Optimization of New Energy Systems

A Survey of Activities 2000-2025 at CERMICS

École nationale des ponts et chaussées, IP Paris

Pierre CARPENTIER
Jean-Philippe CHANCELIER
Michel DE LARA

CERMICS
École nationale des ponts et chaussées

Outline of the presentation

Long term industry-ENPC/Cermics/Optimization cooperation

Past and current activities in optimization and energy

Our distinguishing research features

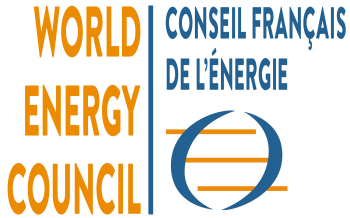
L'École nationale des ponts et chaussées

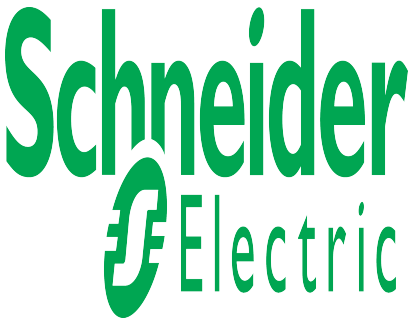
Context: birth of research in optimization at ENPC labs

- In 2000, the Optimization and Systems team was created at École nationale des ponts et chaussées
- We were encouraged and supported by Électricité de France Research and Development (EDF R& D / OSIRIS: René Aïd, Yannick Jacquemart) to develop a research activity in stochastic optimization,
- Between 2010 and 2013, we have trained several PhD students with continuous support (financial, scientific) from EDF R& D
- Since 2011, we have been witnessing a growing demand from small and large energy firms for stochastic optimization, fueled by a deep and fast transformation of power systems — distributed, uncertain and intermittent renewable energies, flexibility, storage

Small and medium-sized partner companies

Large partner companies





More than 25 years of cooperation with partner companies

- As academics, we cooperate with partner companies, looking for longlasting close relations
- We are ~~not consultants~~ working for clients, but we focus on capacity building
- Our job consists mainly in
  - training and supervising Master and PhD students, working (mostly) within the company
  - formalizing problems raised by the company
  - developing resolution methods and algorithms
  - contributing to computer codes developed within the company
  - training professional engineers in the company
- We often start a collaboration by giving a four-day workshop-course

Outline of the presentation


eDF

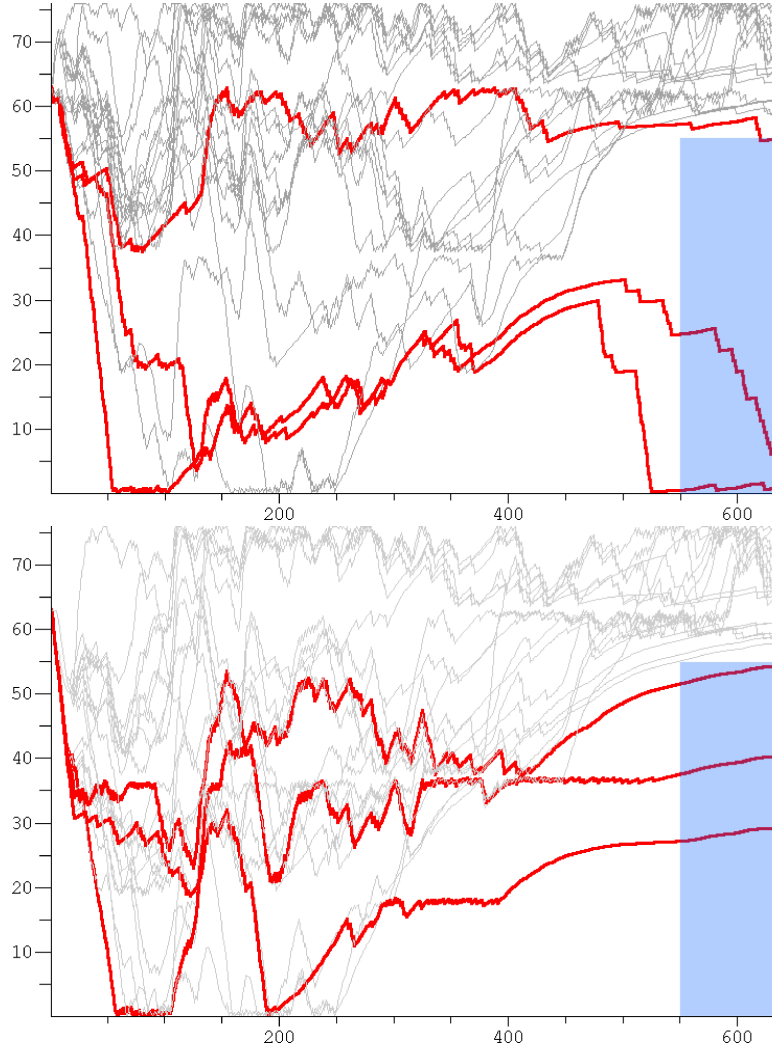
Électricité de France R & D / Département OSIRIS

- *Contributions to the Discretization of Measurability Constraints for Stochastic Optimization Problems*
  Kengy Barty, 2004
- *Optimization under Probability Constraint*
  Laetitia Andrieu, 2004
- *Variational Approaches and other Contributions in Stochastic Optimization*
  Cyrille Strugarek, 2006
- *Particular Methods in Stochastic Optimal Control*
  Anes Dallagi, 2007

Électricité de France R & D / Département OSIRIS

- *From Risk Constraints in Stochastic Optimization Problems to Utility Functions*
  Babacar Seck, 2008
- *Resolution of Large Size Problems in Dynamic Stochastic Optimization and Synthesis of Control Laws*
  Pierre Girardeau, 2010
- *Risk and Optimization for Energies Management*
  Jean-Christophe Alais, 2013
- *Stochastic optimization of maintenance scheduling: blackbox methods, decomposition approaches – Theoretical and numerical aspects*
  Thomas Bittar, 2021


ES
233


70
60
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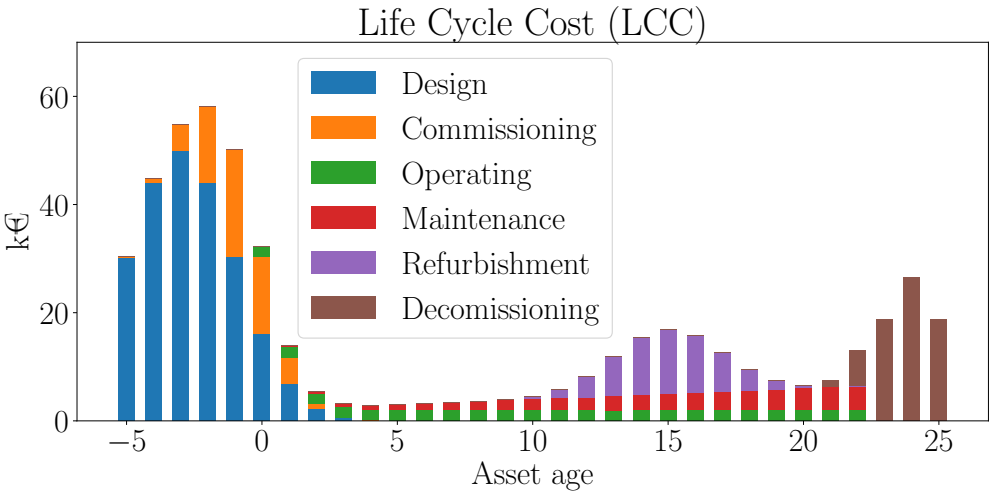
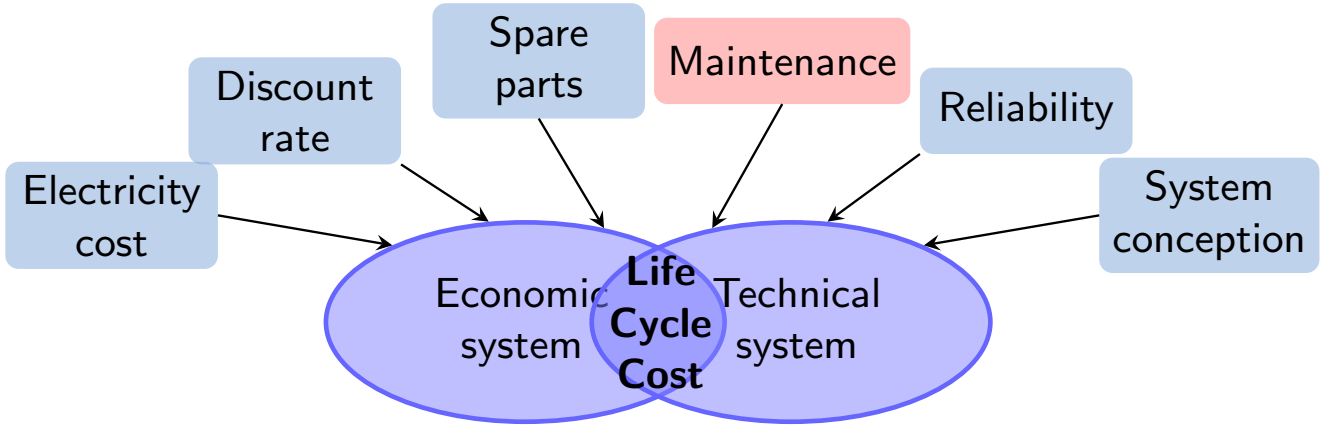
400
600


