# Efficacité énergétique pour les smart grids grâce à l’optimisation et à la prédiction

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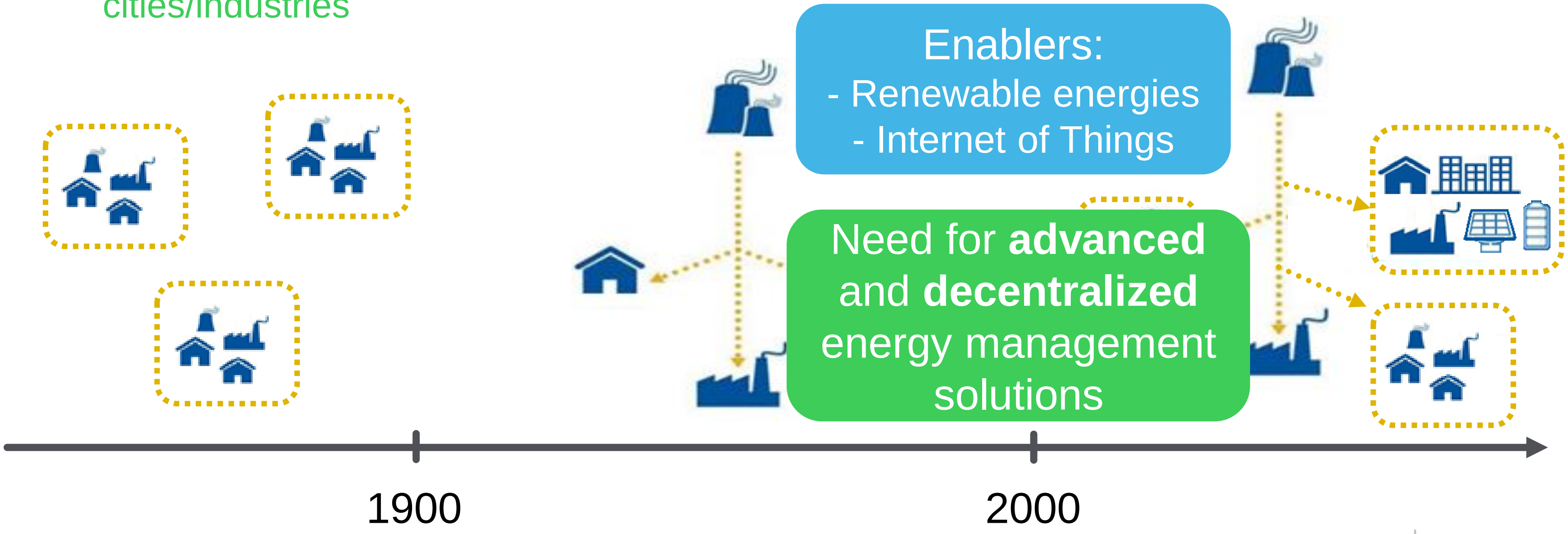
# The emergence of smart grids

Production islands operated by cities/industries

CENTRALISATION for availability service

DECENTRALISATION for « territory » services



# Energy management context

## Energy vs. Power Management:

| | **Power** Management | **Energy** Management |
|---|---|---|
| Scope | Stability | Energy efficiency |
| Time scale | ms ~ s | mins ~ hours |

## Energy management objectives:

- Minimize energy costs
- Reduce $CO_2$ emissions
- Mitigate power outages
- Improve the Quality of Service

# Model Predictive Control

## Principle & Ingredients

At each decision instant: **Anticipate the future** to find the **optimal control**.

# Two energy management examples

- PV farm with storage

→ Flexibility for grid support

- Learning Grid by Grenoble


→ Flexibility for energy self-consumption



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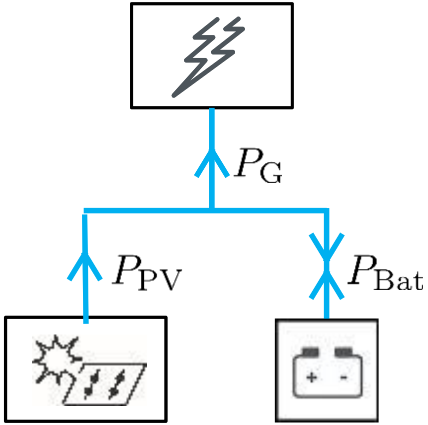
# Energy context examples

