From an observatory approach to modeling and optimization paradigms for a socio-technical approach for Energy Transition

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workshop, “Energy, Mathematics, and Theoretical Challenges,” on October 3rd & 4th 2024 in Paris

financed by IDEX Université Grenoble Alpes

Outline:

From an observatory approach to modeling and optimization paradigms for a socio-technical approach for Energy Transition

- The Need of Energy Transition for Climate
- Building and district as key-pillars for an energy transition toward sustainability
- From a model based approach for optimization
  - at building level
  - At district scale
- But the necessity of humans in the loop
  - Why the necessity of humans in the loop
  - From a living lab approach to a real field approach
- From Social sciences and engineering sciences to models and tools
  - Quantitative models
  - Qualitative models
- To a data driven approach with the human in the loop
  - An experiment with humans in the loop
- We need the data: the need of an observatory approach

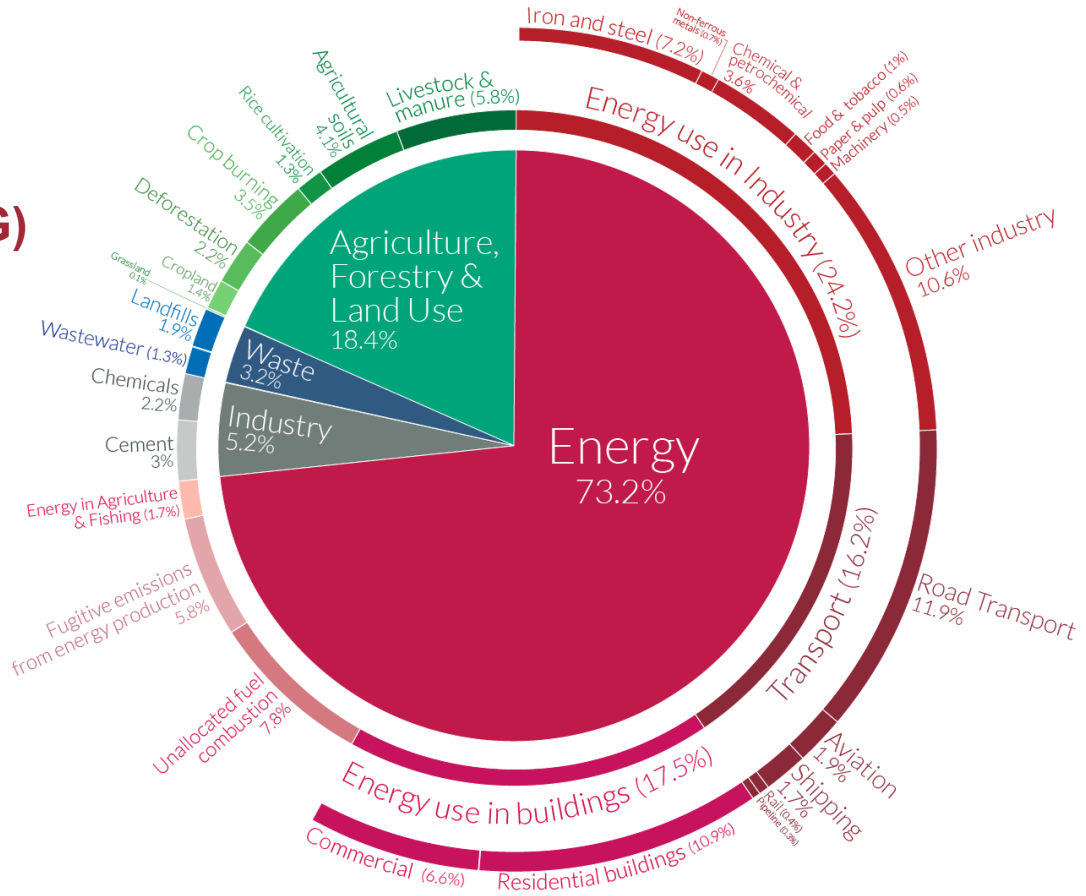
The Need of an Energy Transition for Climate

THE GLOBAL IMPACT AND IMPORTANCE OF ENERGY FOR ENVIRONMENTAL TRANSITION

- **Energy consumption of human activities account for more than 70% of GHG emissions worldwide**

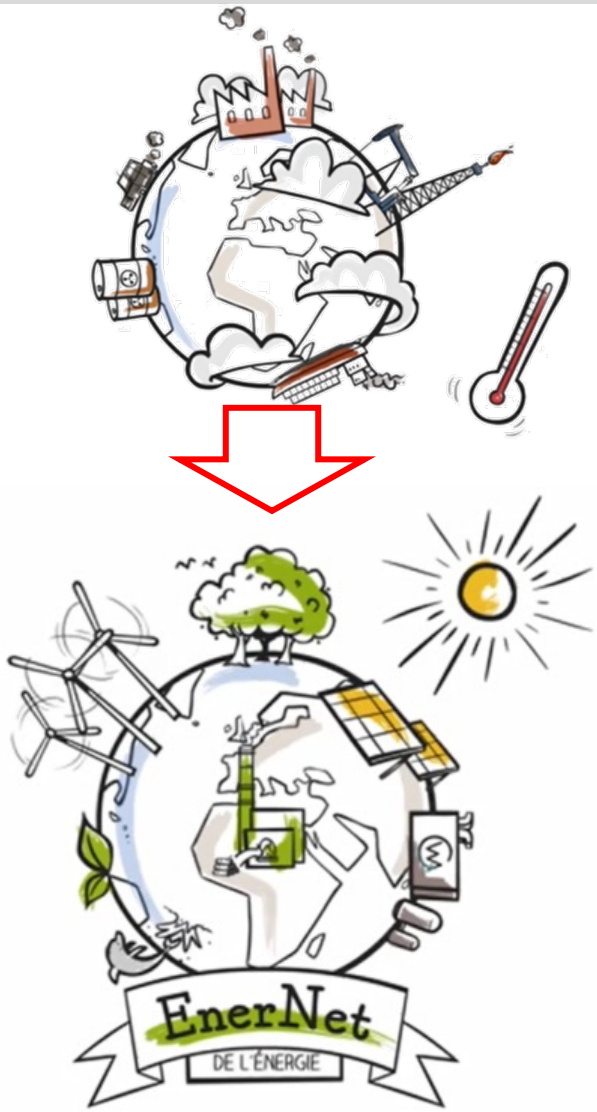
Global Greenhouse Gases (GHG) emissions per sector

2016
49.4 billion tonnes CO_2eq.

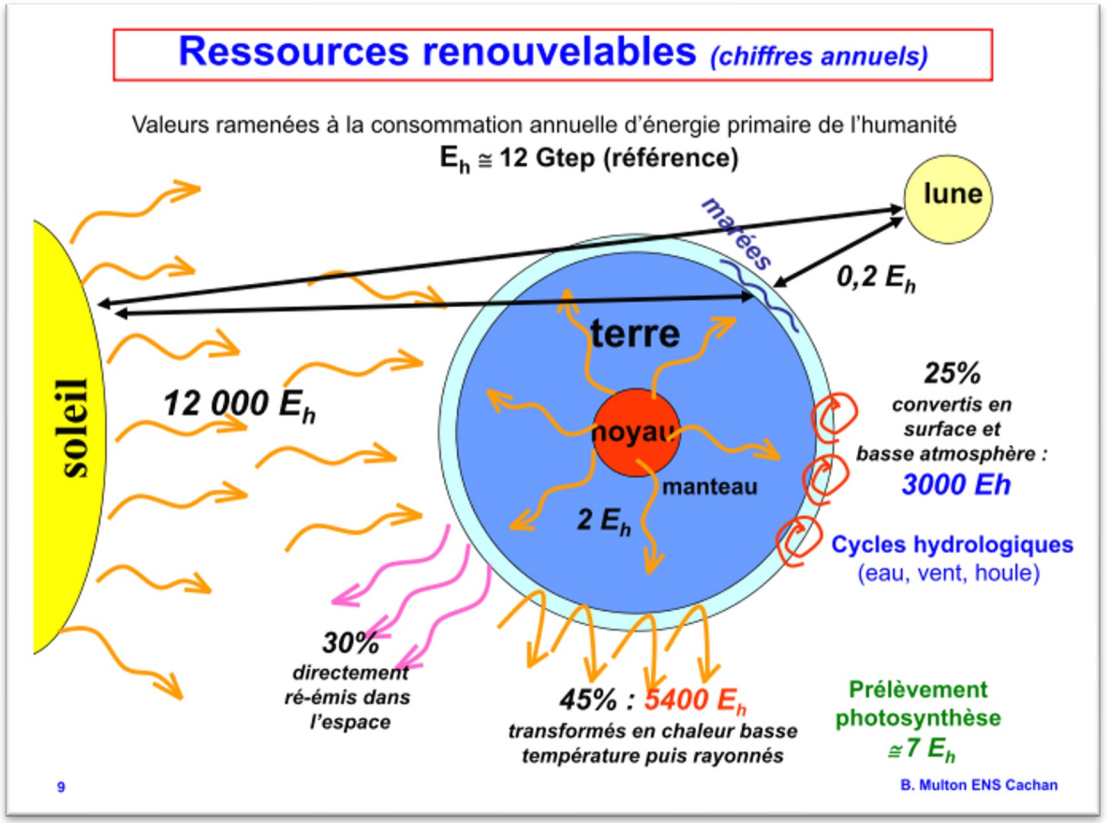


OurWorldinData.org – Research and data to make progress against the world's largest problems.
Source: Climate Watch, the World Resources Institute (2020).

The need for an energy transition for the climate



Need to reverse the trend !



Building and district as key-pillars for an energy transition toward sustainability

Besides the climate

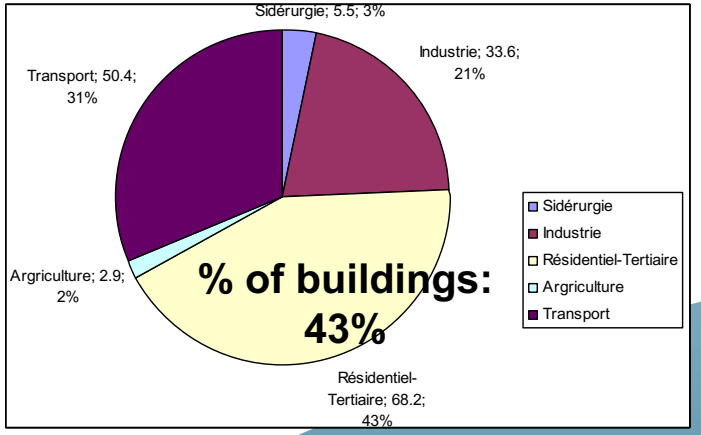
Focus on the socio-technical energy system !

Buildings are the first consumers of energy – In France (mild climate)

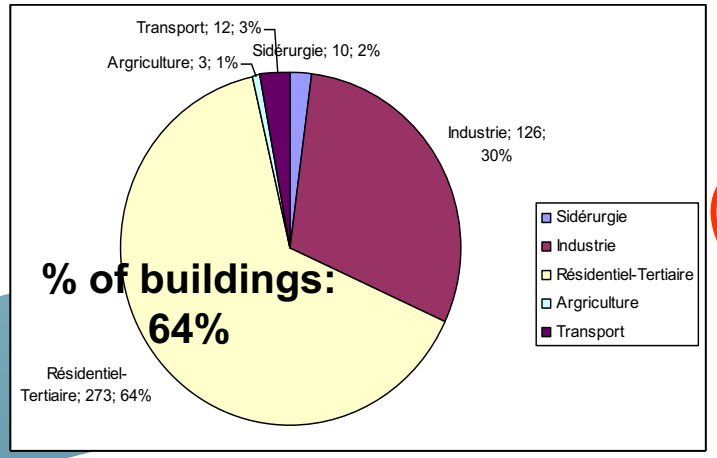
Buildings: main consumer of energy

The importance of energy in buildings in France

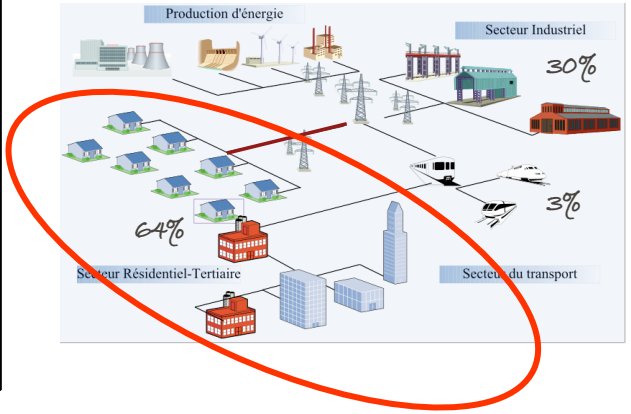
Source: http://www.industrie.gouv.fr



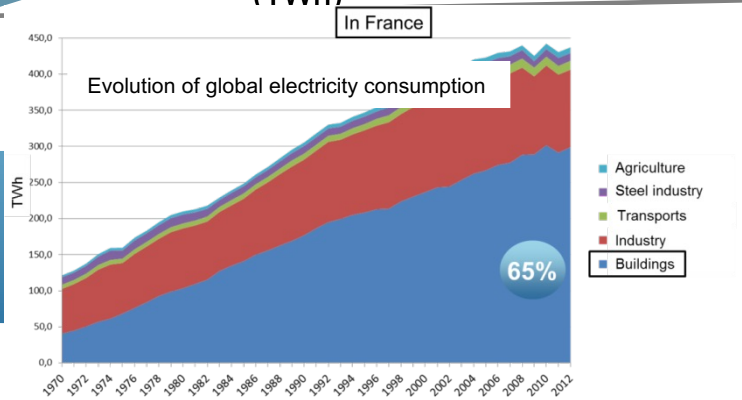
French final energy consumption 2005 (Mtep)

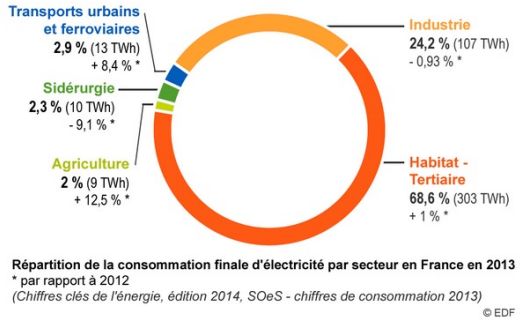


French electricity consumption 2005 (TWh)



From 2005 to 2015: Buildings are widely the greatest consumers in the network with a clear increase trend



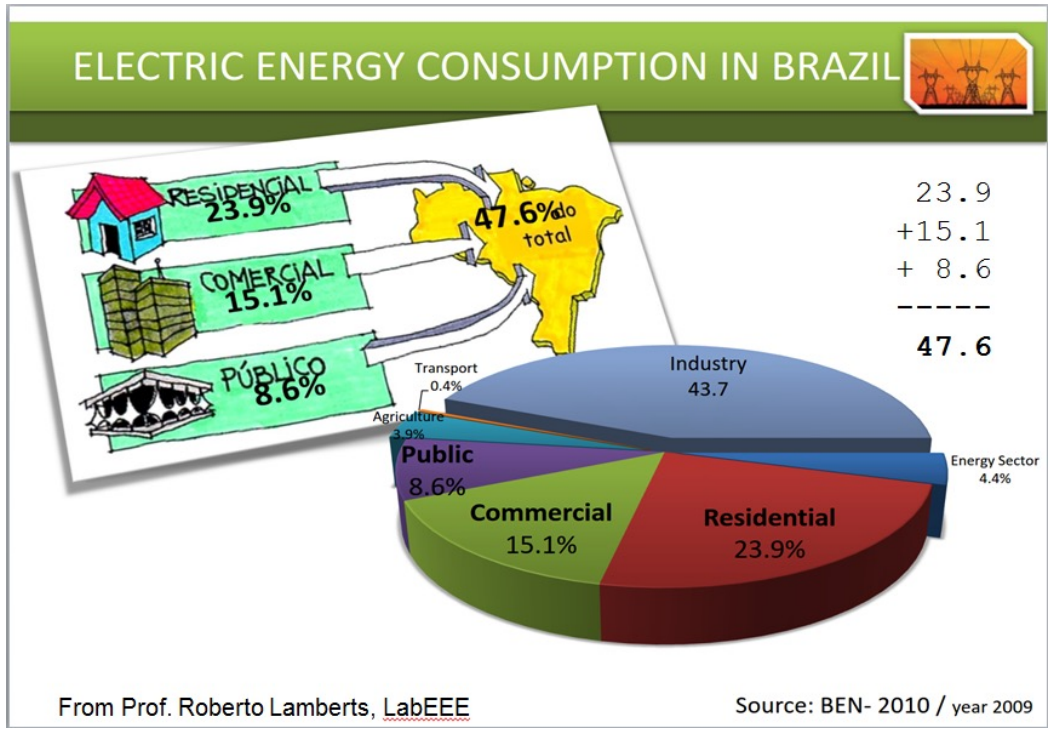


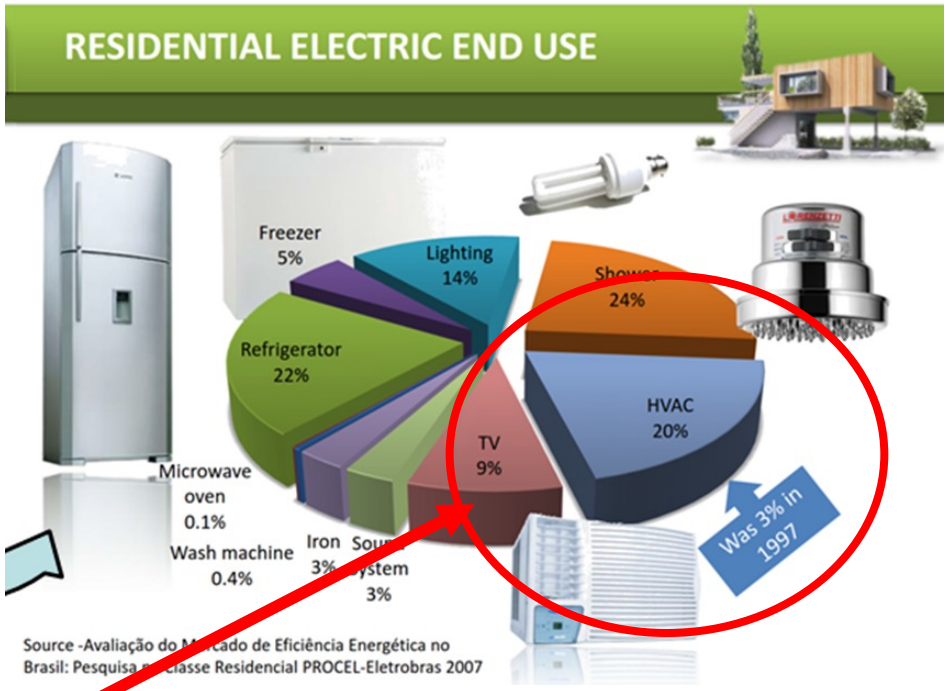
"Bilan énergétique de la France pour 2014", observations and statistics from the french government, but the data exist up to 2016, search on internet - Link found 20.01.22: https://www.statistiques.developpement-durable.gouv.fr/sites/default/files/2018-10/ref-bilan-energie-2014-juillet2015_b.pdf

EDF, 2015. Electricité de France. La consommation d'électricité en chiffres :

Buildings are the first consumers of energy – In Brazil (tropical climate)

Buildings: main consumer of energy

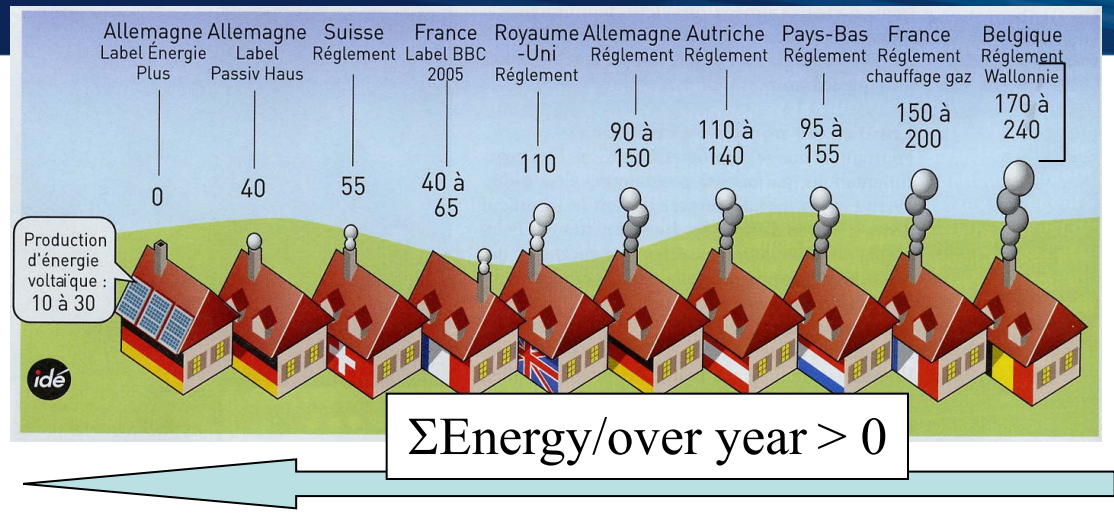




- Increase of HVAC

Buildings could be one of greatest producer of renewable energy

A building can get, over a year, more renewable energy that it needs



Consumption in kwh/year/m²

Buildings can help to:

- **Harvest**
- **Store**
- **Manage**

renewable energy

Building can produce more energy than they need (in average over 1 year)