Life Cycle Cost (LCC)
Design
Commissioning
Operating
Maintenance
Refurbishment
Decomissioning
k€
60
40
20
0
−5
0
5
10
15
20
25
Asset age


Spare parts
Maintenance
Discount rate
Reliability
Electricity cost
System conception
Economic system
Life Cycle Cost
Technical system

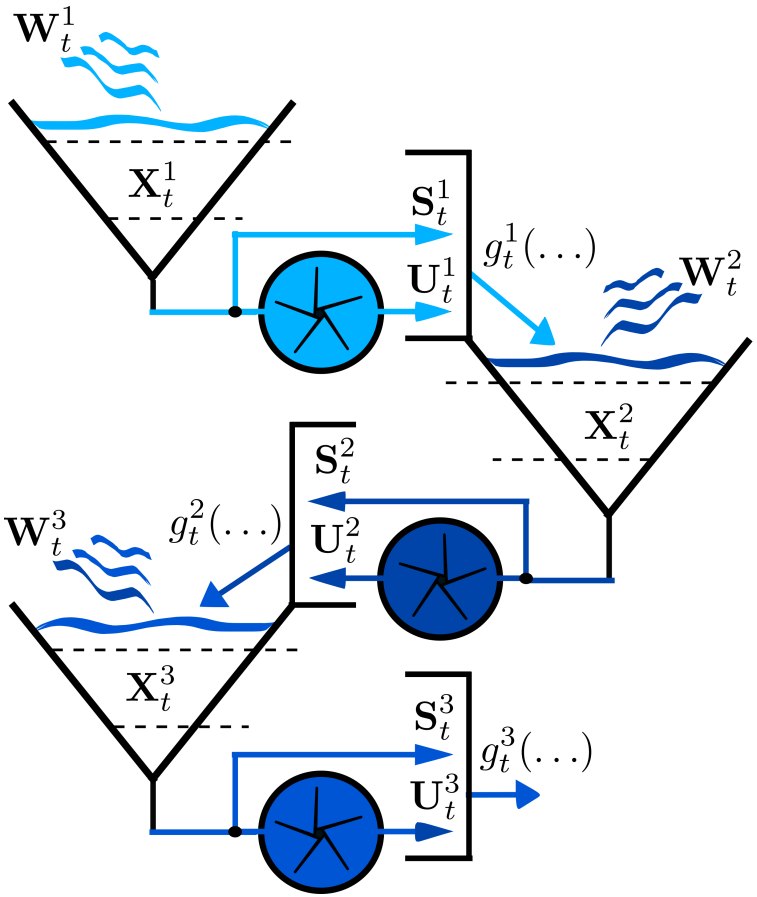
Programme Gaspard Monge pour l'Optimisation, la recherche opérationnelle et leurs interactions avec les sciences des données (PGMO: EDF and FMJH)

- PGMO project 2014-1605H STORY
  Scientific network on Stochastic and Robust Optimization and Applications
- PGMO/IROE project 2014-1604H LASON2
  Centralized versus Decentralized Energy Management in a Stochastic Setting
- PGMO/IROE project 2016-1749H OGRE
  Optimization, Games and Renewable Energy
- PGMO/IROE project 2023
  Optimal Operation and Valuation of Electricity Storage
- PGMO/IROE project 2024
  Leader-Follower Problems in Energy with Witsenhausen Model

French Energy Council, member of the World Energy Council

- *Uncertainty, Inertia and Optimal Decision. Optimal Control Models Applied to Greenhouse Gas Abatment Policies Selection*
  Laurent Gilotte, 2004
- 2012 report on
  Optimization Methods for Smart Grids

SETEC Energy Solutions



Dam Optimal Management Under Uncertainties
(to assess the economic value of a hydro-valley), 2012

- Private course on stochastic optimization for the management of energies
- Supervision of a student

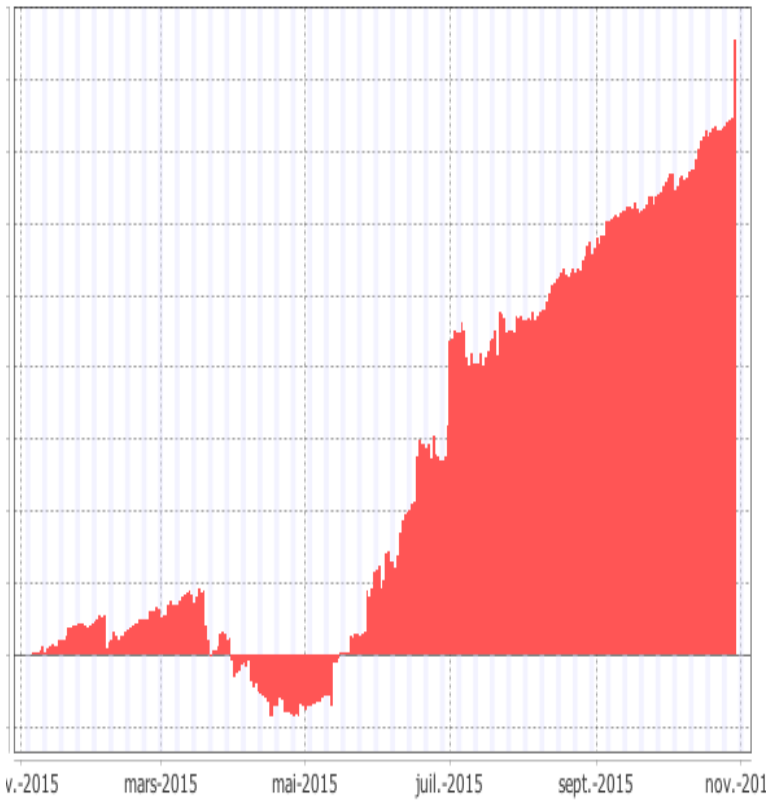
The collaboration has led to the development of the SETEC Energy Solutions *software Hydroptim®*

Sun'R Smart Energy company

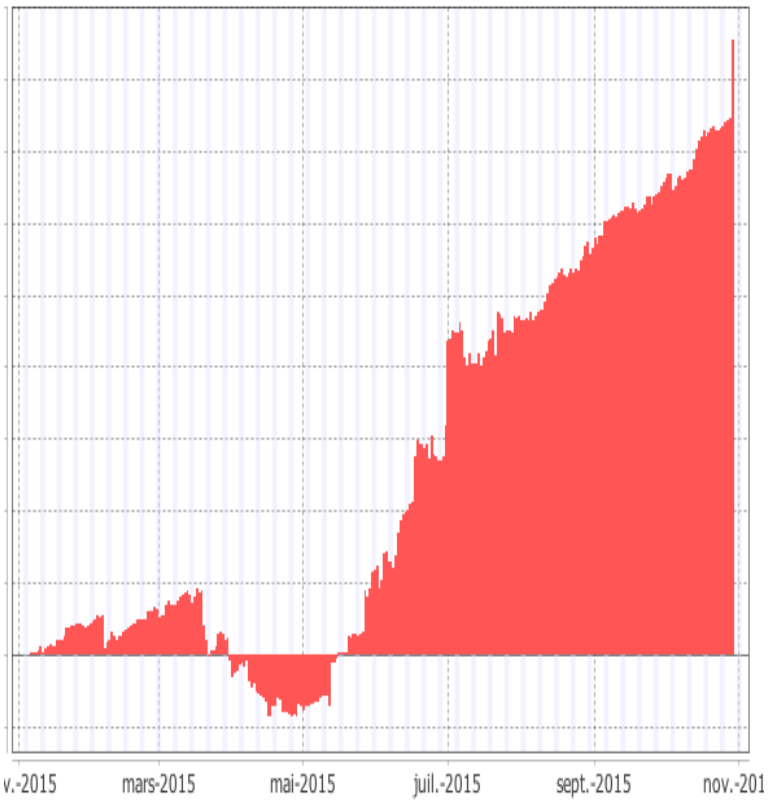
R & D SunHydrO project
(FUI, public and private funding)

