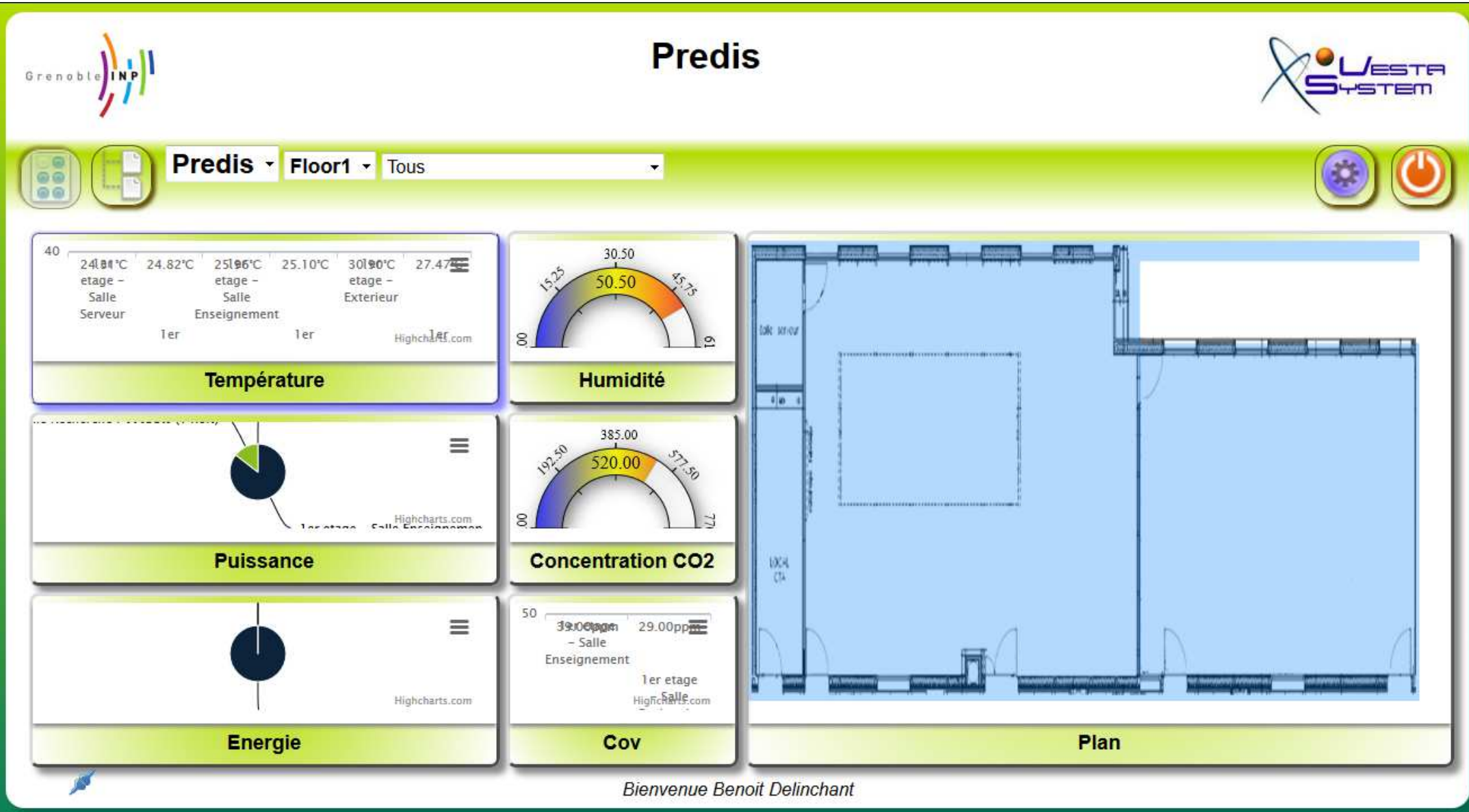
Web services :

- PV production
- Meteorology forecast
- Day ahead electricity prices
- Classroom occupancy forecast

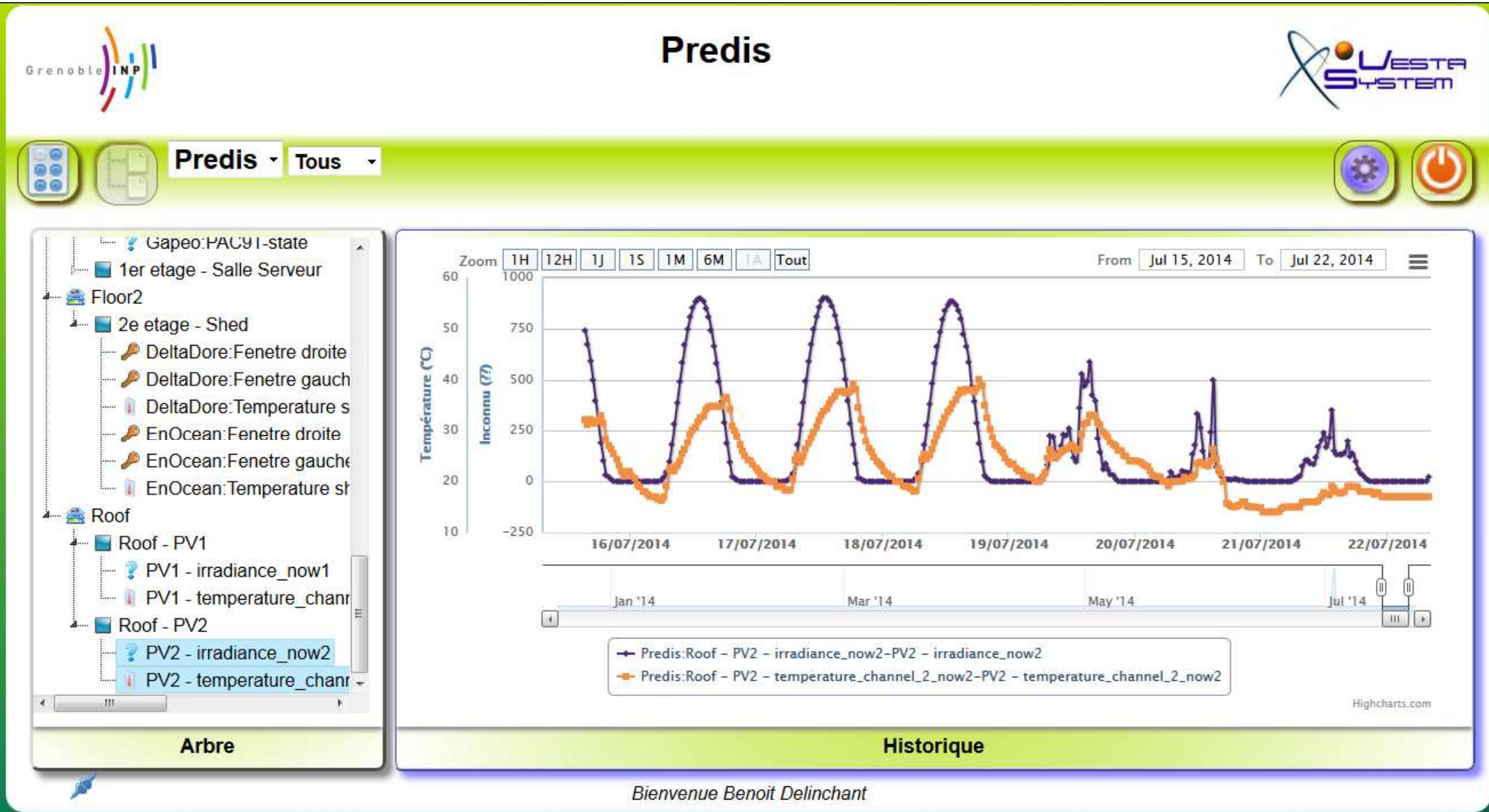


S. Abras T. Calmant S. Ploix D. Donsez F. Wurtz, O. Gattaz B. Delinchant « Developing Dynamic Heterogeneous Environments in Smart Building Using iPOPO » SmartGreen'14, International Conference on Smart Grids and green IT Systems, Barcelona, Spain, 3:4 April 2014