District as key-pillars for an energy transition toward sustainability

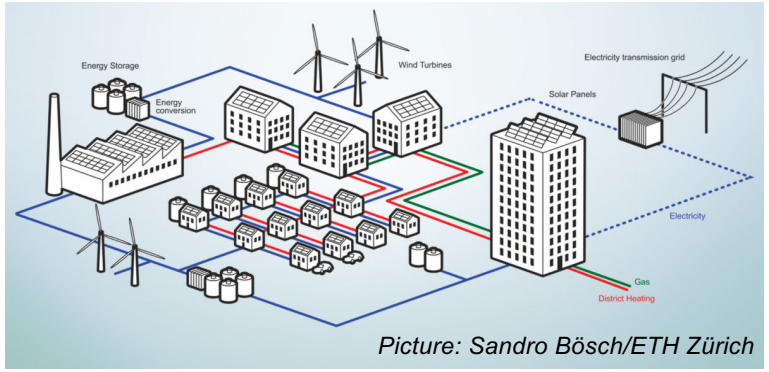
- **Cities dominate the global energy demand…**
  - Urban areas accounted for about **64%** of the global primary energy use [IEA]

- **… but they can also be the next place for energy production**
  - Decentralised renewable energies
  - Energy recovery potential

Electricity

Heat

Gas



Picture: Sandro Bösch/ETH Zürich

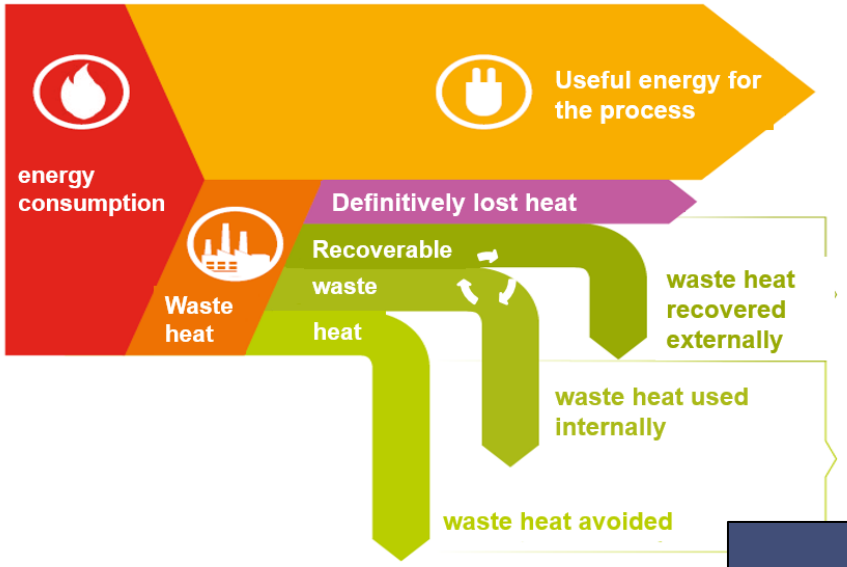
- **New challenges & solutions for the new energy sources**
  - **Intermittence**: flexibility, multi-carrier energy systems, storage
  - **Distributed**: well designed and operated energy networks
  - **New actors**: prosumers, local authorities, energy communities

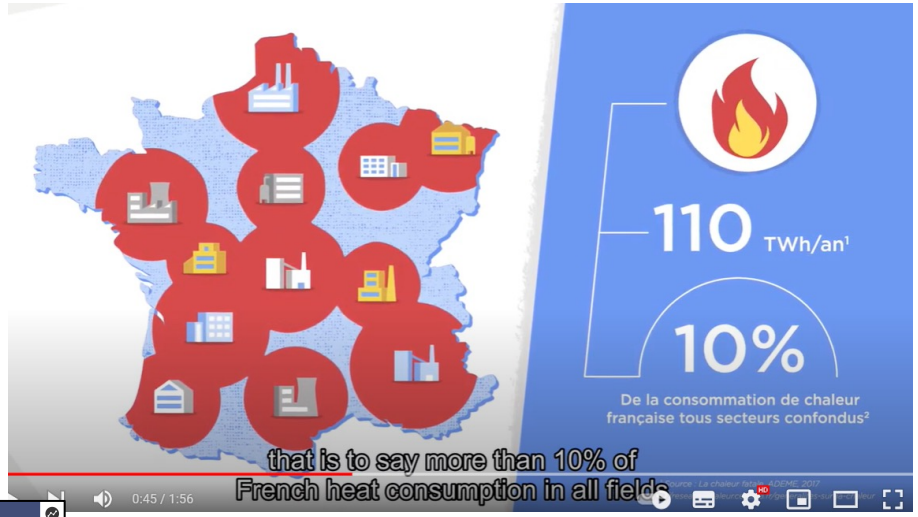
→ Complex system with the need of a new socio-technical approach

[IEA]: https://www.iea.org/news/cities-are-at-the-frontline-of-the-energy-transition

THE ISSUE OF WASTE ENERGY AT DISTRICT LEVEL

- **Waste heat:** heat generated in a process which is not its first end and that is not used by the process.



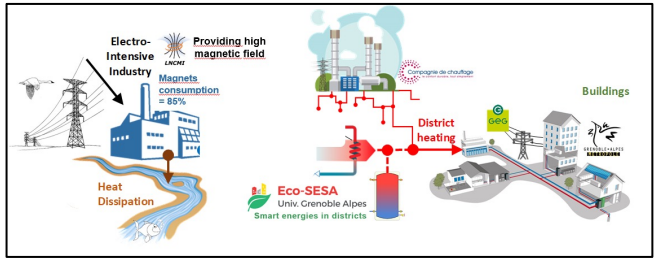


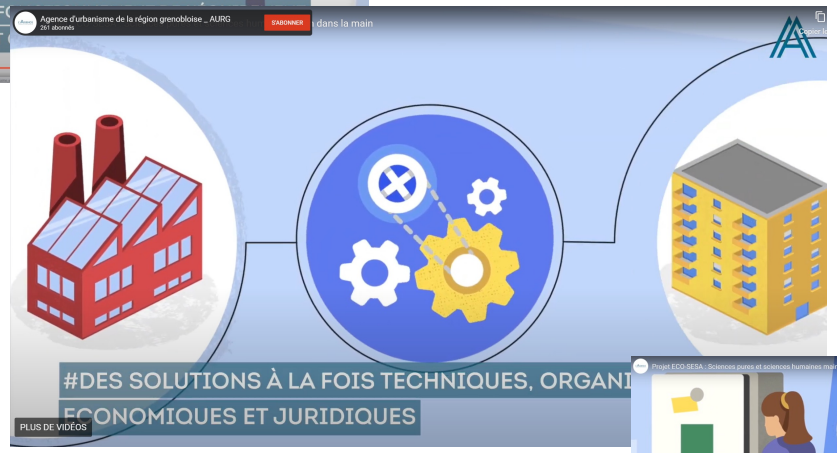
https://ecosesa.univ-grenoble-alpes.fr/training-and-dissemination/videos/valorisation-chaleur-fatale-waste-heat-valorization

Source: La chaleur fatale, Ademe, 2017
https://www.ademe.fr/chaleur-fatale

THE ISSUE OF FLEXIBILITY AT DISTRICT LEVEL

- **Between production and demand of energy**





https://ecosesa.univ-grenoble-alpes.fr/training-and-dissemination/videos/valorisation-chaleur-fatale-waste-heat-valorization

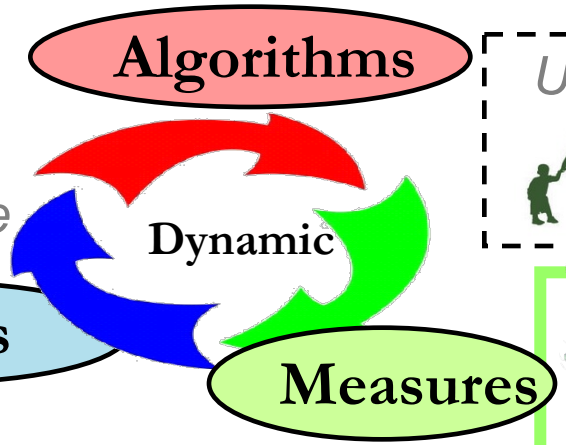
https://www.anrt.asso.fr/fr/actualites/rapport-de-synthese-snre-quelles-flexibilites-pour-le-systeme-electrique-35382

From a model based approach for optimization at Buildings Level

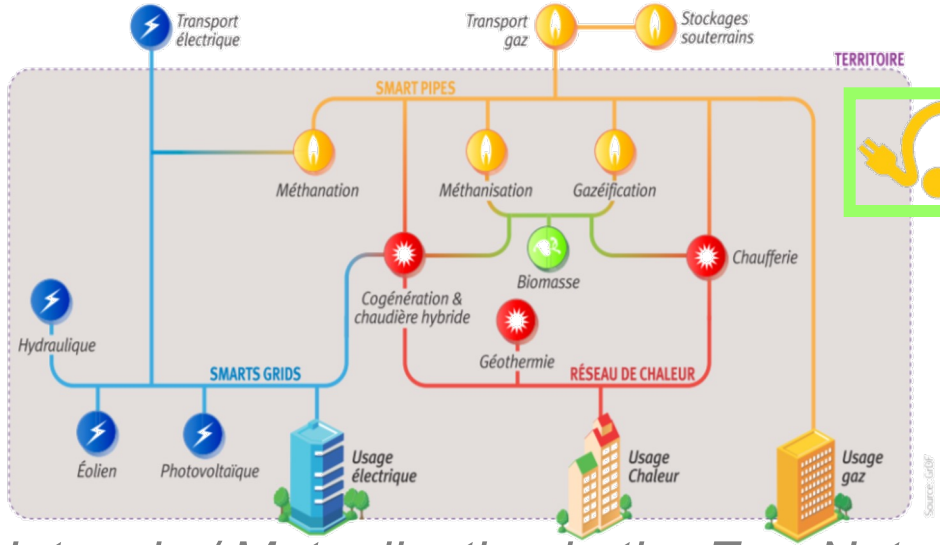
- What is a smart-building ?
- “Smart Buildings” thanks to software using Physical models and optimization
-What issues and scientific problematics of SB in interaction with SG
- “Smart Buildings” thanks to software using optimisation algorithms
- Model Predictive Control with open source approaches
- From experimental platform to prototype and industrial projects

What is a smart-building ?

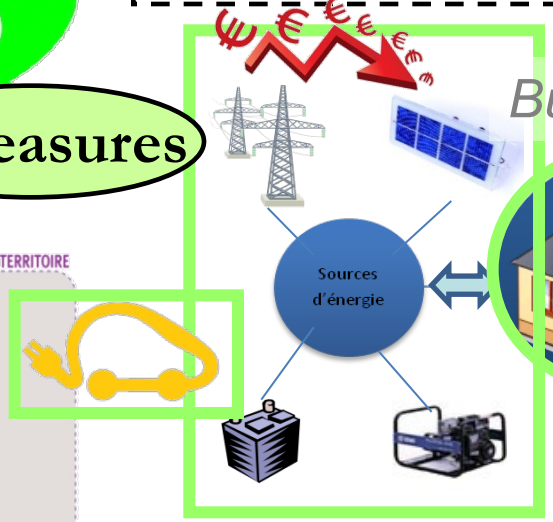
Distributed Intelligence



Uncertainties



Networks/ Mutualisation in the EnerNet



Building

Sources and storage

Local intelligence

Loads

"Smart Buildings" thanks to software using physical models and optimization

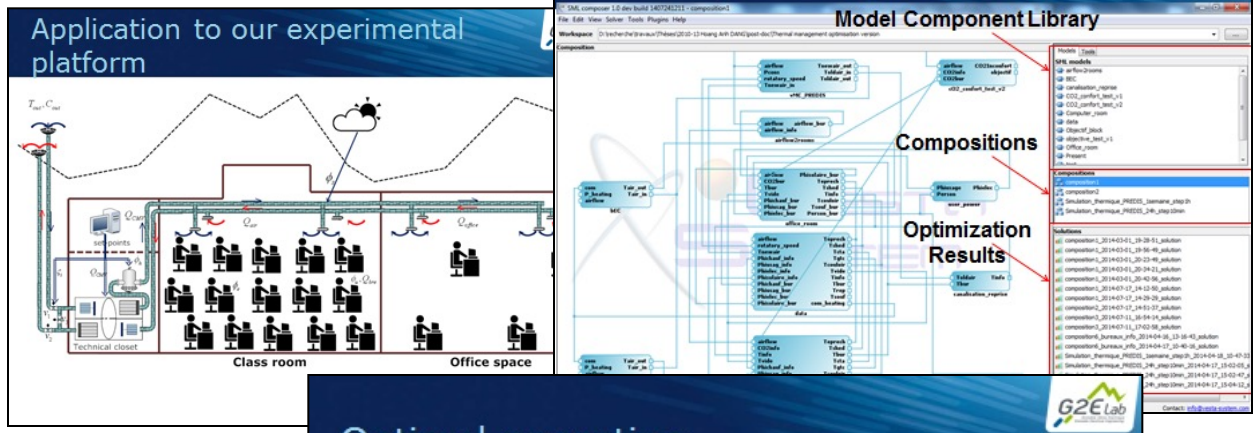
Anticipative demande side Management: trade off consumption - comfort

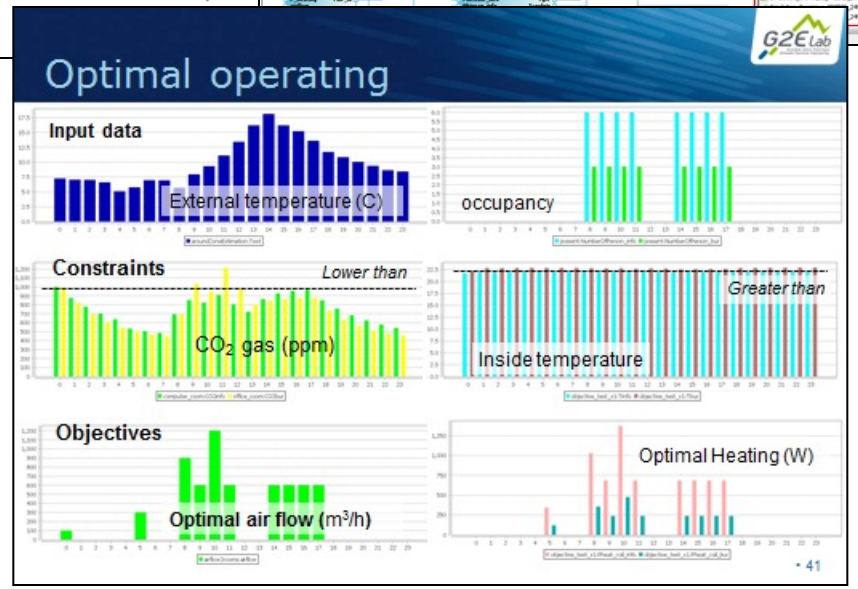
24 hours prevision

Weather

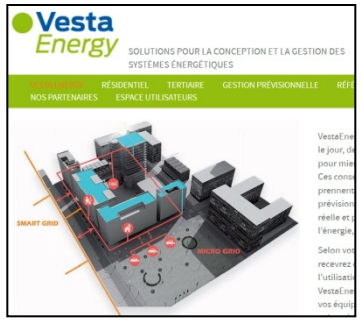
Dynamic prices

- Anticipative supervision





Example of an Industrial solution available at

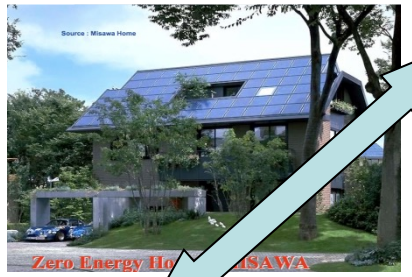


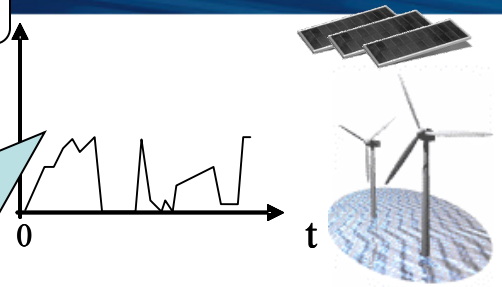
http://www.vesta-system.fr/fr/produits/vestaenergy/vesta-energy.html

What issues and scientific problematics of Smart Buildings

The scientific problematic

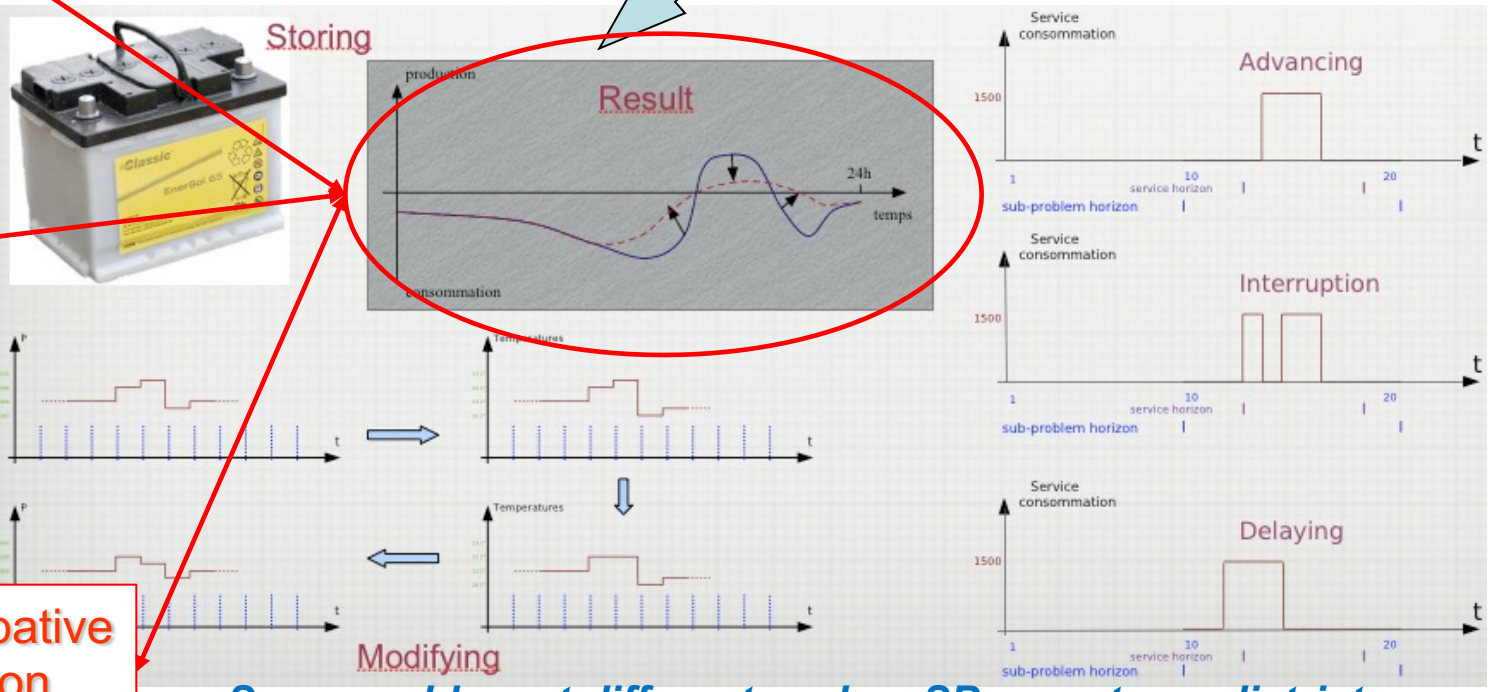
At the scale of the building: locally adaptation of production to needs





- Demand side Management
- Load Matching

- Demand Response



24 hours prevision

Weather

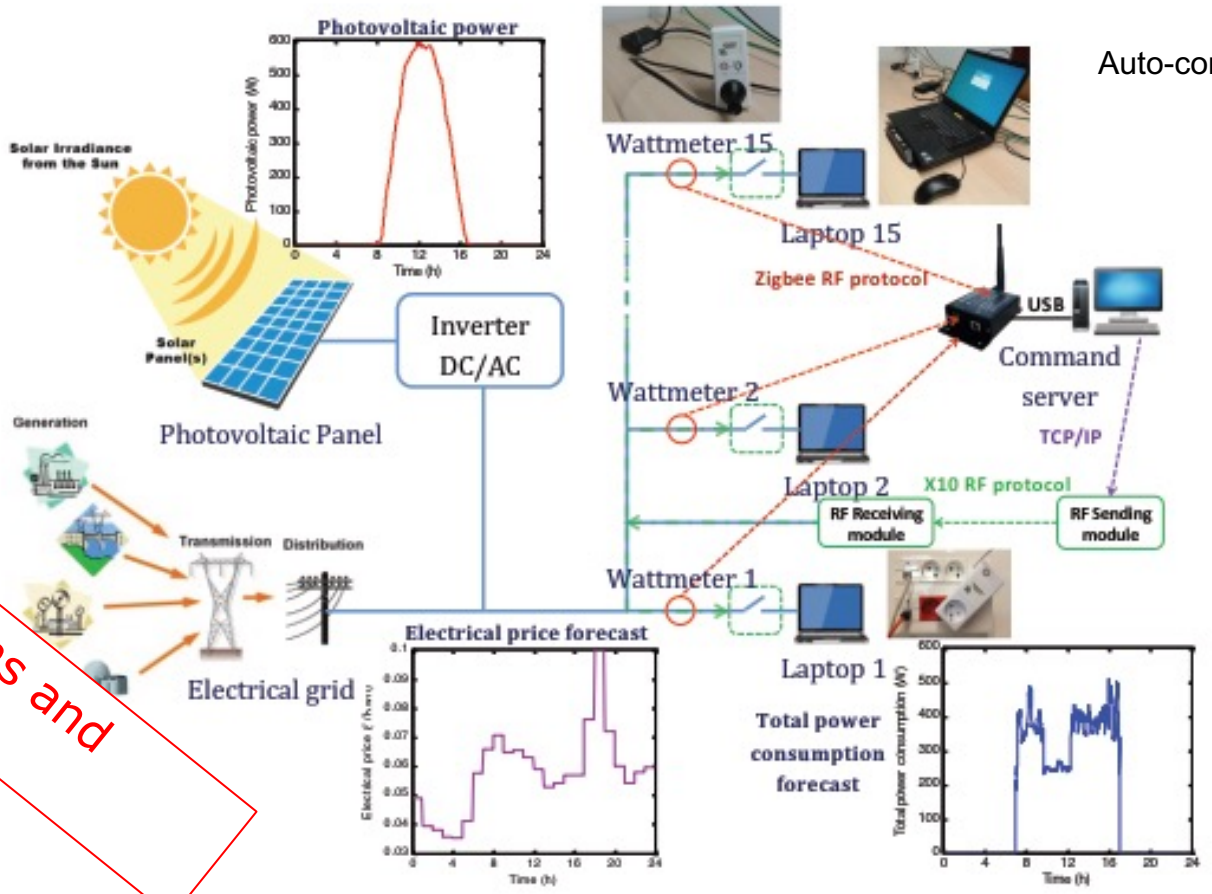
Dynamic prices

- Anticipative supervision

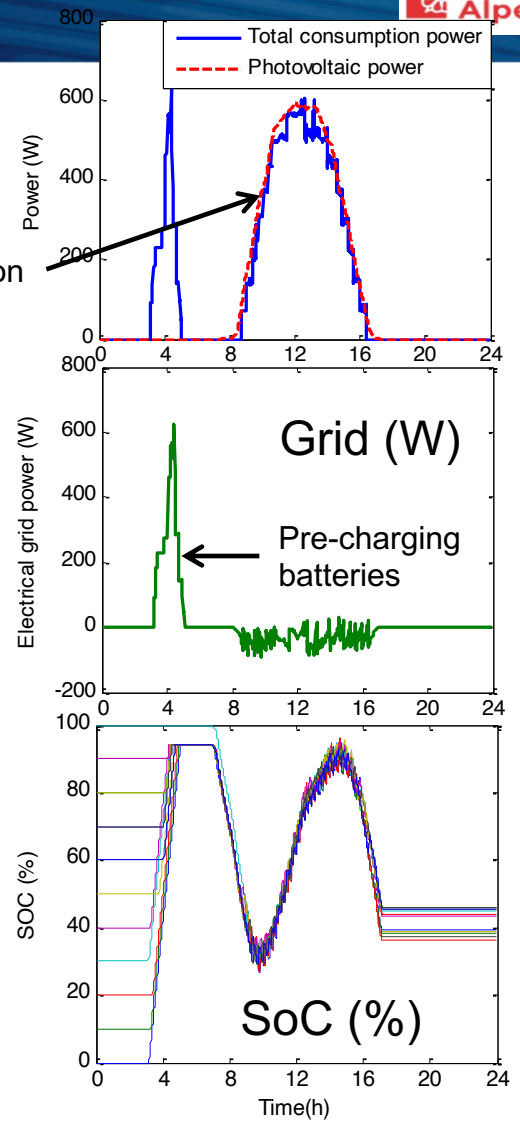
Same problem at different scales: SB, smart-eco district, smart city, national smartgrid, …