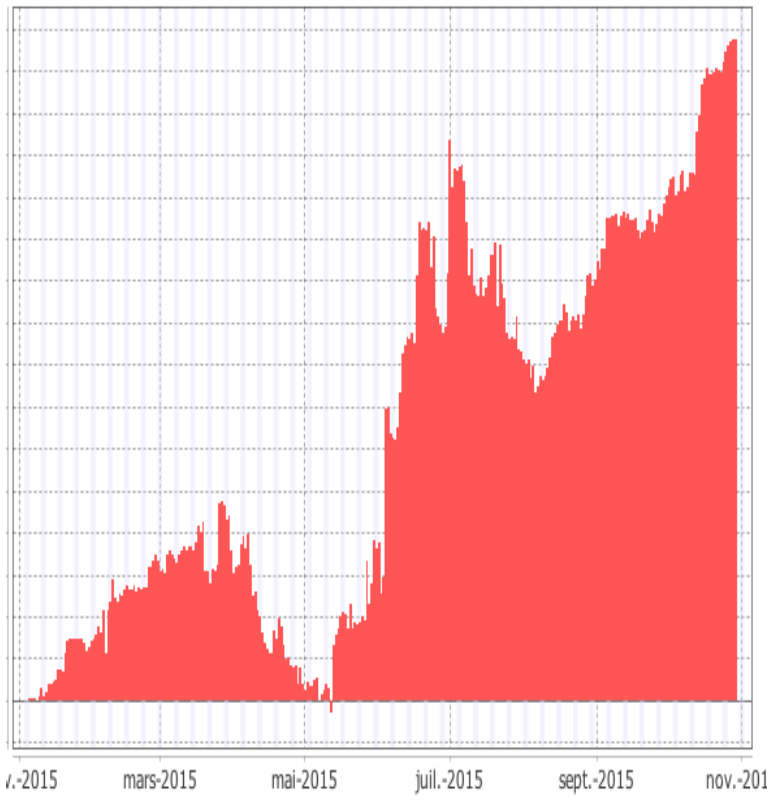
- *Design and build a pumping station for energy transfer (10–12 MW) with profit-making business model*
- Supervision of a post-doctorate recruited by SUN'R Smart Energy, Ariel Waserhole, 2016

The financial director gasp!



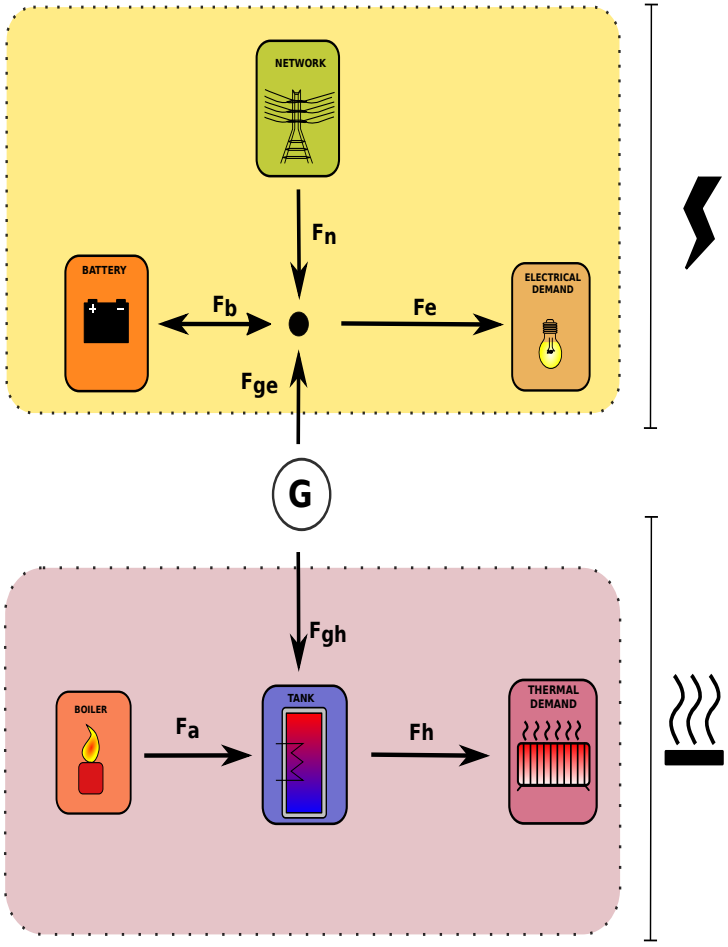
The financial director gasp!

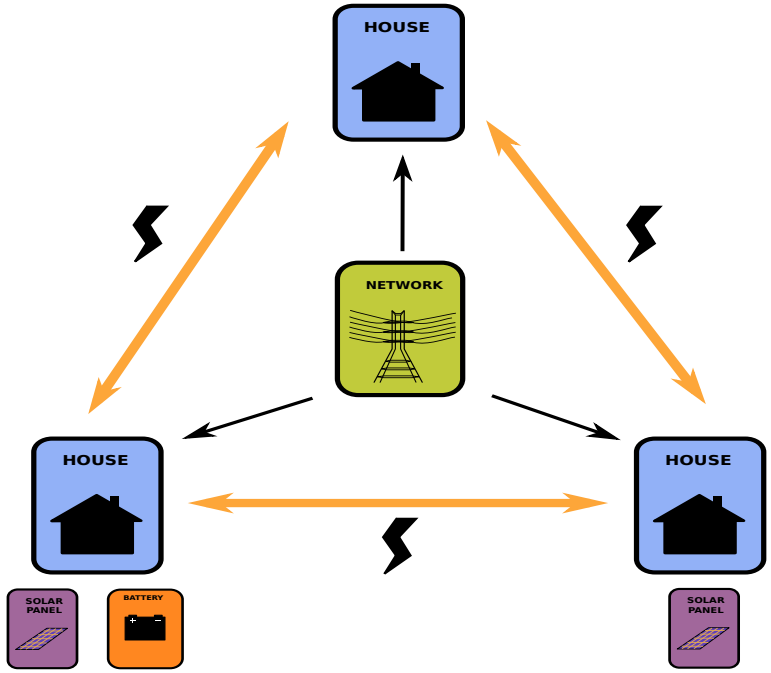


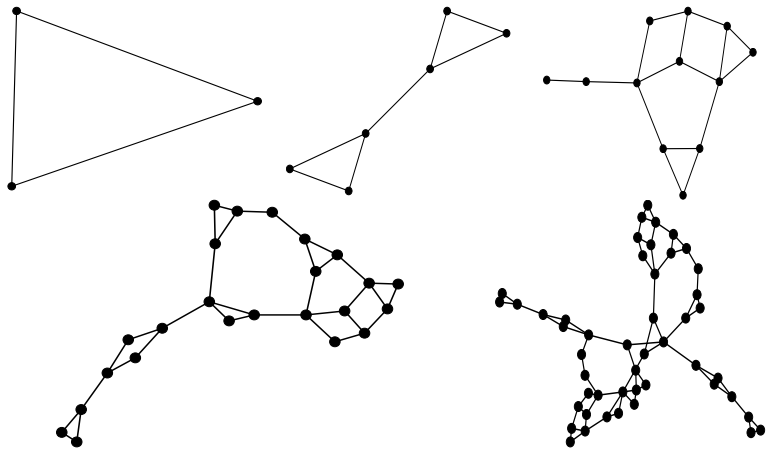


Institute for energy transition Efficacity

- *Decentralized Optimization Methods for Energy Efficiency Management under Stochasticity*
  François Pacaud, 2018