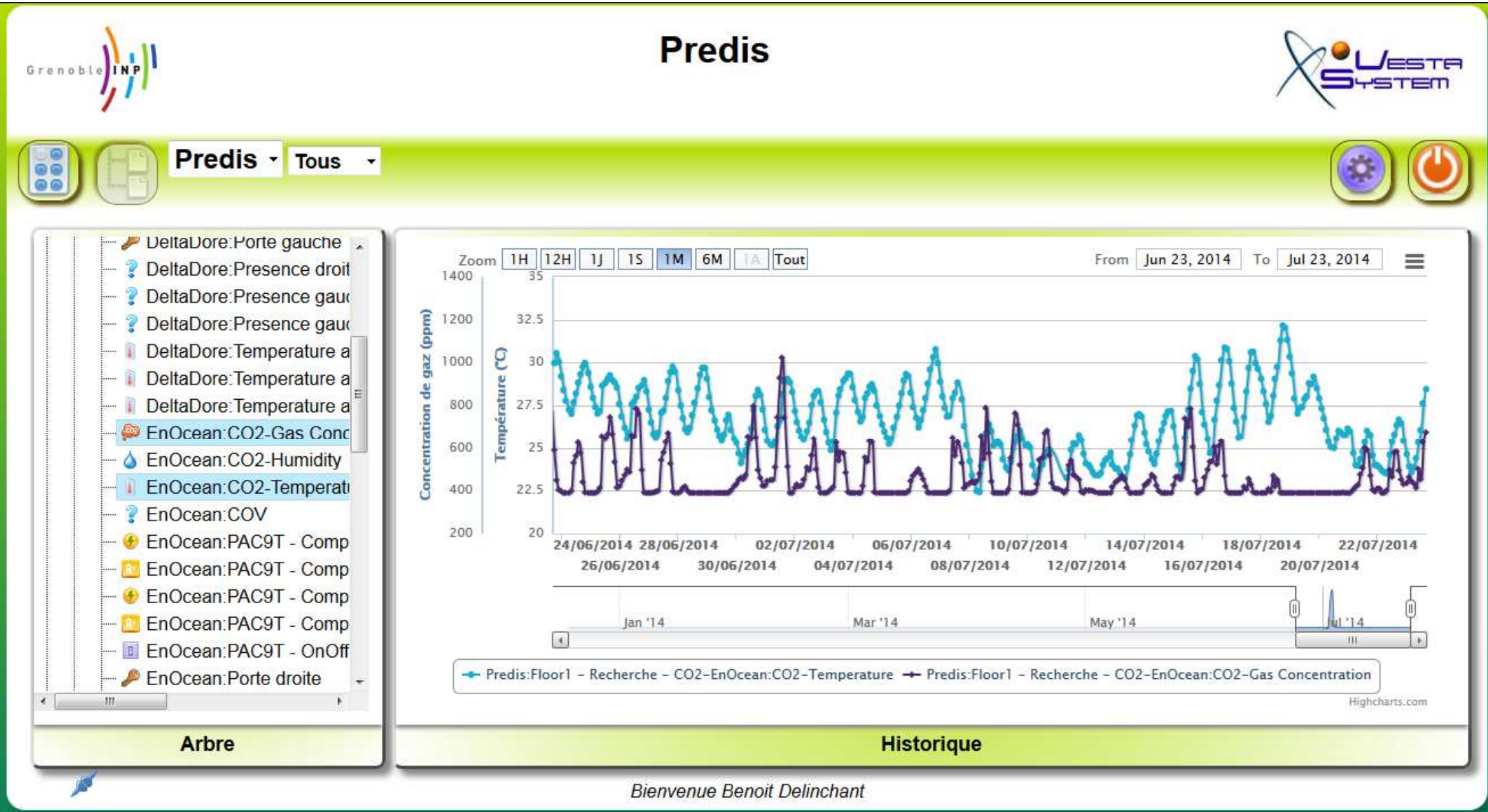
Global overview



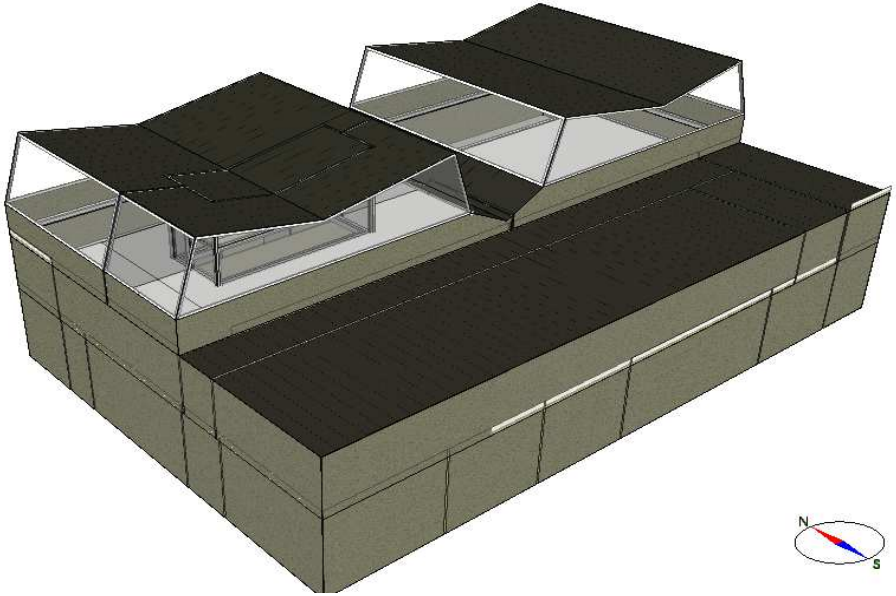
PV Production

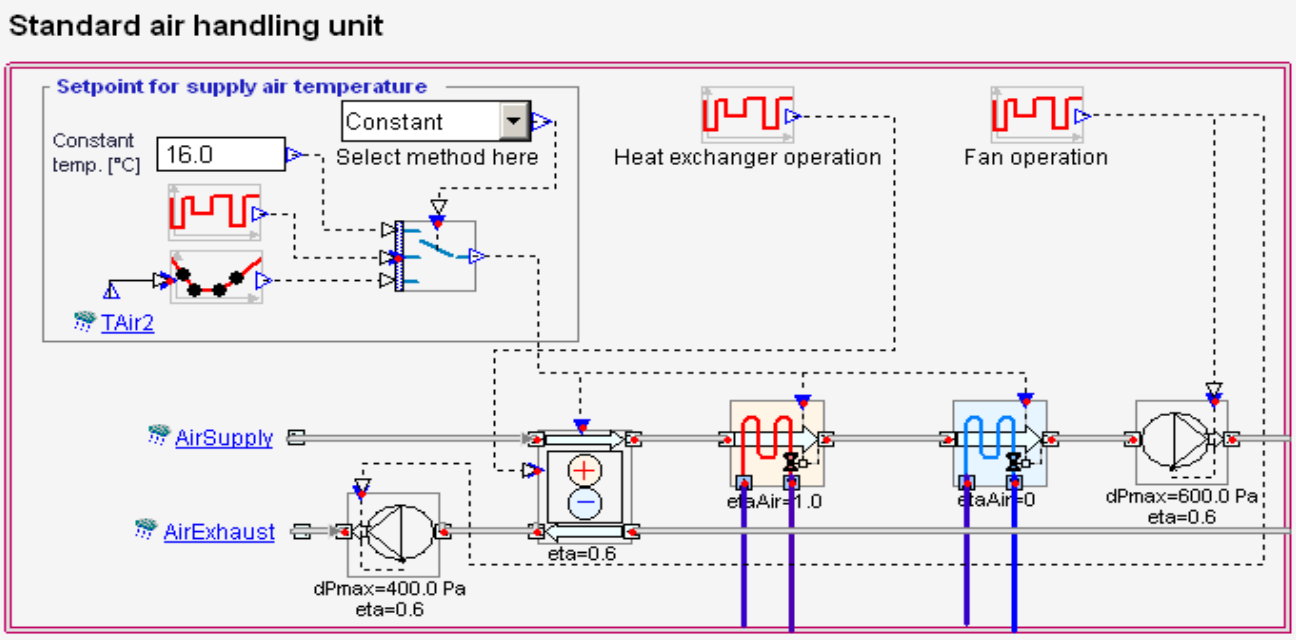


Comfort (Temperature / CO2)



Dynamic Thermal simulation



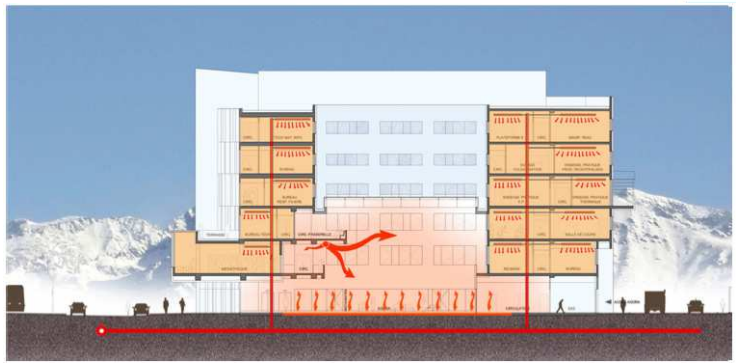


		Energie fournie	
		kWh	kWh/m²
	Eclairage, service industriel	8945	5.5
	Refroidissement	2359	1.5
	Chauffage/climatisation aux.	3108	1.9
	Total, Services électrique	14412	8.9
	Chauffage	9071	5.6
	Eau chaude sanitaire	7865	4.9
	Total, Services mazout*	16936	10.5
	Total	31348	19.4
	Equipement, locataire	19621	12.1
	Total, Consommateur électrique	19621	12.1
	Somme globale	50969	31.5