“Smart Buildings” thanks to software using optimisation algorithms and physical models

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



Use of algorithms and physical models



Hoang:Anh Dang, Benoit Delinchant, and Frederic Wurtz, “Toward autonomous photovoltaic building energy management: modeling and control of electrochemical batteries”, IBPSA 2013, Chambery, August 2013, http://www.ibpsa.org/proceedings/BS2013/p_2095.pdf

"Smart Buildings" thanks to software using optimisation algorithms

For anticipative management, demand Response, Load Matching

The approach used: Optimization

Formulation : 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

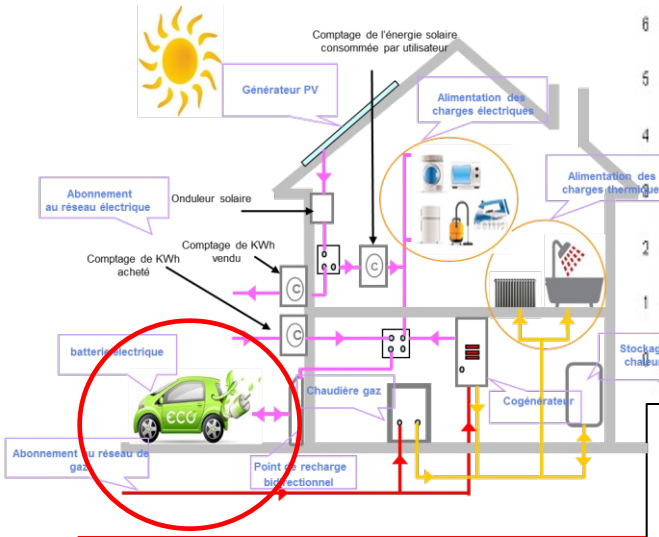
Solved with : Matlab

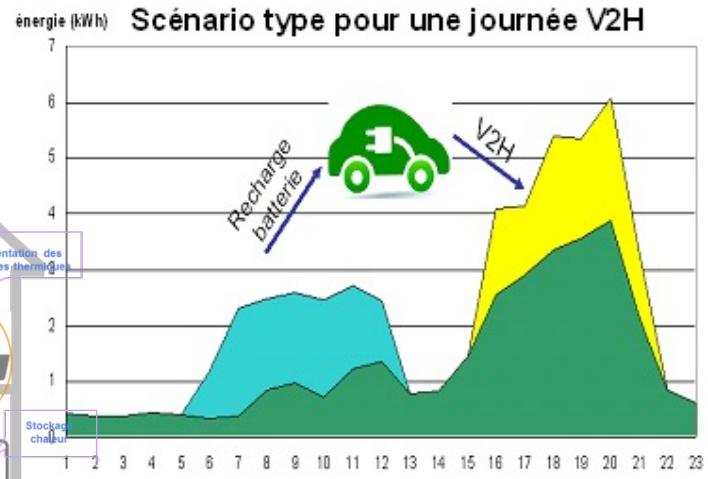
CPLEX (Ilog), GUROBI

"Optimal Household Energy Management and Economic Analysis: From Sizing To Operation Scheduling",T. T. HA PHAM, C. CLASTRES, F. WURTZ, S. BACHA, and E. ZAMAI, publié dans Advances and Applications in Mechanical Engineering and Technology, Vol. 1, n° 1, pp. 35-68
https://halshs.archives-ouvertes.fr/halshs-00323581

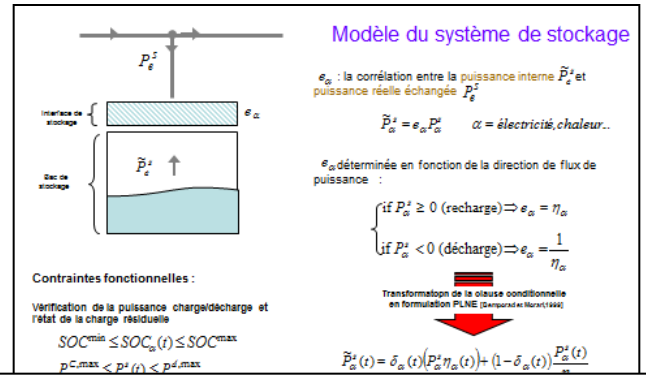
Smart Buildings thanks to software using optimisation algorithms and physical models

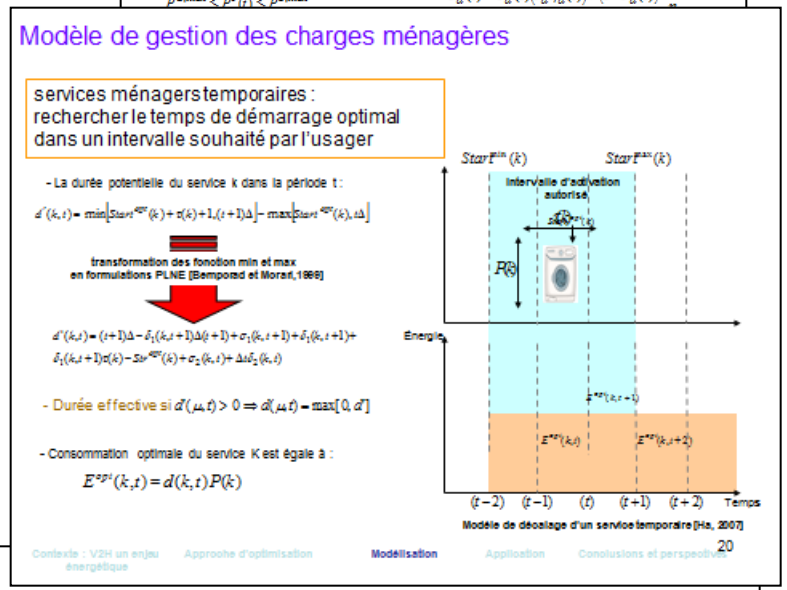
Anticipative demande side Management of Vehicule to Home (V2H)





- **Charging of the battery with carbon free energy during the day**
- **Use of the energy stored in the battery for shaving the peek demand of the evening**



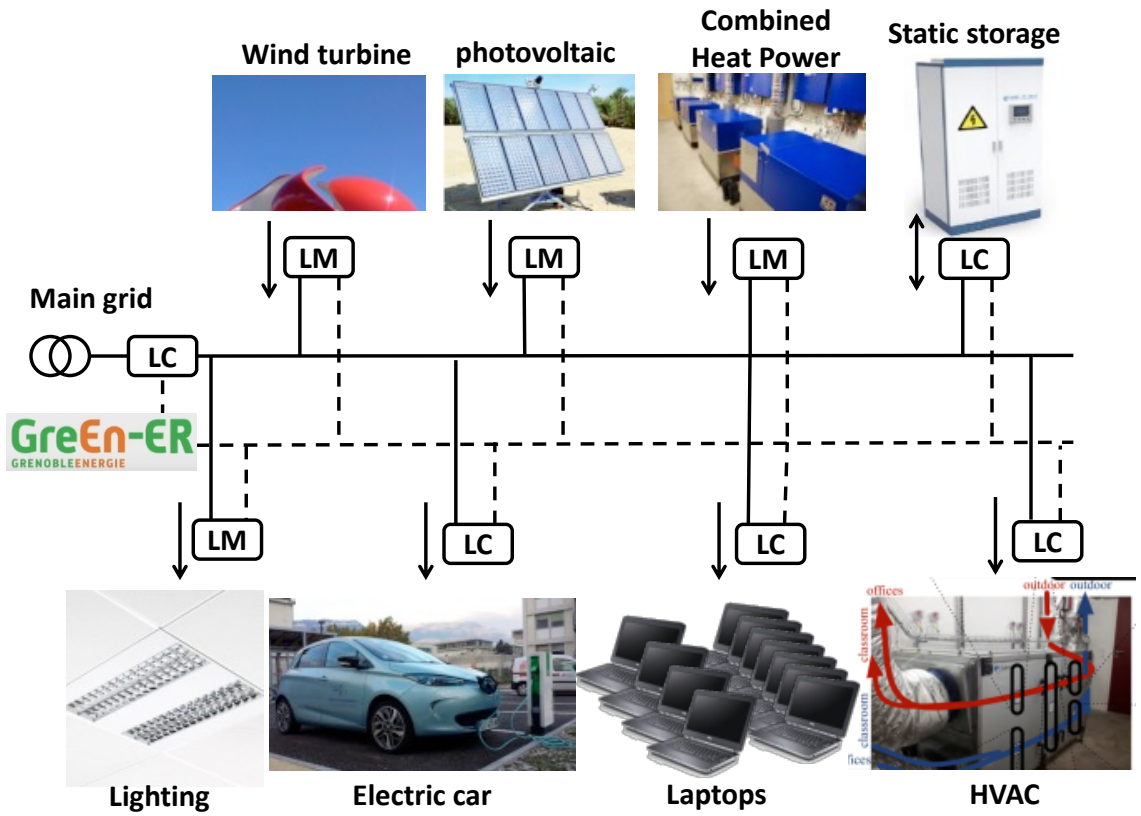


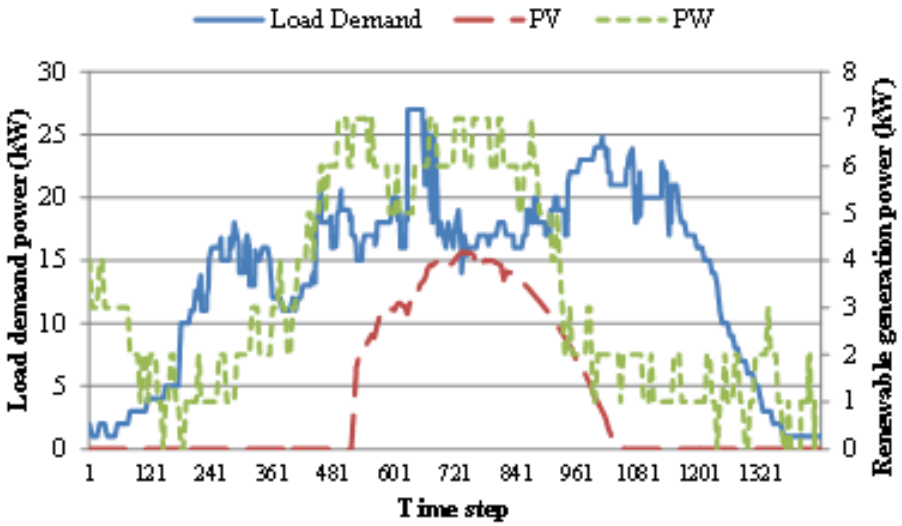
- 185 inputs
- (50x24)+11=1211 continues variables
- (24x24)= 576 binary discretes variables
- (178x24)+1=4273 constraints

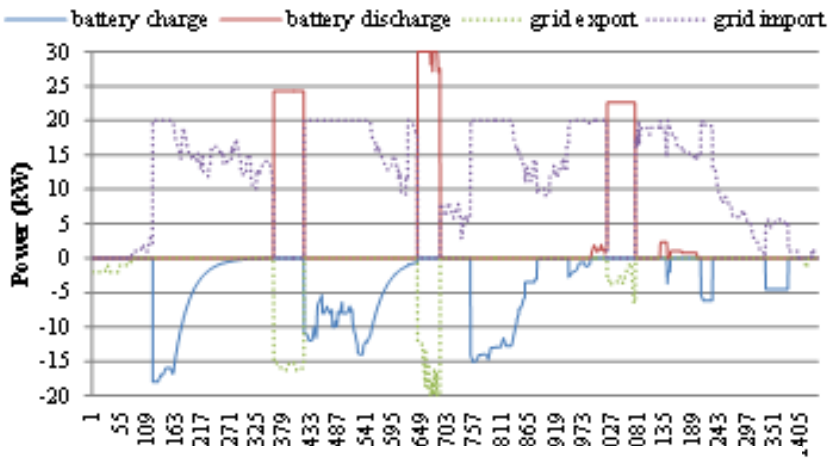
- « Gestion des flux multi-énergie pour les systèmes V2H», A. Dargahi, thèse de l'Université de Grenoble, 26 Septembre 2014, https://tel.archives-ouvertes.fr/tel-01111994
- A. Dargahi, S. Ploix, A. Soroudi, F. Wurtz, (2014) "Optimal household energy management using V2H flexibilities", COMPEL: The International Journal for Computation and Mathematics in Electrical and Electronic Engineering, Vol. 33 Iss: 3, pp.777, DOI:10.1108/COMPEL-10-2012-0223

Building microgrid optimal control

- Complex modeling
  - Events: occupants, vehicle ...
  - Nonlinearities (eg, ventilation)







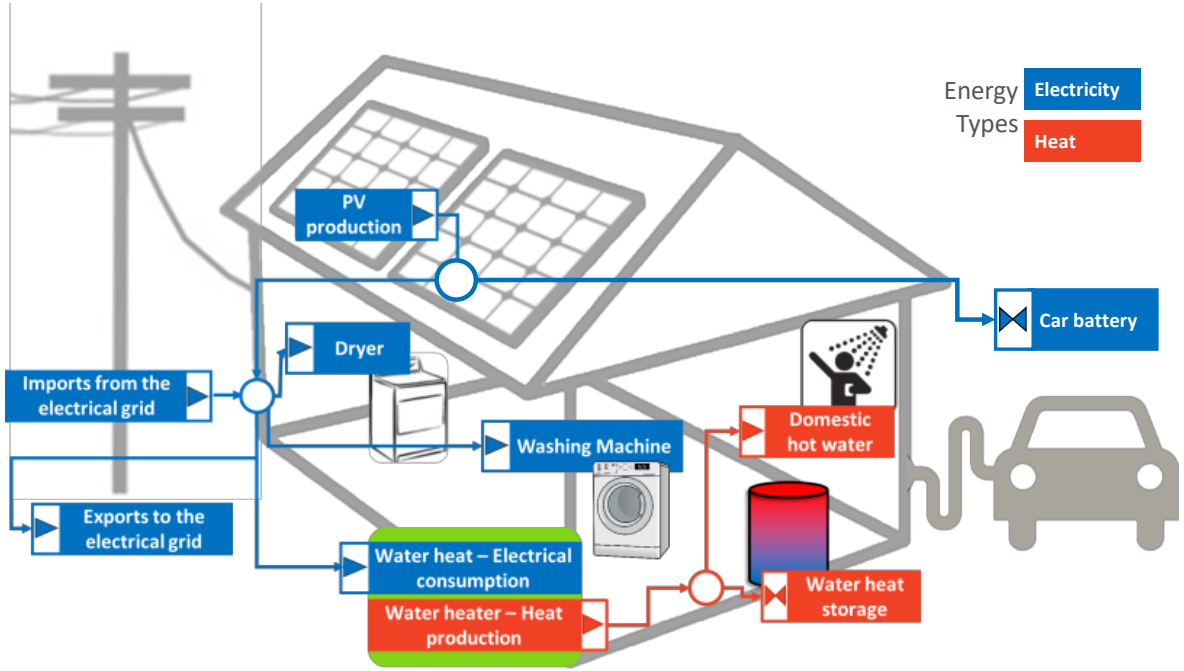
24h, 1440x1min opt time < 1min

(2016) Daniel Tenfen, Erlon C. Finardi, Benoit Delinchant, Frédéric Wurtz "Lithium-ion Battery Modelling for the Energy Management Problem of Microgrids", **IET Generation, Transmission & Distribution**, Jan 2016, DOI: 10.1049/iet-gtd.2015.0423

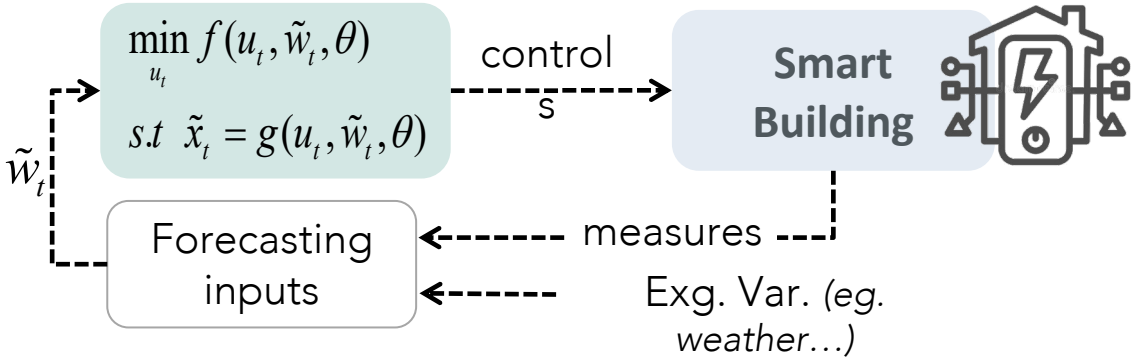
Model Predictive Control with open source approaches

https://omegalpes.readthedocs.io/

OMEGAlpes modeling formalism



MPC on MILP Optimization



Building scale conclusions :

- Direct flexibility can be implemented on Home Energy Management

But it requiers :

- Metering/control interoperable infrastructure
- **knowledge and data for modeling and forecasting**

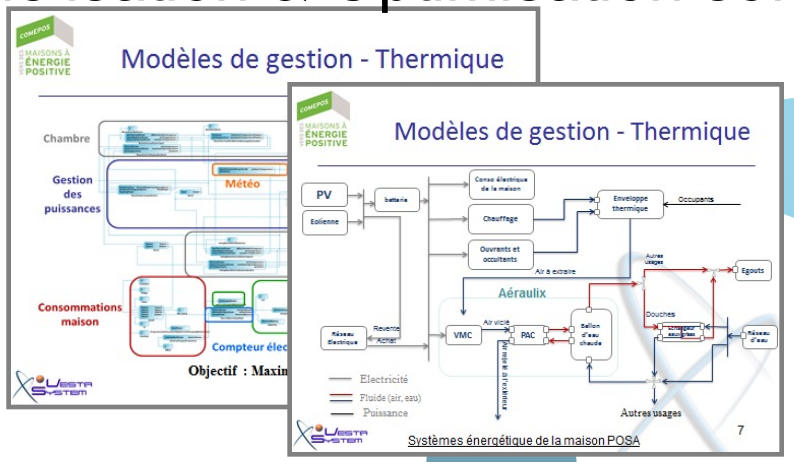
Drawbacks :

- Lack of robstness (continual maintenance)
- Bad scalabililty (slow deployment)

Hodencq, S.; Brugeron, M.; Fitó, J.; Morriet, L.; Delinchant, B.; Wurtz, F. OMEGAlpes, an Open-Source Optimisation Model Generation Tool to Support Energy Stakeholders at District Scale. *Energies* 2021, 14, 5928. https://doi.org/10.3390/en14185928

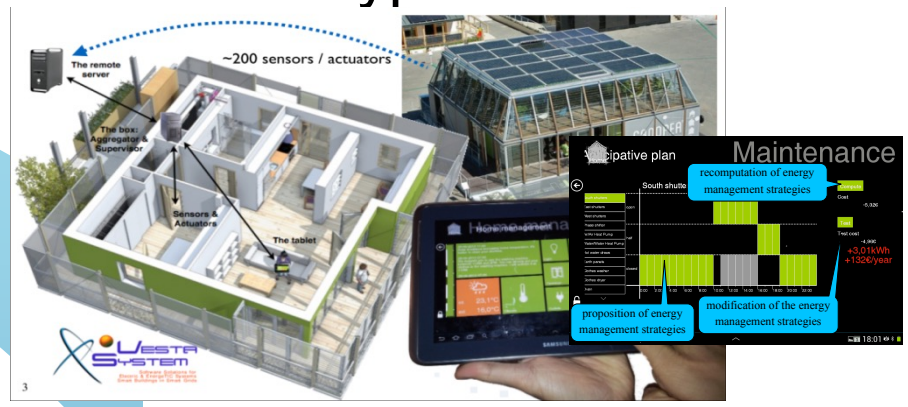
From modelisation and optimization to platforms, prototypes and industrial projects