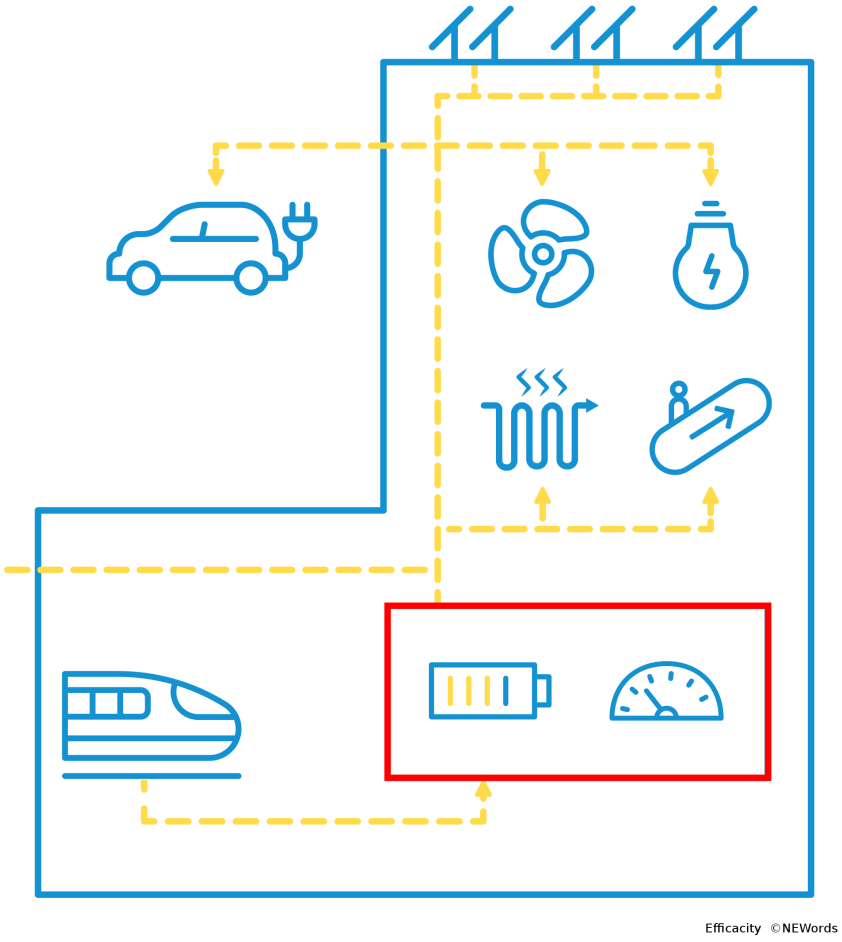

NETWORK
Fn
BATTERY
Fb
Fe
ELECTRICAL DEMAND
Fge
G
Fgh
BOILER
Fa
TANK
Fh
THERMAL DEMAND


HOUSE
NETWORK
HOUSE
HOUSE
SOLAR PANEL
BATTERY
SOLAR PANEL

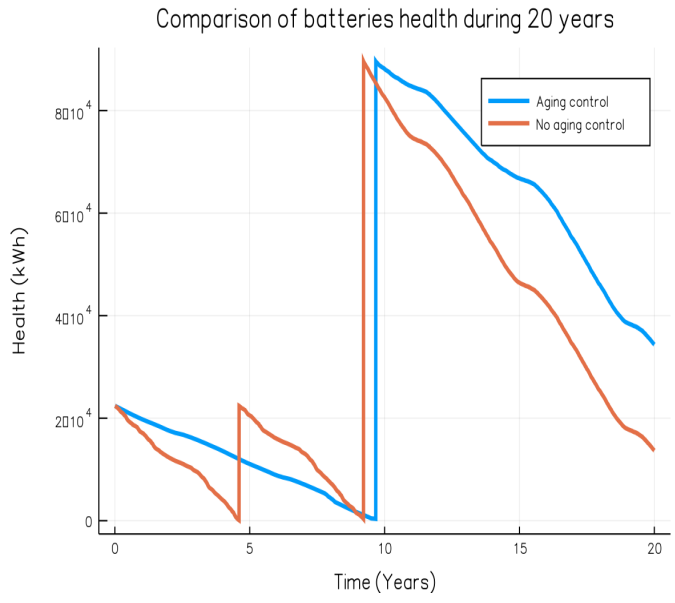


Institute for energy transition Efficacity

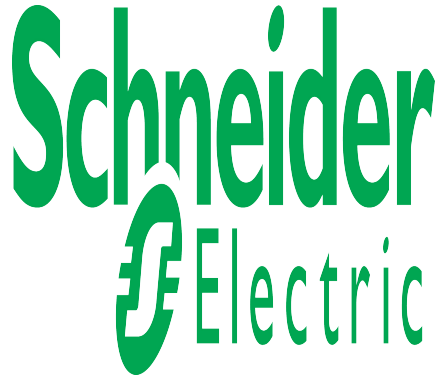
- *Time Decomposition Methods for Optimal Management of Energy Storage under Stochasticity*
  Tristan Rigaut, 2019



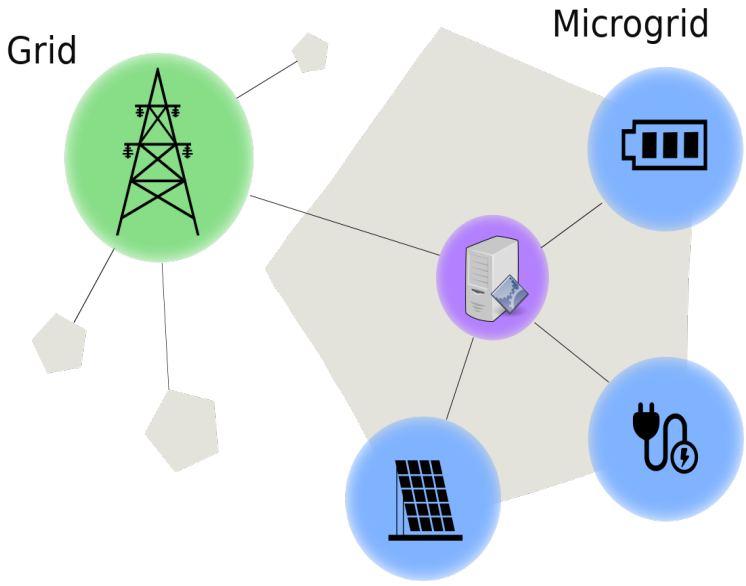
Efficacity ©NEWords

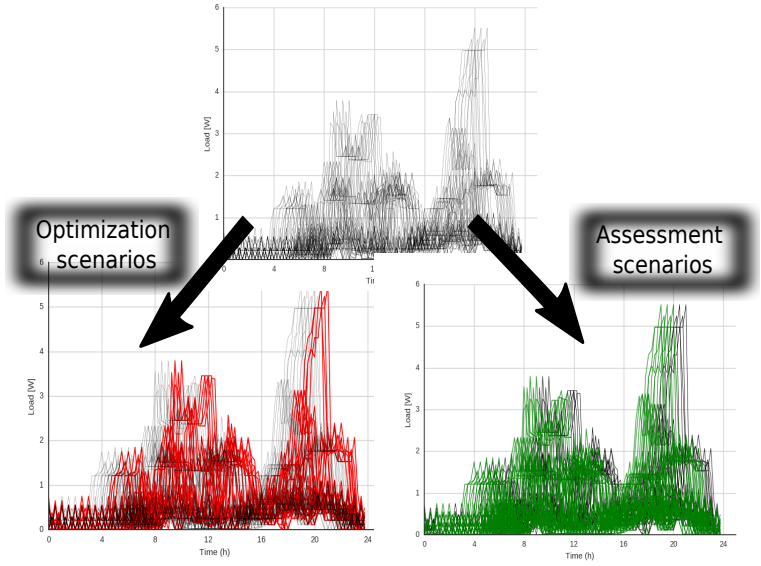


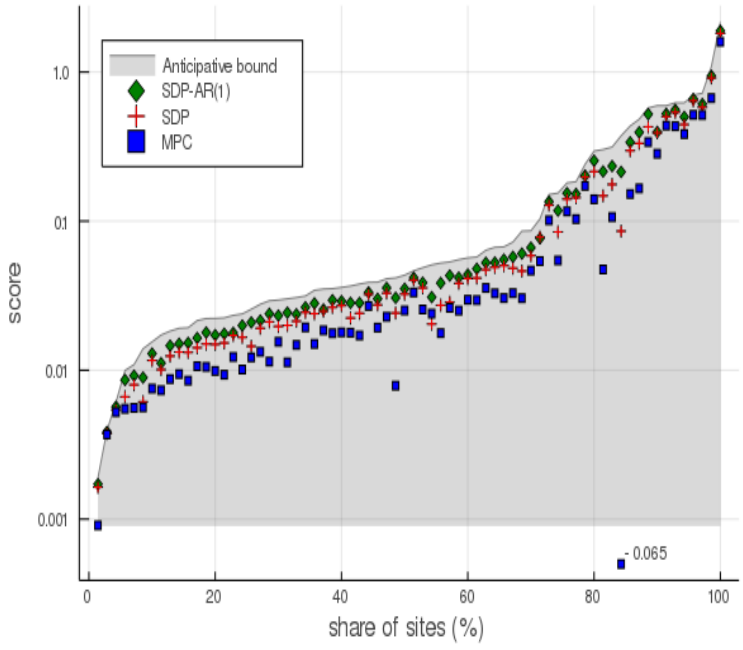
Schneider Electric and Efficacity

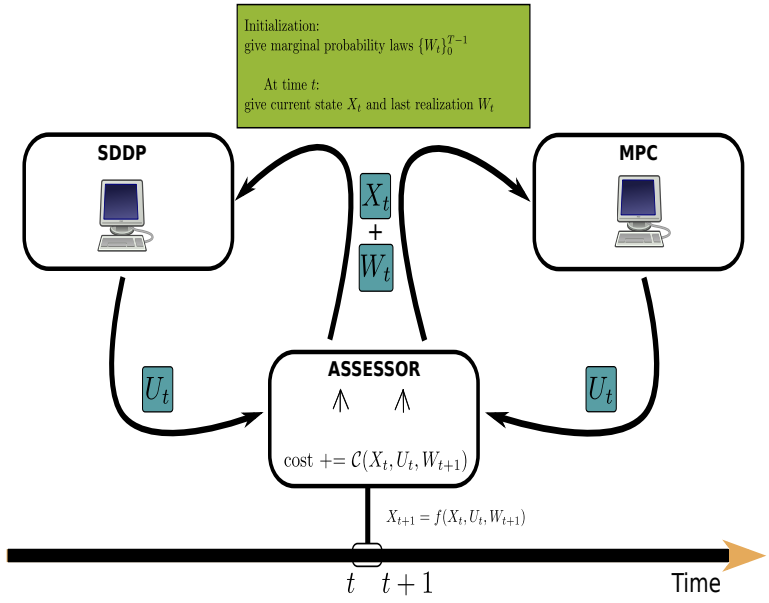


- *Subdifferentiability in Convex and Stochastic Optimization Applied to Renewable Power Systems*
  Adrien Le Franc, 2021


