METRON

CERMICS
École des Ponts
ParisTech

PhD Subject presentation

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January 2023

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1. Operation Research
2. My PHD Subject
3. Technical Challenges
4. Toy example
5. Energy Markets

PRESENTATION OUTLINE

1. Operation Research
2. My PHD Subject
   - PHD Organization
   - General problem
3. Technical Challenges
   - Challenges Overview
   - Binary variables
   - Uncertainties
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OPERATION RESEARCH

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Operation Research is a discipline that deals with the development and application of analytical methods to improve decision-making.

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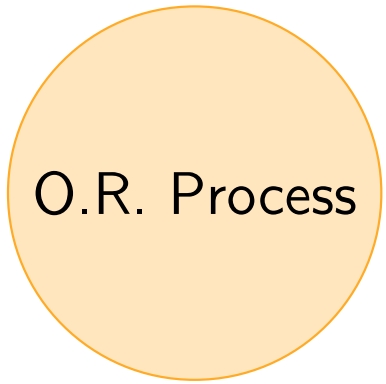

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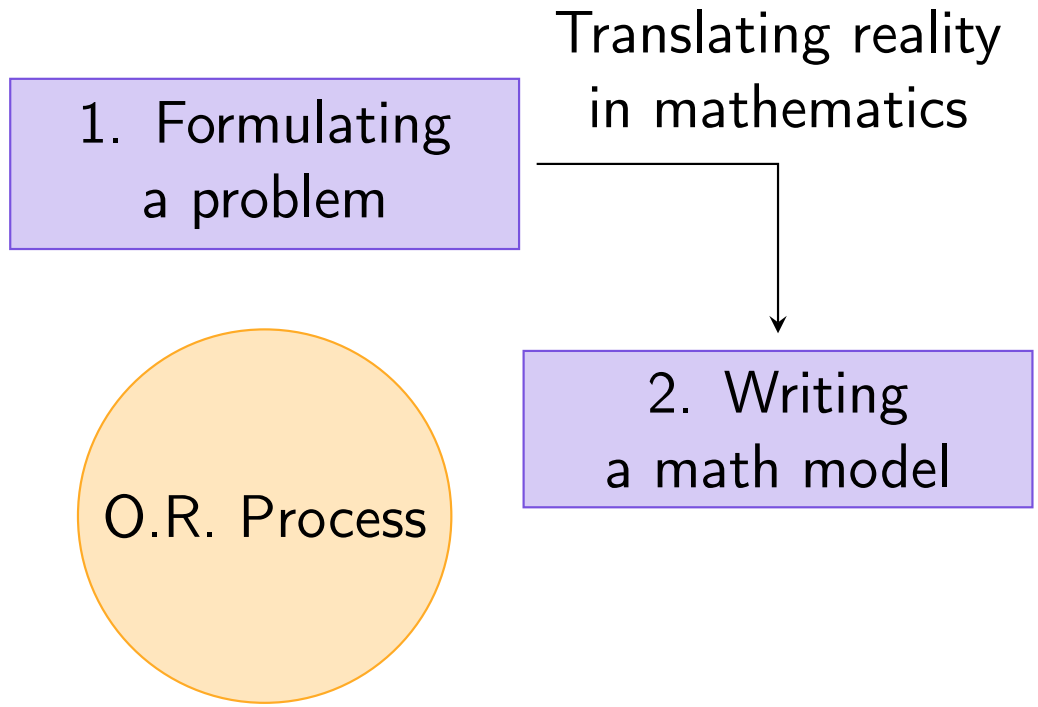

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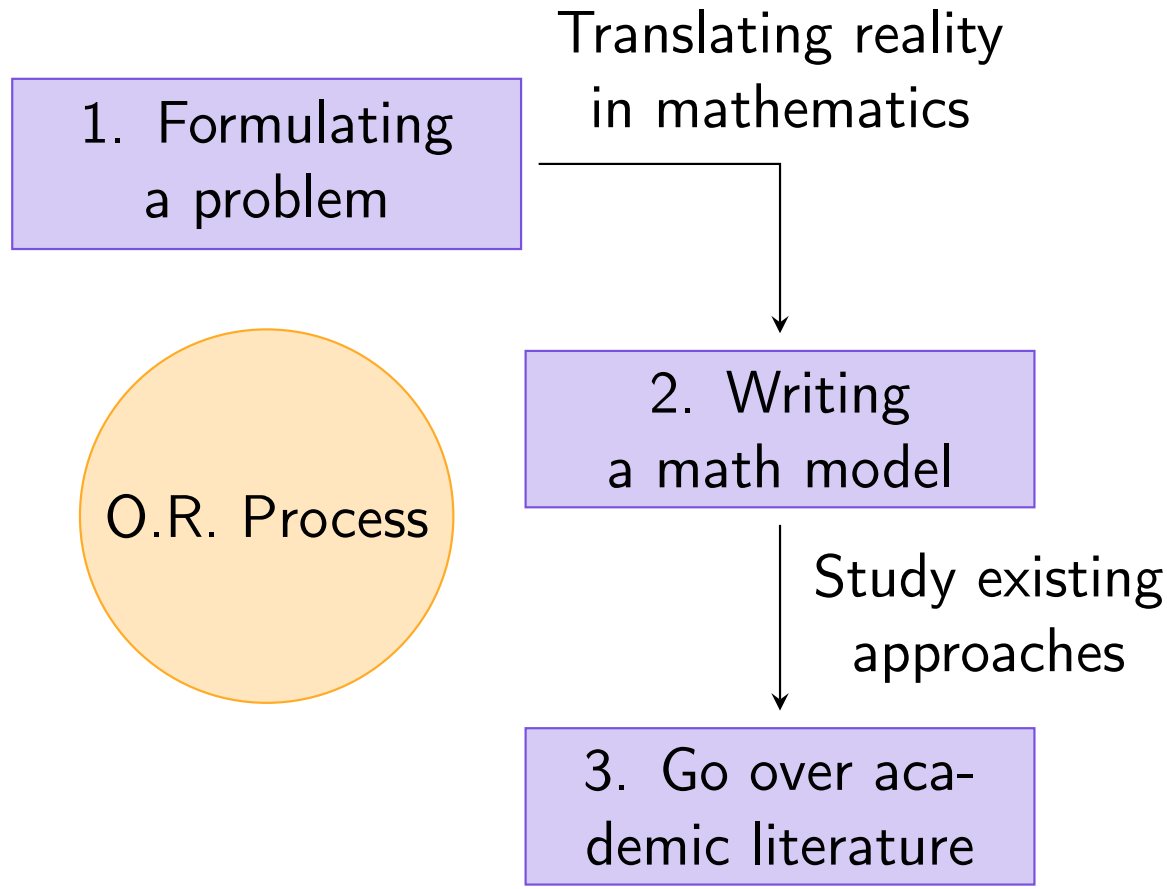

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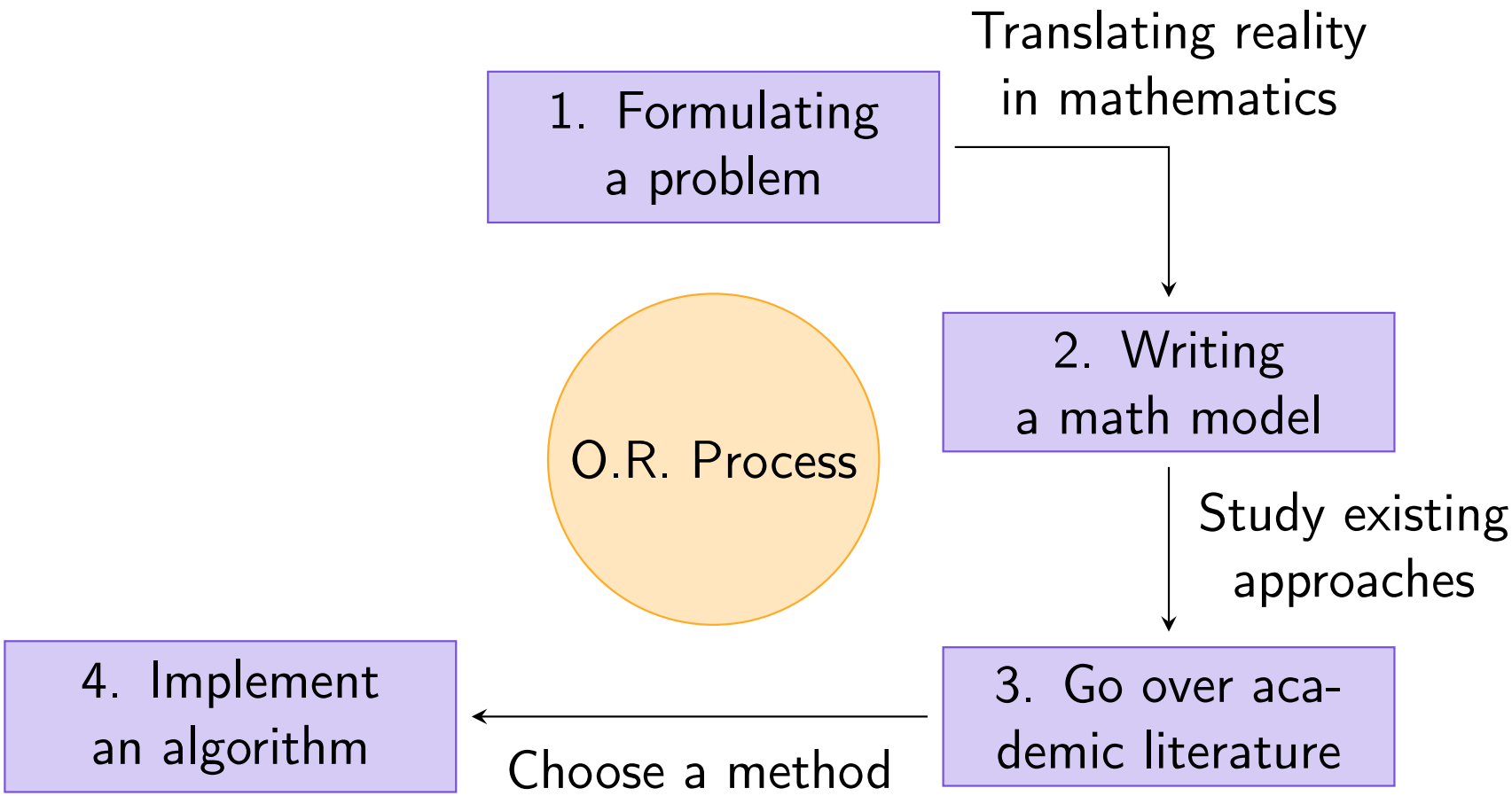