Modélisation & Optimisation software



http://www.vesta-system.fr/fr/produits/vestaenergy/vesta-energy.html

Prototype



Canopea - Presentation Movie - Solar Decathlon 2012:
https://www.youtube.com/watch?v=p28tFxd9MZY

Experimental Plat-form

- Complete description: http://predis.grenoble-inp.fr/
- « Modélisation en vue de la simulation énergétique des bâtiments : Application au prototypage virtuel et à la gestion optimale de PREDIS MHI», thèse de l'université de Grenoble, 04 Novembre 2013, http://tel.archives-ouvertes.fr/tel-00957613
- "Building Simulation of Energy Consumption and Ambient Temperature: Application to The Predis Platform« , HOANG-ANH DANG, S. GAALOUL, B. DELINCHANT, AND **F. WURTZ**, IBPSA 2013 , http://www.ibpsa.org/proceedings/BS2013/p_2096.pdf
- https://www.researchgate.net/publication/339412260_Overview_Of_A_Large_Scale_Monitoring_Project_Of_Energy_Positive_Houses_Complementarity_Between_Simulations_And_Measurements

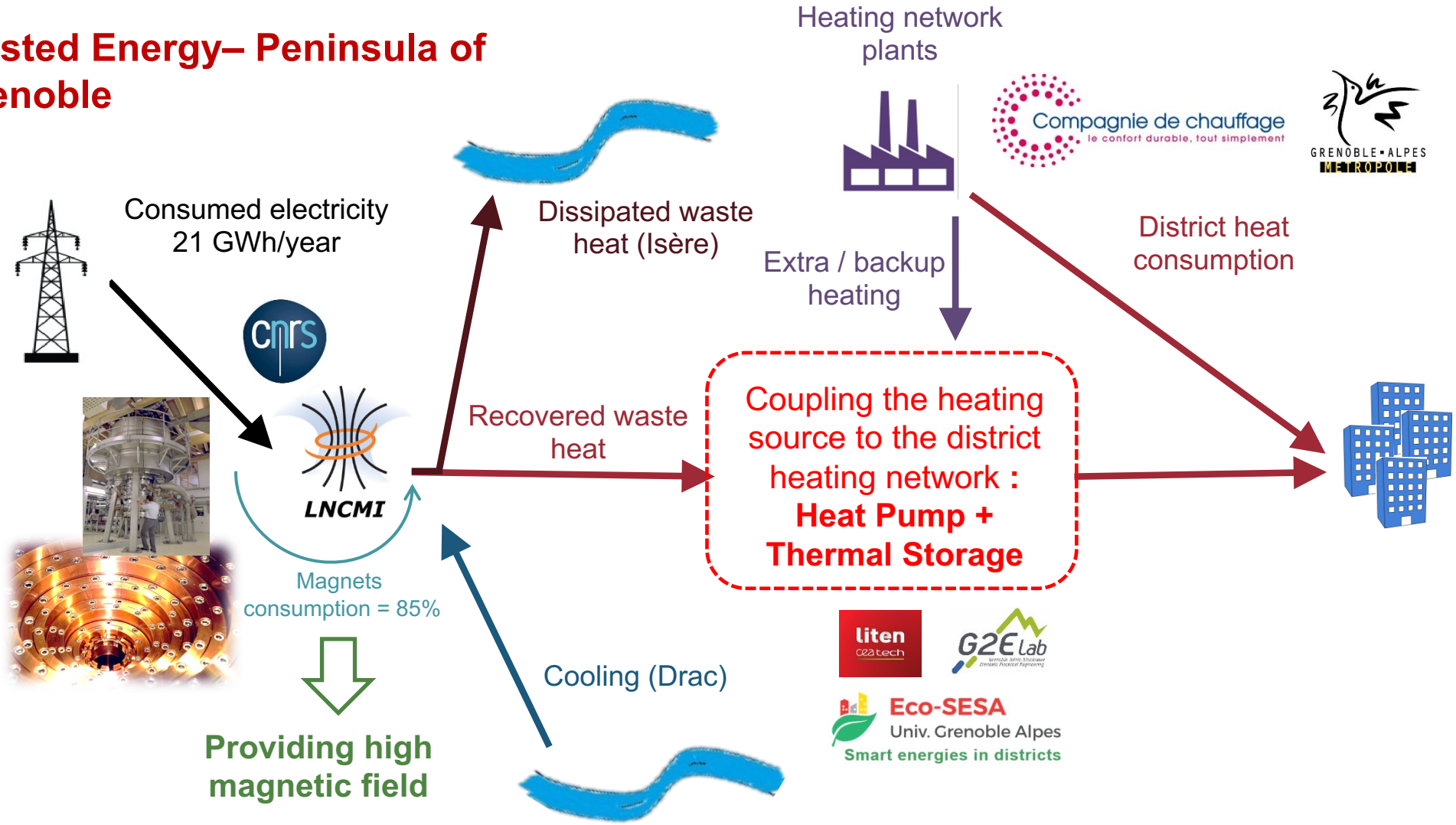
Comercialized buildings

Project COMEPOS: Deployement of energy postive buildings in France

From a model based approach for optimization at District Level

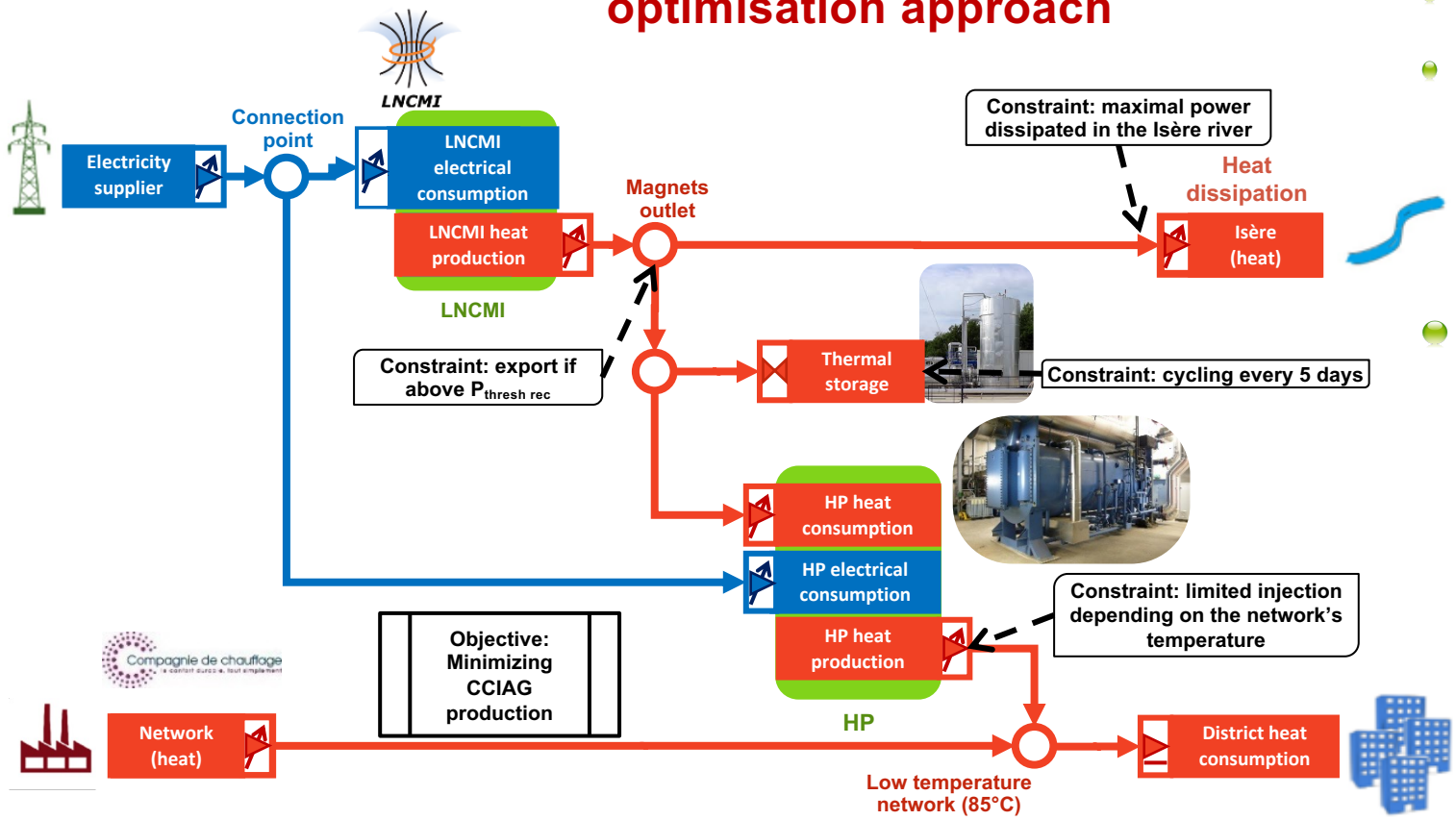
THE PROBLEMATIC OF WASTE HEAT RECOVERY AT DISTRICT LEVEL

- **Wasted Energy– Peninsula of Grenoble**



OMEGALPES MODELING FORMALISM: USE CASE LNCMI

- **Energy system modeling –**
  OMEGAlpes modeling formalism for MILP optimisation approach



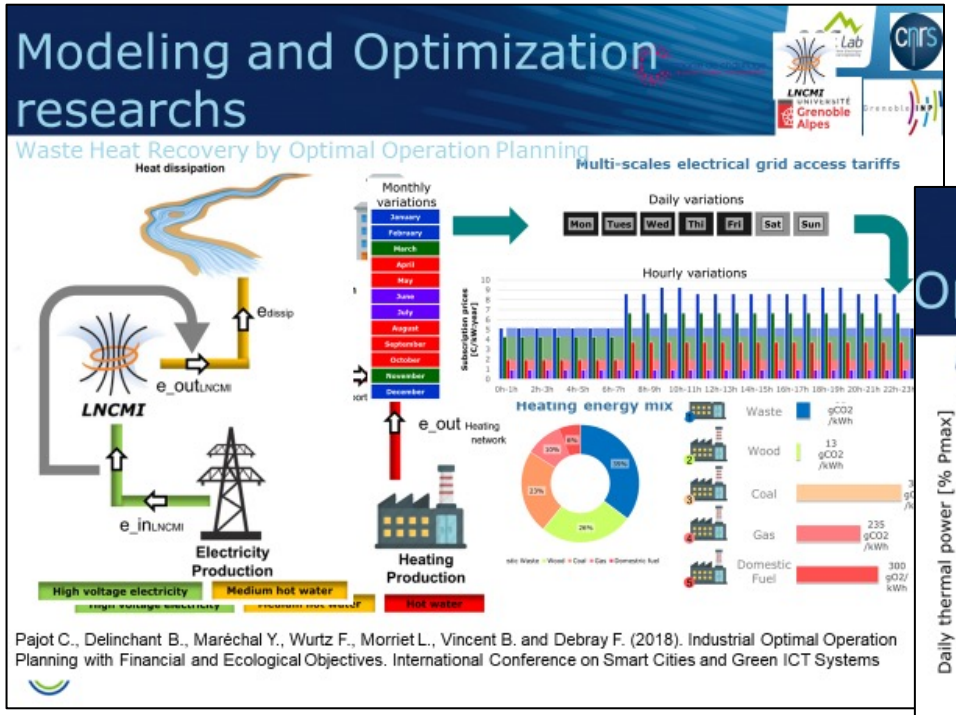
LNCMI — Compagnie de chauffage

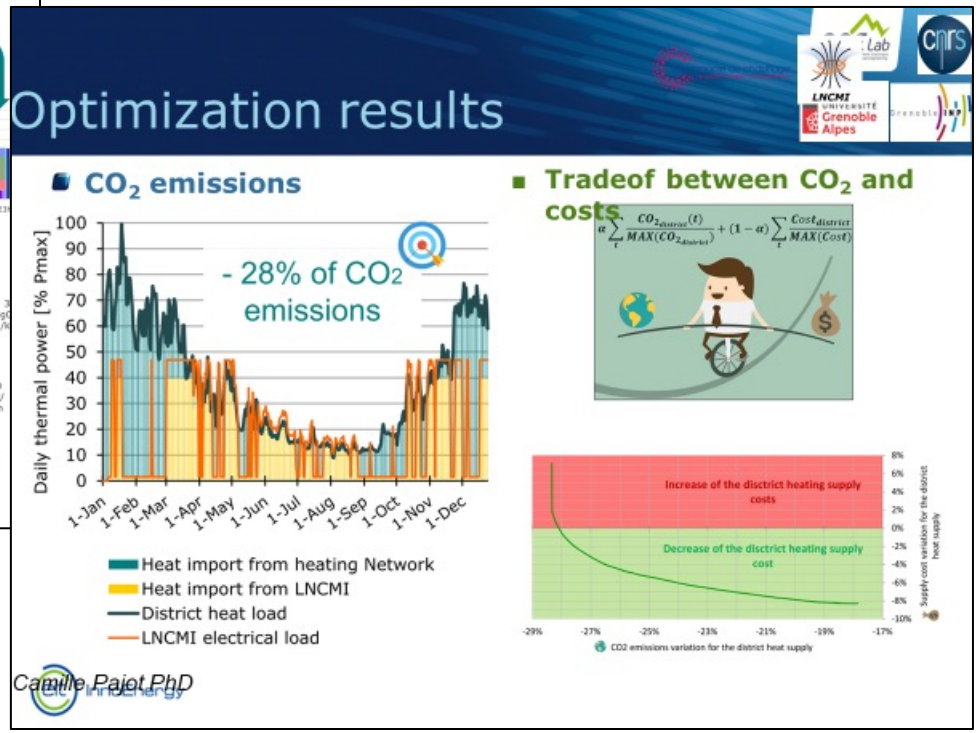
- Hourly timestep study
- Generating the optimisation problem
  - 228k variables (158k continuous et 70k binaires)
  - 316k constraints
  - 13h solving (Gurobi)
- **Various studies:**
  - Balancing between CO_2 emissions from the LNCMI and district heating, free profile
  - Using HP according to the electricity price, typical profiles
  - Study of operational performances under constraints, fixed profile

Source: Camille Pajot PhD defense

THE KIND OF RESULTS PRODUCED

- **Results around flexibility and energy decarbonation**



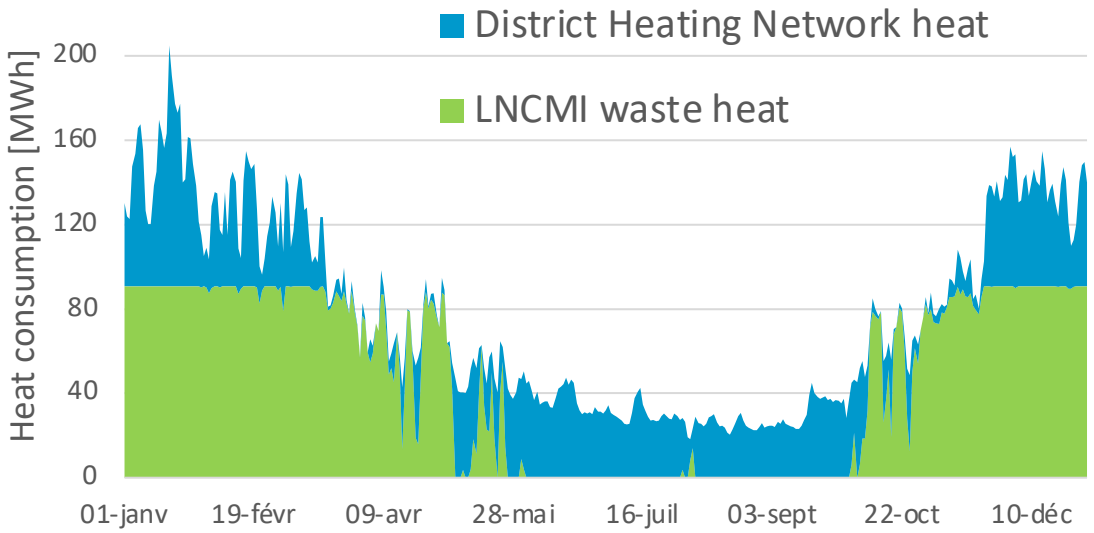


La thèse de Camille Pajot: « OMEGAlpes : outil d'aide à la décision pour une planification énergétique multi-fluides optimale à l'échelle des quartiers », thèse de l'Université Grenoble, https://hal.archives-ouvertes.fr/tel-02520569

THE KIND OF RESULTS PRODUCED

- **Results around flexibility, energy**
- **Providing the heat of the district over a year**

  - **60% of the annual needs could be covered by the LNCMI waste heat (60% reduction in CO_2 emissions)**
  - 20MWh / 6,7MW storage



Scenarios	Heating network (GWh)	CO_2 em. (g/kWh)
Reference	28,2	144
LNCMI waste heat recovery project	10,8	57,8

Annual study with 1 hour time step

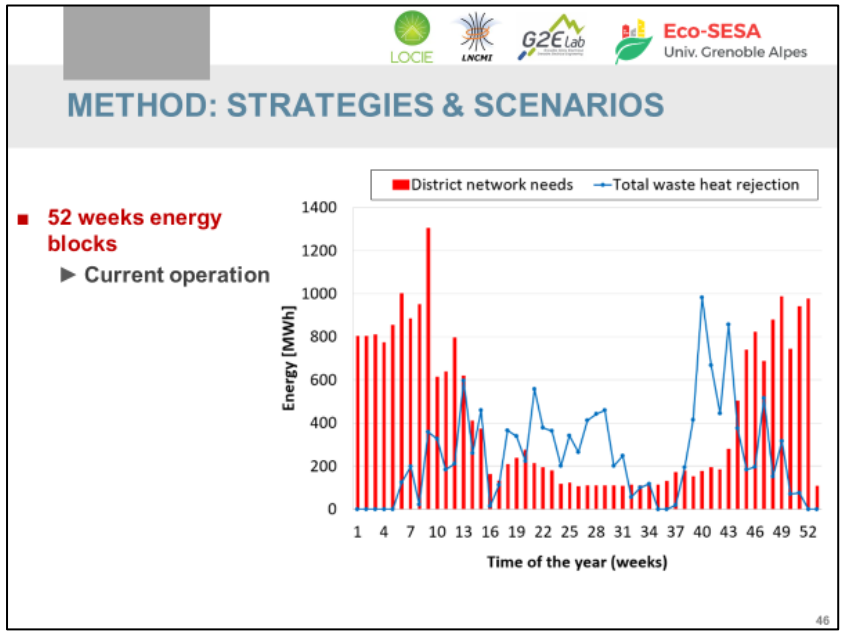
Automatic generation of the optimisation problem

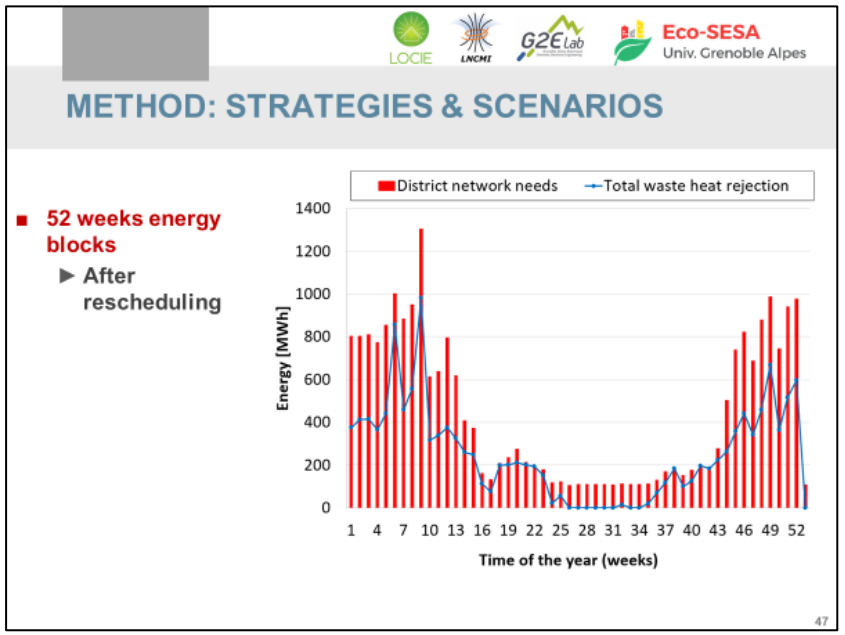
- 228k variables (158k continues et 70k binaires)
- 316k contraintes
- Résolution en 13h (Gurobi)

La thèse de Camille Pajot: « OMEGAlpes : outil d'aide à la décision pour une planification énergétique multi-fluides optimale à l'échelle des quartiers », thèse de l'Université Grenoble, https://hal.archives-ouvertes.fr/tel-02520569

THE KIND OF RESULTS PRODUCED

- **Results around flexibility, energy**





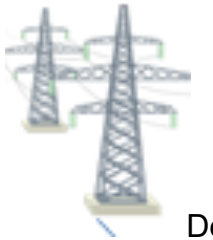
Sacha Hodencq, Jaume Fitó, François Debray, Benjamin Vincent, Julien Ramousse, et al.. Flexible waste heat management and recovery for an electro-intensive industrial process through energy/exergy criteria. Proceedings of Ecos 2021 - The 34rth International Conference On Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems, Jun 2021, Taormina, Italy. ⟨hal-03290126⟩

But the necessity of humans in the loop

- Why the necessity of humans in the loop
- From a living lab approach to a real field approach