Grid
Microgrid


Optimization scenarios
Assessment scenarios
Load [W]
Time (h)


Anticipative bound
SDP-AR(1)
SDP
MPC
score
share of sites (%)
0.065

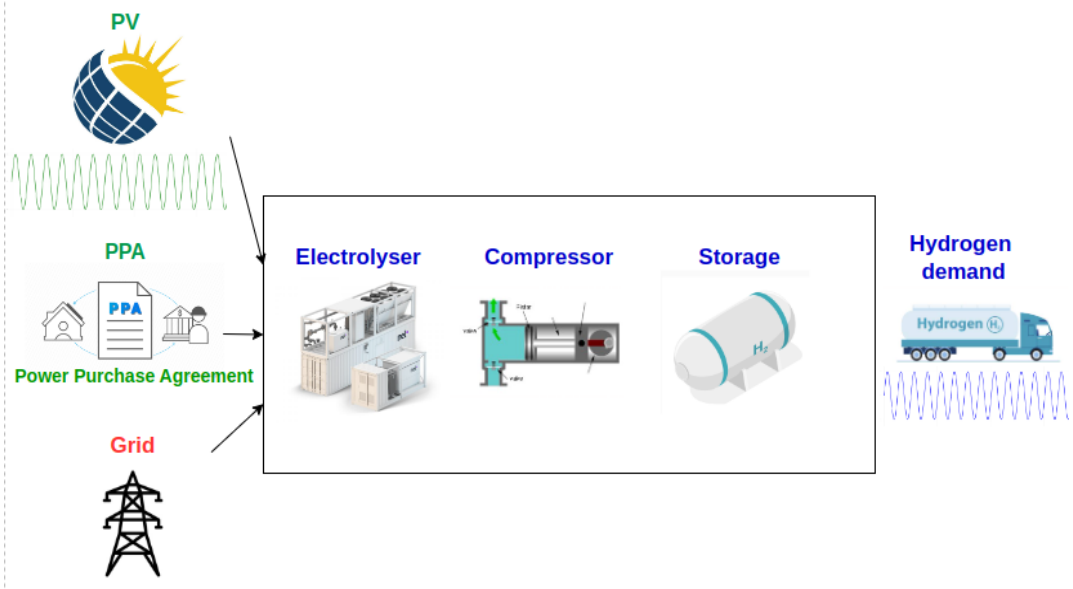

Initialization:
give marginal probability laws $\{W_t\}_0^{T-1}$
At time t:
give current state X_t and last realization W_t
SDDP
MPC
X_t
+
W_t
U_t
U_t
ASSESSOR
cost += $\mathcal{C}(X_t, U_t, W_{t+1})$
$X_{t+1} = f(X_t, U_t, W_{t+1})$
t
$t+1$
Time

TotalEnergies

- *Stochastic Optimization for the Procurement of Crude Oil in Refineries*
  Thomas Martin, 2021
- *Design and operation management of oil-fields taking into account partially observed uncertainties*
  Cyrille Vessaire, 2021

