# Microgrid Energy Management with Renewables and Storage

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Presented by Bernardo Pagnoncelli

# Outline

1 Introduction

2 The model

3 Results

4 Conclusions and future work

# Background

- New technologies allow us to use weather-dependent energy generation
- Until 2035 it is estimated that 31% of generation will be from renewables (50% hydro)
- In addition, we are aiming at efficiency and cost-effectiveness of fossil-fueled generation (CHP plants, heat and power)
- The current efficiency level is around 33%

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- The microgrid operation combines unit commitment with economic dispatch (hard problems!)
- Centralization versus Decentralization (the objectives are not obvious).
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- We assume there is a central grid (the network), external to the microgrid, from which energy can be bought and sold
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# Elements of our model

- A battery storage
- Water pump storage
- A photovoltaic panel (PV)
- A consumer
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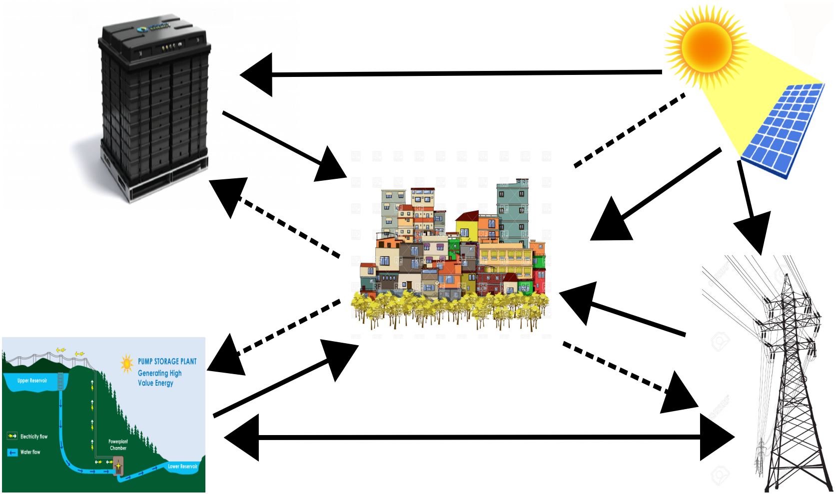

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- Batteries are for storing smaller quantities of energy, with instant response time
- In order to model those differences in a meaningful way, we need finer time frames (more later)

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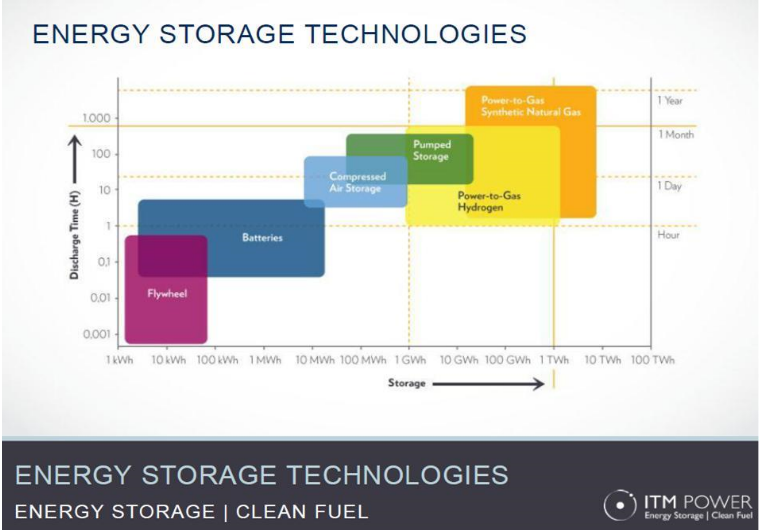
# Storage technologies



# Batteries

$$B_{t+1} = B_t + \alpha_B \overbrace{\left(F_{PV-Battery,t} + F_{Network-Battery,t}\right)}^{\text{into the battery}}$$
$$- \overbrace{\left(F_{Battery-Demand,t} + F_{Battery-Network,t}\right)}^{\text{from the battery}},$$

with $\alpha_B \leq 1$.

$$F_{PV-Battery,t} + F_{Network-Battery,t} \leq \text{max charge power } \times \Delta T$$
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# Water pump storage

$$S_{t+1} = S_t + \alpha_S \beta \overbrace{\left(F_{PV-STEP,t} + F_{Network-STEP,t}\right)}^{\text{into the step}} - \beta \overbrace{\left(F_{STEP-Demand,t} + F_{STEP-Network,t}\right)}^{\text{from the step}}$$

with $\alpha_S \leq 1$, and where $\beta$ converts electrical energy into water volume.

$$F_{PV-STEP,t} + F_{Network-STEP,t} \leq \text{max pumping power} \times \Delta T$$
$$F_{STEP-Demand,t} + F_{STEP-Network,t} \leq \text{max turbine power} \times \Delta T$$