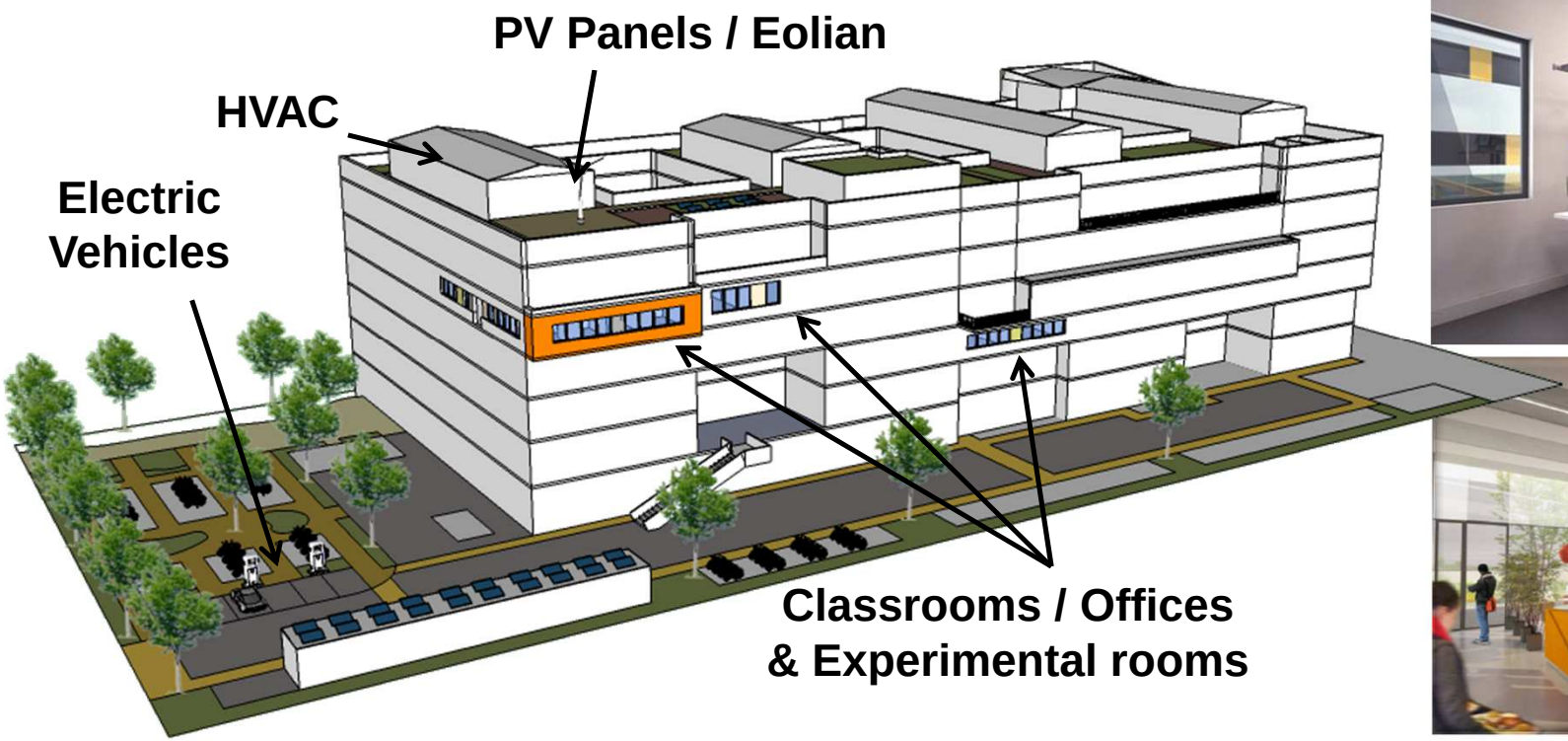
New Experimental plateform

GreEn-ER
Grenoble, FRANCE

New Building – Sept 2015



Smart Building Platform: A part of Green-ER



Energy production

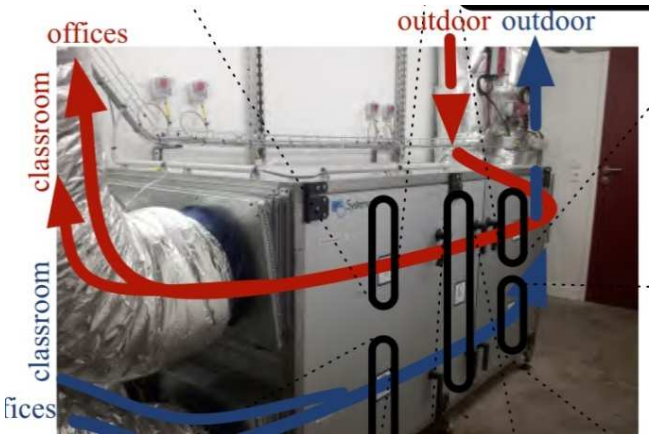
- **CPV :** Concentrating Photovoltaics, 2-axis sun tracker. 10kWp (9x1.14kWp)
- **Eolian :** vertical axis, (1kW per unit)
- **CHP :** Combined Heat & power (10kW electric, 25kW thermic)

Storage and Loads

- **Stationary battery :** 50kWh, 60 Ah
- **4 Electric vehicles :** 4 x 22 kWh lithium ion battery
- **50 Laptop computers :** 50*0.1kWh, 8Ah
- **LOADS :** HVAC/Lighting/Computers…

	kWh/day	kWh/an
Computers	23	8550
Ventilation	22	8000
Lighting	11	4000
Pumps	5	2000
Total Electric	**61**	**22550**
Heating (thermic)	24 (winter)	2400
Cooling (thermic)	28 (summer)	2800
Total Thermic	**26**	**5200**

Renault Zoé



Demand side management by using modelisation and optimisation

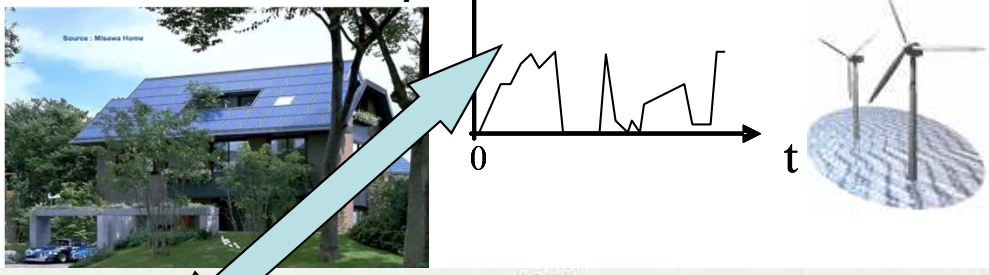
Optimization trade-off between :