Pers-ee company

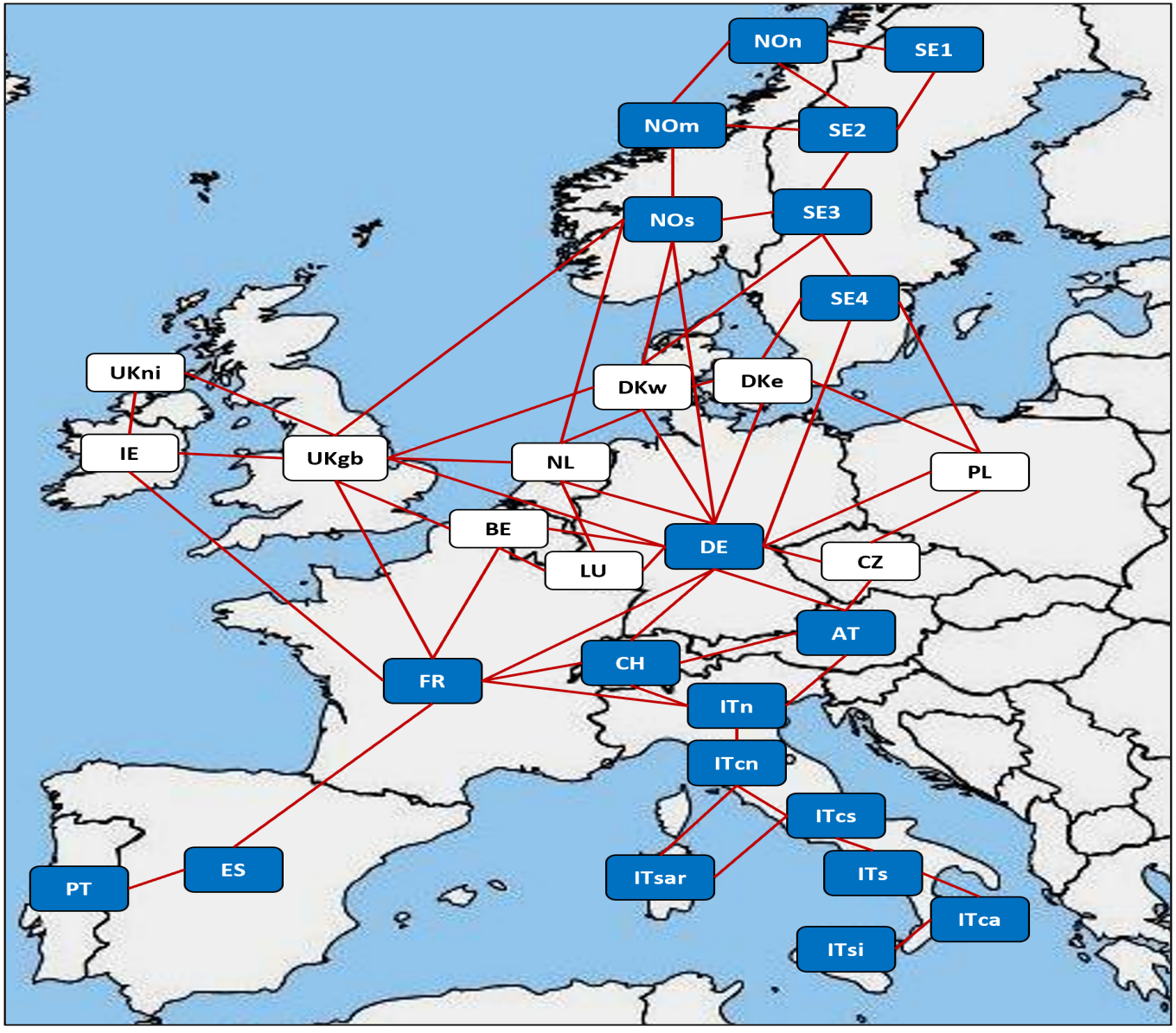
PersEE Innovation

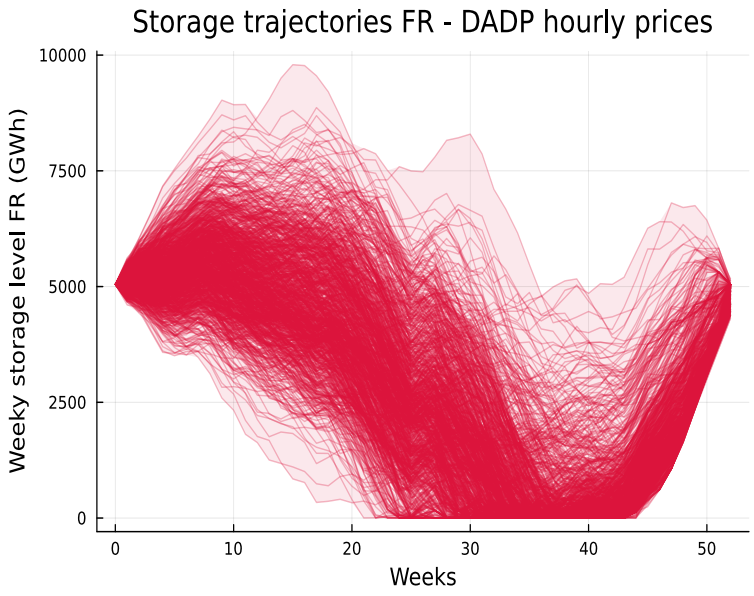


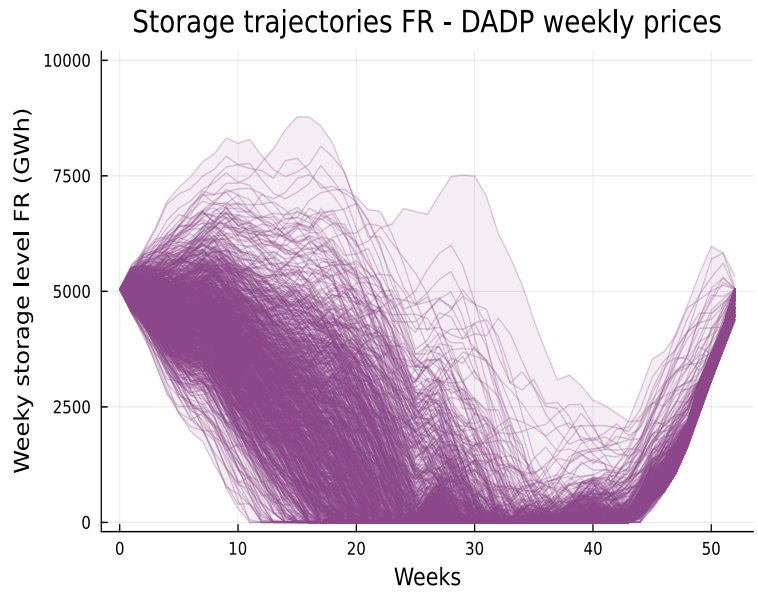
- *Design and Operation of Hydrogen Supply Chains under Renewable Production and Demand Uncertainties*
  Raian Lefgoum, 2025

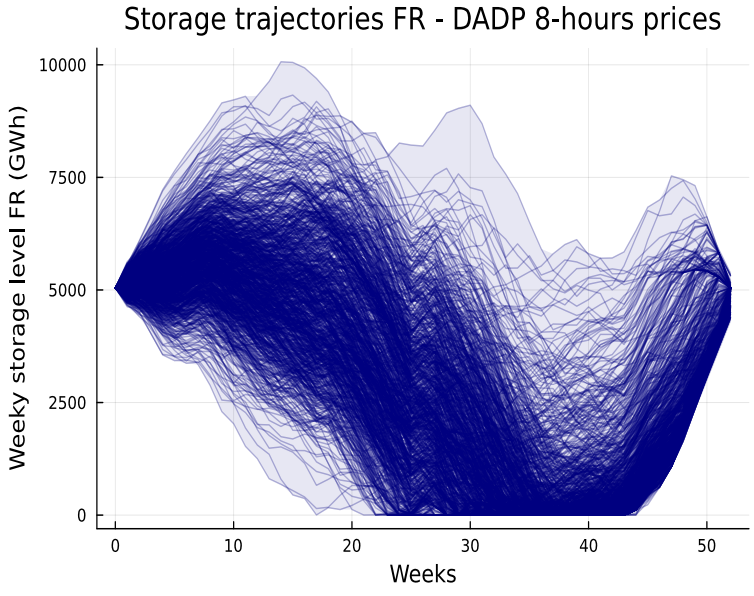
RTE, France's Transmission System Operator

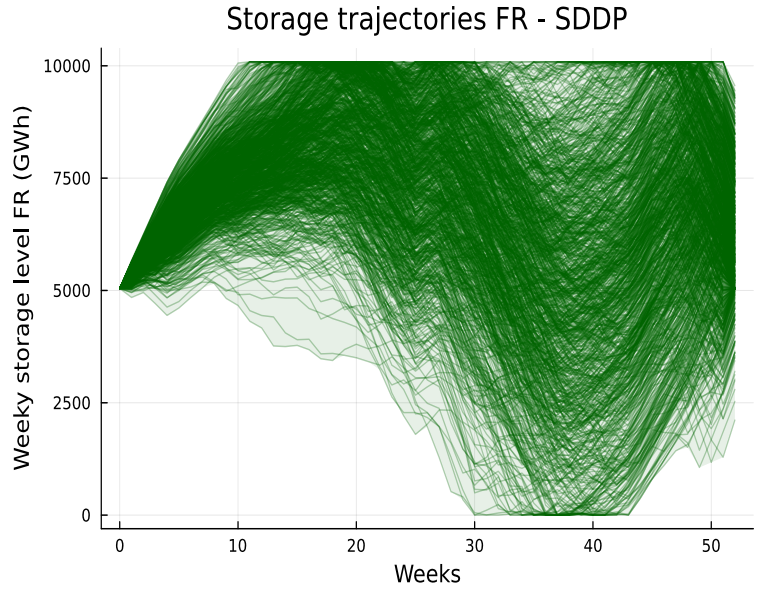
- Private course on stochastic optimization and risk handling for the management of energies
- *Dynamic Programming and Decomposition Methods for Prospective Studies in Energy Systems*
  Camila Martínez Parra, 2025


NOn
SE1
NOm
SE2
NOs
SE3
SE4
UKni
DKw
DKe
IE
UKgb
NL
PL
BE
DE
LU
CZ
AT
CH
FR
ITn
ITcn
ITcs
ES
PT
ITsar
ITs
ITca
ITsi


Storage trajectories FR - DADP hourly prices
Weeky storage level FR (GWh)
Weeks
0
2500
5000
7500
10000
0
10
20
30
40
50


Storage trajectories FR - DADP weekly prices
Weeky storage level FR (GWh)
Weeks
0
2500
5000
7500
10000
0
10
20
30
40
50


Storage trajectories FR - DADP 8-hours prices
Weeky storage level FR (GWh)
Weeks
0
2500
5000
7500
10000
0
10
20
30
40
50


Storage trajectories FR - SDDP
Weeky storage level FR (GWh)
Weeks
0
2500
5000
7500
10000
0
10
20
30
40
50

Natixis

Optimal Management of a Battery to Bid on Energy Markets, 2025

- Private course on stochastic optimization for the management of energies
- Supervision of two students

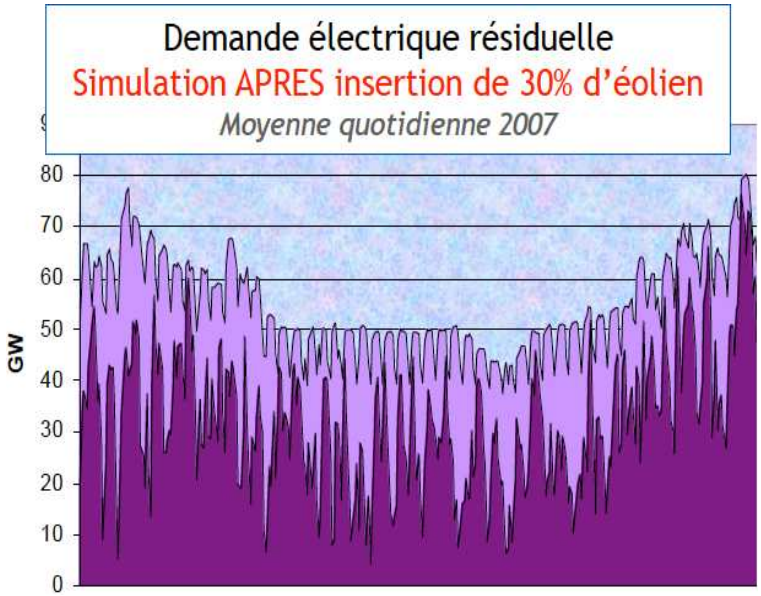
Outline of the presentation

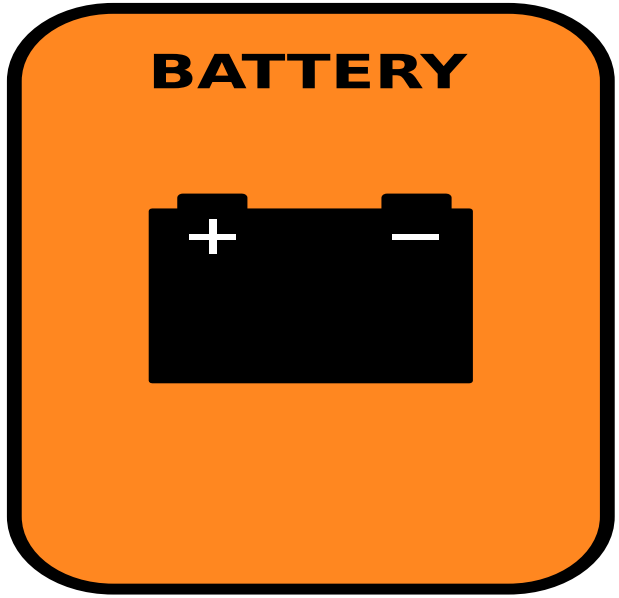
Long term industry-ENPC/Cermics/Optimization cooperation