- Example 1: **Langa Solar, Corsica**

- PV plant revenue maximization under regulatory constraints

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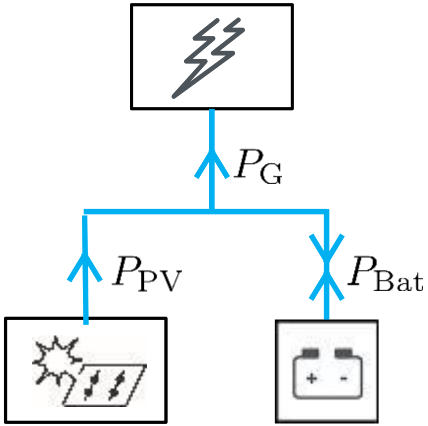
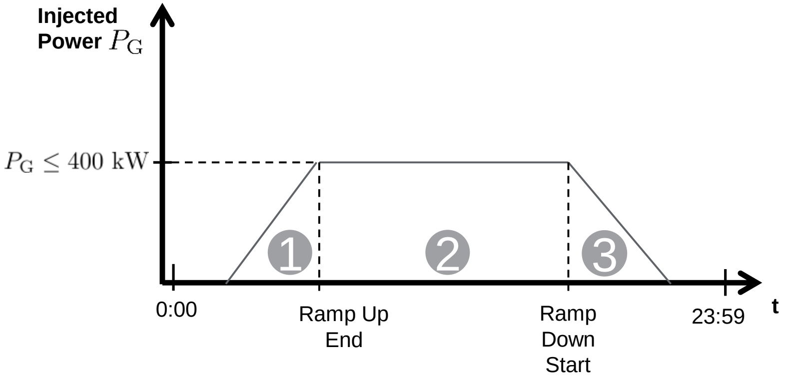
# Energy context examples

- Example 1: **Langa Solar, Corsica**

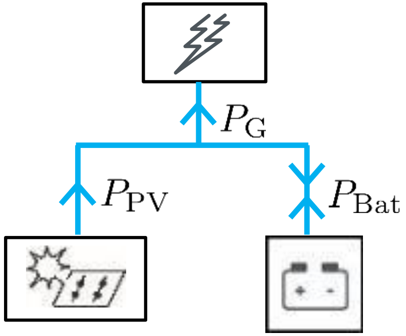
- PV plant revenue maximization under regulatory constraints

- Context
  - Declare day-ahead injection profile $P_G$
  - Respect trapezoidal profile shape
  - Penalty if realized $P_G$ ≠ declared $P_G$



# Energy context examples




- Example 1: **Langa Solar, Corsica**
- Control problem formulation (Mixed-Integer-Linear-Programming)

$$\underset{P_G, P_{Bat}, SoC}{\textbf{Maximize}} \int_{t=0}^{24} P_G(t)$$

$$\text{s.t.} \quad P_G(t) = P_{PV}(t) - P_{Bat}(t)$$

$$SoC(t+1) = \begin{cases} SoC(t+1) + P_{Bat} \cdot \Delta t \cdot \eta_{charge} & \text{if} \quad P_{Bat} \geq 0 \\ SoC(t+1) + P_{Bat} \cdot \Delta t \cdot \eta_{discharge} & \text{if} \quad P_{Bat} < 0 \end{cases}$$

$$0 \leq SoC(t) \leq SoC_{max}$$

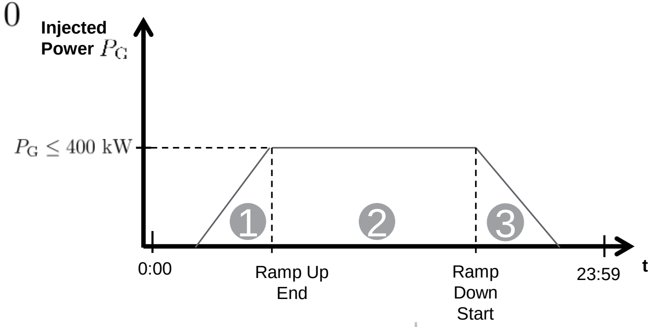
$$-P_{Bat,max} \leq P_{Bat}(t) \leq P_{Bat,max}$$

$$0 \leq P_G(t) \leq P_{G,max}$$

$$|P_G(t+1) - P_G(t)| \leq 6\, kW/min$$

Several logical constraints to distinguish between the three phases.

| | |
|---|---|
| $SoC$ | State of Charge |
| η | battery efficiency |
| $\Delta t$ | time step |