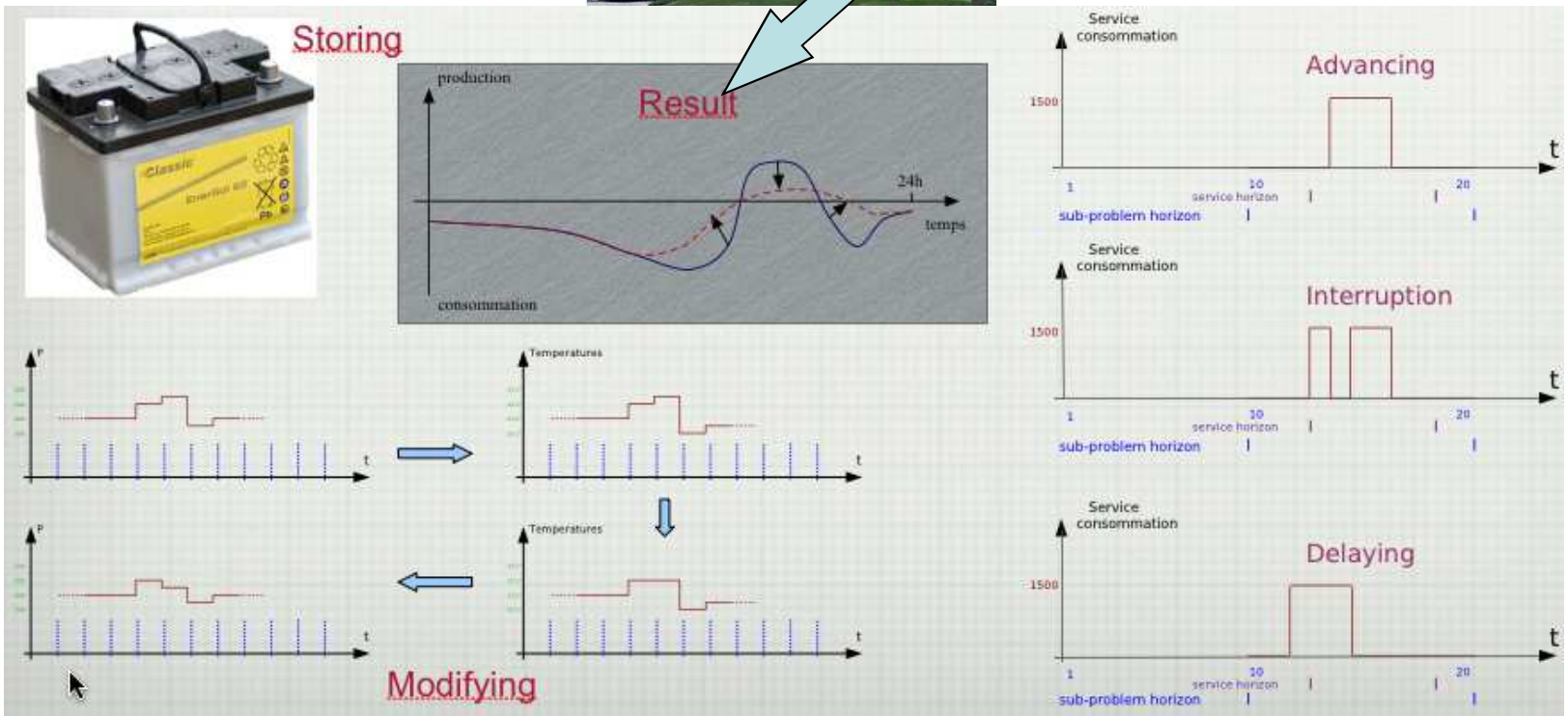
- Energy consumption (or energy price)
- **Human comfort**

Buildings as an active energy management system in the network

The scientific problematic (A)

At the scale of the building:
locally adaptation
of production to needs





The approach used: Optimization

Anticipative management

The approach used: Optimization

Formulation : Mainly Mixed Linear Programming

Objective function to minimize : $f^T x$

Under constraints :

$Ax \leq b$

$A_{eq}.x = b_{eq}$

$lb \leq x \leq ub$

With :

x are the variables (continue, binary or integers)

A, A_{eq} are matrixes;

f, b, b_{eq} are vectors

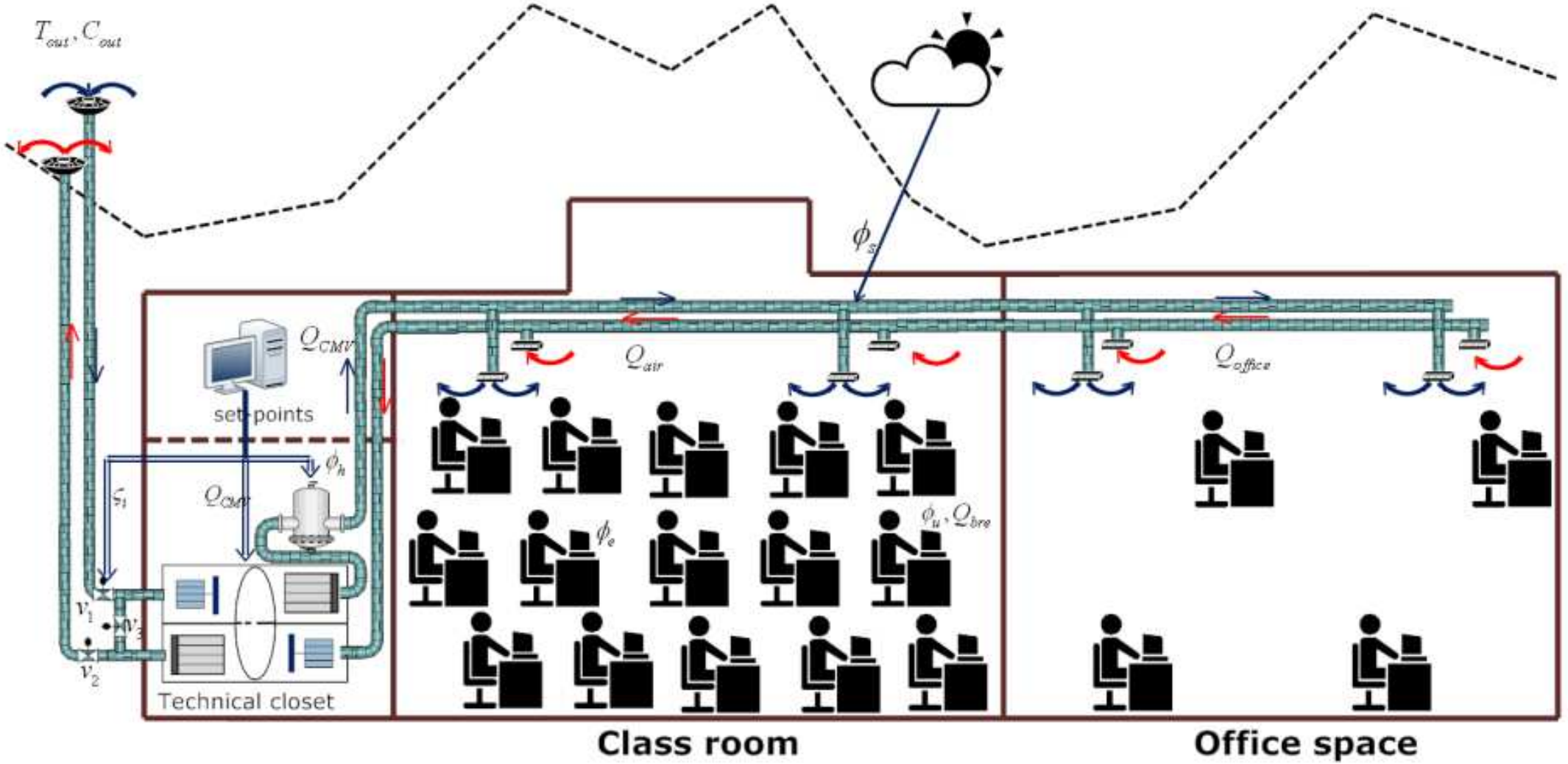
But also : MILP, MINLP, SQP and dynamic approaches

Solved with : Matlab

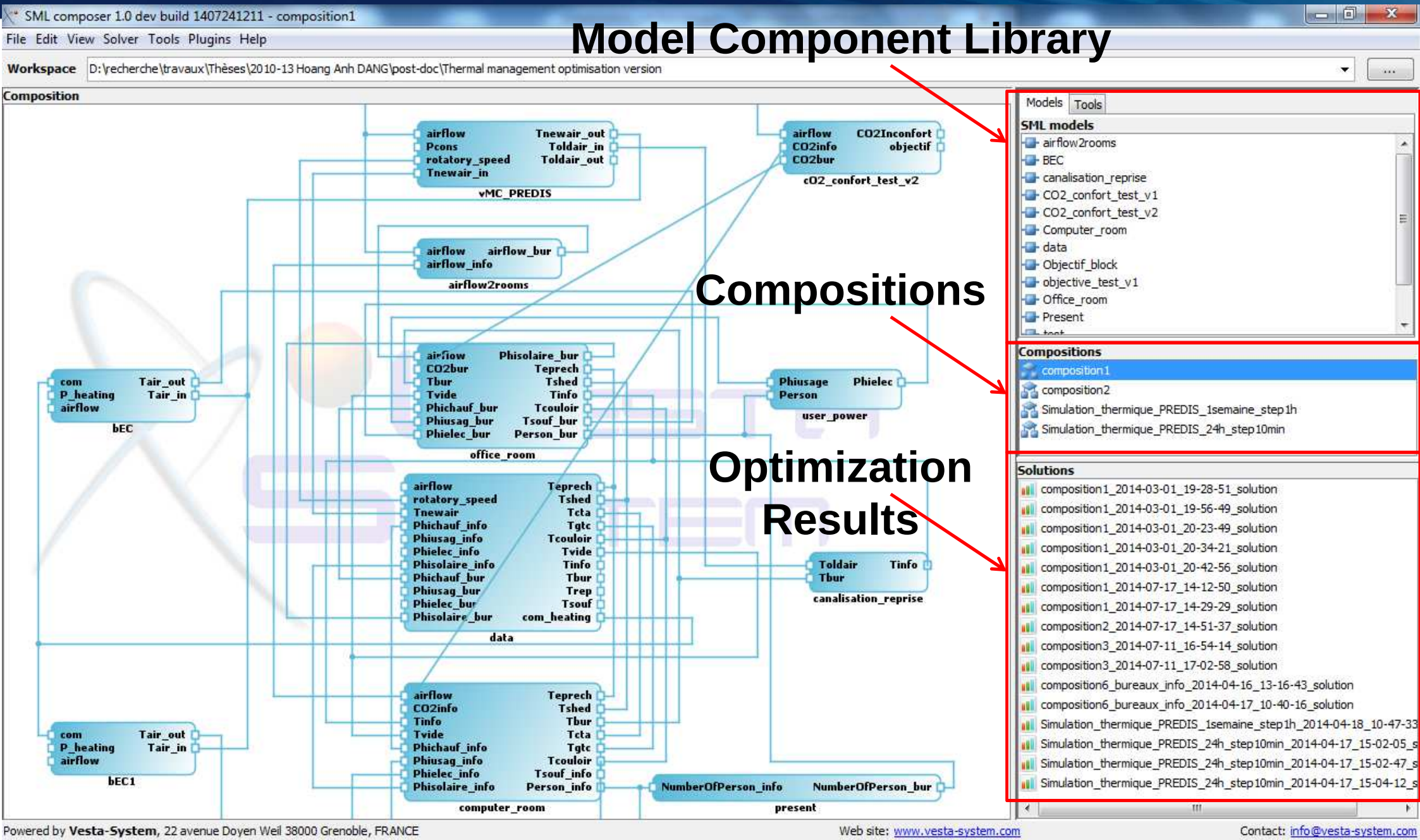
CPLEX (Ilog)