In addition,

$$\left|\frac{\partial^2 S_t}{\partial t^2}\right| \leq \Gamma \Leftrightarrow$$
$$\frac{-S_{t-\Delta t} + 2S_t - S_{t+\Delta t}}{(\Delta t)^2} \leq \Gamma_{pumping}$$
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# The PV

- We assume energy generated by the PV is random
- We use 4 years of data, and use clusters and $k$-means to construct the scenarios and their probabilities
- If the amount generated is higher than expected demand, the microgrid can sell the surplus to the network
- If it is smaller energy must be bought from the network

$$ProdPV = F_{PV-STEP} + F_{PV-Bat} + F_{PV-Demand} + F_{PV-Network}$$

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- We face the usual granularity trade-off:
- Too fine-grained and we cannot solve the problem, too coarse-grained and the model becomes meaningless.
- We propose a compromise solution: decision are taken every 15 minutes in the first day, and uncertainty is revealed every hour.
- In the upcoming days the problem is essentially a two-stage stochastic programming problem.

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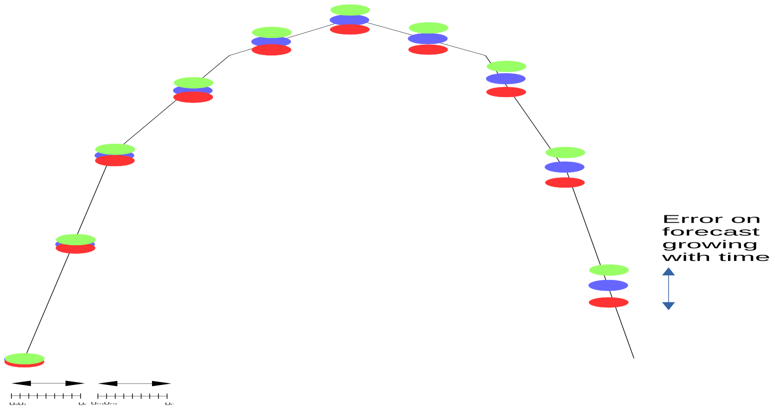
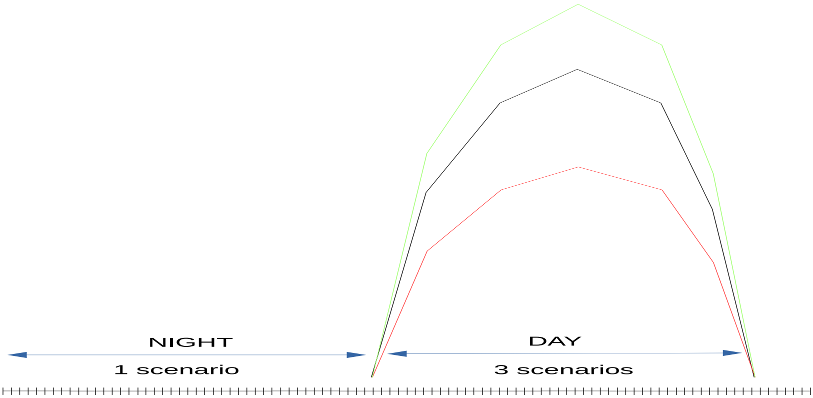
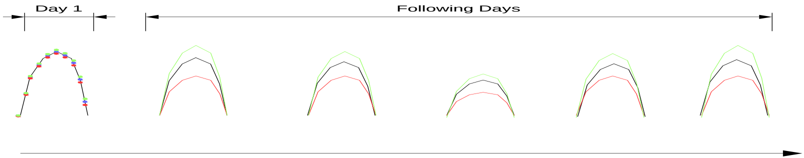
# First day



# Following days



# The whole horizon



## Consumer

- It is not deterministic, but...
- It exhibits less variability than the PV, and it is often defined by contracts (e,g, mining companies, shopping centers, etc)
- We assume it is deterministic in our model

$$Demand = F_{PV-Demand} + \alpha_B F_{Battery-Demand} + \alpha_S F_{STEP-Demand} + F_{Network-Demand}$$