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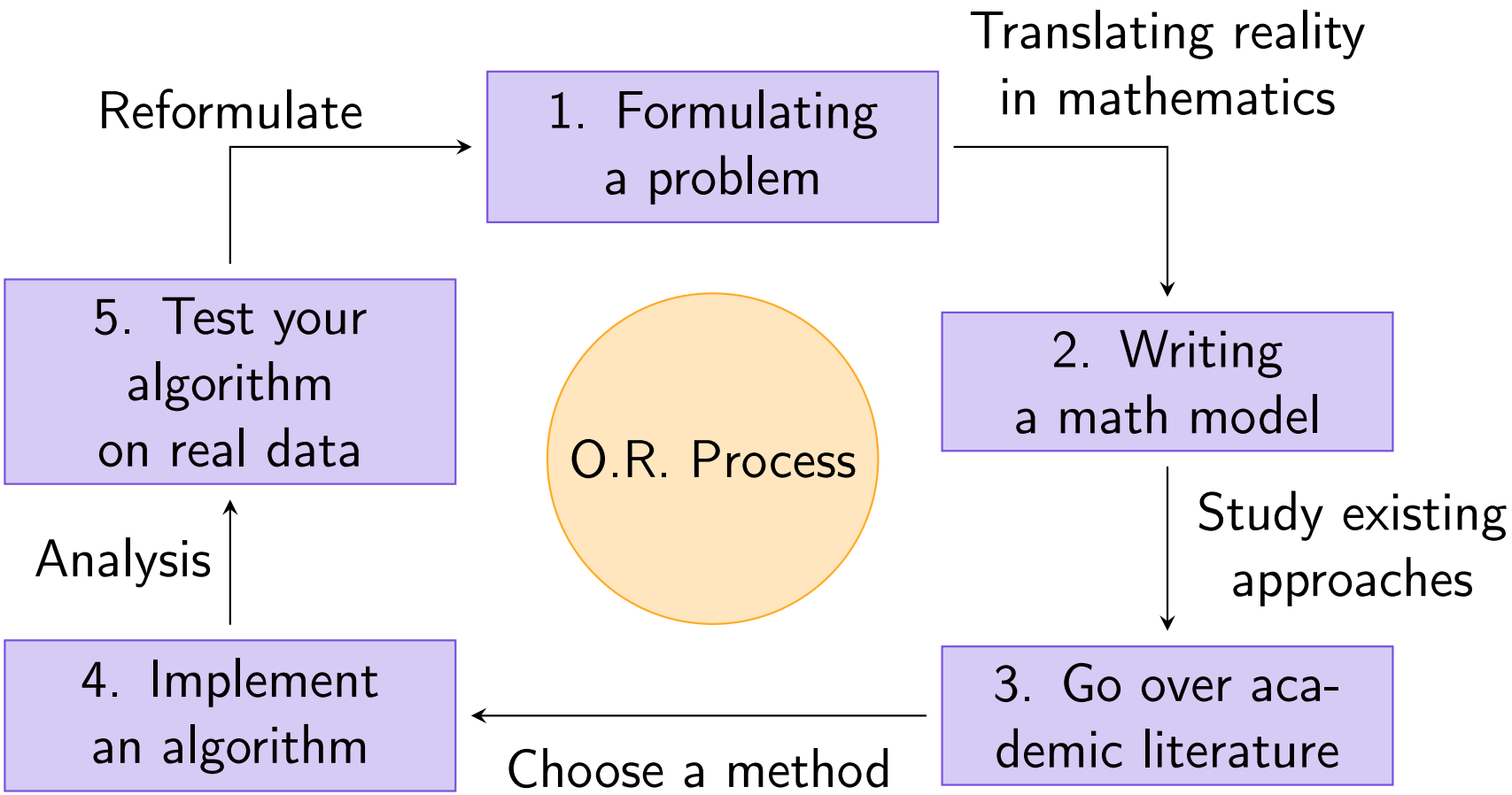

OPERATION RESEARCH

OR Tools

- Computer Science
- Business Analytics

- Probability theory
- Statistics
- Data Science

- Graph Theory
- Optimization
- Game Theory
- Simulation

Industrial Applications

- Scheduling problems: crew scheduling, schools
  ...
- Routing problems: delivery routes, recycling tours, SNCF scheduling
  ...
- Multiportfolios optimization
- Energy dispatch problems
- Waiting rooms in hospital (Queueing theory)
- Telecom networks optimization

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PHD SUBJECT

Main Motivation

Be able to give industrial advices regarding renewable investments.

PHD Subject

Optimize the joint production and energy supply planning of an industrial microgrid.

- What we have worked on
  1. Solving the operational problem;
  2. Solving the design problem with day-ahead purchases.
- What is next
  1. Working on different industrial constraints;
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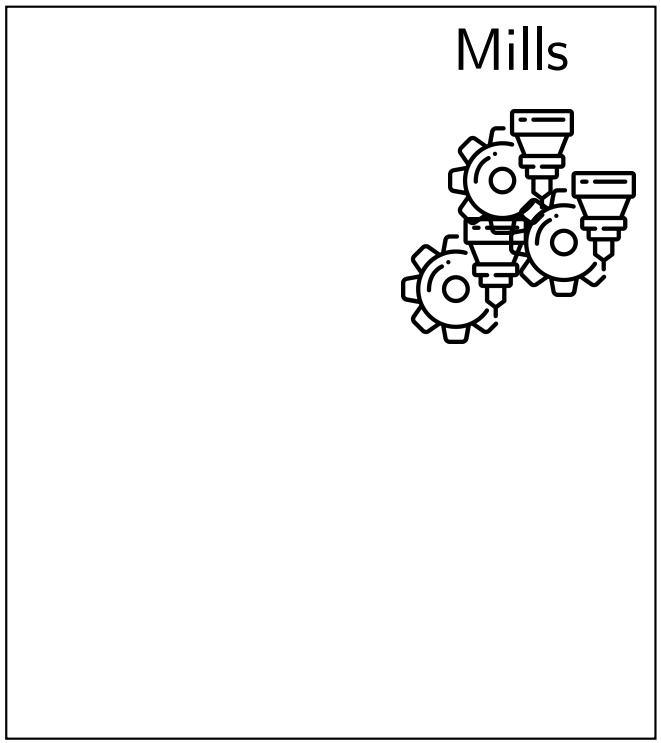

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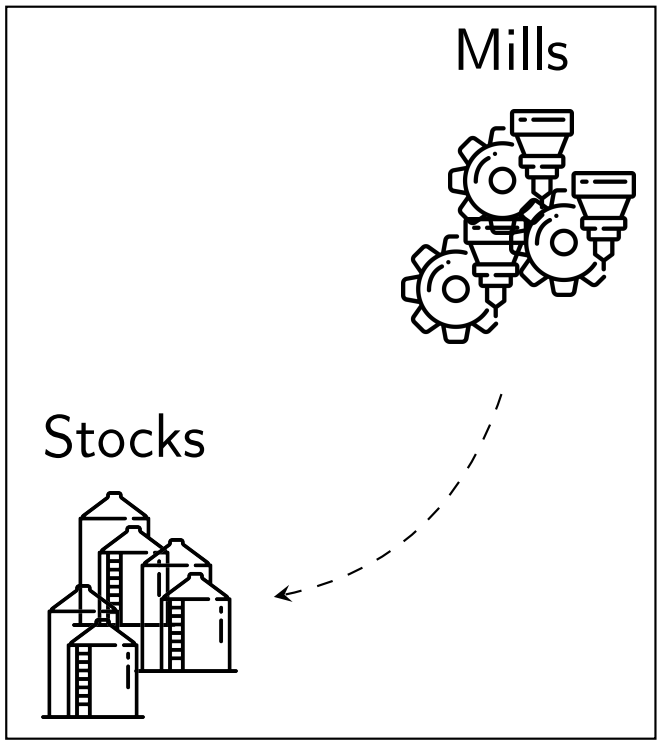

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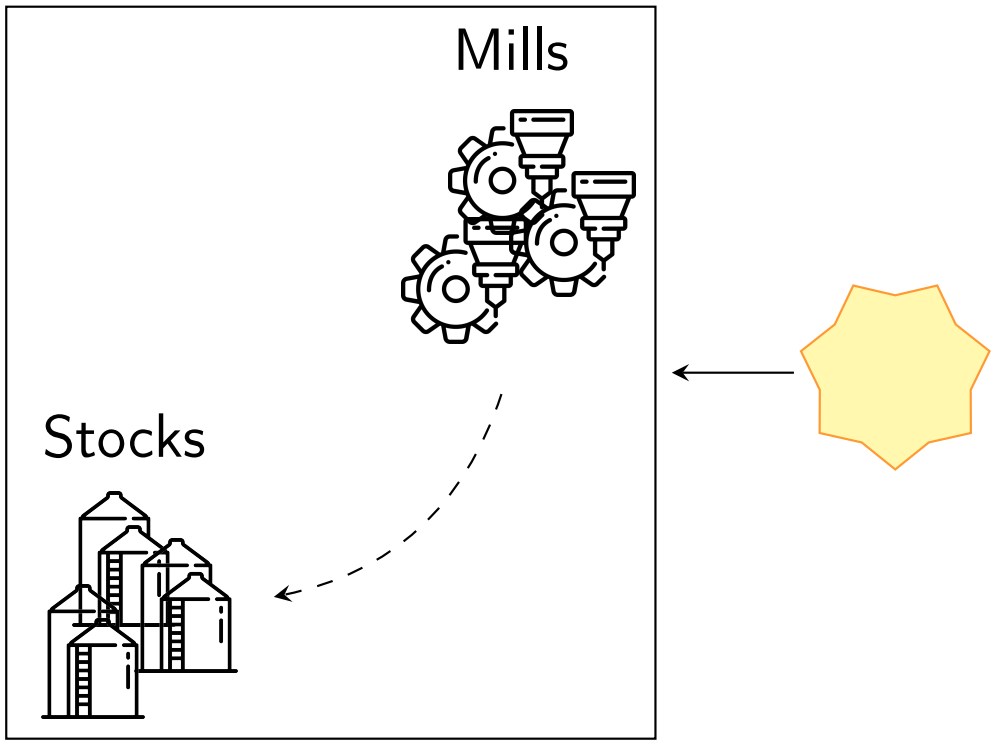

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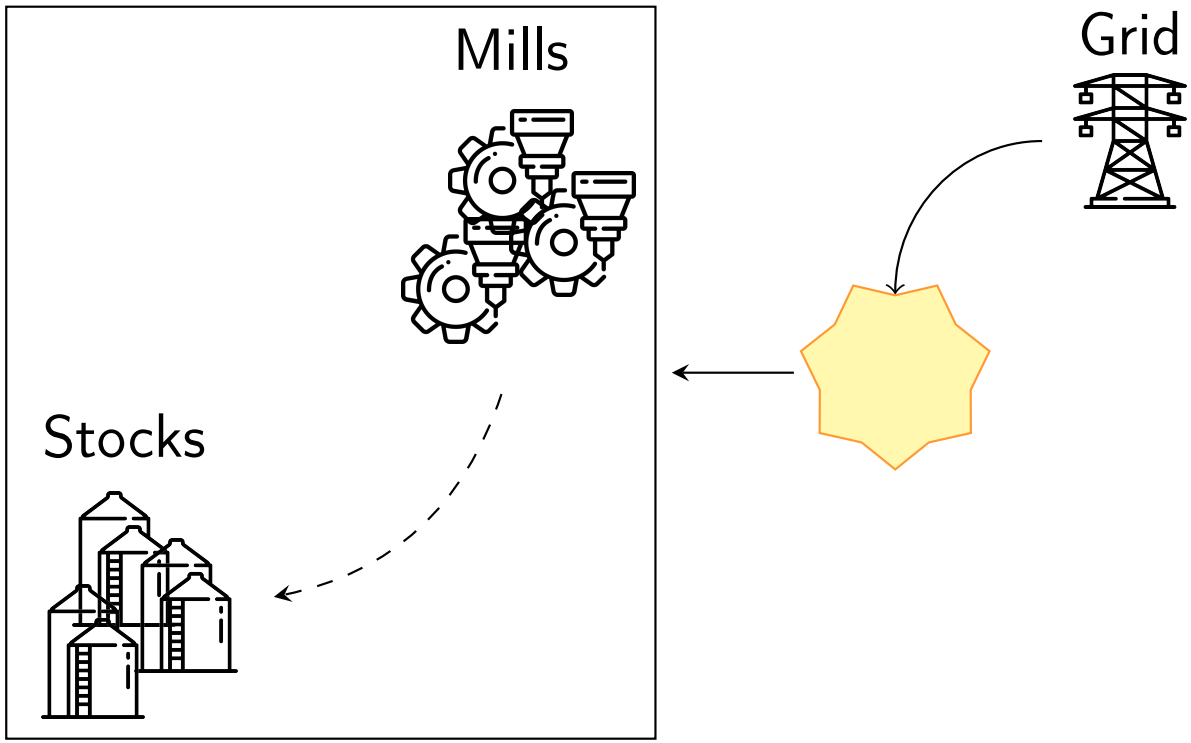