Why the necessity of new inter-disciplinary approach with the « human in the loop »

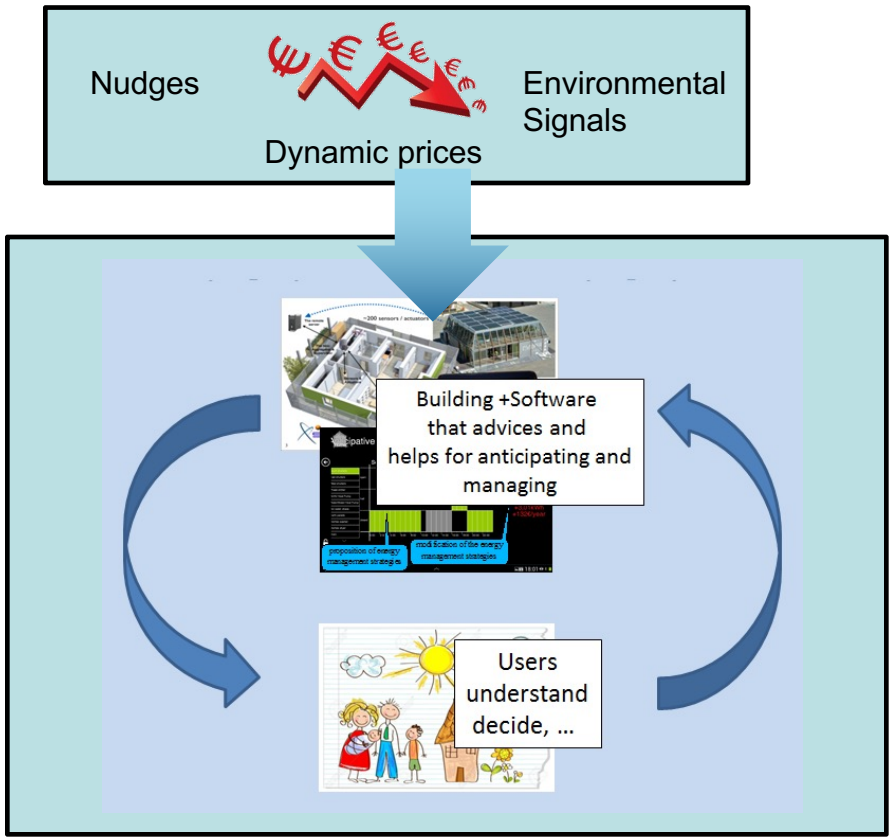
- **In Smart-Building will everything be automatic ?**
  - Was, may be, our first idea, but …
  - Our current hypothesis is that the **user/inhabitants** must be involved
    - Inhabitant want to decide, must understand, …
    - If they can not decide, and do not understand -> **Reject**
- **The consumer will become an active pro'sumer in the EnerNet**



Consumption of Energy

Demand Response

Sell/exchange of energie



The need of a new inter-disciplinary approach with the « human in the loop »

- **Uncertainty linked to human actors and usage**
- **Relatively to heating**
  - "identical houses can have heating consumption that vary with a factor 2-3 depending on user practices, and thus that user practices are at least as important as building physics"
    - See references available in: "Smart buildings" integrated in "smart grids": A key challenge for the energy transition by using physical models and optimization with a "human-in-the-loop" approach", F. Wurtz, B. Delinchant, Comptes Rendus Physique, Volume 18, Issues 7–8, September–October 2017, Pages 428-444, https://doi.org/10.1016/j.crhy.2017.09.007
  - Study on 26 Energy Positive Buildings
    - "factor 3 in variations in heat consumption depending on user practices" – from 46 kWh/m²/year to 144.9 kWh/m²/year
      - Z. M. Gill, M. J. Tierney, I. M. Pegg, N. Allan, Measured energy and water performance of an aspiring low energy/carbon affordable housing site in the UK. Energy and Buildings 43, 2011,117–125
- **Relatively to electricity**
  - when comparing households living in similar houses, electricity consumption can vary with a factor 5, thus indicating that electricity consumption is even still less linked with building size type than heating consumption
    - Gram-Hanssen, K. (2011). Households' energy use - which is the more important: efficient technologies or user practices? In Proceedings of the World Renewable Energy Congress 2011 (WREC 2011) Linköping: Linköping University Electronic Press

To have the complete Story

- **Of why the need of an approach with « … humans in the loop » …**

C. R. Physique 18 (2017) 428–444

Contents lists available at ScienceDirect

Comptes Rendus Physique

www.sciencedirect.com

Demain l'énergie – Séminaire Daniel-Dautreppe, Grenoble, France, 2016

"Smart buildings" integrated in "smart grids": A key challenge for the energy transition by using physical models and optimization with a "human-in-the-loop" approach

Le « bâtiment intelligent » intégré dans les « réseaux intelligents » : un défi clé pour la transition énergétique. Modèles physiques et optimisation associés à une approche intégrant l'acteur humain dans la boucle

Frédéric Wurtz, Benoît Delinchant

Université Grenoble Alpes, CNRS, Grenoble INP, G2Elab, 38000 Grenoble, France

Wurtz, F., Delinchant, B., 2017. "Smart buildings" integrated in "smart grids": A key challenge for the energy transition by using physical models and optimization with a "human-in-the-loop" approach. Comptes Rendus Phys., Demain l'énergie 18, 428–444. https://doi.org/10.1016/j.crhy.2017.09.007

From Social sciences and engineering sciences to tools and models

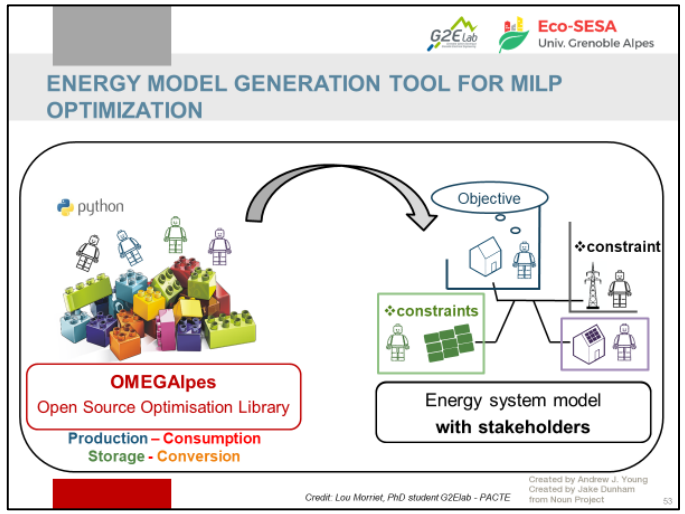
- Quantitative modelisation
- Qualitative modelisation

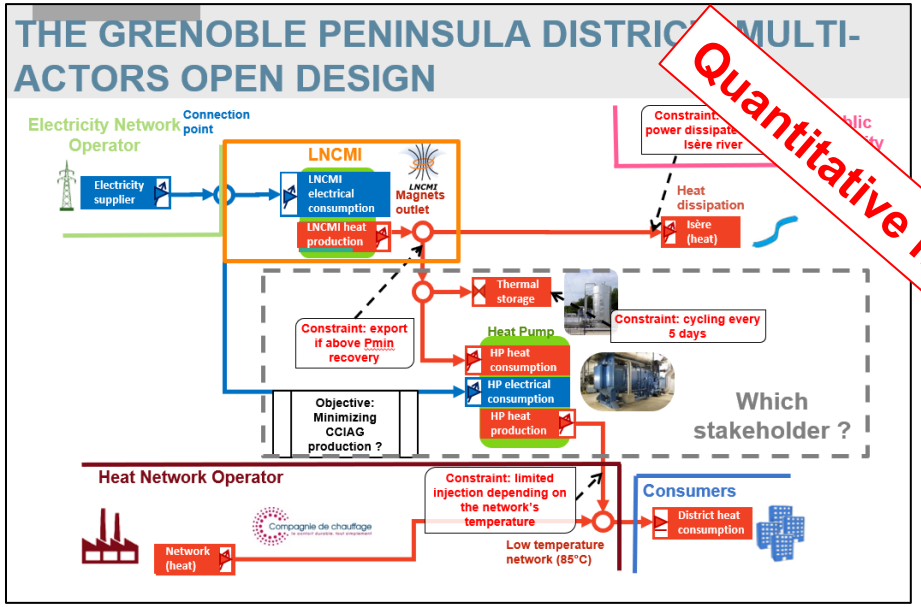
FROM SOCIAL SCIENCES AND ENGINEERING SCIENCES TO MODELS AND TOOLS

- **From identification of actors with social sciences to the development of Tools for Design and Energy management and socio technic modelisation**

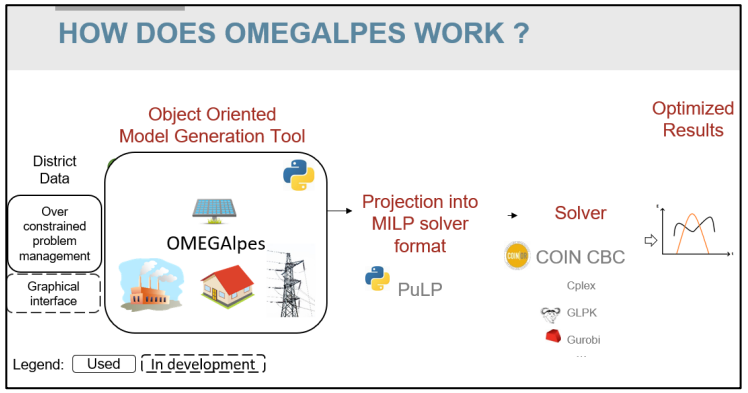
Social Science

Pacte
Laboratoire de sciences sociales





Quantitative modelisation



La thèse de Lou Morriet: « Conception multiacteur de systèmes énergétiques locaux bas-carbone : outils, modèles et analyses qualitatives », thèse de l'Université Grenoble Alpes Soutenue le 8 mars 2021, https://hal.archives-ouvertes.fr/tel-03285666v1

OMEGAlpes code: gricad-gitlab.univ-grenoble-alpes.fr/omegalpes
OMEGAlpes documentation: omegalpes.readthedocs.io

THE KIND OF RESULTS PRODUCED

- **Collaborative and participative science: the Transect**

Collaboration with social science and urban science

« L'eau dans les paysages de l'énergie, Le cas de la Presqu'île de Grenoble
Water in Energy Landscapes – The Case of the Grenoble Peninsula »,
Sylvie Laroche et Nicolas Tixier, Revue scientifique sur la conception et l'aménagement de l'espace, 20 | 2019, Paysages de l'eau, https://journals.openedition.org/paysage/680

http://grand-a.aurg.org/ancrage-energie/parole-croisee-de-chercheurs

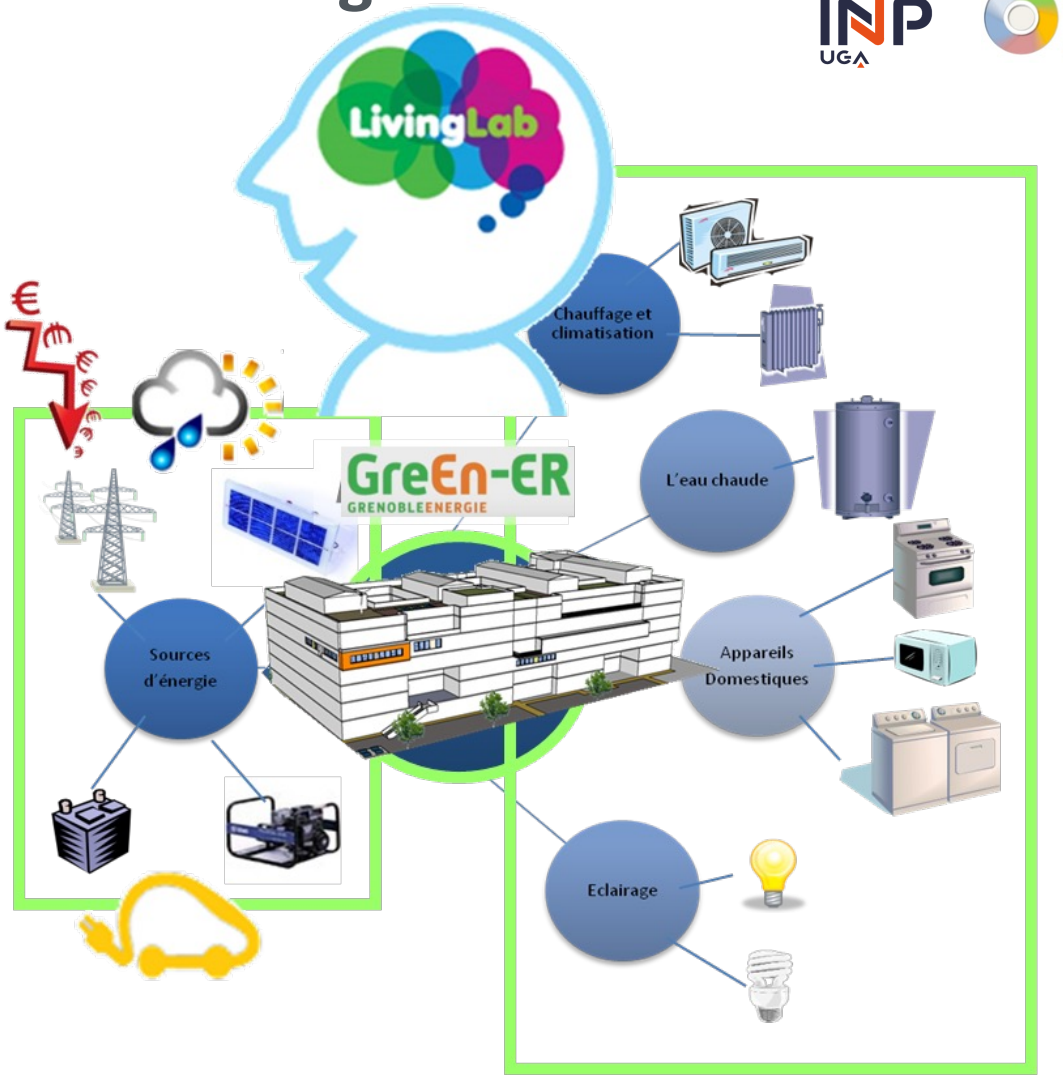
To a data driven approach with the human in the loop

From a living lab approach to a real field approach

A real field experiment with humans in the loop

We need the data

GreEn-ER : Grenoble Energy – Living-Lab for Teaching & Research



- 6 floors, 4500 m², 2000 people (incl. 1500 students)
- Energy efficient building (95 $kWh_{PE}/(m^2.y)$)
- PV installed (205kWp)
- EV Charging
- Highly monitored (>1000 measuring point)

Delinchant B., Wurtz F., Ploix S., Schanen J.-L. and Marechal Y. (2016). "GreEn-ER Living Lab - A Green Building with Energy Aware Occupants". **SmartGreen'16**, In Proceedings of the 5th International Conference on Smart Cities and Green ICT Systems. ISBN 978-989-758-184-7, pages 316-323. DOI: 10.5220/0005795303160323

Smart-Building & Human in the loop – The need of the concept of living lab

GreEn-ER-MHI our new platfom is a Living Lab

Producing science and technology

Test it with real users

Those users can innovate

See what works (or not) with real users

« Google » innovation strategy !

User can become designers of the building (and reciprocally)

Une explication dui problème pourrait tenir dans le fait que le boitier de la sonde de régulation est très proche de l'écran Magelis qui est une forte source de chaleur

Les photos ci-jointes semblent confirmer le problème:

La solution va donc consister:

- à augmenter la température de consigne dans un premier temps
- à déplacer le capteur dans un second temps

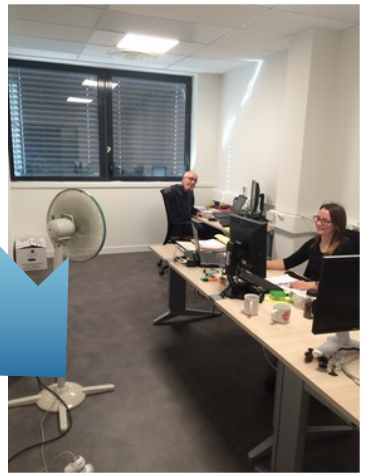
Users can modify, Model, diagnose the « smart-building »

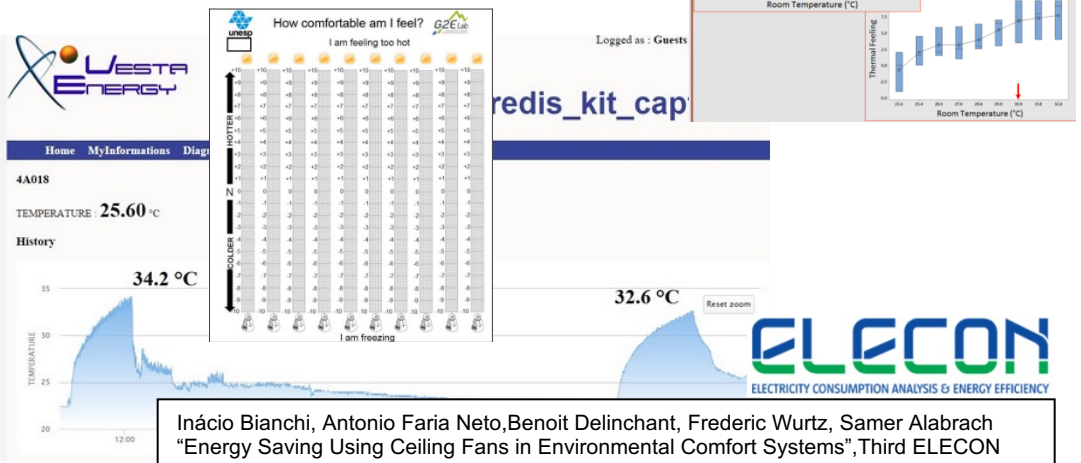
ELECON
ELECTRICITY CONSUMPTION ANALYSIS & ENERGY EFFICIENCY

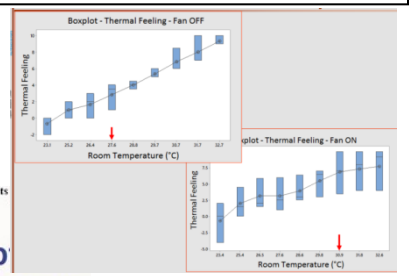
Benoit Delinchant, Frédéric Wurtz, "The Grenoble PREDIS – Building platform: A living lab and experimentallab for the study of energy and comfort in Smart-Buildings", Third ELECON Workshop , url: http://www.elecon.ipp.pt/images/Workshop3/Presentations/Elecon3.pdf

Experiments with the « Human in the loop »

- **Measure and modeling of comfort directly feeled by the users**





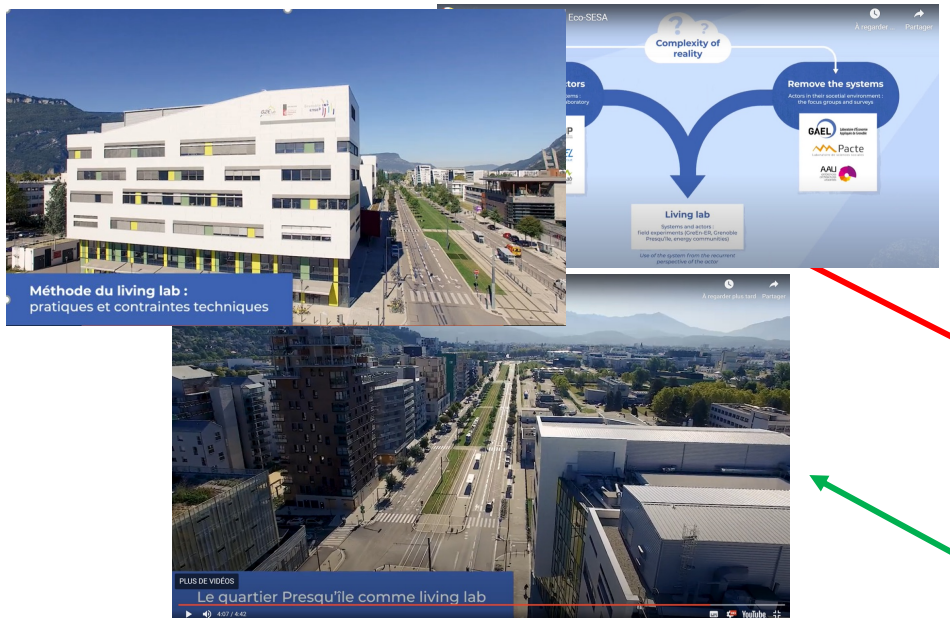


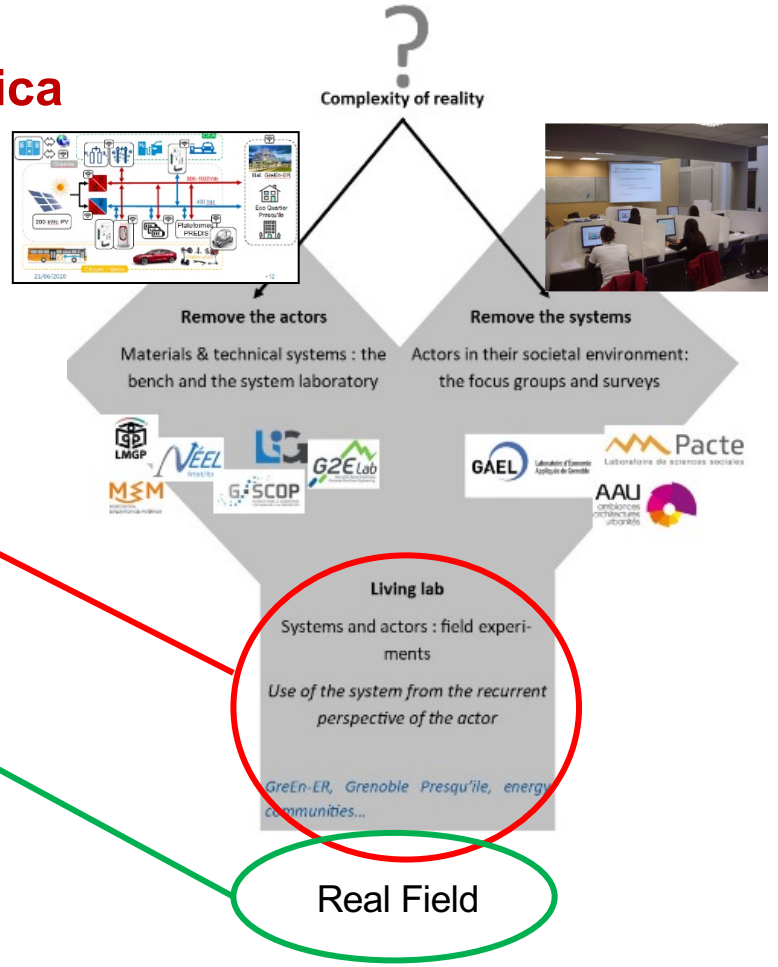
ELECON
ELECTRICITY CONSUMPTION ANALYSIS & ENERGY EFFICIENCY

Inácio Bianchi, Antonio Faria Neto,Benoit Delinchant, Frederic Wurtz, Samer Alabrach "Energy Saving Using Ceiling Fans in Environmental Comfort Systems",Third ELECON Workshop, url: http://www.elecon.ipp.pt/images/Workshop3/Presentations/Elecon9.pdf

LABS, LIVINGS-LAB & FIELD: AN INTERDISCIPLINAR APPROACH BETWEEN TECHNICAL AND SOCIAL SCIENCE

- **The Y research strategy for a socio-technica research for energy transition**





https://ecosesa.univ-grenoble-alpes.fr/training-and-dissemination/videos/lapproche-living-lab-eco-sesa-living-lab-approach-eco-sesa

Delinchant B., Wurtz F., Ploix S., Schanen J. and Marechal Y. (2016). GreEn-ER Living Lab - A Green Building with Energy Aware Occupants.In Proceedings of the 5th International Conference on Smart Cities and Green ICT Systems - Volume 1: SMARTGREENS, ISBN 978-989-758-184-7, pages 316-323. DOI: 10.5220/0005795303160323, https://hal.archives-ouvertes.fr/hal-01317470/

To a data driven approach with the human in the loop

From a living lab approach to a real field approach

A real field experiment with humans in the loop

We need the data

Experiment on energy demand flexibility

- Randomized Controlled Trial (RCT)
- 174 on households in the Grenoble area in France from June 2019 to October 2021.