with $\alpha_B \leq 1$ and $\alpha_S \leq 1$

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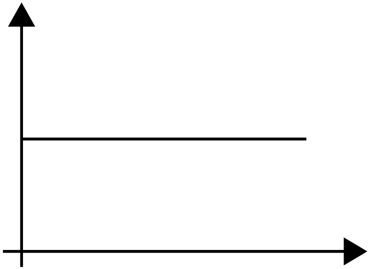
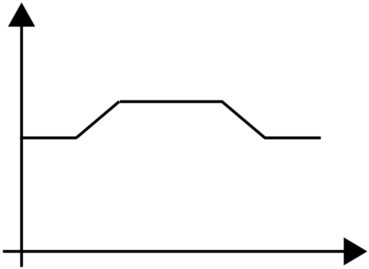
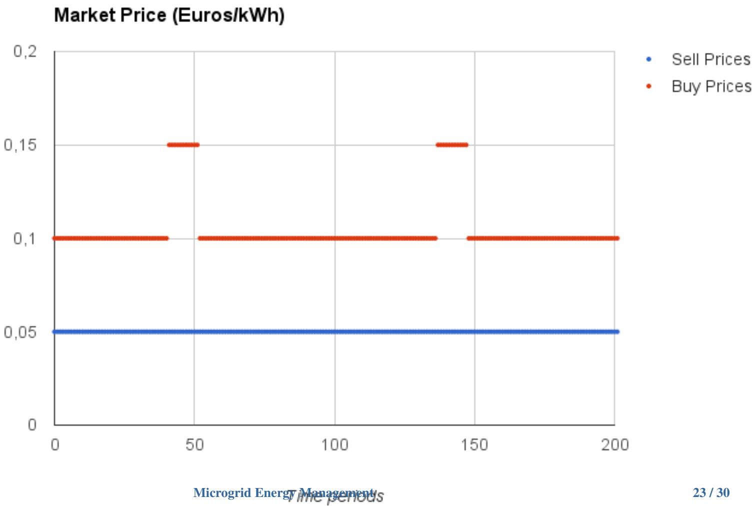
# Demand patterns





# Electrical network



# Objective function

$$\min_F \mathbb{E}\Big[\sum_{t=0}^{T}\{(F_{Network-Demand,t} + F_{Network-Battery,t} + F_{Network-STEP,t}) \times buyprice_t$$
$$-(F_{PV-Network,t} + \alpha_B F_{Battery-Network,t} + \alpha_S F_{STEP-Network,t}) \times sellprice_t\}\Big]$$
$$+\text{Value of energy at time } T.$$

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- Trying to solve this problem directly (extensive form) is impossible!
- Even decomposition schemes such as the nested decomposition are intractable

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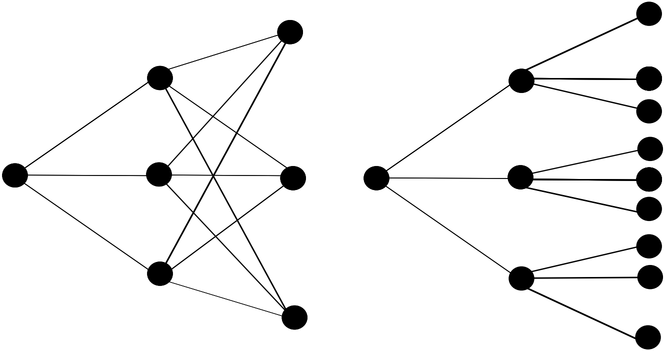
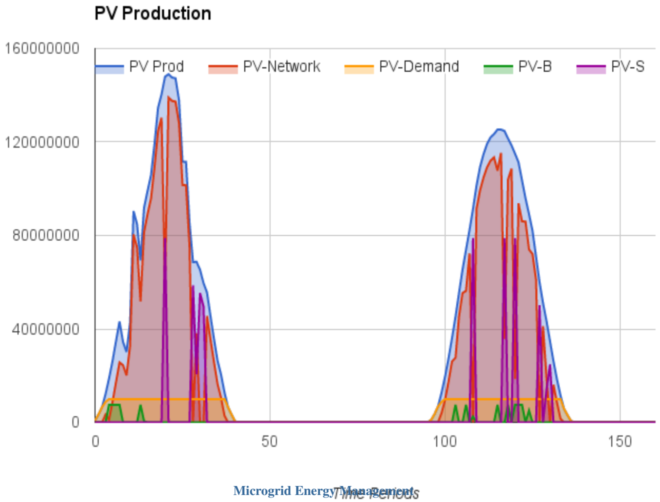
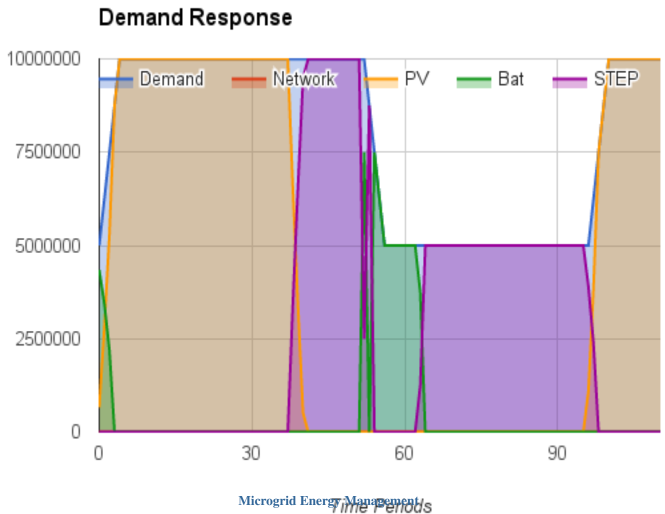
# SDDP with cut sharing



# Destination of PV production



# Units and Demand satisfaction



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