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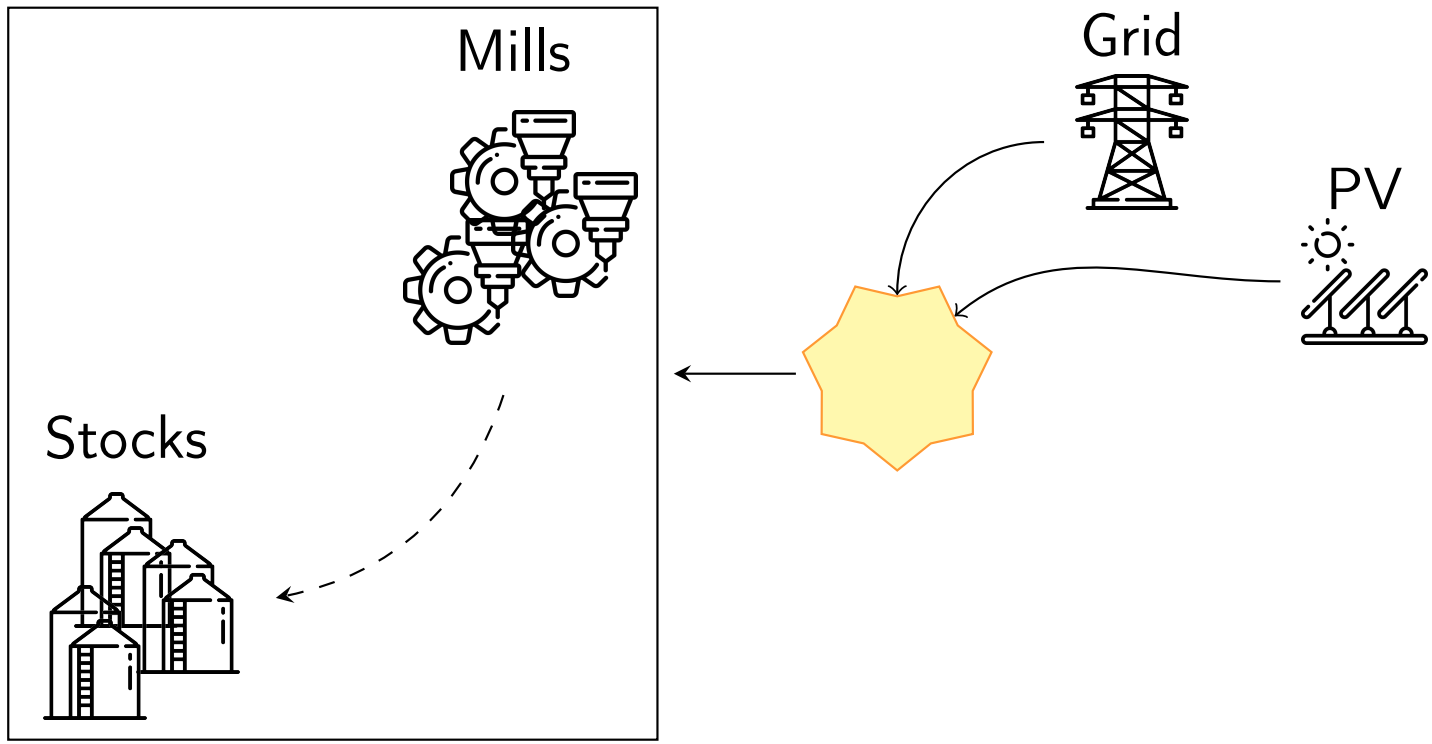

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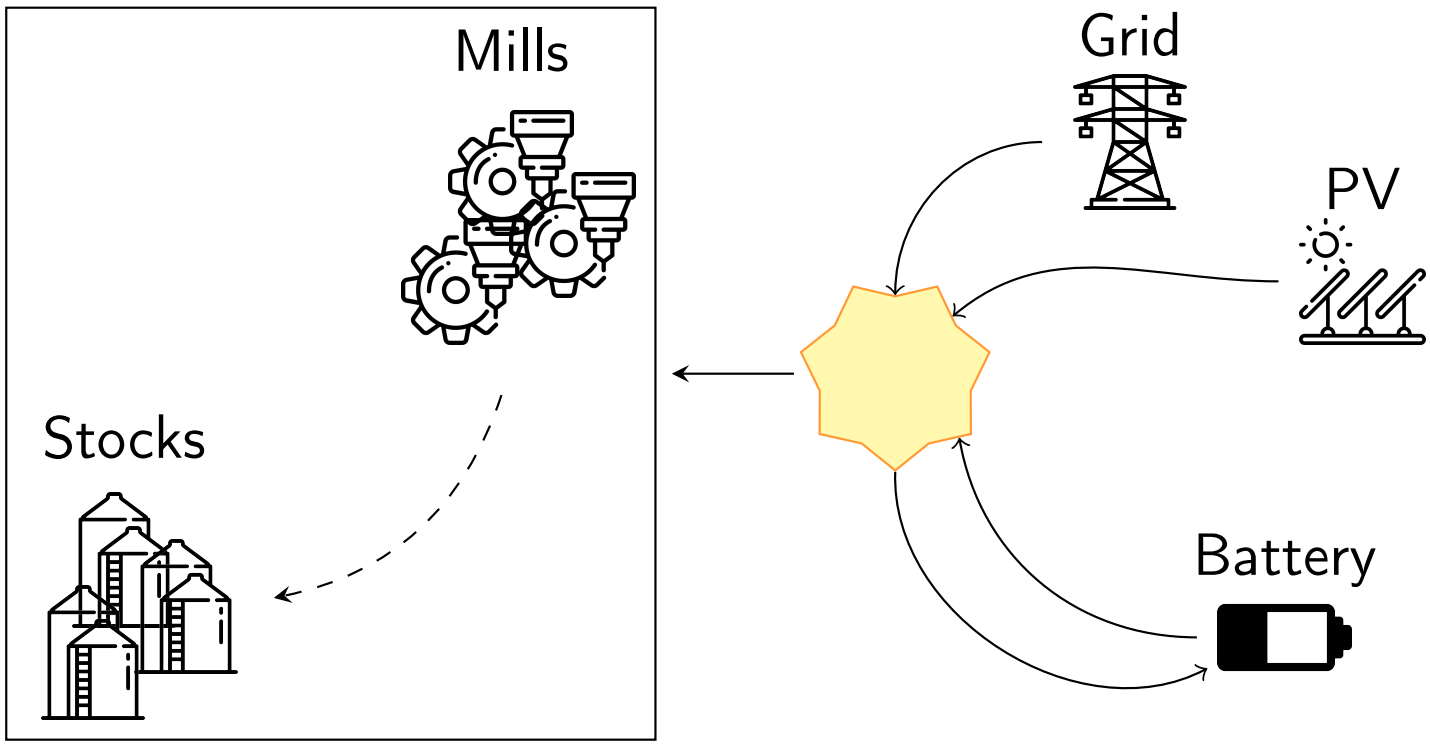

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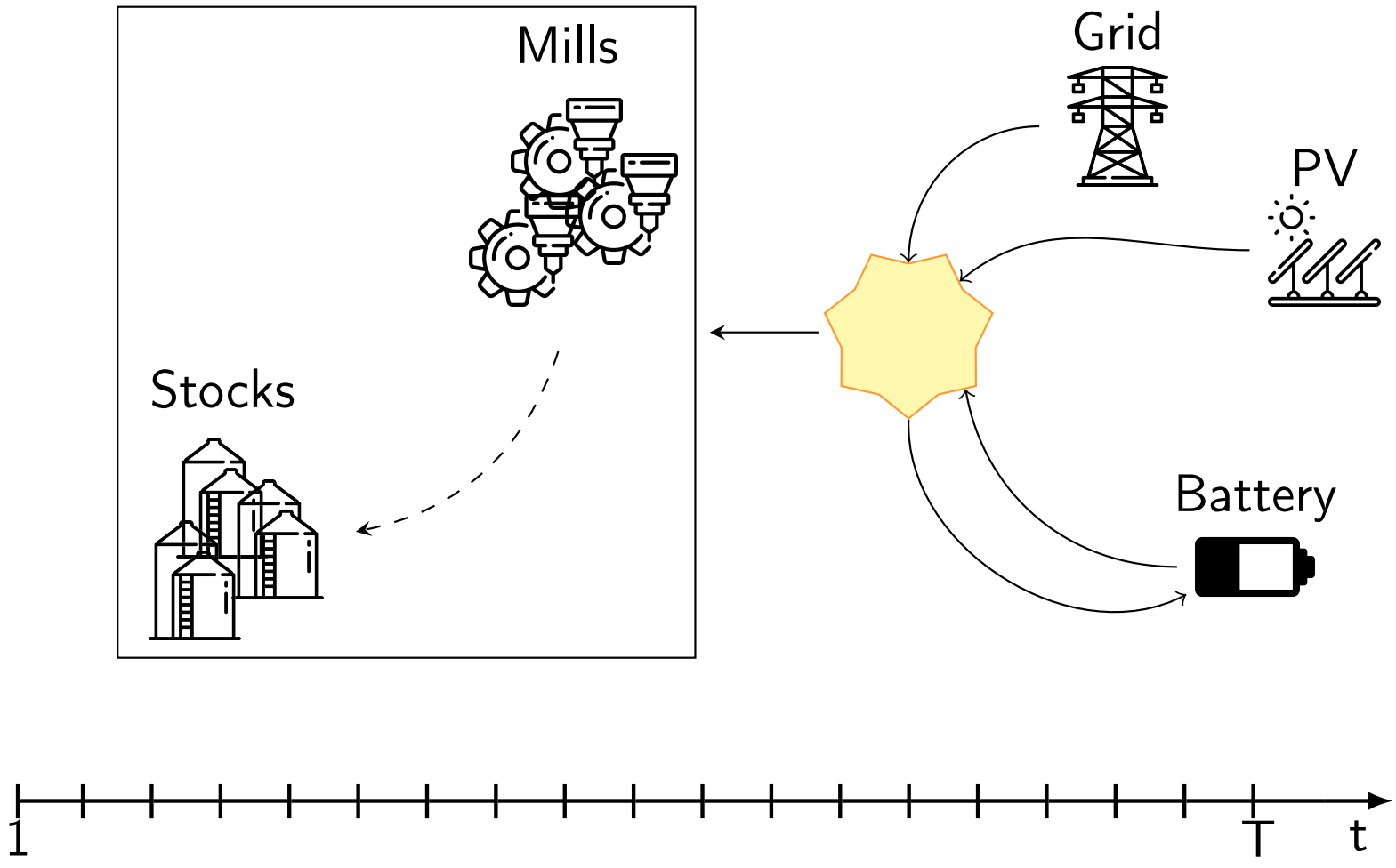