Own developed tools (CADES, SML – Composer)

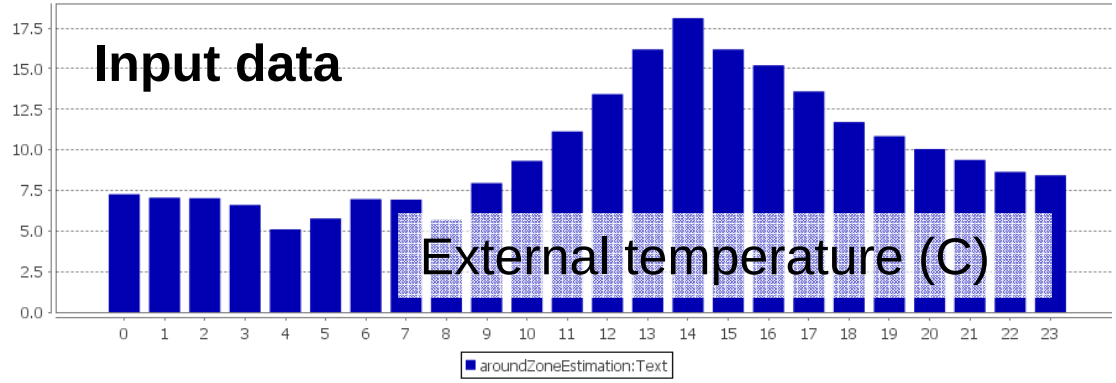
Application to our experimental platform