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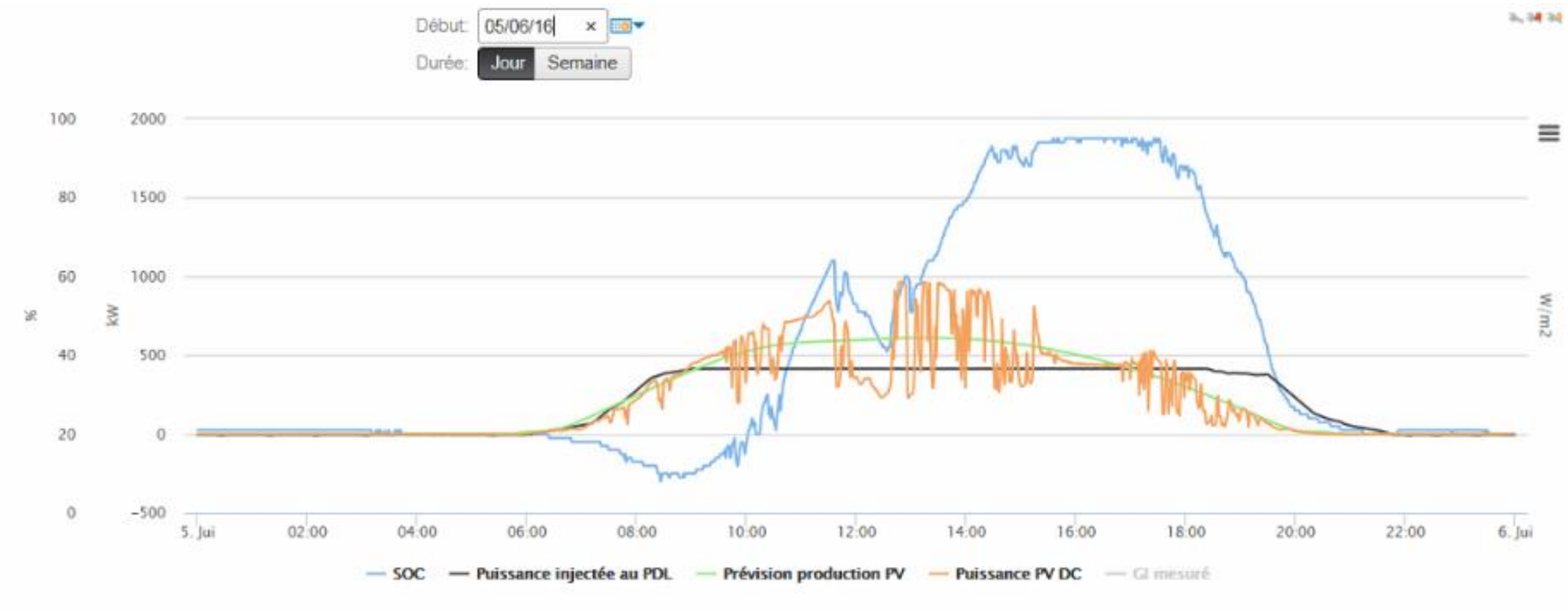
# Screenshot from the Langa Solar monitoring system



# Energy context examples

- Ex. 2: **Learning Grid by Grenoble**

- Multi-energy campus
  - Electricity- and District heating network
  - Batteries
  - Solar panels
  - CHP (Combined heat and power plant)
  - EV charging station


- Use flexibilities for local purposes
  - Maximize local usage of renewables
  - Minimize energy costs<br>(based on variable energy tariffs)