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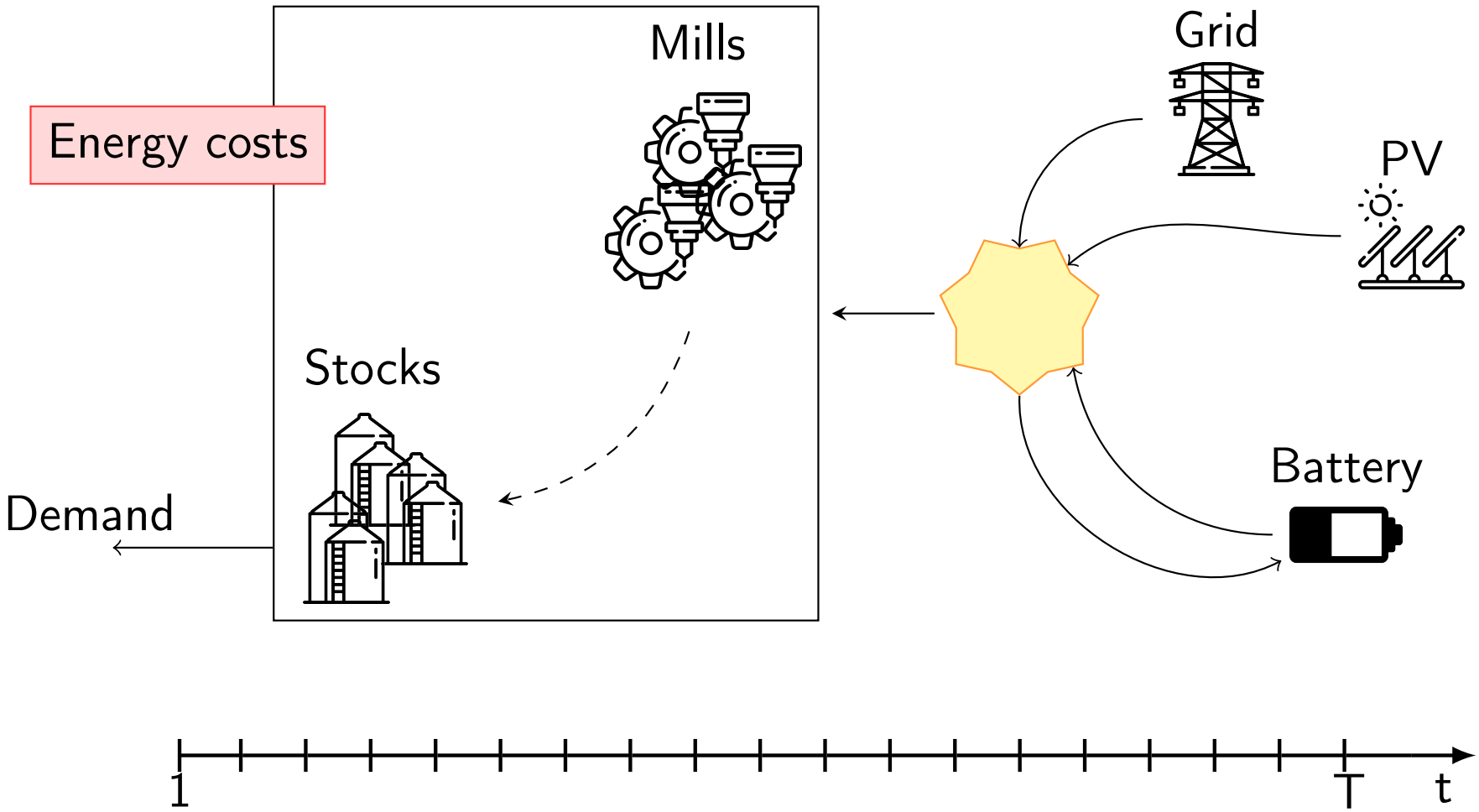
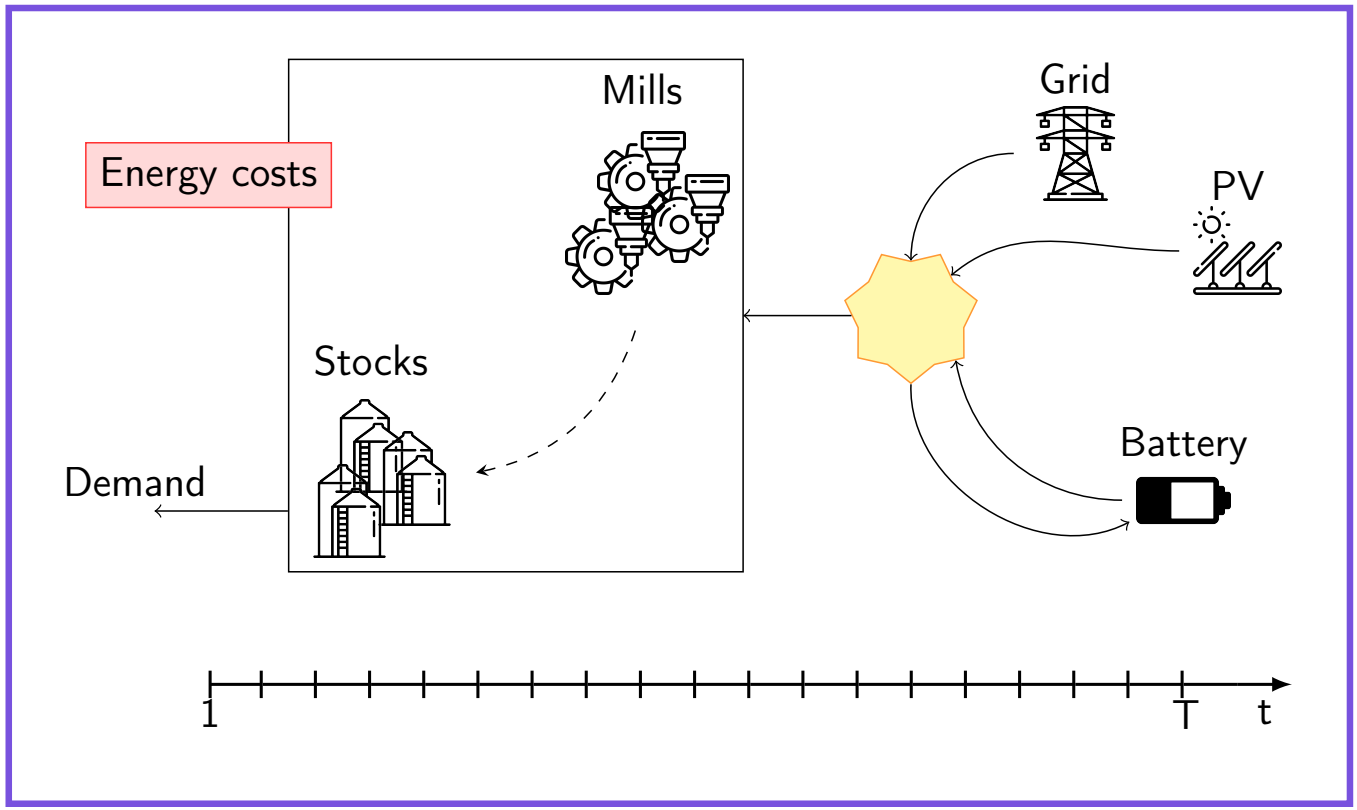


GENERAL PROBLEM

Operational Problem



GENERAL PROBLEM

Design Problem

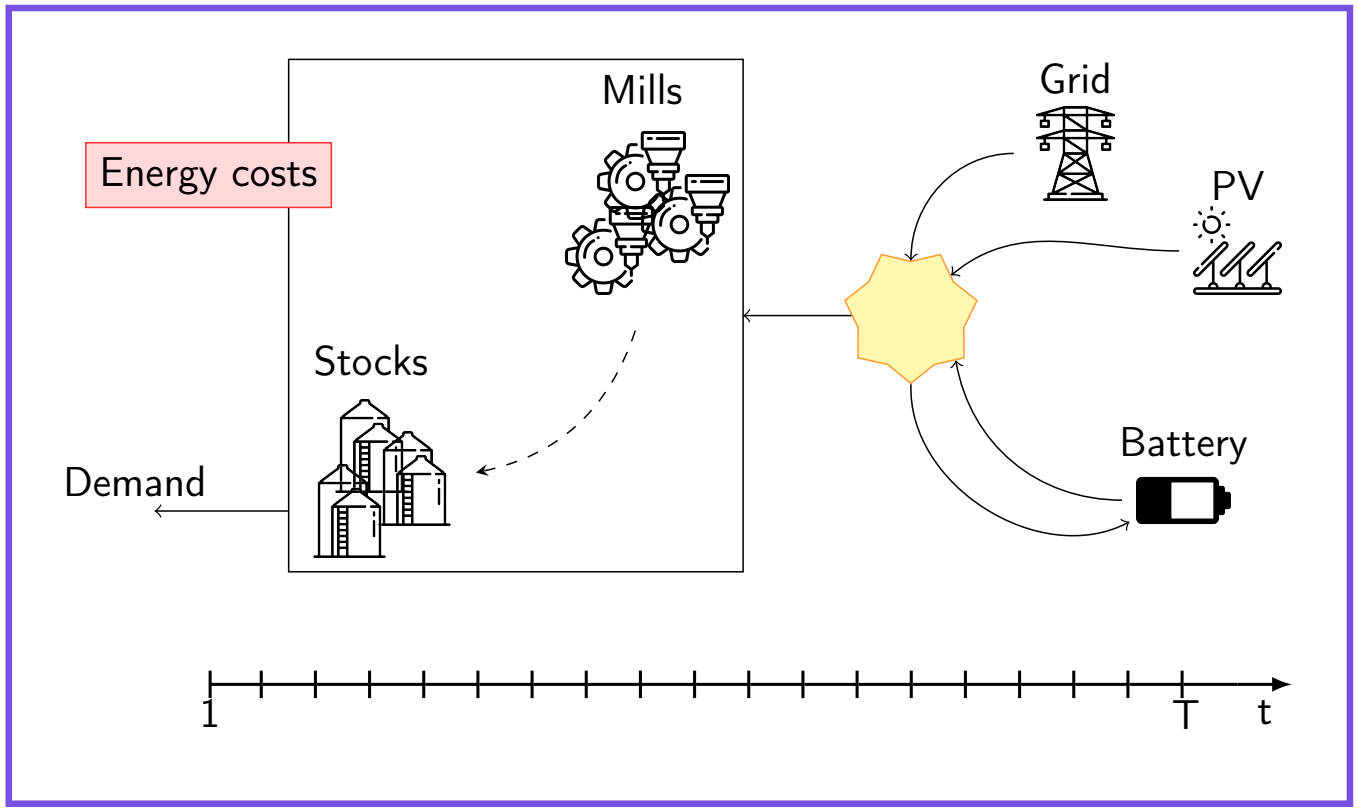
We parametrize

→ Day-ahead energy purchases

Battery sizing

Material investment

Operational Problem



OPERATIONAL AND DESIGN PROBLEM

PHD Subject

Optimize the joint production and energy supply planning of an industrial microgrid.