Past and current activities in optimization and energy

Our distinguishing research features

Optimal management of energy storage under uncertain production and demand

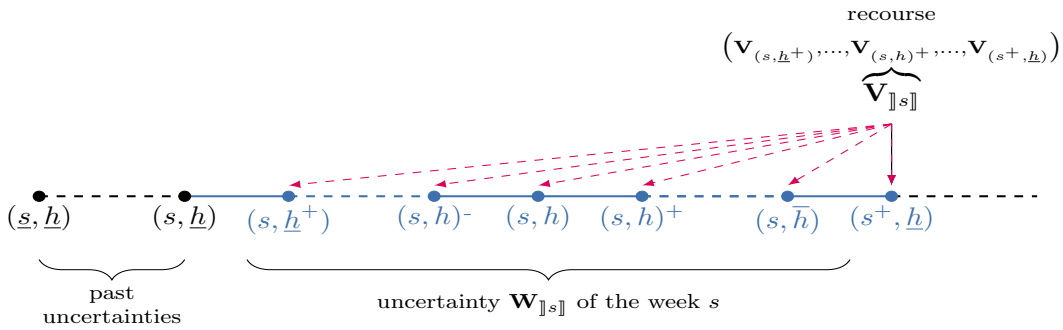




Optimal management of energy storage (dam, battery, hydrogen) to offer flexibility in handling the instantaneous matching of uncertain production (wind, solar) with uncertain demand

Handling of timescales and information patterns

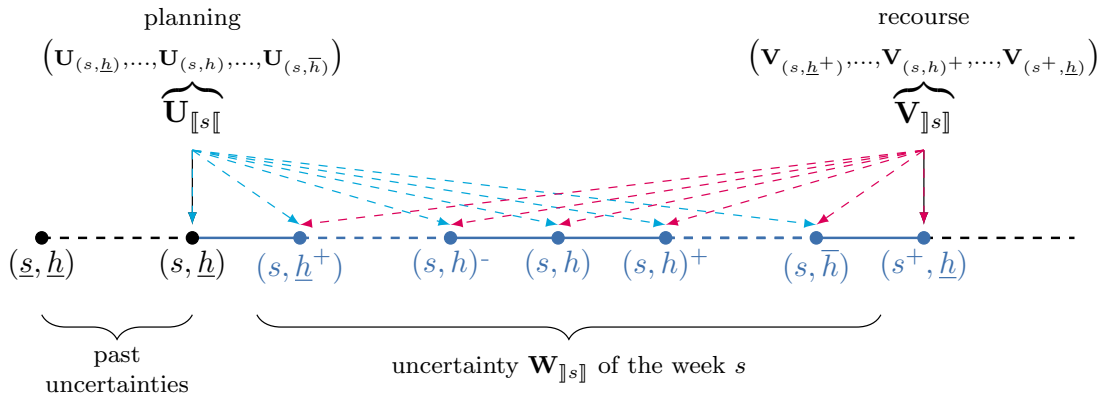
The arrows from right to left represent ANTICIPATIVITY



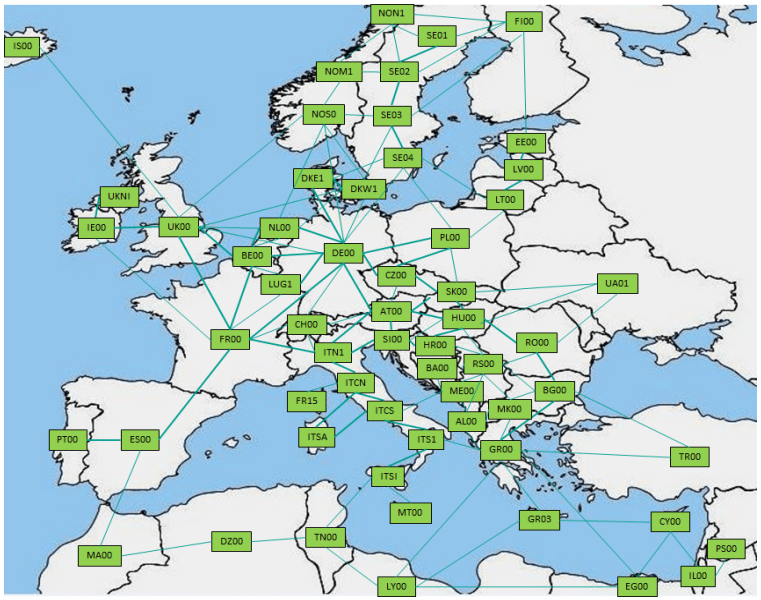
The decision maker knows all the uncertainties for the week in advance, even the outages!

The arrows from left to right represent NONANTICIPATIVITY

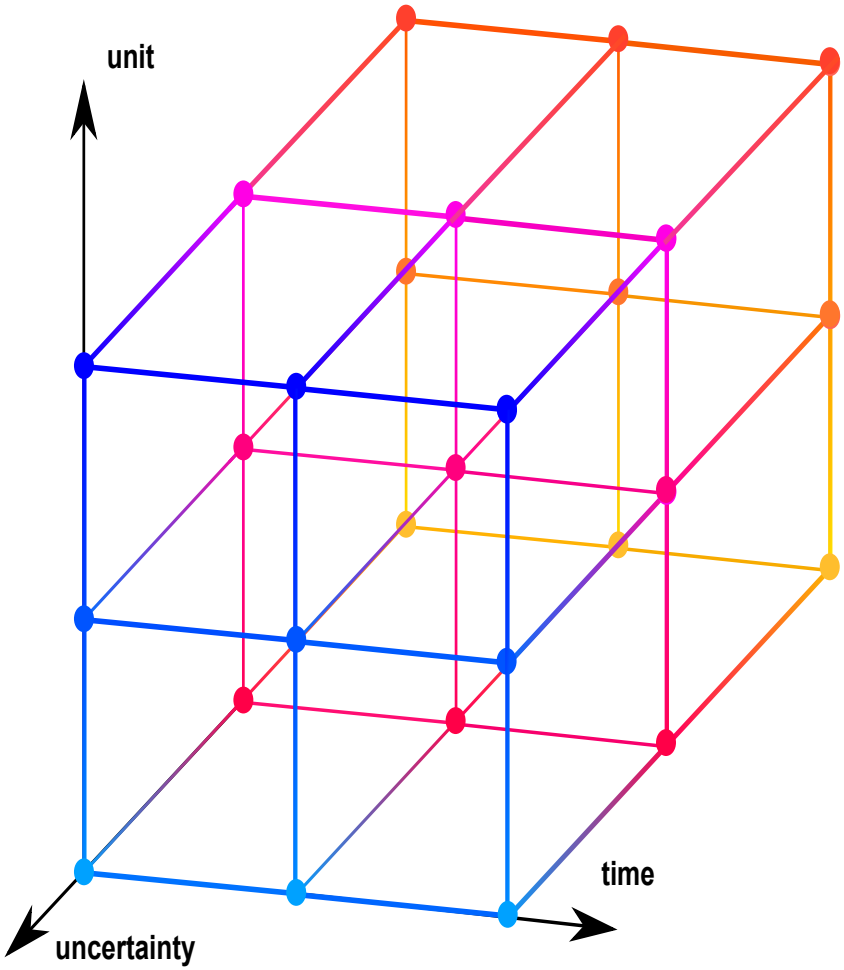
The arrows from right to left represent ANTICIPATIVITY



Handling of spatially distributed energy systems



Multistage stochastic optimization display couplings between time/uncertainty/space



$$\min \mathbb{E} \sum_i \sum_t L_t^i(\mathbf{H}_t^i, \mathbf{U}_t^i, \mathbf{W}_{t+1})$$

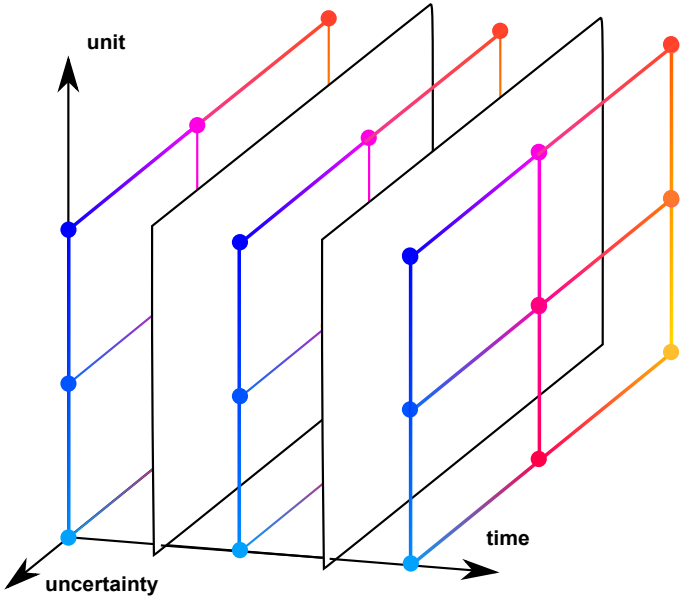
$$\text{s.t. } \mathbf{H}_{t+1}^i = (\mathbf{H}_t^i, \mathbf{U}_t^i, \mathbf{W}_{t+1})$$