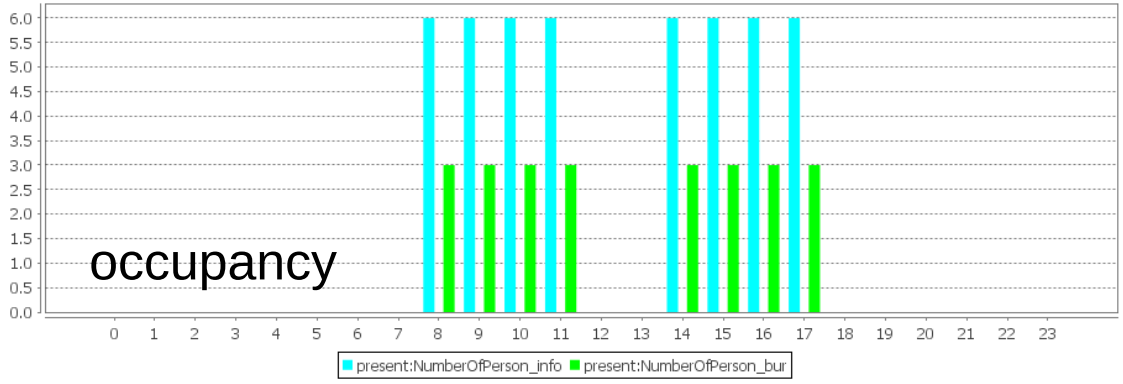


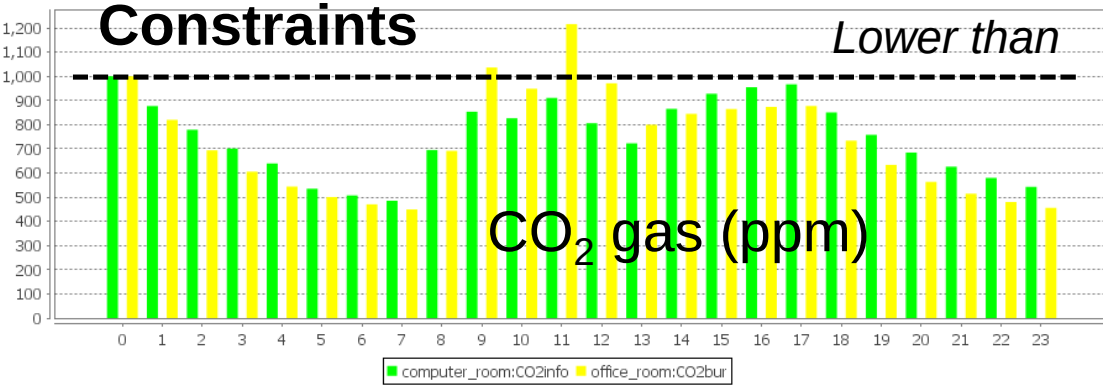
MILP - Optimization software

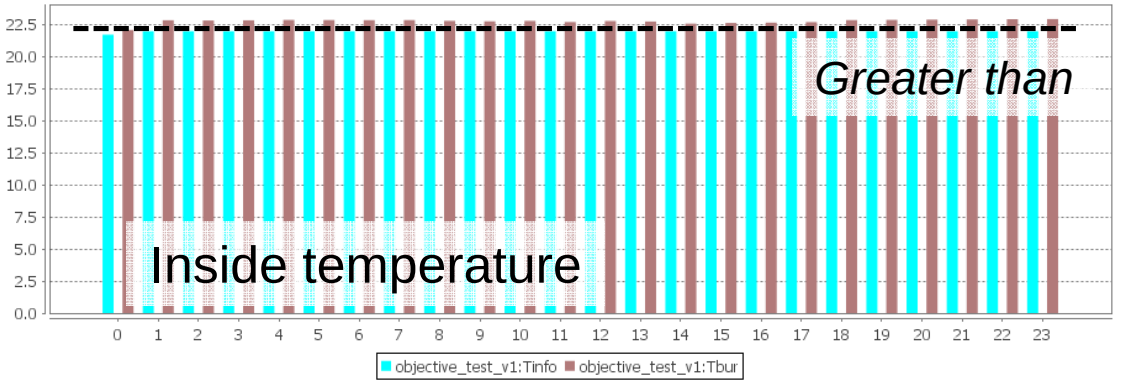


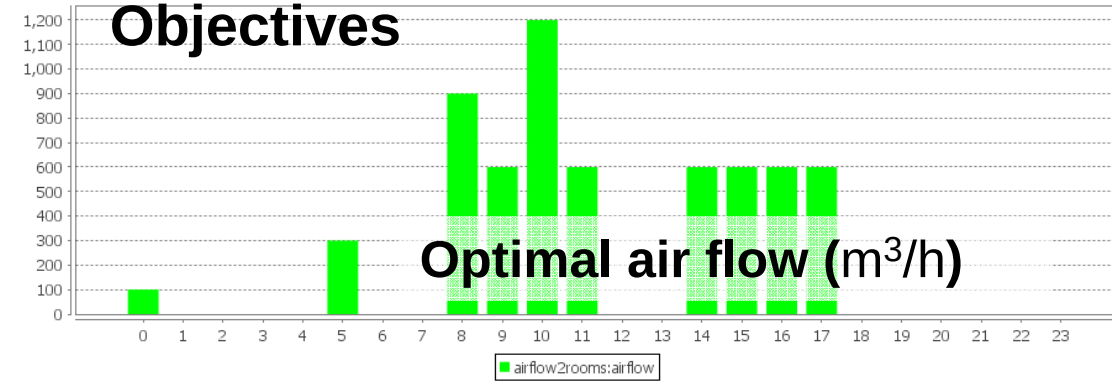
Optimal operating

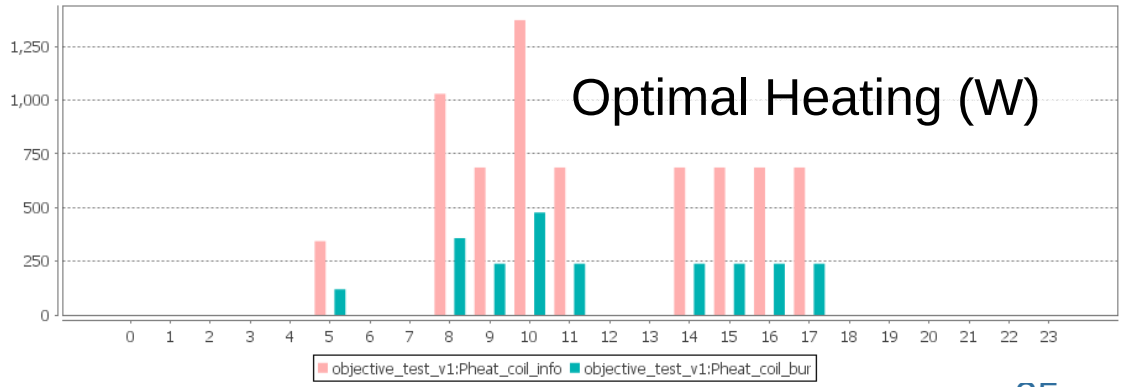




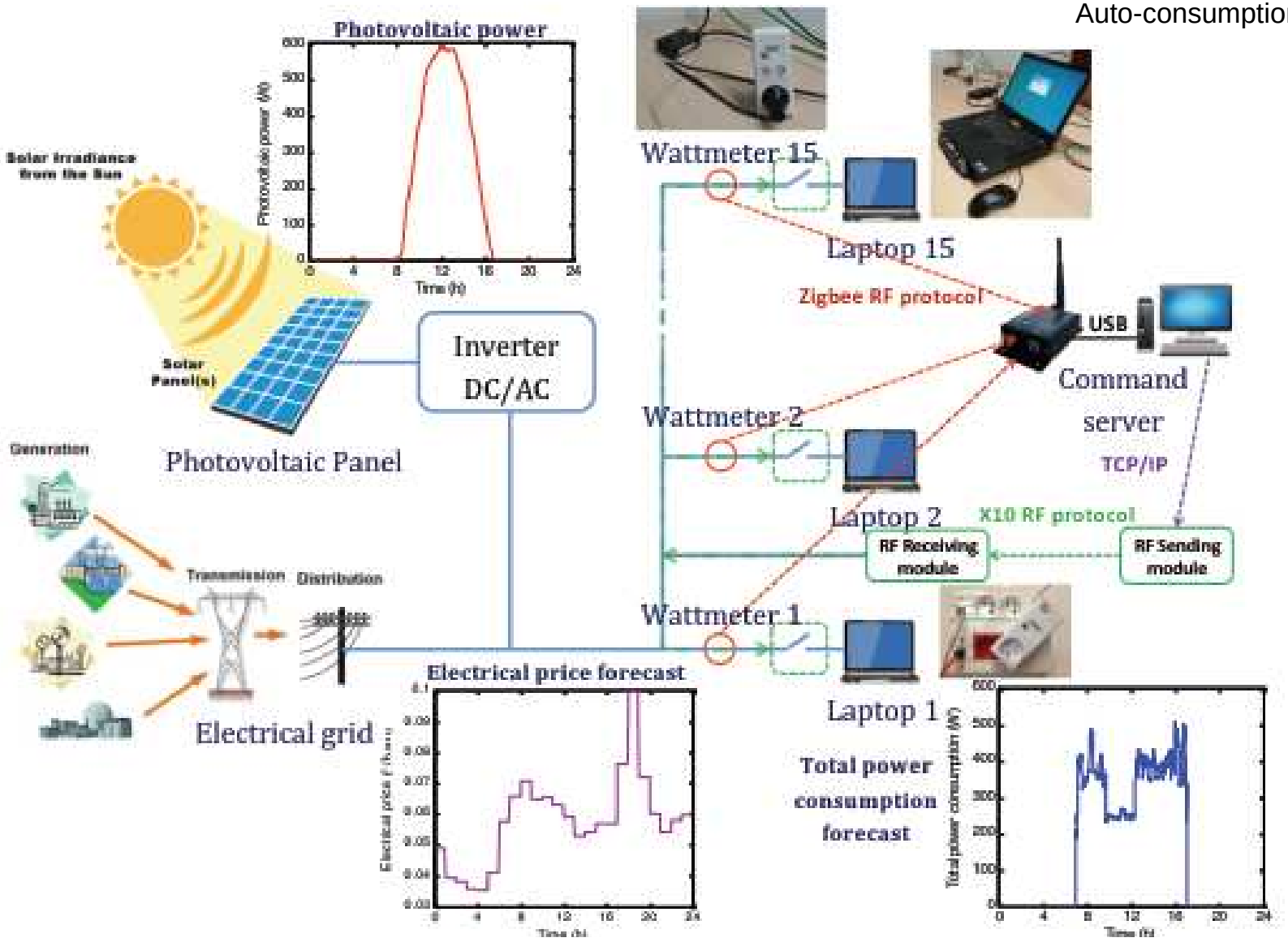




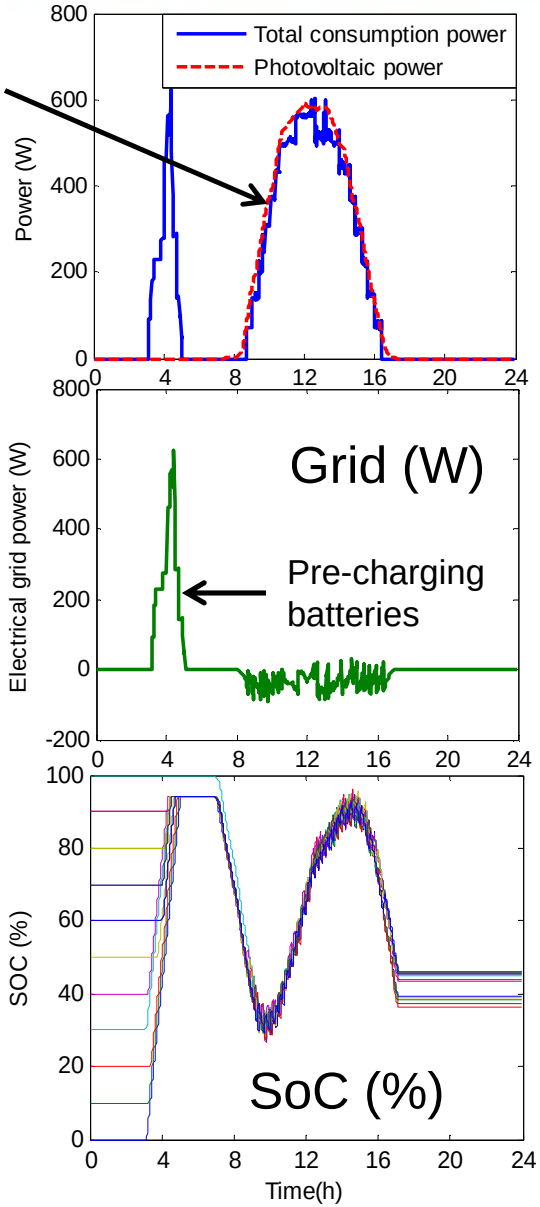




Optimal operating of laptops power supply, in order to maximize autonomy



Auto-consumption



Hoang:Anh Dang, Benoit Delinchant, and Frederic Wurtz, “Toward autonomous photovoltaic building energy management: modeling and control of electrochemical batteries”, Proceedings of Building Simulation 2013: 13th Conference of IBPSA 2013, Chambery, August 2013