Industrial Aspects

- A factory with 3 mills and 3 types of products
- A daily demand for each product
- Shared resources constraints: some products can't be planned simultaneously
- Bounds on production
- Stocks dynamics

Energy Aspects

- A microgrid onsite *i.e.*, solar panels coupled with an Energy System Storage
- A main external grid with Time of Use prices
- Day-ahead market (energy can be bought a day in advance)

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CHALLENGES OVERVIEW

Mathematical Challenges

- Binary variables; otherwise continuous variables and linear constraints
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Mathematical Challenges

- Binary variables; otherwise continuous variables and linear constraints
- Uncertainties over a large horizon, with independence assumptions

➥ With uncertainties but without binary variables, an algorithm exists (SDDP).

➥ With binary variables but without uncertainties, solvers are efficient.

➥ The difficulty lies in considering both uncertainties and binary variables.

BINARY VARIABLES

Binary variables: yes/no variables that are necessary to model physical hard constraints.

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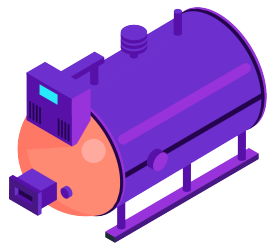

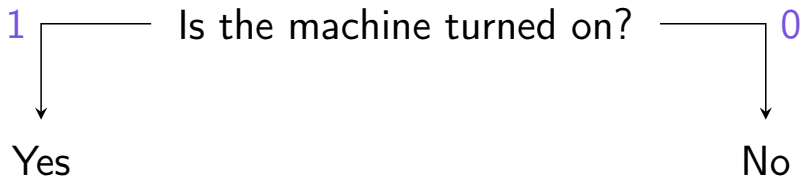

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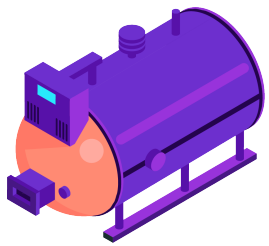
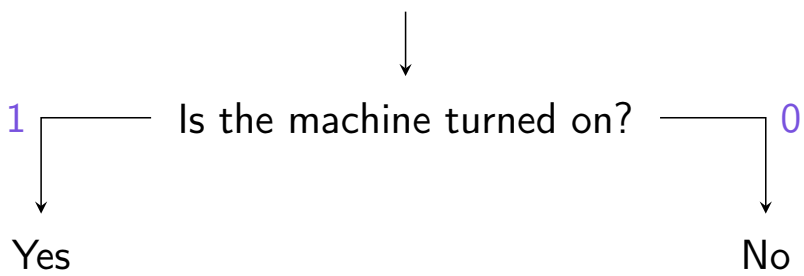


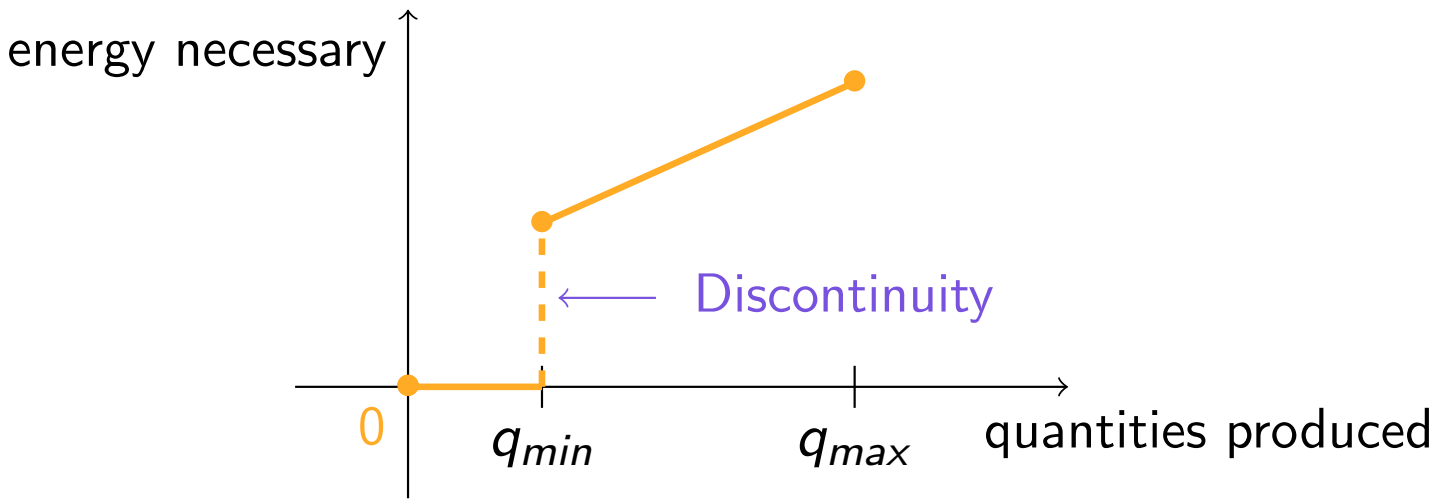


Examples of hard physical constraints:

- Semi-continuous variables;
- Shared resources;
- Counters;
- Minimum down/up times.

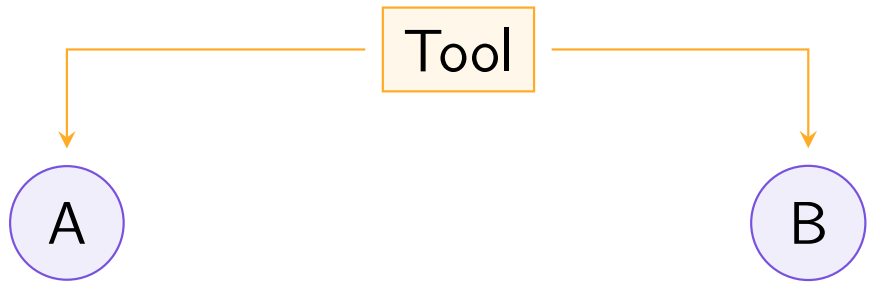
BINARY VARIABLES

- Semi-continuous production: either we don't produce, or we produce at least a certain quantity.



BINARY VARIABLES

- Shared resources: we must choose between producing A or B.



$$c_A = \begin{cases} 1 \text{ if A is produced;} \\ 0 \text{ otherwise.} \end{cases} \qquad c_B = \begin{cases} 1 \text{ if I produce B;} \\ 0 \text{ otherwise.} \end{cases}$$

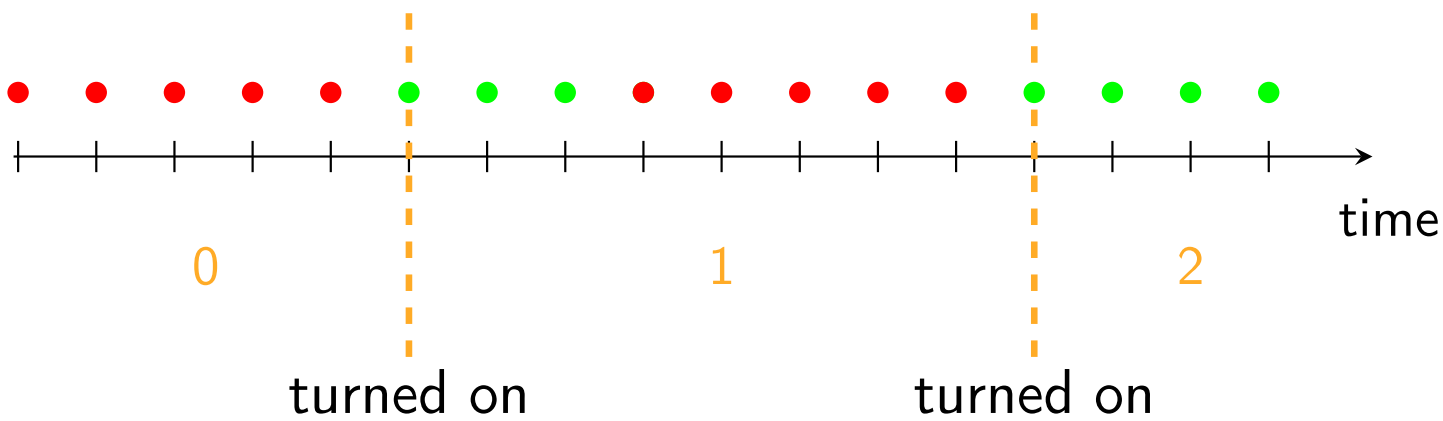
We can't have $c_A = 1$ and $c_B = 1$

BINARY VARIABLES

- Counters: I can't turn on/off a machine as many times as I want

  - : turned on (1)
  - : turned off (0)

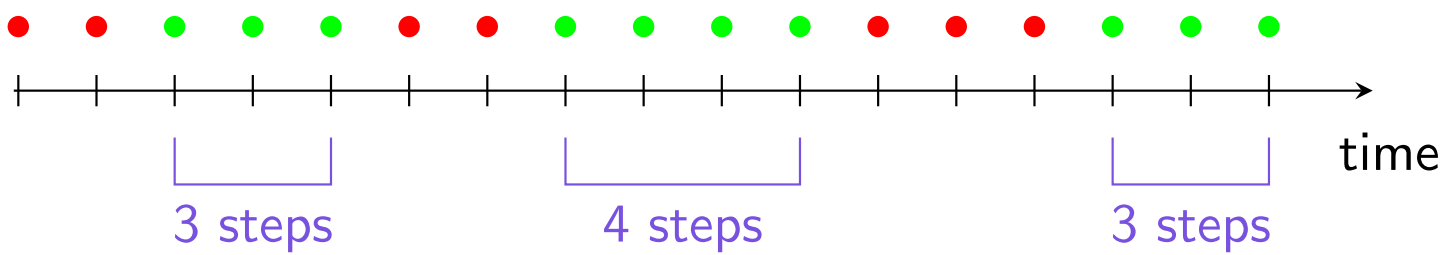
count : number of times I turned on the machine



BINARY VARIABLES

- Minimum Up-Down time: if I turn on a machine, it must stay on at least a certain time.

● : turned on (1)
● : turned off (0)
3 time steps minimum



UNCERTAINTIES

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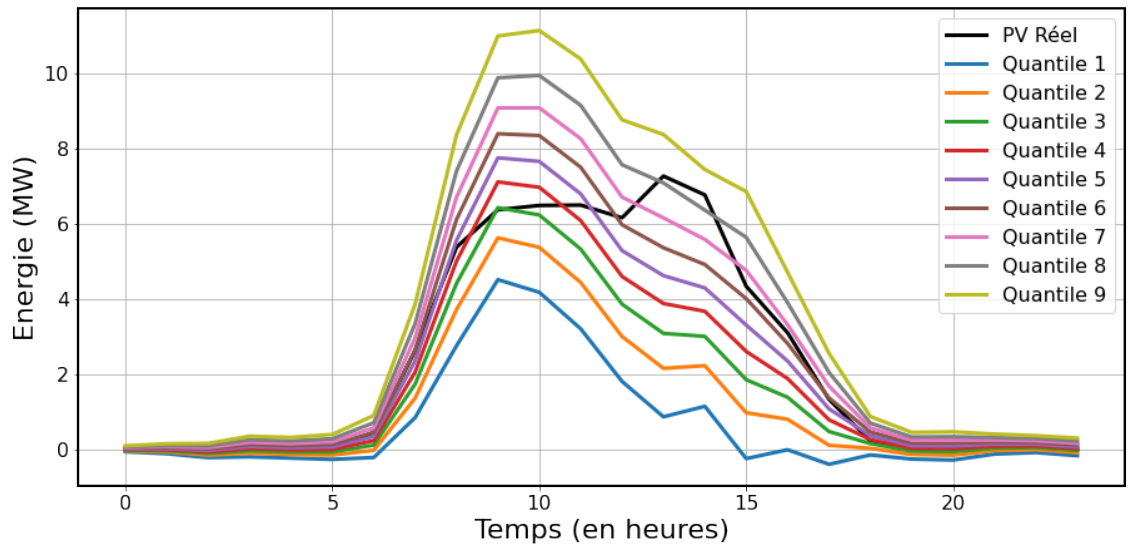

Figure: Predictions over the next day on the solar energy available

➥ **Pascal Lu** for more information on the forecast algorithm.