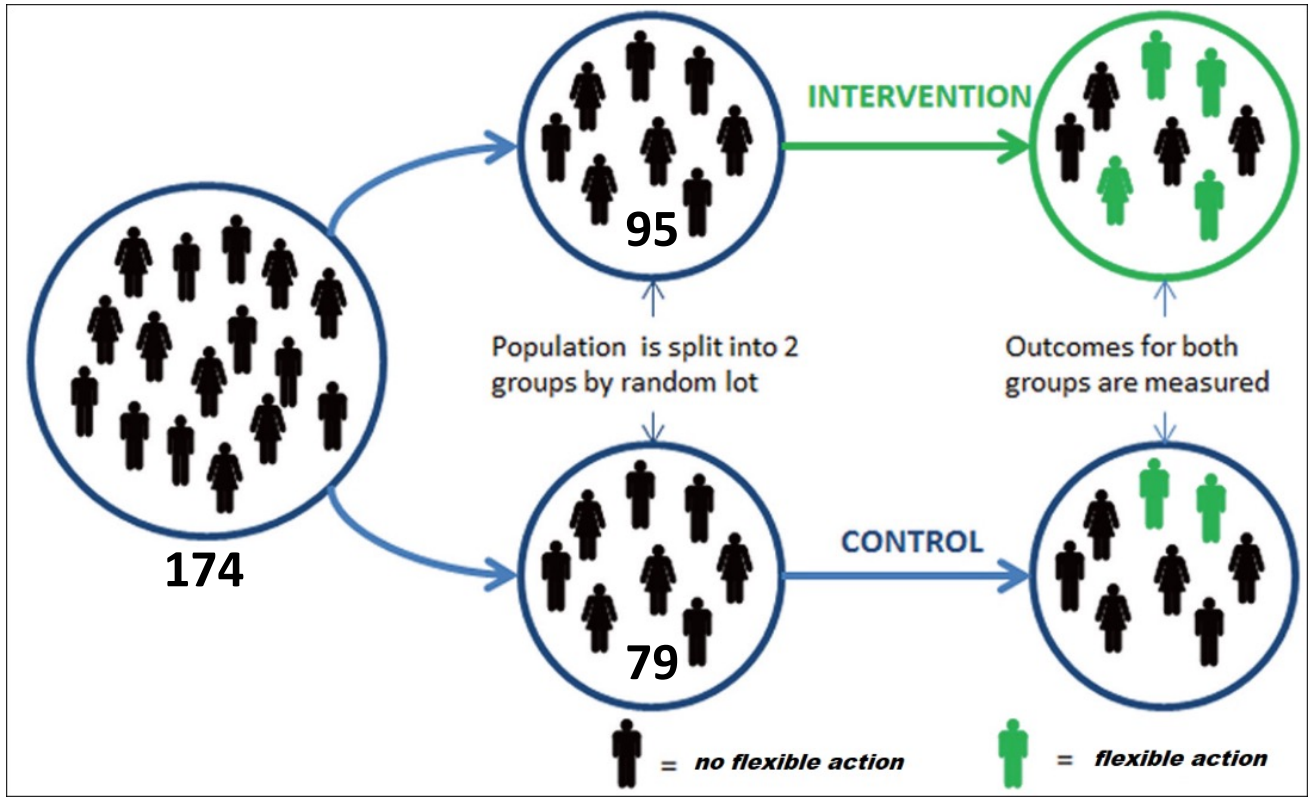
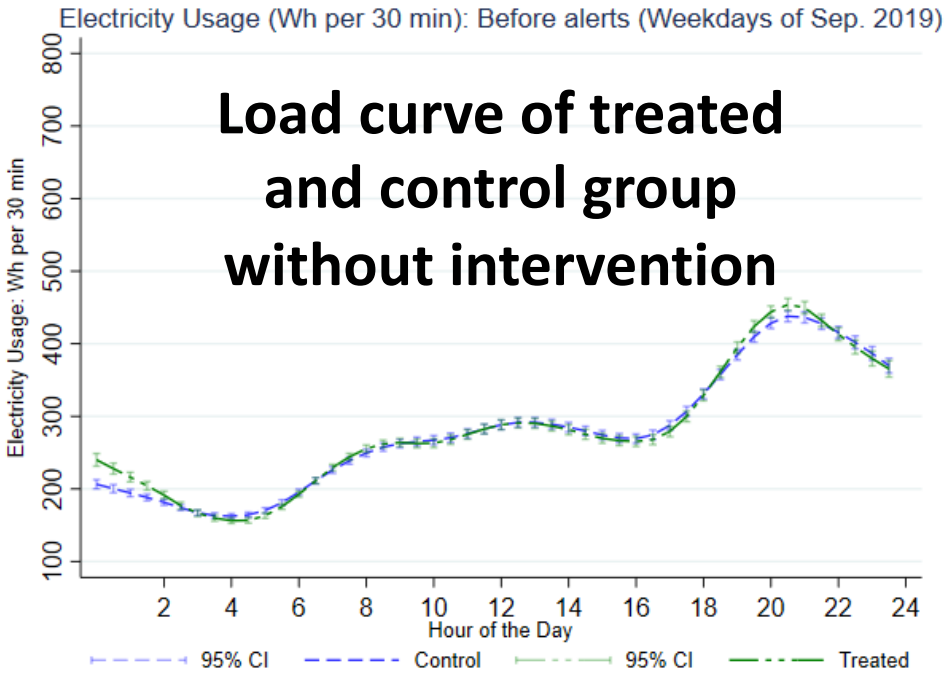


Image adapted from https://emmatomkinson.com/2013/05/20/randomised-controlled-trials-rcts-in-public-policy/

- **Recruiting** : mailbox flyers, journal paper; for a "study on energy consumption and the development of renewable energy"
- **Monetary indemnity 3 x 40€ for :**
  - **Survey** : type of housing and composition, the socio-professional category, heating system, etc
  - **Data consent** : Consumption data 30' min



A methodology for experimentations and scientific results with “Humans in the Loop”

- Expesigno – A scientific evaluation of potential of flexibility in real field
  - A methodology for experimentations and scientific results
  - Examples of research methodology from living

Eco-SESA
Univ. Grenoble Alpes

SAMPLE DESCRIPTION AND LOCALIZATION

Table 2: Households Characteristics

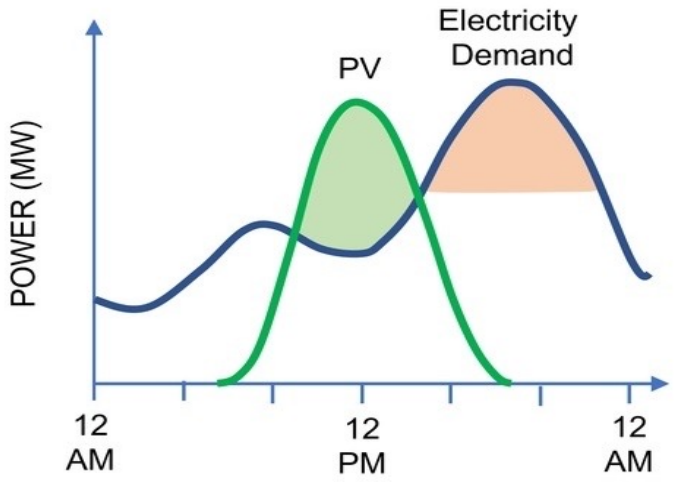
	(1) Control		(2) Treated		(3) T-test	
	Mean	S.D.	Mean	S.D.	b	p-value
Surface	102.23	45.86	98.41	41.37	3.82	(0.58)
Household Size	3.09	1.27	2.93	1.31	0.16	(0.43)
Share of						
At home at least 3d/w	0.46	0.50	0.62	0.49	-0.16*	(0.04)
home_owner	0.78	0.42	0.78	0.42	0.00	(0.99)
house	0.46	0.50	0.52	0.50	-0.06	(0.48)
Elec. Heat.	0.09	0.29	0.09	0.29	-0.00	(0.96)
Heat Pump	1.05	0.22	1.07	0.25	-0.02	(0.63)
Air conditioner	1.06	0.25	1.07	0.25	-0.00	(0.90)
Building date						
Before 1974	0.53	0.50	0.46	0.50	0.07	(0.40)
Between 1974 and 1990	0.18	0.39	0.17	0.38	0.01	(0.91)
Between 1990 to 2012	0.23	0.42	0.25	0.44	-0.02	(0.74)
After 2012	0.06	0.25	0.11	0.32	-0.05	(0.25)
Monthly electricity consumption (kWh)	255.16	240.40	247.65	211.10	7.51	(0.29)
Number of households	78		87		165	

Notes : S.D.= Standard Deviation.
* for p<.05, ** for p<.01, and *** for p<.001

Localisation of the participants to the study

175 participating dwellings

Indirect control experiment
Global Architecture

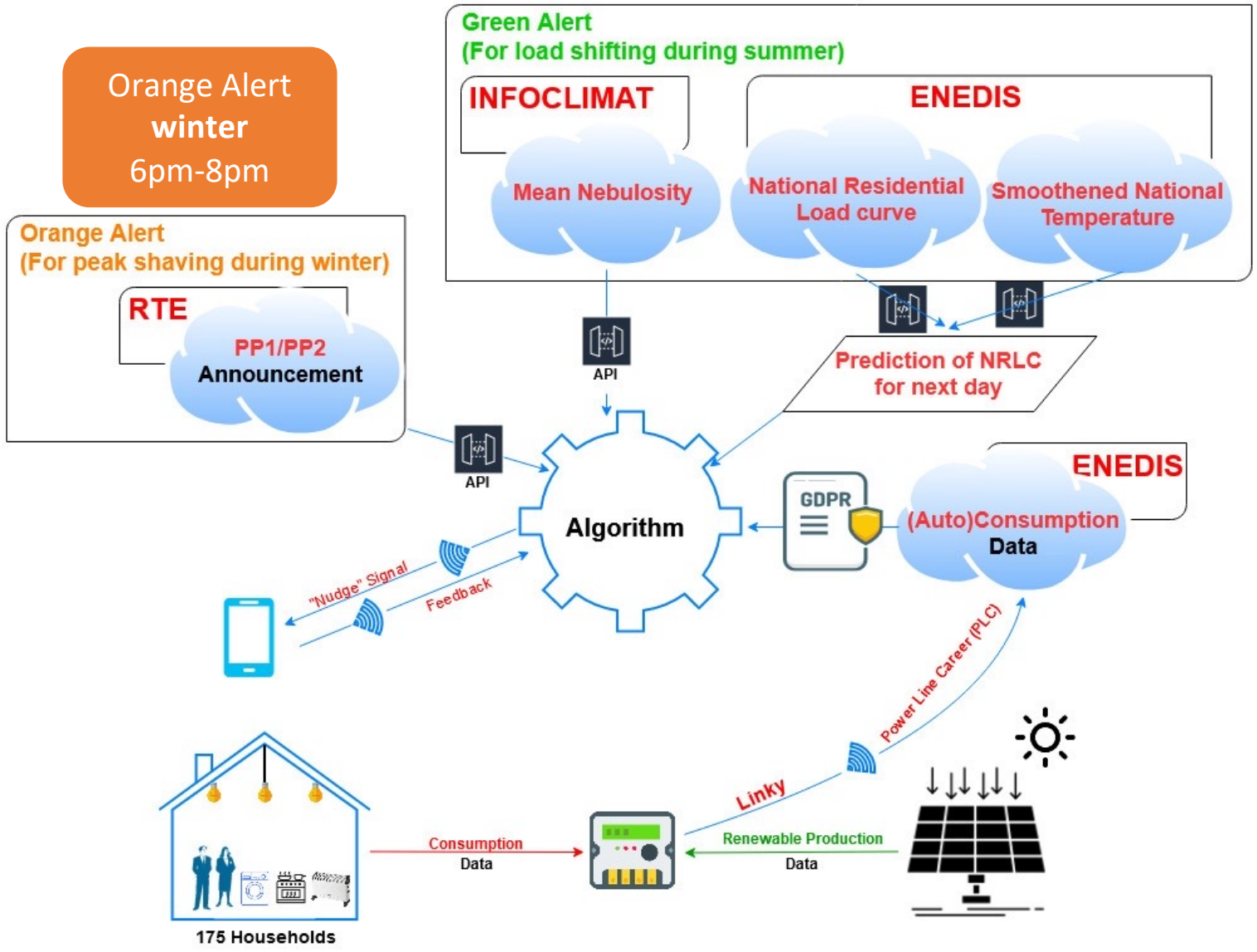


Realtime treatments to :

- Forecast
  - electrical grid stress
  - PV production
  - Load demand
- Generate alerts (D-1)
- Remind commitments (D)
- Get households consumption (D+3)
- Generate feedback (D+3)