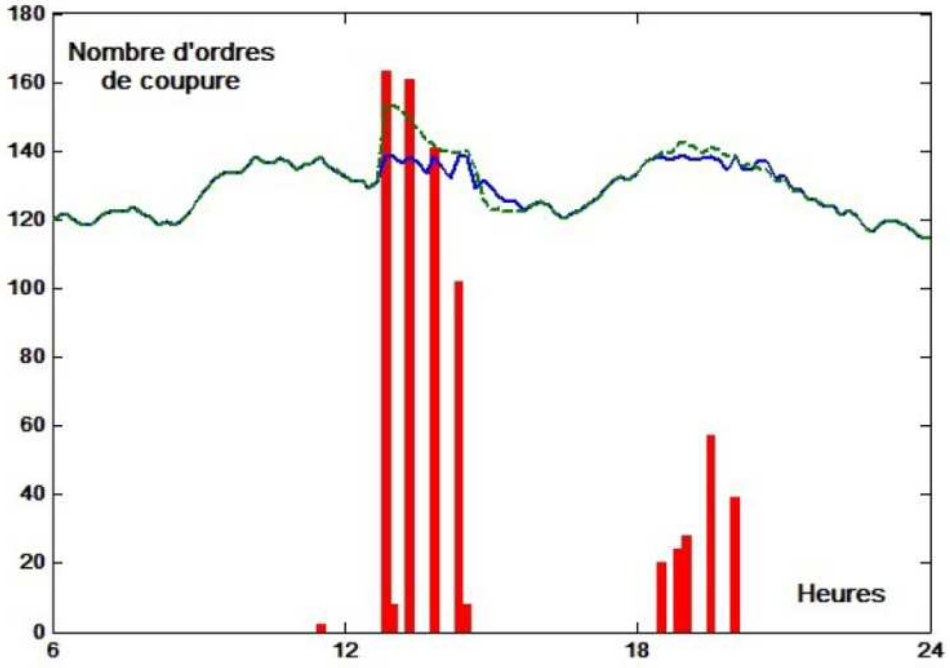
Projects at the level of the city

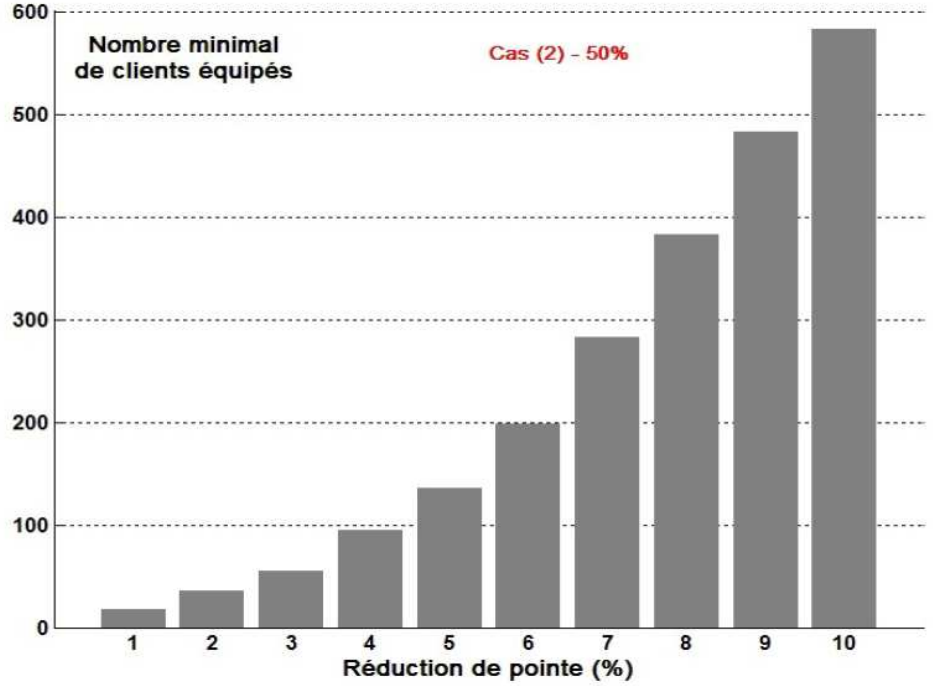
For Planning & Control

Diffuse load shedding

- Many buildings x low consumption reduction
  = shedding capacity invisible from the demand side.

⇒ **aggregated load curve is smoothed.**





Guillaume FOGGIA
2011 : G2ELab

- **It is starting in France :**
  - the shedding power capacity has reached the milestone of **100 MW** in February 2013 (many electrical heater)
  - the volume of active diffuse in shedding amounted to **10 GWh** during 2013

Diapositive 38

d1 http://www.raee.org/docs/RECUEIL_INTERV_CONF/2011/ALPENERGY_071011/6.pdf
delinchant; 05/09/2014

GreenLys Project

A huge scale experiment in Grenoble and Lyon cities, « Rhône-Alpes » Region

GreenLys Smart Grid

- **Partners : major stakeholders in the French electricity market with complementary skills:**
  - Électricité Réseau Distribution France (ERDF), the project leader,
  - GDF Suez, Gaz Électricité de Grenoble (GEG),
  - Schneider Electric,
  - Institut polytechnique de Grenoble (Grenoble INP),
  - Atos Worldgrid, Réseau de Transport d'Électricité (RTE), Alstom, the CEA national solar energy institute (CEA INES), Rhône-Alpes Énergie Environnement (RAEE), Hespul and the CNRS LEPII-EDDEN (Économie de développement durable et de l'énergie) laboratory.
- **Two cities : Grenoble and Lyon**
- **Project : 43M€ invested for 4 years (2012-2016)**
- **Diffuse Load Shedding experimentation :**
  - ~1000 Household are connected
  - ~100 Commercial buildings