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Sources: uncertainties can come from the solar energy available, energy prices, energy demand ...

Independence assumption: if the noise is stagewise independent then methods exist to solve the problem (though temporal variability is ok).

➥ We are interested in the uncertainty in the gap between prediction and reality.

Without independence assumption: we can handle an auto regressive dependence in the constraints. Any dependence in the costs is hard.

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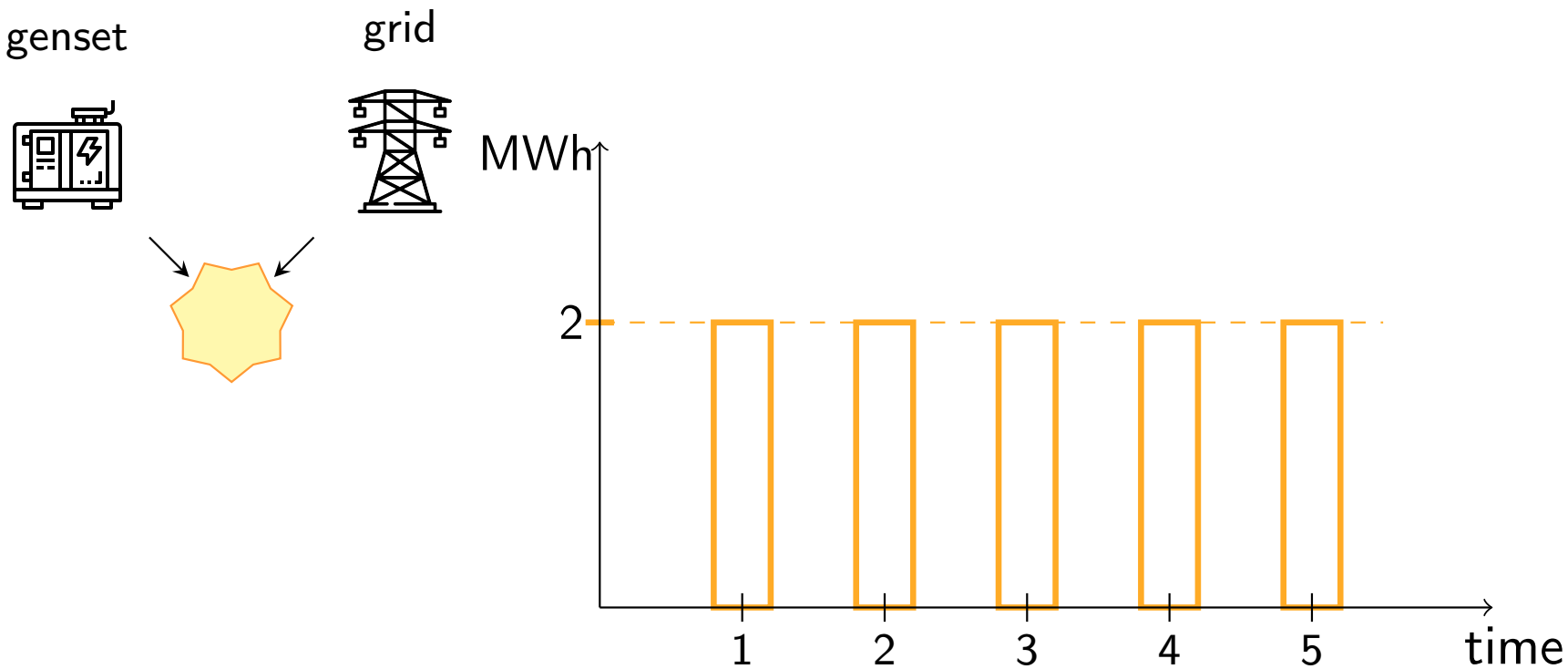

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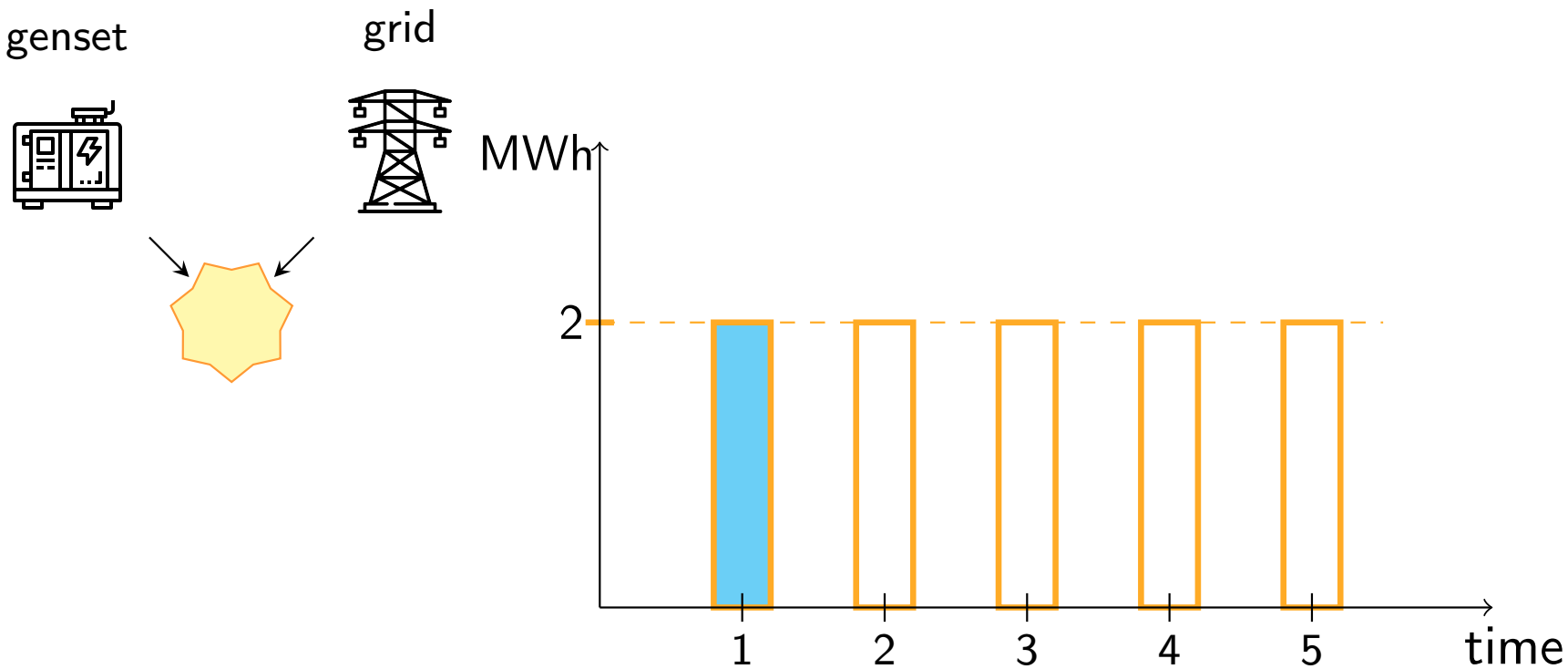

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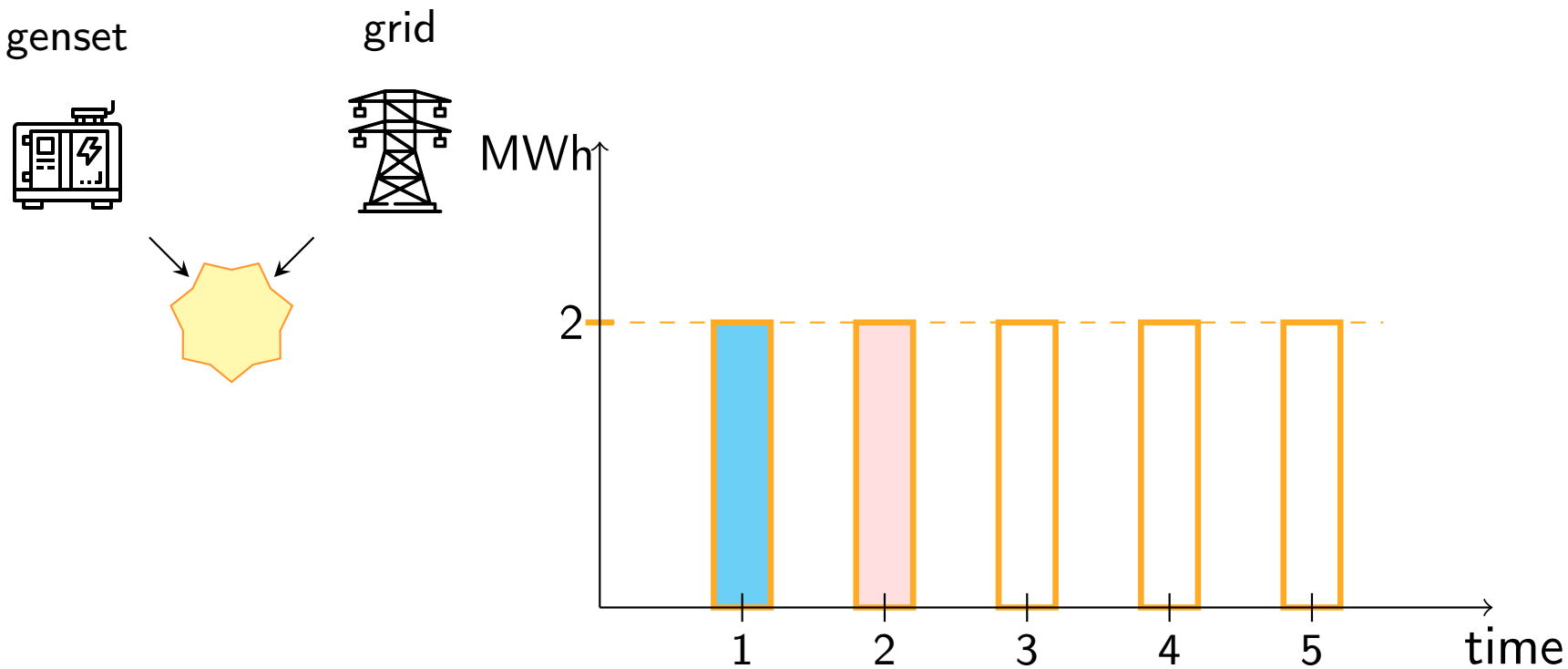