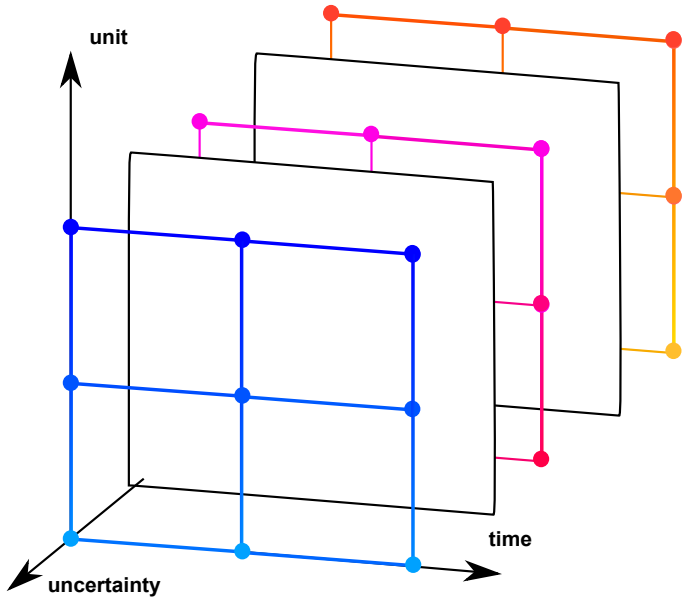
$$\mathbf{U}_t^i = \mathbb{E}\left[\mathbf{U}_t^i \,\middle|\, \mathbf{W}_0, \ldots, \mathbf{W}_t\right]$$

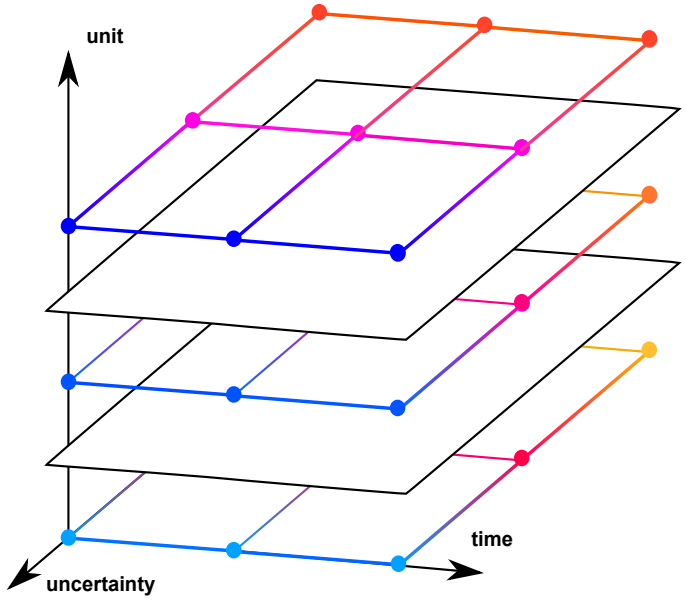
$$\sum_i Y_t^i(\mathbf{H}_t^i, \mathbf{U}_t^i, \mathbf{W}_{t+1}) = 0$$

Algorithms based on mixing decomposition methods

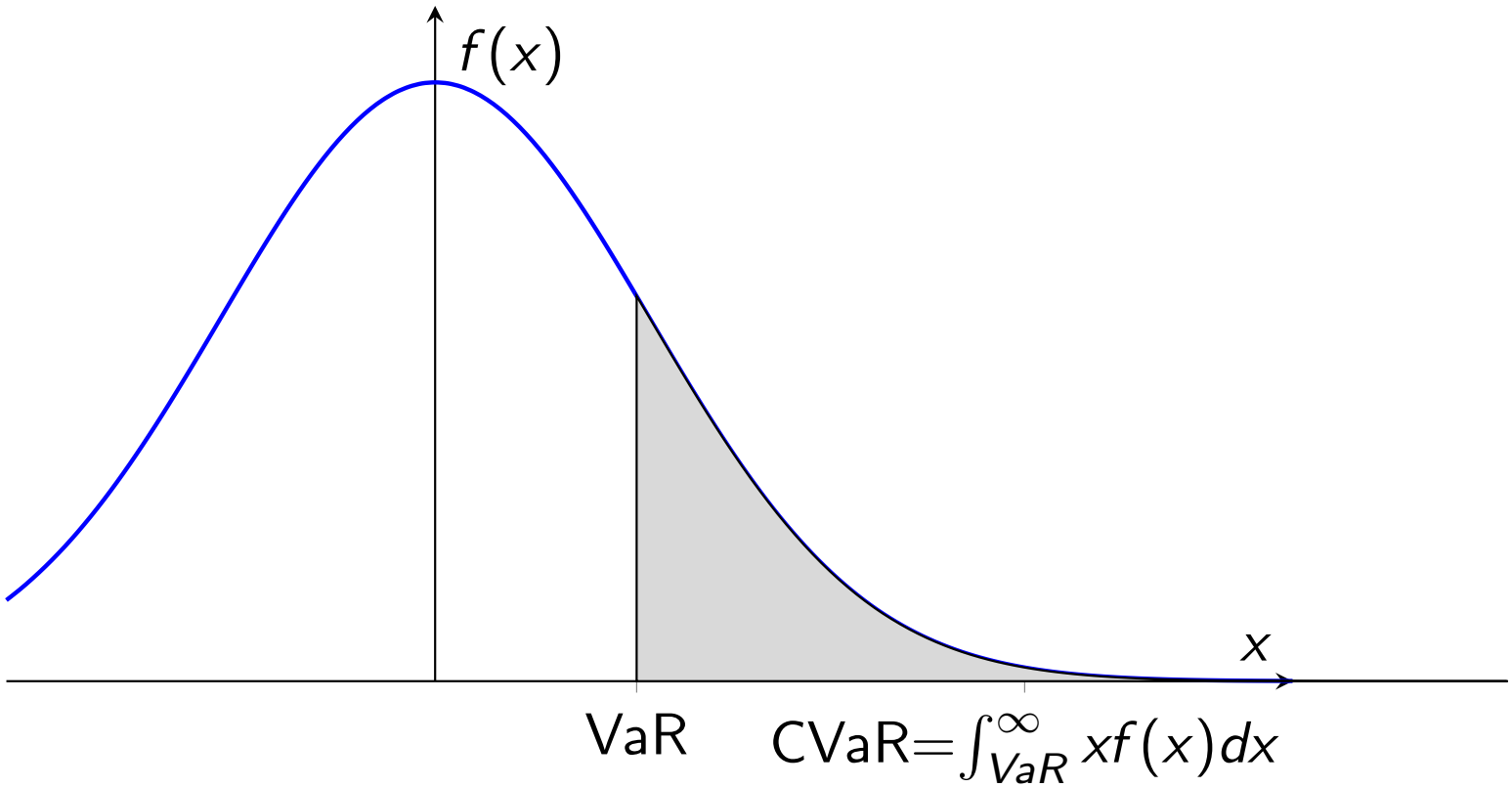
- Time decomposition (dynamic programming)
- Scenario decomposition (progressive hedging)
- Spatial decomposition







Design and tune suitable risk quantifiers



Moving from violation (Value at Risk [quantile])
to
severity (Conditional Value at Risk [superquantile])

Publications in energy journals

Jean-Christophe Alais, Pierre Carpentier, and Michel De Lara.

Multi-usage hydropower single dam management: chance-constrained optimization and stochastic viability.
Energy Systems, 8(1):7–30, February 2017.

Laetitia Andrieu, Michel De Lara, and Babacar Seck.

Taking risk into account in electricity portfolio management.
In Mario V.F. Pereira Steffen Rebennack, Panos M. Pardalos and Niko A. Iliadis, editors, *Handbook of Power Systems 1*. Springer Verlag, 2009.

Thomas Buchholtzer and Michel De Lara.

Games in Product Form for Demand Response Modelling.
Foundations and Trends in Electric Energy Systems, 2026.

Adrien Le Franc, Pierre Carpentier, Jean-Philippe Chancelier, and Michel De Lara.

EMSx: A numerical benchmark for energy management systems.
Energy Systems, 14:817–843, 2023.

François Pacaud, Michel De Lara, Jean-Philippe Chancelier, and Pierre Carpentier.

Distributed multistage optimization of large-scale microgrids under stochasticity.
IEEE Transactions on Power Systems, 37(1):204–211, 2022.

François Pacaud, Pierre Carpentier, Jean-Philippe Chancelier, and Michel De Lara.

Optimization of a domestic microgrid equipped with solar panel and battery: Model predictive control and stochastic dual dynamic programming approaches.
Energy Systems, 15:115–139, 2024.

Tristan Rigaut, Pierre Carpentier, Jean-Philippe Chancelier, Michel De Lara, and Julien Waeytens.

Stochastic Optimization of Braking Energy Storage and Ventilation in a Subway Station.
IEEE Transactions on Power Systems, 34(2):1256–1263, March 2019.