GreenLys residential SCADA

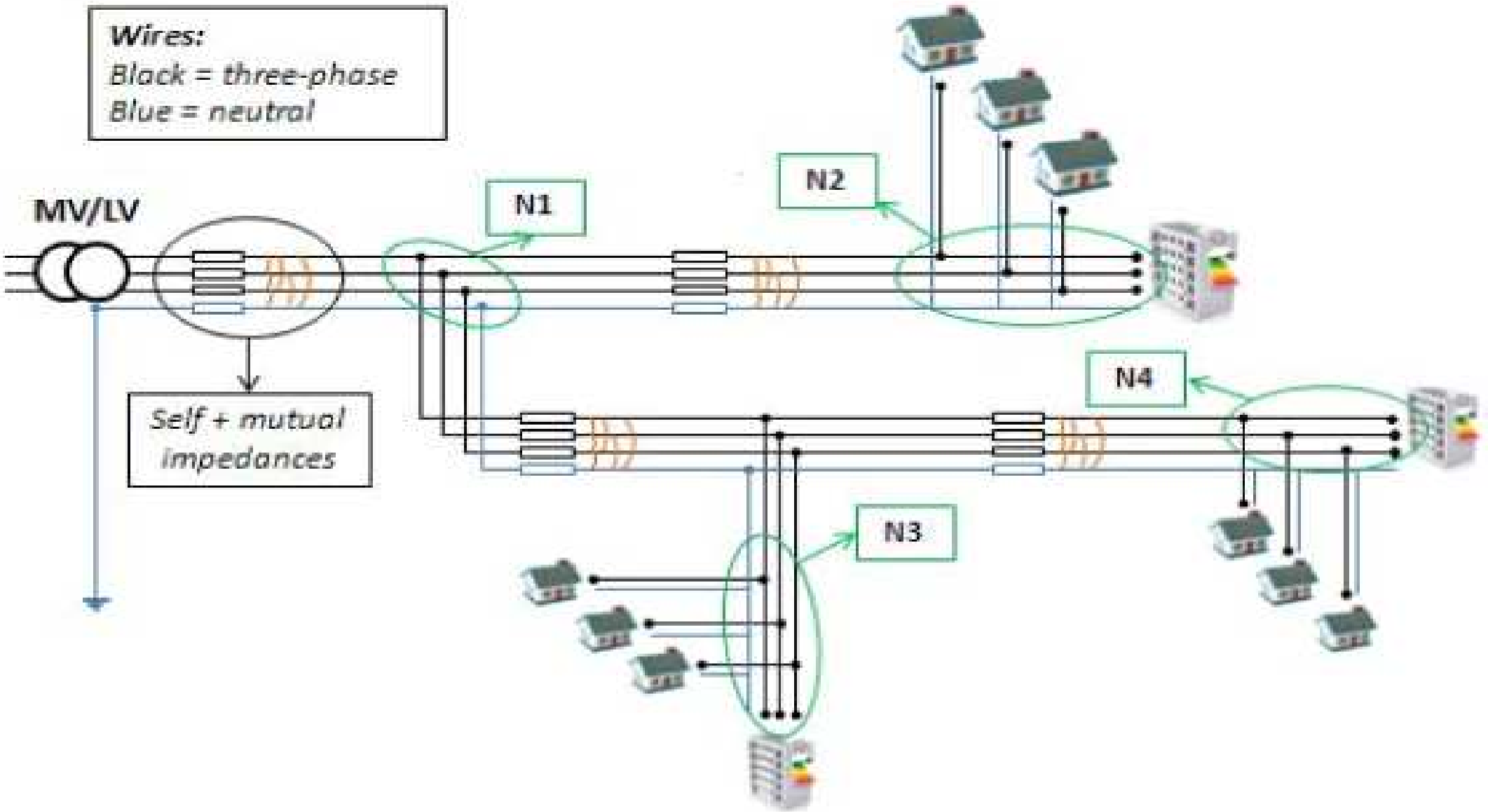
energy meter

controllable plug

controllable heater and hot water

room thermostat

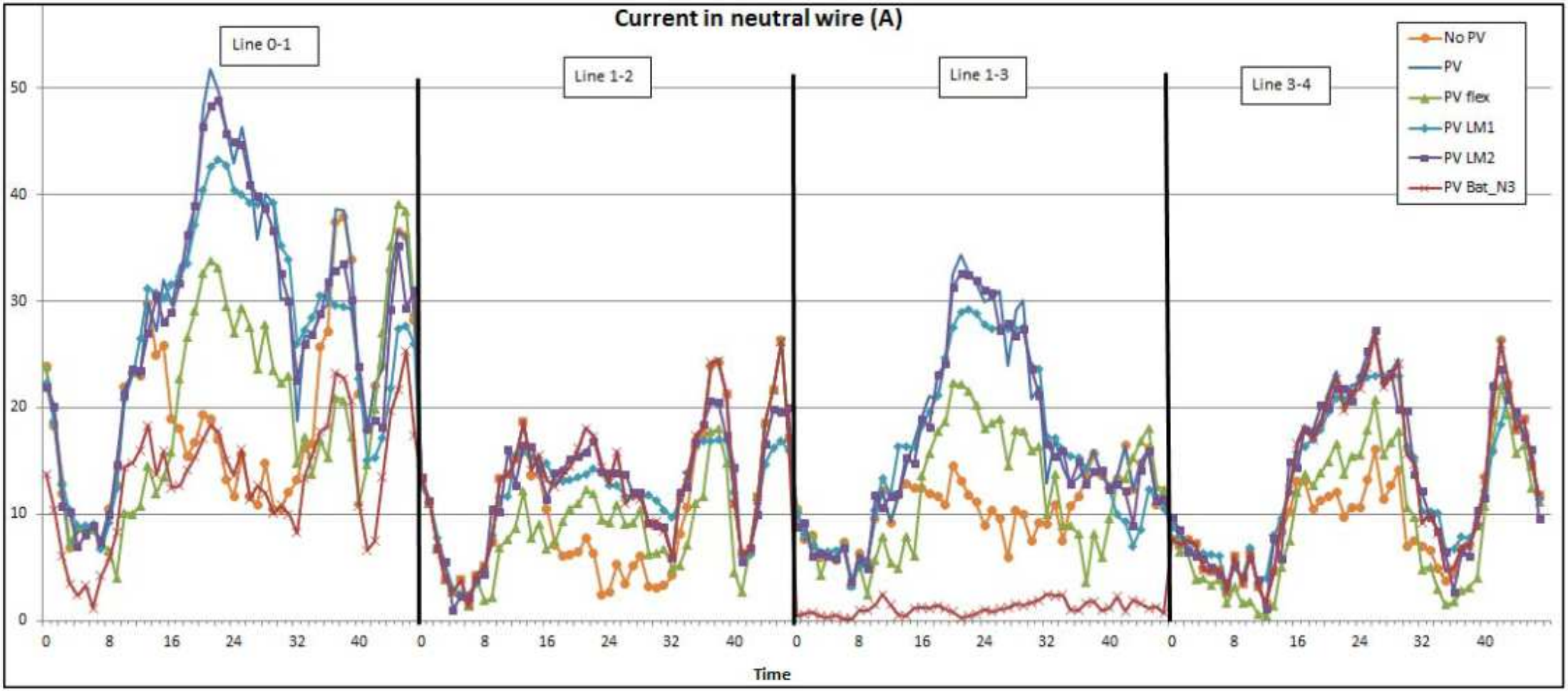
Optimization based on GreenLys distribution network



Clémentine Benoit, “Deterministic optimal power flow for smart grid short-term predictive energy management”, IEEE PowerTech 2013, Grenoble, France

Load Management scenarios	
/	No optimization
LM1	Active power optimization: equations 6 and 7, with a maximum amount of power that can be shifted of 20%
LM2	Active power optimization with load shedding limited to once every two half an hour: equation 6, 7 and 8.

PV scenarios	
/	No PV panels
PV	Non controllable three-phased PV panels + single-phased PV in phases 2 and 3
PV flex	Active and reactive power optimization: equations 2, 3 and 4 (S_{DIM} = kW peak)



Conclusions & Perspectives

Conclusions & Perspectives

- **Smart building**
  - ⇒ **Must be included with the grid as an overall system**
- **Modeling**
  - For optimisation: linear & non linear
  - Prediction including uncertainties (weather & human behaviour)
  - Real time model identification using sensors for reactive adaptation
  - ⇒ **Deterministic / stochastic modelling, fine and coarse approaches**
- **Optimization**
  - System with many constraints, objectives and decision variables
  - Mixed discrete / continuous algorithms
  - ⇒ **lots of technics to be developed and compared**

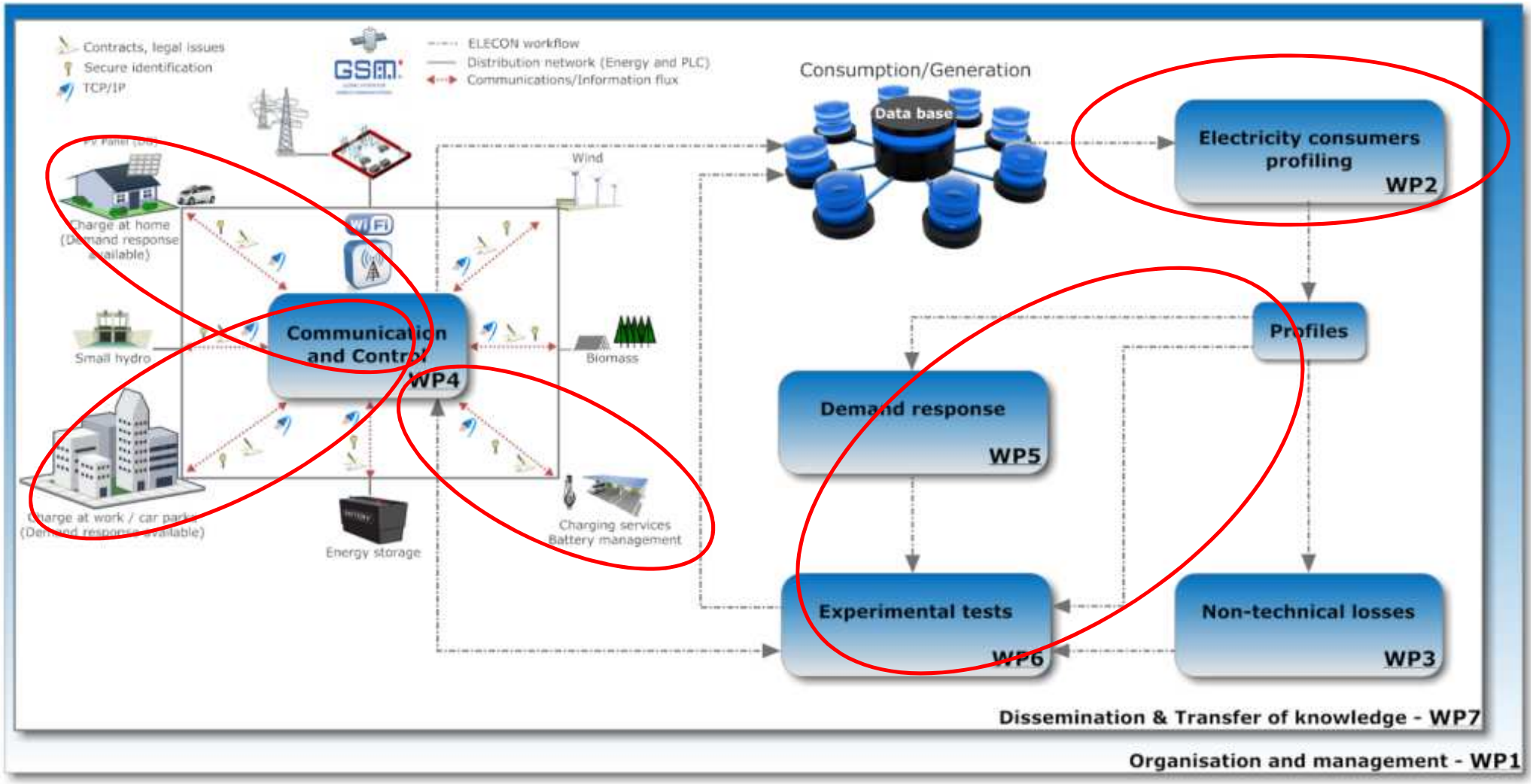
⇒ **For a global decrease of peak consumption**

⇒ **and an increase of reliability in electricity delivery.**

Contributions to the Elecon Program

Contributions to the Elecon Program

- **The links with the elecon objectives:**



Muito obrigado
Vielen dank
Merci beaucoup

Magdeburg, Oktober 2014

Benoit DELINCHANT
Frederic Wurtz