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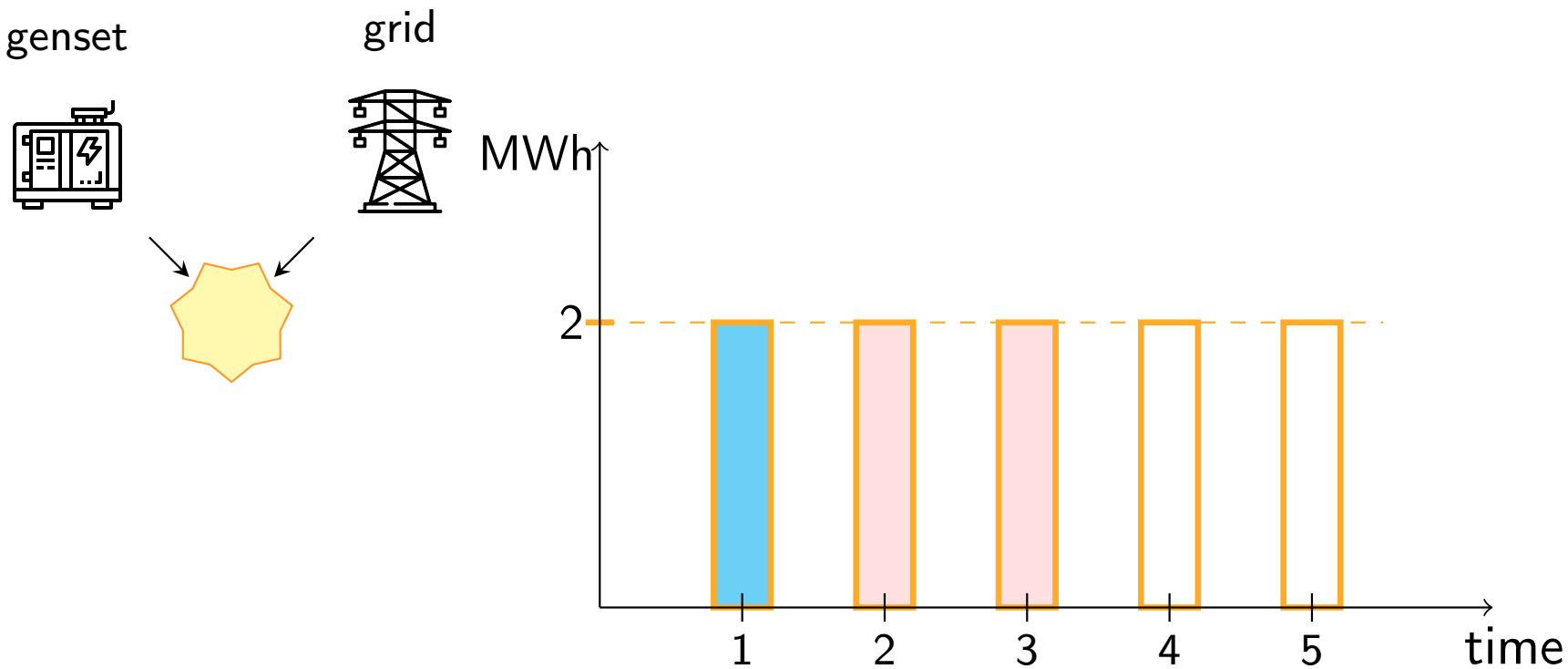

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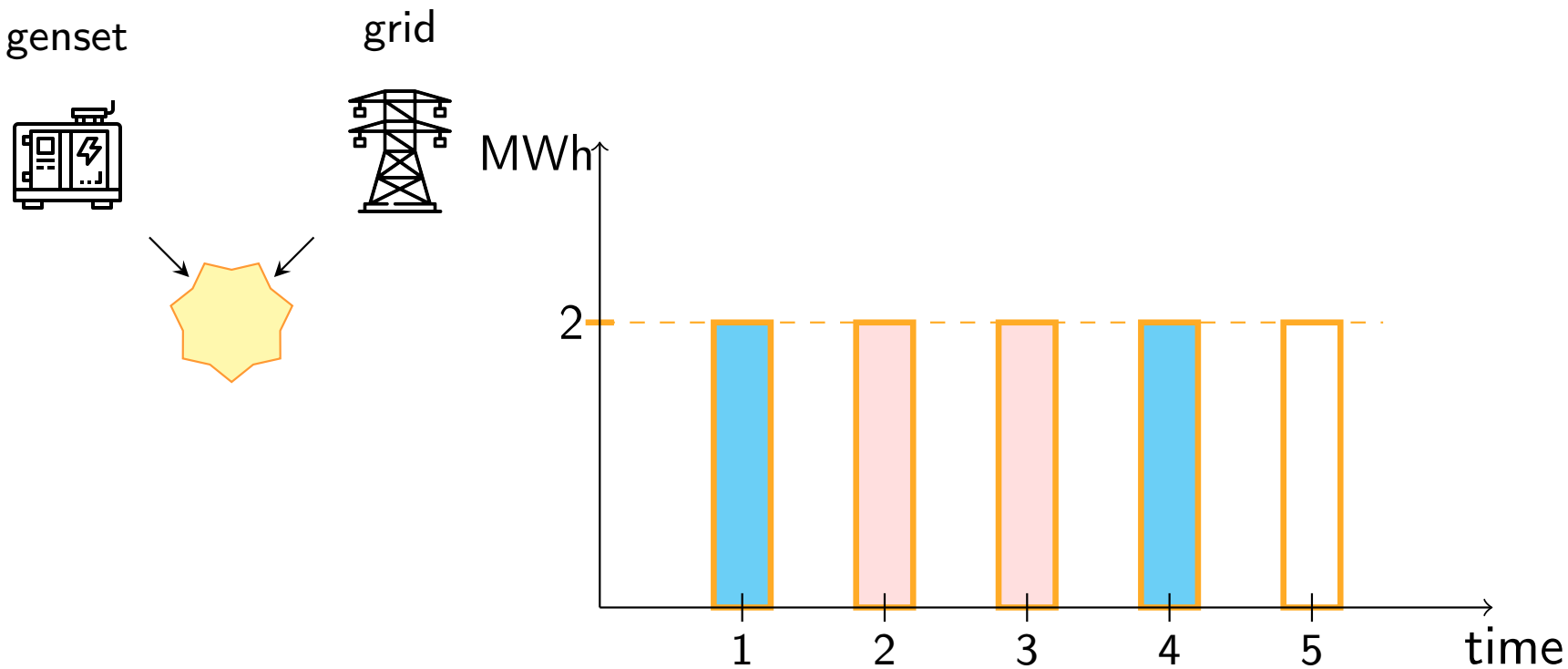

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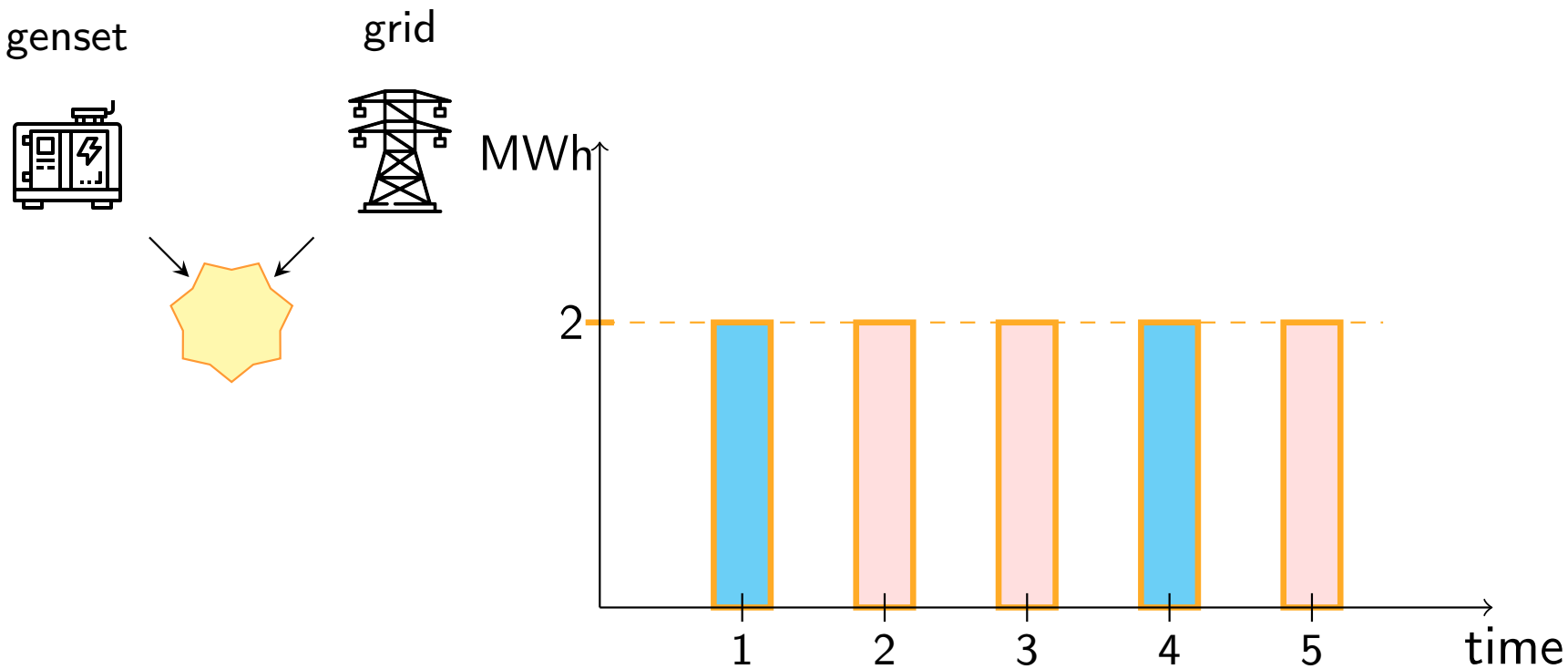

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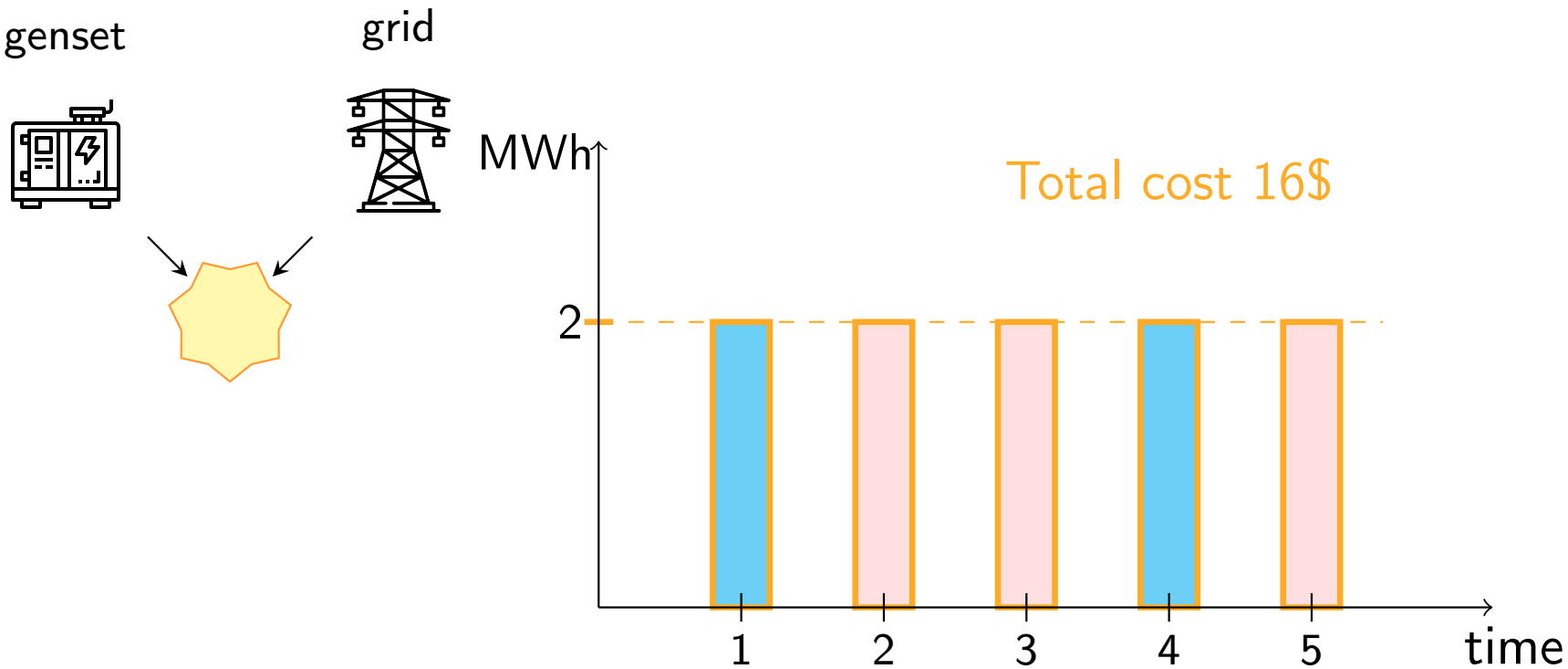