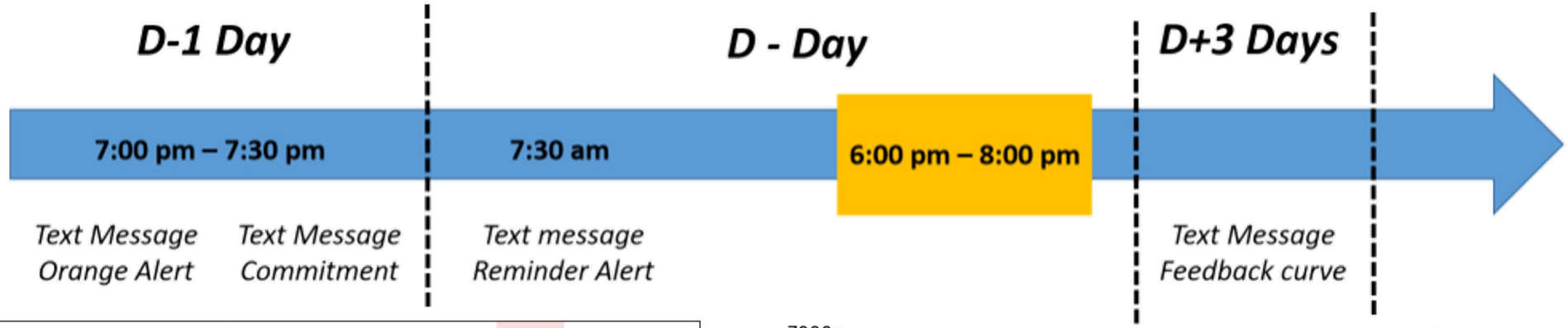
Green Alert
Summer
12pm-3pm

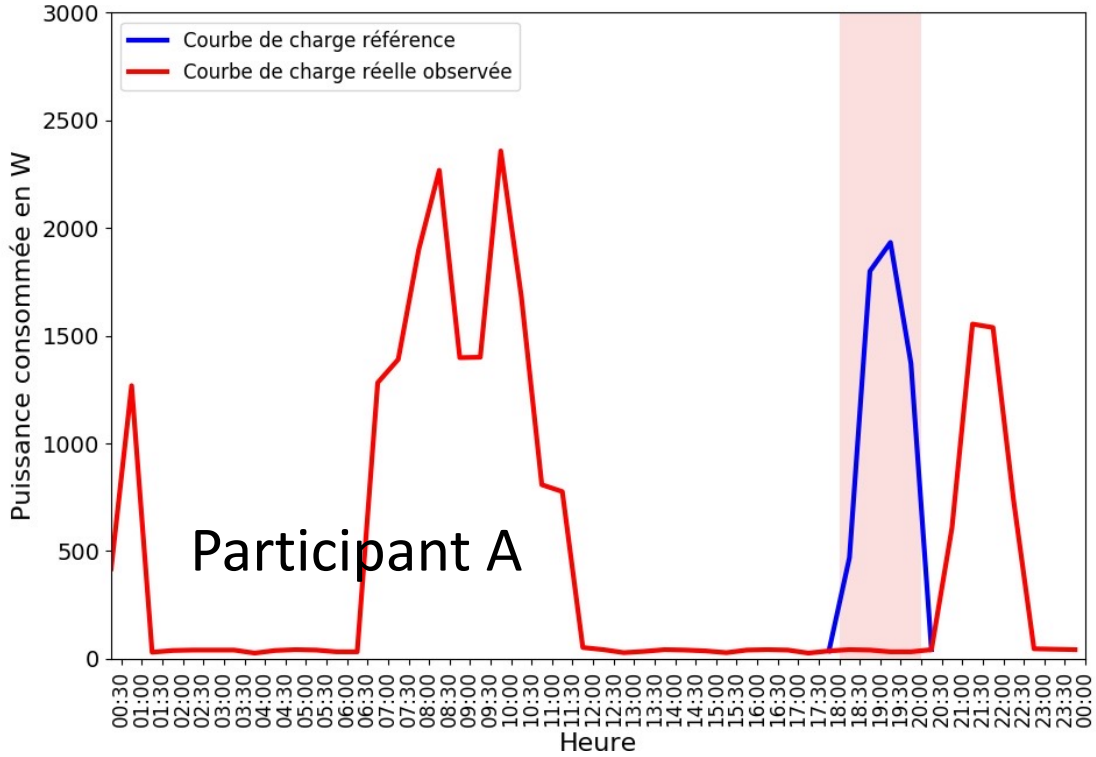
Orange Alert
winter
6pm-8pm

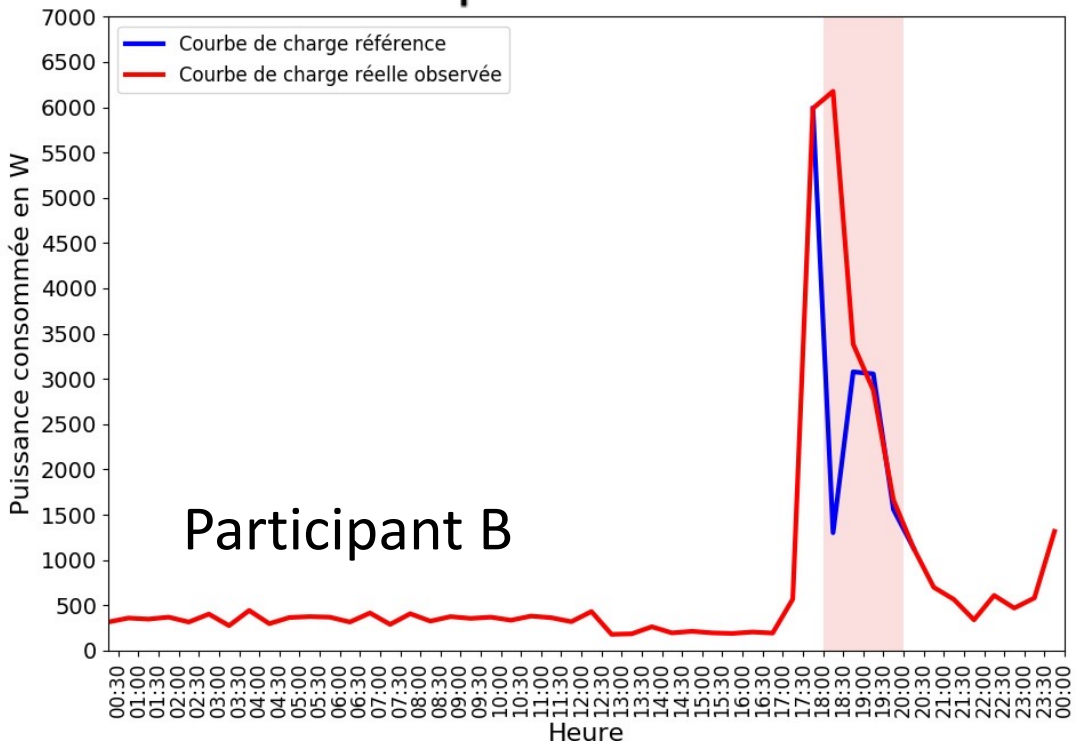


Experiment on energy demand flexibility

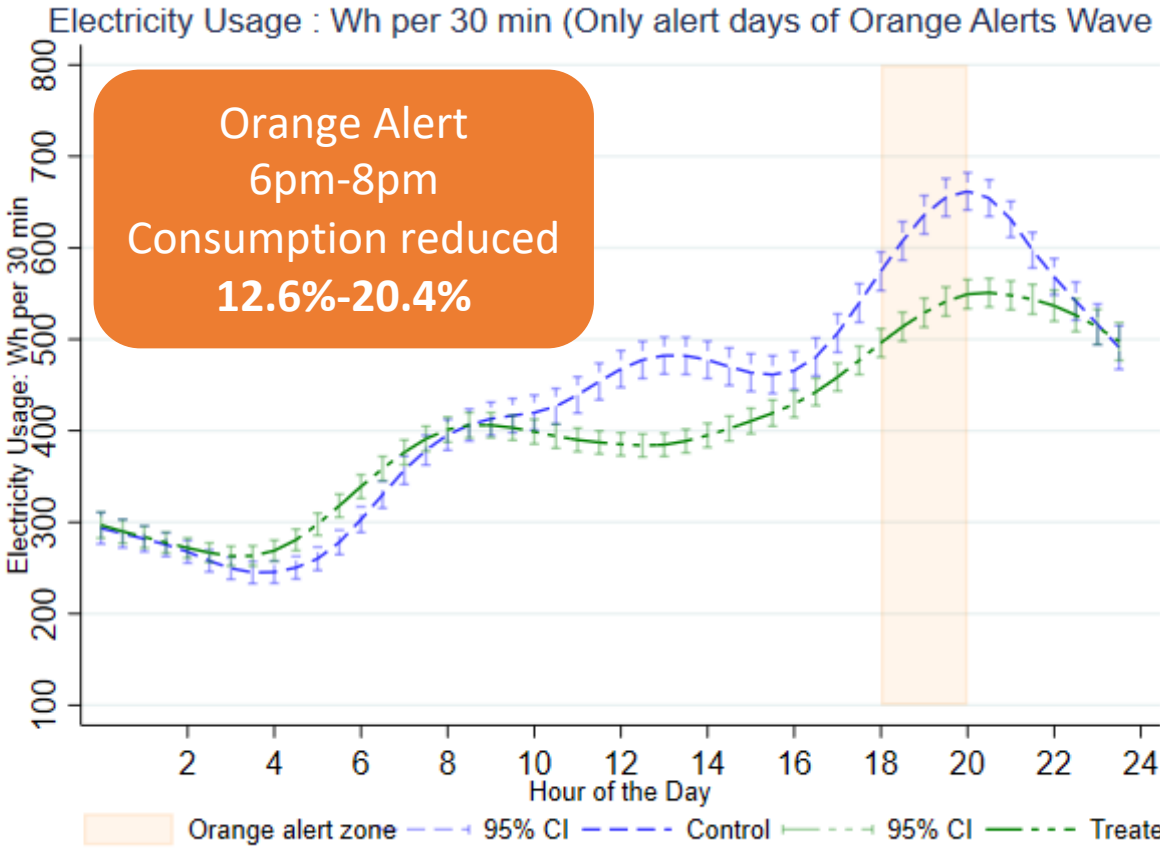
Feedback load curve







Experiment on energy demand flexibility



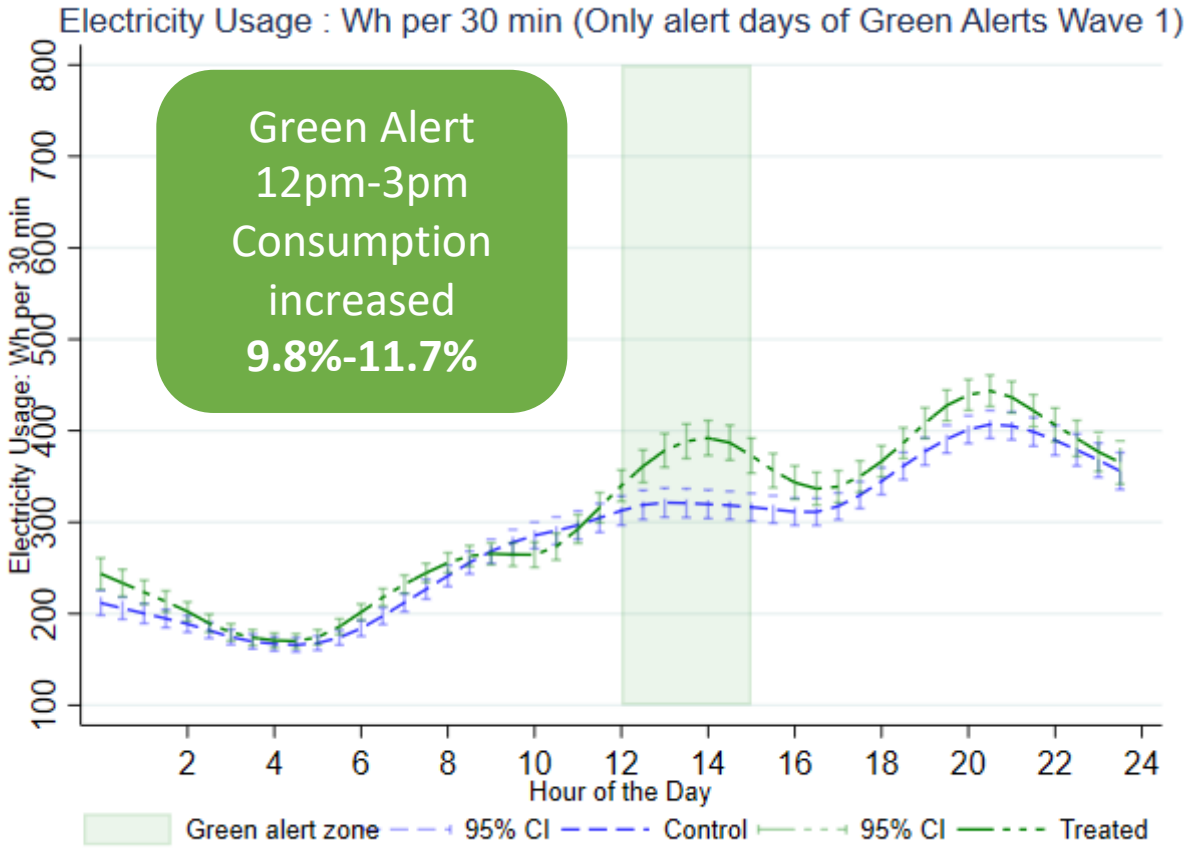


Table 8: KWh per 30 min (Orange Alerts Wave 1 - 6pm-8pm)

	(1) Control		(2) Treated		(3) T-test	
	mean	sd	mean	sd	b	p
KWh 18h-20h	688.22	857.18	530.95	708.72	157.27***	(0.00)
Observations	2776		3092		5868	

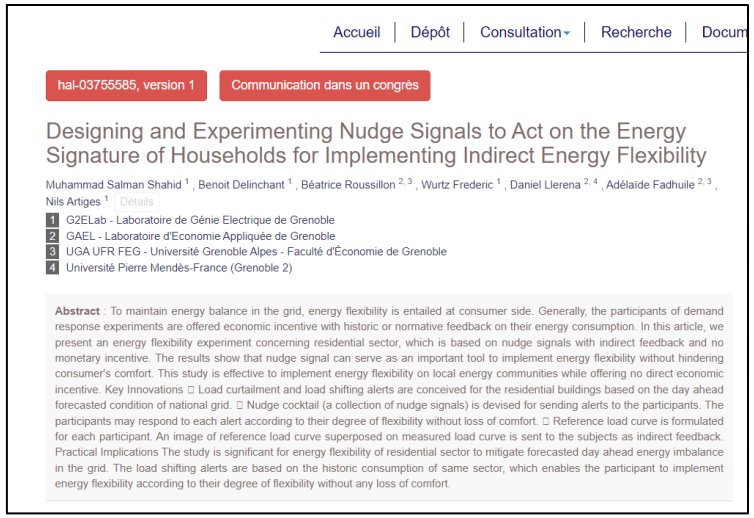
Table 9: KWh per 30 min (Green Alerts Wave 1 - 12pm-3pm)

	(1) Control		(2) Treated		(3) T-test	
	mean	sd	mean	sd	b	p
KWh 12h-15h	326.54	434.42	407.83	555.36	-81.29***	(0.00)
Observations	1764		1968		3732	

OBSERVATOIRE DE LA TRANSITION ÉNERGÉTIQUE

A methodology for experimentations and scientific results with “Humans in the Loop”

- Expesigno:
  - A methodology for experimentations and scientific results
  - Examples of research



Accueil | Dépôt | Consultation | Recherche | Docum

hal-03755585, version 1 | Communication dans un congrès

Designing and Experimenting Nudge Signals to Act on the Energy Signature of Households for Implementing Indirect Energy Flexibility

Muhammad Salman Shahid [1], Benoit Delinchant [1], Béatrice Roussillon [2, 3], Wurtz Frederic [1], Daniel Llerena [2, 4], Adélaïde Fadhuile [2, 3], Nils Artiges [1]

1 G2ELab - Laboratoire de Génie Electrique de Grenoble
2 GAEL - Laboratoire d'Economie Appliquée de Grenoble
3 UGA UFR FEG - Université Grenoble Alpes - Faculté d'Économie de Grenoble
4 Université Pierre Mendès-France (Grenoble 2)

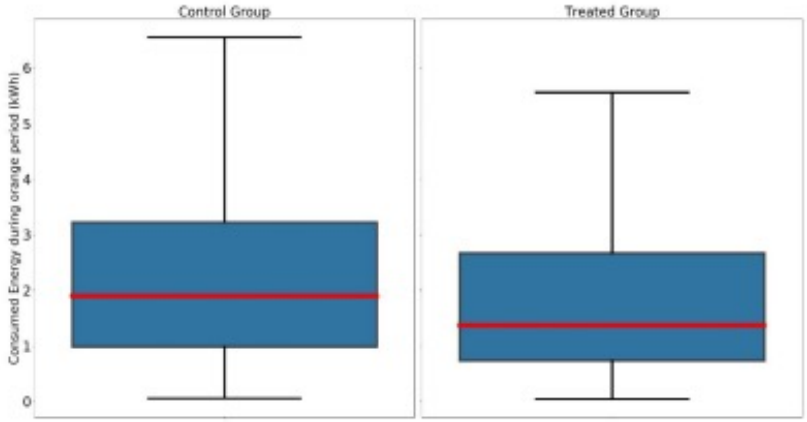
Abstract : To maintain energy balance in the grid, energy flexibility is entailed at consumer side. Generally, the participants of demand response experiments are offered economic incentive with historic or normative feedback on their energy consumption. In this article, we present an energy flexibility experiment concerning residential sector, which is based on nudge signals with indirect feedback and no monetary incentive. The results show that nudge signal can serve as an important tool to implement energy flexibility without hindering consumer's comfort. This study is effective to implement energy flexibility on local energy communities while offering no direct economic incentive. Key Innovations □ Load curtailment and load shifting alerts are conceived for the residential buildings based on the day ahead forecasted condition of national grid. □ Nudge cocktail (a collection of nudge signals) is devised for sending alerts to the participants. The participants may respond to each alert according to their degree of flexibility without loss of comfort. □ Reference load curve is formulated for each participant. An image of reference load curve superposed on measured load curve is sent to the subjects as indirect feedback. Practical Implications The study is significant for energy flexibility of residential sector to mitigate forecasted day ahead energy imbalance in the grid. The load shifting alerts are based on the historic consumption of same sector, which enables the participant to implement energy flexibility according to their degree of flexibility without any loss of comfort.

Muhammad Salman Shahid, Benoit Delinchant, Béatrice Roussillon, Wurtz Frederic, Daniel Llerena, et al.. Designing and Experimenting Nudge Signals to Act on the Energy Signature of Households for Implementing Indirect Energy Flexibility. BS 2021 – International Building Simulation Conference 2021, Sep 2021, Bruges, Belgium. (hal-03755585), https://hal.archives-ouvertes.fr/hal-03755585

La Région Auvergne-Rhône-Alpes — Pack Ambition Recherche 2017 EXPESIGNO | Eco-SESA Univ. Grenoble Alpes | GAEL | G2Elab

Results and Discussion

- **Comparison of both groups during alert days**
  - The difference of mean values yields that the treated group saved 280 Wh/h of energy per orange period.
  - Extrapolating for 29 million French households (INSEE France 2019 [1]) gives an energy saving of 8.12 GWh/h (between 6 PM and 8 PM).



Reference:
[1] INSEE France. 2019. “Tableaux de l'économie Française - Tableaux de l'Économie Française | Insee.” 2019.

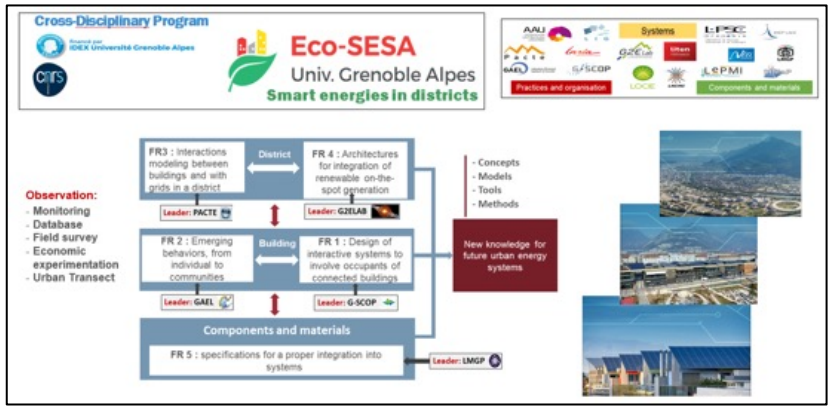
To a data driven approach with the human in the loop

Why the necessity of humans in the loop
From a living lab approach to a real field approach
A real field experiment with humans in the loop
We need the data

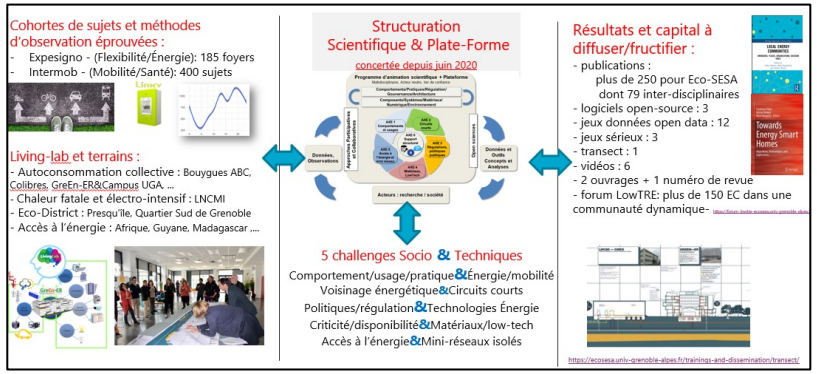
SOCIO-TECHNICAL PROGRAMS BASED ON LIVING-LABS: FROM ECO-SESA TO OTE FOR ACCESS TO FIELDS AND DATA

- **The need of a socio-technic approach with the community of users « in the loop » based on living-lab**

From eco-SESA



To OTE: Observatory of Transition for Energy



Eco-SESA
Univ. Grenoble Alpes

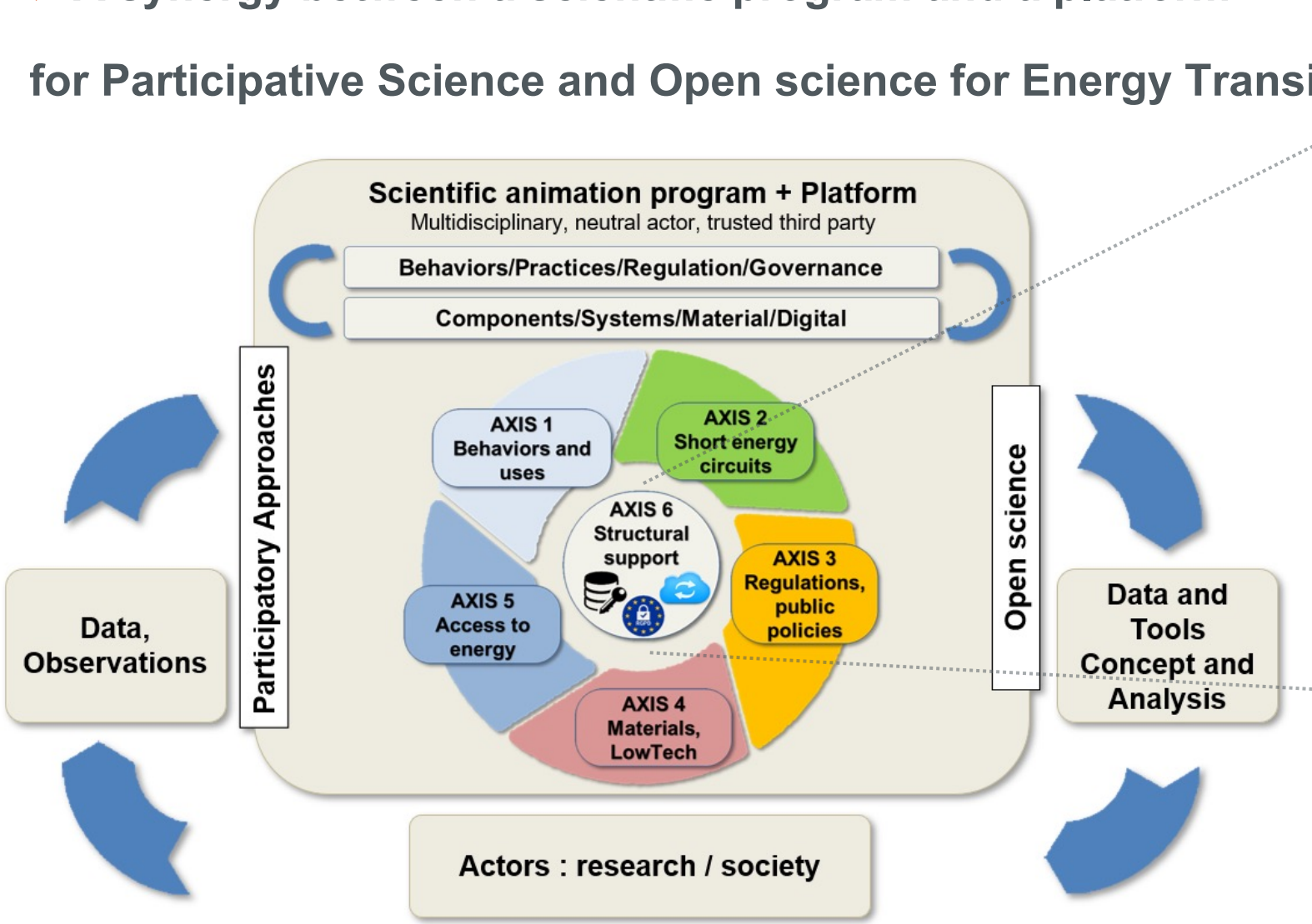
https://ecosesa.univ-grenoble-alpes.fr/

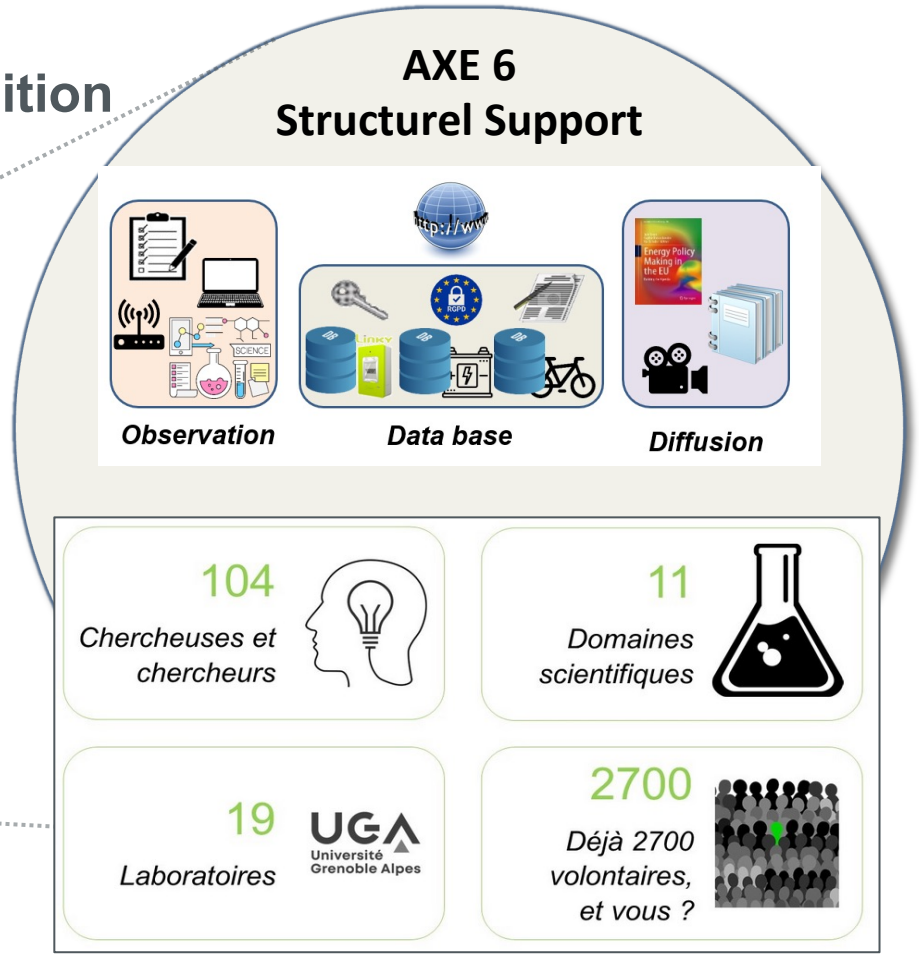
https://ote.univ-grenoble-alpes.fr/

OTE: Observatory of Transition for Energy

- A synergy between a scientific program and a platform

for Participative Science and Open science for Energy Transition

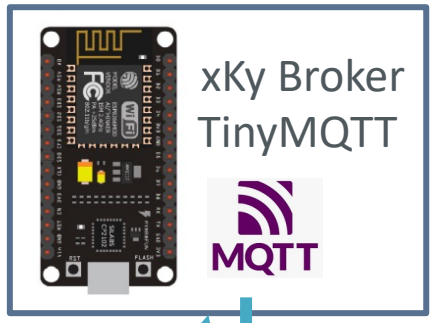


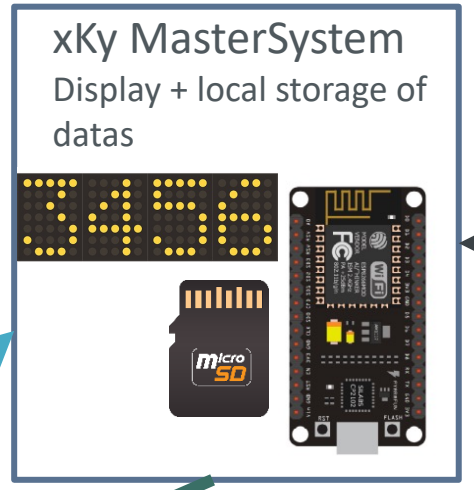


More than 2700 dwellings involved

Open-hardware technical infrastructure

https://predis.g2elab.grenoble-inp.fr/smartbuilding/index.php/2022/02/04/winky-version-2-open-source-projet-pour-linky-avec-wifi/