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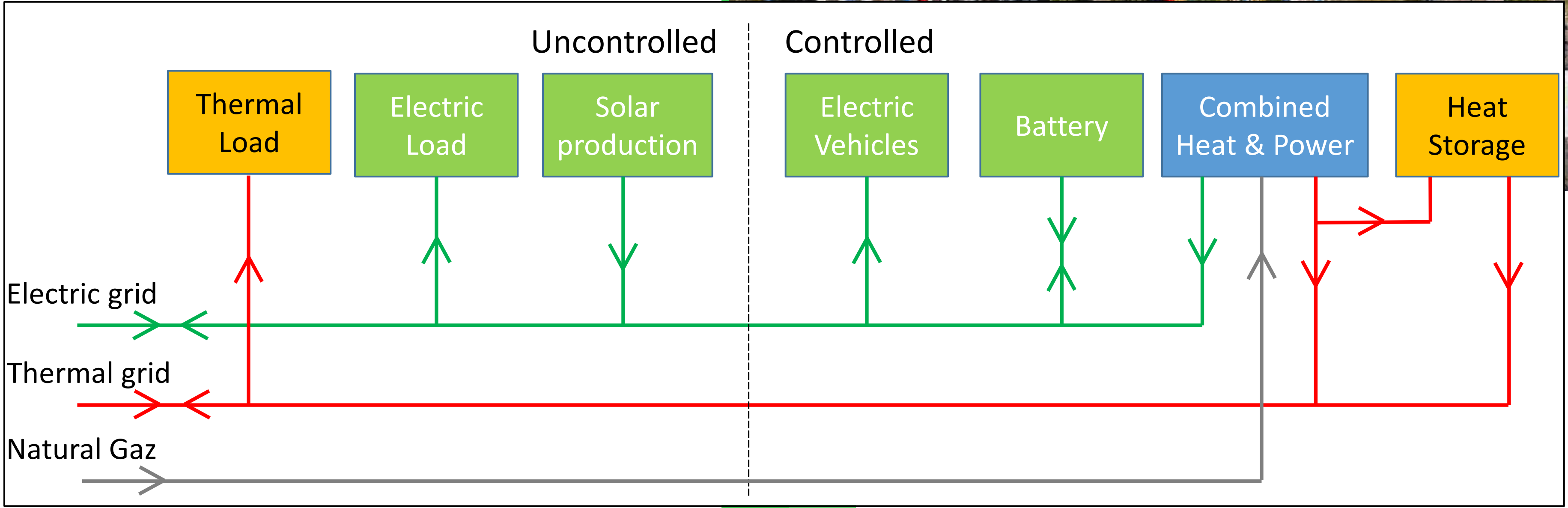
# Energy context examples

- Ex. 2: **Learning Grid by Grenoble**

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# Conclusion

- **Model Predictive Control** is a powerful method for **energy management** applications

Ambassador — 14 partners, 10 M€

ARROWHEAD — 80 partners, 68 M€

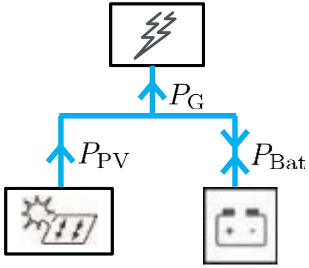
ENERGETIC — Projet FUI Minalogic Green IT

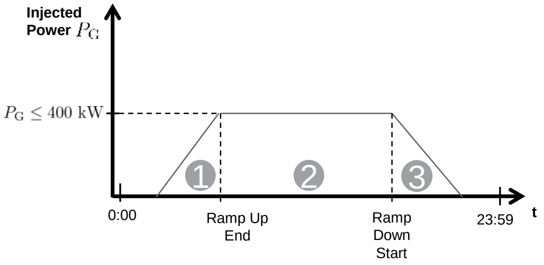
- **Reliable forecasts** are a crucial prerequisite to obtain good performances

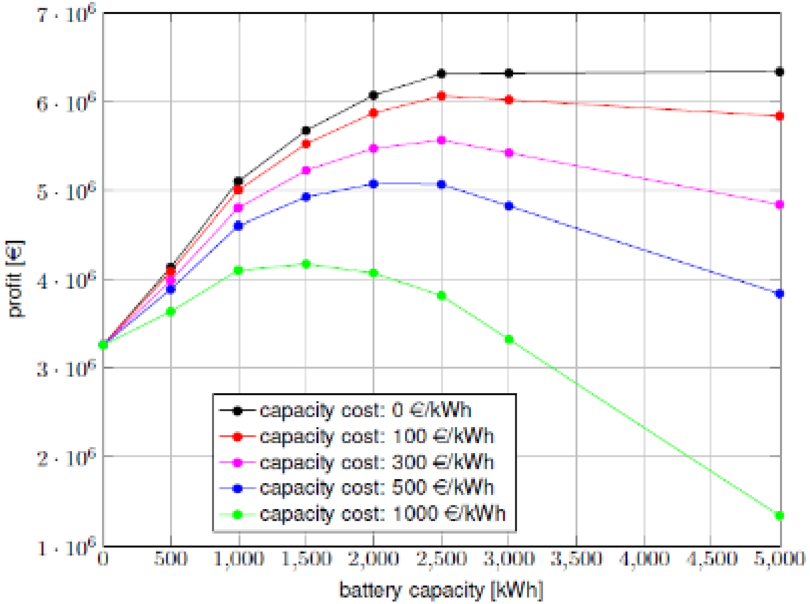
# Conclusion

Challenges:

- **Optimal sizing** of smart grid components must **integrate advanced control solutions**




- In **multi-owner use cases**, the **economic model for flexibility** will have a strong impact on the control/optimization model

# Thank you!