Raw Data

Household

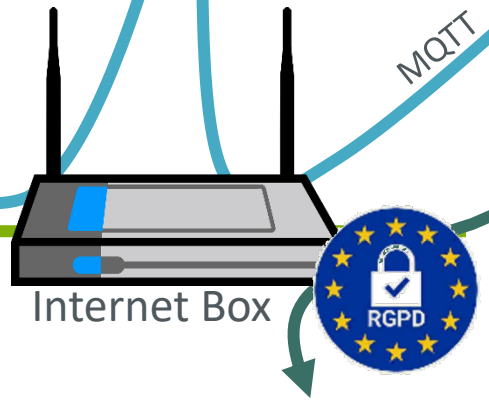
MQTT

MQTT

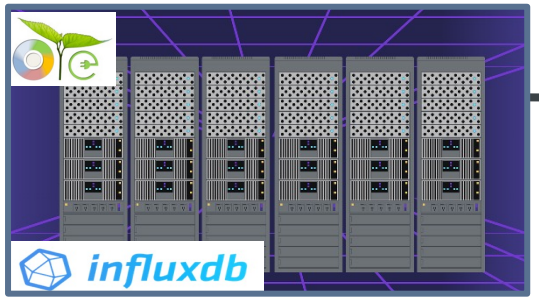
InfluxDB

Dwelling of the participant

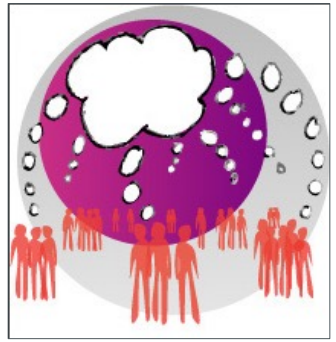
Observatory (OTE)



OTE Server



Anonymised
Agregated data



Scientific community

Study to make reliable real-time recovery data from the Linky meter
Jerome Ferrari – G2ELAB

WE NEED YOUR

DATA

GRENOBLE INP UGA

G2Elab Grenoble Génie Electrique Grenoble Electrical Engineering

cnrs

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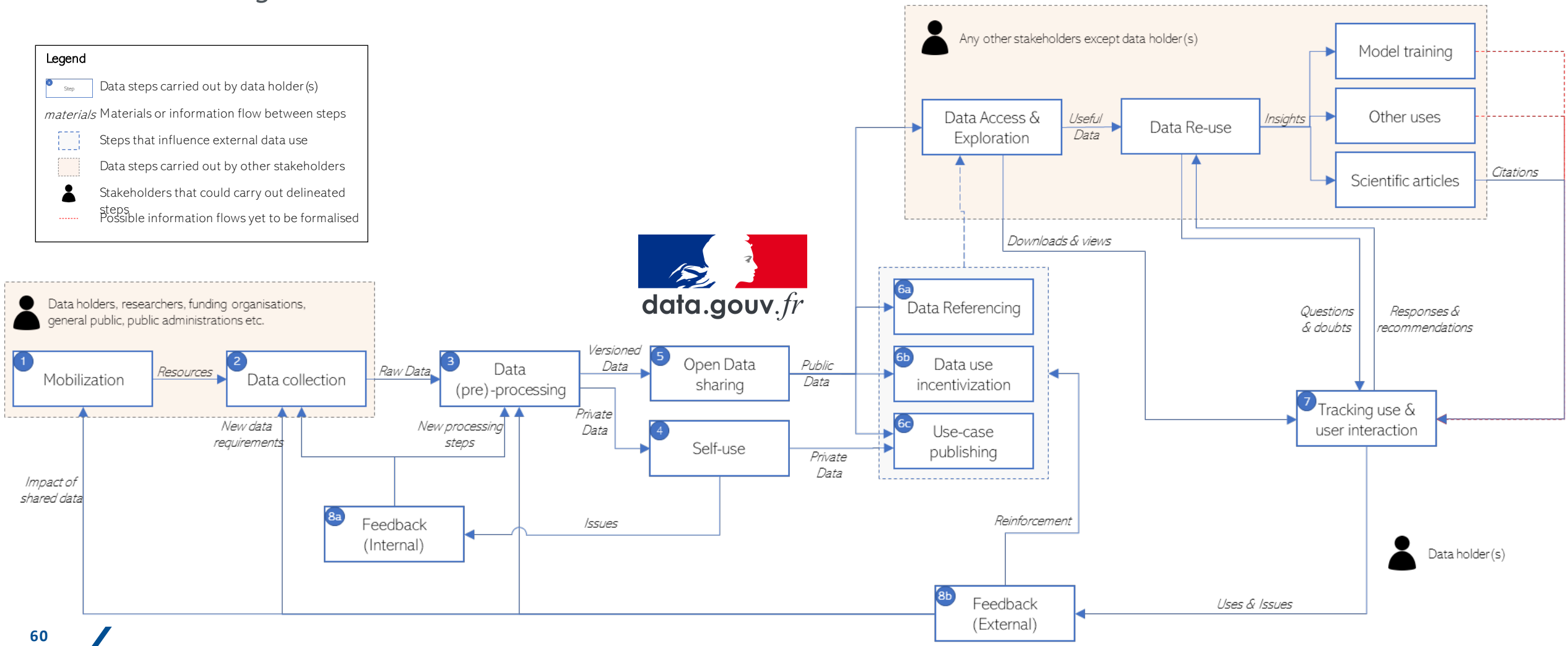
financed by
IDEX Université Grenoble Alpes

General Data Protection Regulation

OPen ENergy DAta Lifecycle (OPENDAL)

Towards an open data lifecycle tailored to citizen-sourced energy datasets

PhD Seun Osonuga

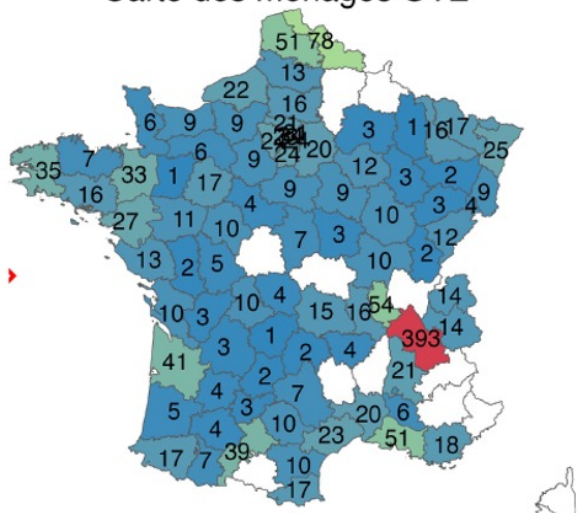


OPen ENergy DAta Lifecycle (OPENDAL)

- The first data set are published by the Observatory

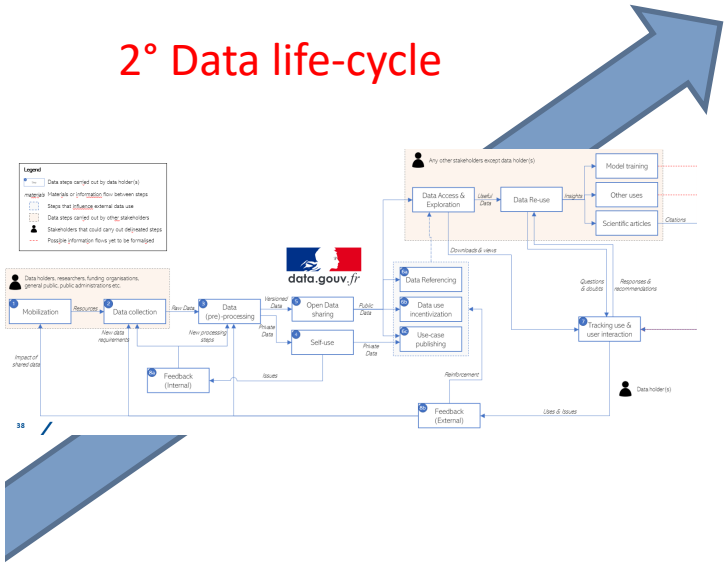
1° Panel of volunteers

Carte des ménages OTE



Source : OTE N=1603 ménages, 2023

2° Data life-cycle



data.gouv.fr

1 à 5 de 5 résultats

Tri

H358 Office data

6 juin 2024

Ploix, Stéphane, 2024, "H358 Office data", https://doi.org/10.57745/6PE4CY, Recherche Data Gouv, V1, UNF:6:D871qH+PYhzfpw08u2tVRg== [fileUNF]

Raw data coming from 20 sensors deployed inside an office, located in Grenoble, with 3 desks during 1 year and a half.

Etude xKy

5 juin 2024

Ferrari, Jérôme; Imar, Vincent; Boisseau, Christophe; Osonuga, Seun; Wurtz, Frederic; Delinchant, Benoit, 2024, "Etude xKy", https://doi.org/10.57745/SHDDTW, Recherche Data Gouv, V1, UNF:6:NVyhGSIhd1LTM2T+1cah0g== [fileUNF]

Jeu de données issue de l'étude xKy. Le projet xky a deux objectifs principaux. Le premier est de fournir des passerelles se branchant sur les compteurs Linky afin de permettre aux personnes désireuses de comprendre et de réduire leur dépense énergétique de pouvoir suivre en temp...

ExpeSmartHouse - Données d'une maison connectée

5 juin 2024

Ferrari, Jérôme; Osonuga, Seun; Wurtz, Frederic; Delinchant, Benoit, 2024, "ExpeSmartHouse - Données d'une maison connectée", https://doi.org/10.57745/NJABDI, Recherche Data Gouv, V1, UNF:6:EiYNL4AfvlcSSbtW8j6P3Q== [fileUNF]

Le projet Expe-smarthouse a été initié en 2019 afin de fournir les données d'un foyer de 120 m² où vit une famille de 5 personnes. Ce projet donne accès à environ 370 points de mesure pour les scientifiques, accessibles aussi en temps réel via un portail Grafana alimenté avec une...

PREDIS-MHI Thermal Data

25 mars 2024

Osonuga, Seun; Shahid, Salman; Chouman, Ali; Wurtz, Frederic; Delinchant, Benoit, 2024, "PREDIS-MHI Thermal Data", https://doi.org/10.57745/TZDEIH, Recherche Data Gouv, V3, UNF:6:UKx5uL0JBYyBByGPUMf4mA== [fileUNF]

This dataset contains the thermal energy datasets for the PREDIS-MHI platform of the GreEn-ER building, a tertiary building with more than a thousand sensors used for research, teaching, and administrative activities in Grenoble. The associated datasets presented include readings...

The EVE Pilot: Usage Data from an Electric Car in France

1 févr. 2024

Osonuga, Seun; Wurtz, Frederic; Delinchant, Benoit, 2023, "The EVE Pilot: Usage Data from an Electric Car in France", https://doi.org/10.57745/5O6QIH, Recherche Data Gouv, V2, UNF:6:FxFjLc9W3RRzI7VHLe8bIQ== [fileUNF]

This dataset contains the usage data of a single electric car collected in as part of the EVE study (Enquête des Vehicles Electrique) run by the Observatoire du Transition Energétique Grenoble (OTE-UGA). This dataset includes the following variables for a single Renault ZOE 2014...

https://entrepot.recherche.data.gouv.fr/dataverse/ote

Focus on the socio technical« Telescope » of the OTE… **The production of « socio-technical » energy pictures**

- contribuer à une **société bas carbone**,
- mener des **recherches scientifiques sur la transition énergétique**,
- diffuser les résultats le plus largement possible,
- faciliter la **science participative et ouverte**.

104 *Chercheuses et chercheurs*

11 *Domaines scientifiques*

19 *Laboratoires* UGA Université Grenoble Alpes

1000 *Bientôt 1000 volontaires, et vous ?*

24/10/22

- Nombre de sujets récupérés : **352**
- Début des données : **Le vendredi 2**
- Fin des données : **Le Dimanche 23/**
- Nombre totale de valeurs anticipée
  - **48** car Linky données échantil
  - **2** car 2 jours
  - **352** car nombre des sujets réc
- Nombre total de points de donnée
- **l'état de santé des données en po**

25/10/22

- Nombre de sujets récupérés : **389**

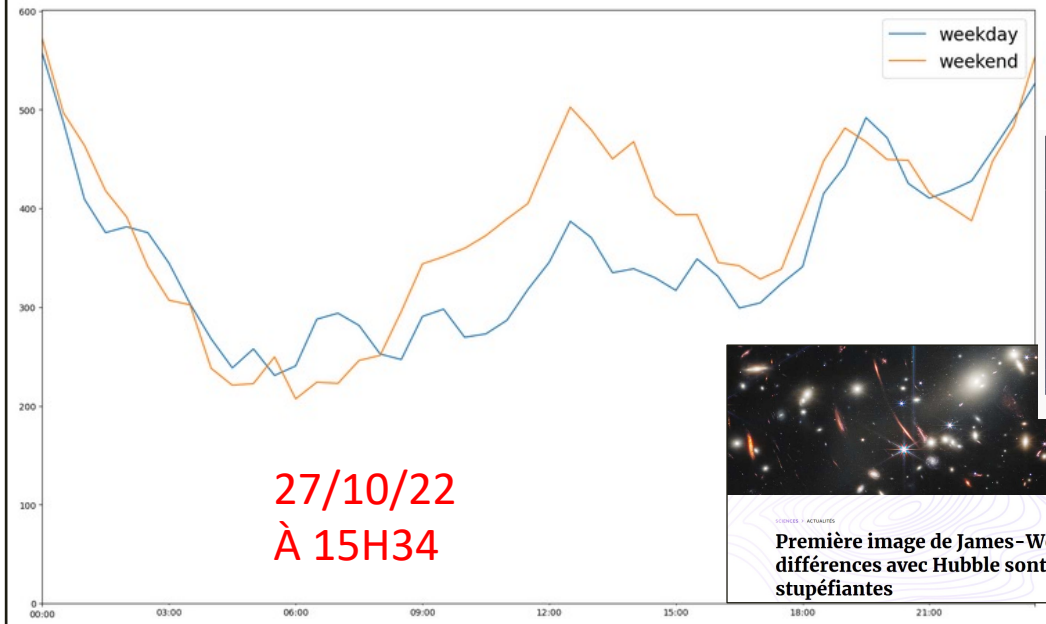
```
Number of PDLs :  450
Overall data health:  79.84 %
Data health of Friday 21-10-2022:  34.0 %
Data health of Saturday 22-10-2022:  72.0 %
health of Sunday 23-10-2022:  81.0 %
health of Monday 24-10-2022:  91.0 %
Tuesday 25-10-2022:  97.0 %
```

450 dwellings involved

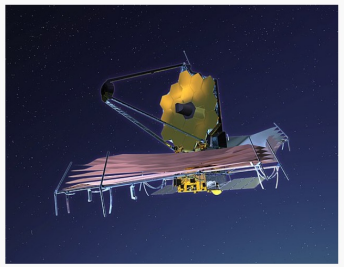
26/10/22

```
2:  34.0 %
022:  72.0 %
2:  81.0 %
2:  91.0 %
```

Voici la courbe moyenne du 151 participants pour lesquels nous disposons de données complètes du vendredi au mardi.



27/10/22
À 15H34



Vue d'artiste du télescope spatial *James-Webb*.

https://fr.wikipedia.org/wiki/James_Webb_(télescope_spatial)

Première image de James-Webb : les différences avec Hubble sont stupéfiantes

https://www.futura-sciences.com/sciences/actualites/james-webb-differences-hubble-sont-stupefiantes

Eco-Watt

https://ote.univ-grenoble-alpes.fr/mte-crise-energetique-de-lhiver-a-venir-faits-avis-et-perspectives-dobservation-et-de-recherche-17-10-2022/

https://www.dailymotion.com/video/x8dooi4

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Conclusion

- Buildings and districts levels are key pillars for energy transition
- From a mainly model and optimization driven approach
- To a Social a Data Approach with the Humans in the loop
- Toward an observatory approach
  - Experiments in living labs and real fields
  - Collect of data and feedbacks from those living labs and real fields -> Toward an observatory approach
    - Technical & Juridical questions
    - Work together on the life-cycle of data;
      - As open as possible, as closed as necessary
- Toward new modelisation paradims as paradigms:
  - multi-agent simulation

OBSERVATOIRE DE LA TRANSITION ÉNERGÉTIQUE

Some References

- [COL]: Steven E Collier, 2017, *The Emerging Enernet: Convergence of the Smart Grid with the Internet of Things*, IEEE Industry Applications Magazine volume 23
- [EU1]: DIRECTIVE (EU) 2019/ 944 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on common rules for the internal market for electricity and amending Directive 2012/ 27/ EU
- [HOD]: Sacha Hodencq, Benoit Delinchant, Wurtz Frederic, Nils Artiges, Jerôme Ferrari, et al.. « Towards an energy open science approach at district level: application to Grenoble Presqu'île.,1st International Workshop on Open Design & Open Source Hardware Product Development, Mar 2020, Grenoble, France. https://hal.archives-ouvertes.fr/hal-03052326
- [IEA]: https://www.iea.org/news/cities-are-at-the-frontline-of-the-energy-transition
- [MHI]: http://mhi-srv.g2elab.grenoble-inp.fr/API/
- [PAJ1]: Pajot, C., Nguyen, Q., Delinchant, B., Maréchal, Y., Wurtz, F., Robin, S., Vincent, B., Debray, F., 2019d. Data-driven Modeling of Building Consumption Profile for Optimal Flexibility: Application to Energy Intensive Industry, in: Building Simulation Conference 2019. Rome, Italy.
- [PAJ2]: Pajot, C., Artiges, N., Delinchant, B., Rouchier, S., Wurtz, F., Maréchal, Y., 2019b. An Approach to Study District Thermal Flexibility Using Generative Modeling from Existing Data. Energies 12, 3632. https://doi.org/10.3390/en12193632
- [PAJ3]: Pajot, C., Morriet, L., Hodencq, S., Delinchant, B., Maréchal, Y., Wurtz, F., Reinbold, V., 2019c. An Optimization Modeler as an Efficient Tool for Design and Operation for City Energy Stakeholders and Decision Makers, in: 16th IBPSA International Conference (Building Simulation 2019). Rome, Italy.
- [WUR]: Wurtz, F., Delinchant, B., 2017. *"Smart buildings" integrated in "smart grids": A key challenge for the energy transition by using physical models and optimization with a "human-in-the-loop" approach*. Comptes Rendus Phys., Demain l'énergie 18, 428–444. https://doi.org/10.1016/j.crhy.2017.09.007

- See also:

- Lou Morriet, Camille Pajot, Benoît Delinchant, Yves Maréchal, Frédéric Wurtz, et al.. Optimisation multi-acteurs appliquée à la valorisation de chaleur fatale d'un acteur industriel flexible. *IBPSA 2018*, May 2018, Bordeaux, France. ⟨hal-01884585⟩
- Lou Morriet, Gilles Debizet, Frédéric Wurtz. Multi-actor modelling for MILP energy systems optimisation: application to collective self-consumption. Building Simulation 2019, Sep 2019, Rome, Italy. ⟨hal-02285965⟩
- La thèse de Lou Morriet: « Conception multiacteur de systèmes énergétiques locaux bas-carbone : outils, modèles et analyses qualitatives », thèse de l'Université Grenoble Alpes Soutenue le 8 mars 2021, https://hal.archives-ouvertes.fr/tel-03285666v1
- La thèse de Camille Pajot: « OMEGAlpes : outil d'aide à la décision pour une planification énergétique multi-fluides optimale à l'échelle des quartiers », thèse de l'Université Grenoble, https://hal.archives-ouvertes.fr/tel-02520569

Acknowledgement

This work has been partially supported by the CDP Eco-SESA receiving fund from the French National Research Agency in the framework of the "Investissements d'avenir" program (ANR-15-IDEX-02) funding also the OTE ("Observatory of Transition for Energy")

The authors are grateful to La Région Auvergne-Rhône-Alpes for their financial support through the OREBE project (Optimisation holistique des Réseaux d'Energie et des Bâtiments producteurs d'énergies dans les Eco-quartiers). They are also grateful to the ADEME (the French Agency for Environment and Energy Management) for their financial support through the RETHINE project (Réseaux Electriques et THermiques InterconNEctés).

The authors thank the corresponding decision-makers from the French National Laboratory of High-intensity Magnetic Fields (LNCMI) for: facilitating real operational data to construct the model hourly energy profile of electricity consumption used in this study; allowing to publish that hourly profile in the articles and making data available for public use under an open data license.

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