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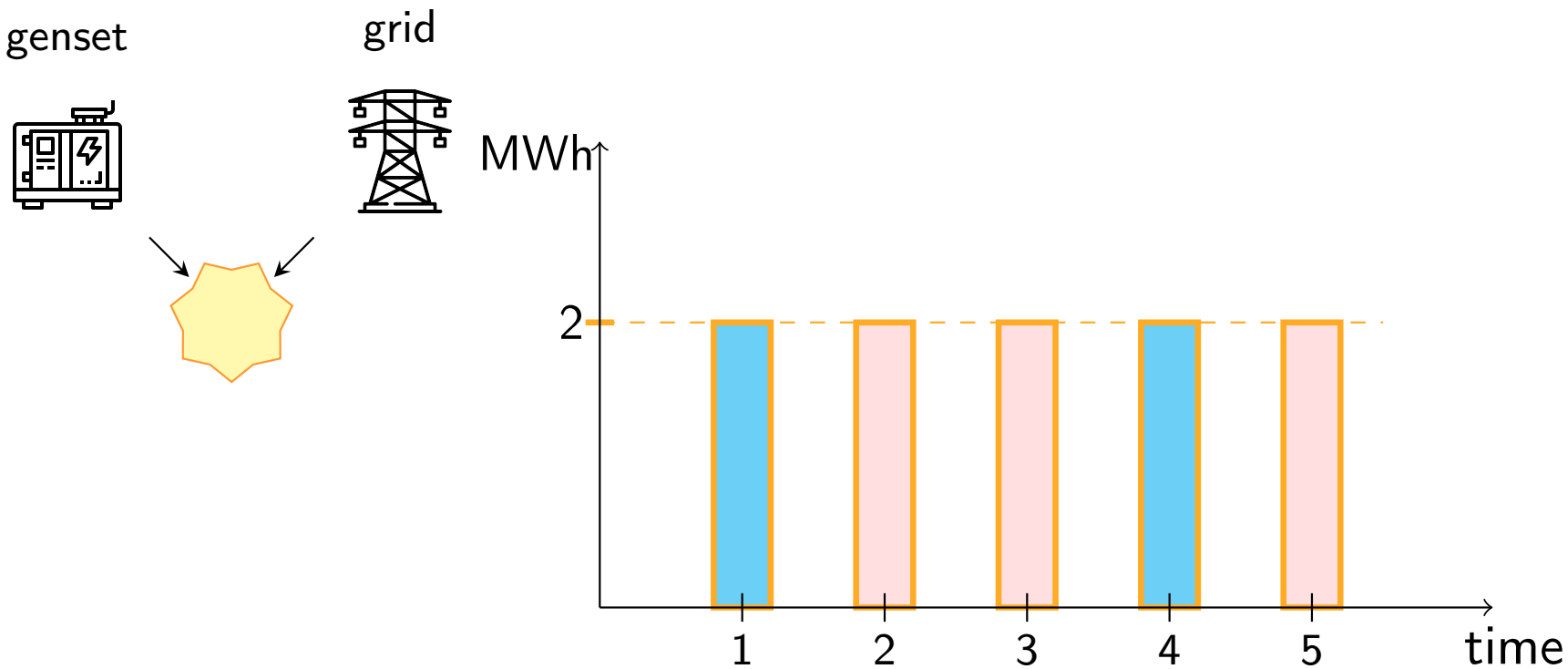

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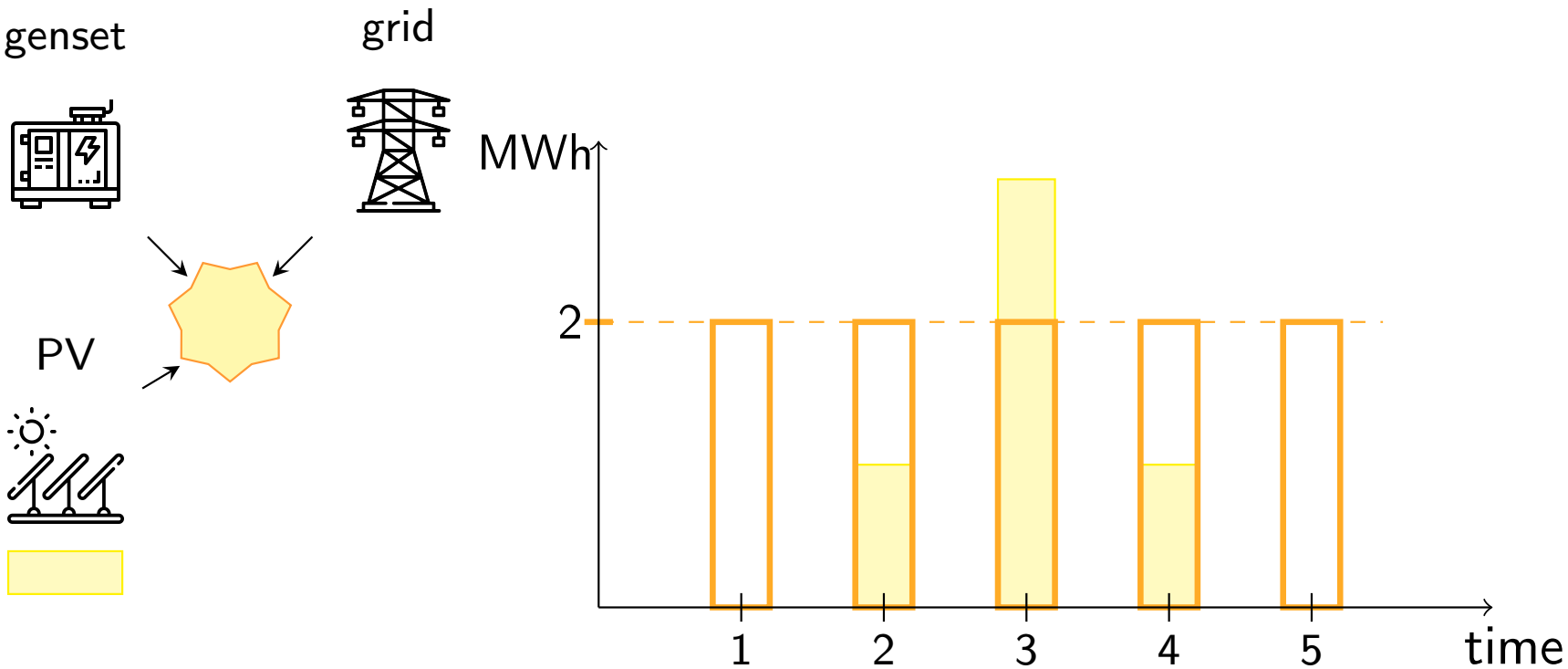

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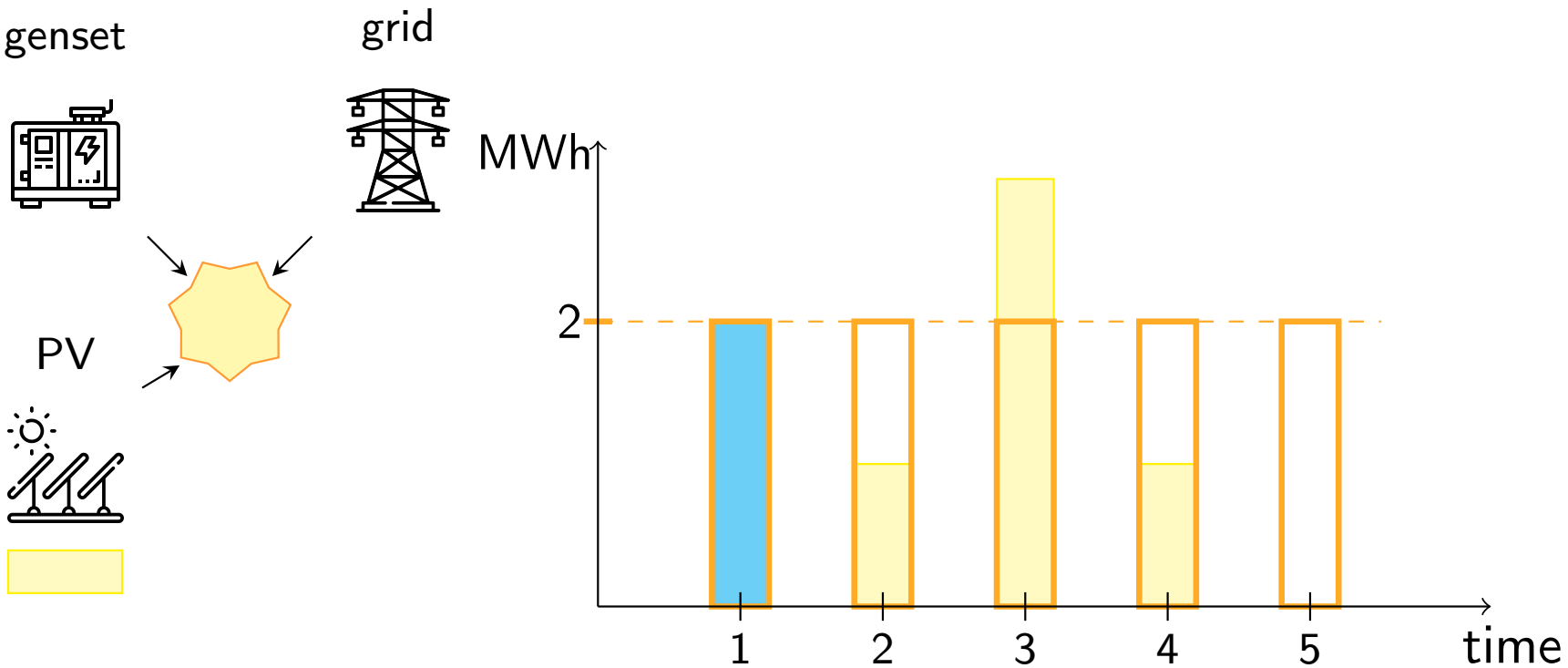

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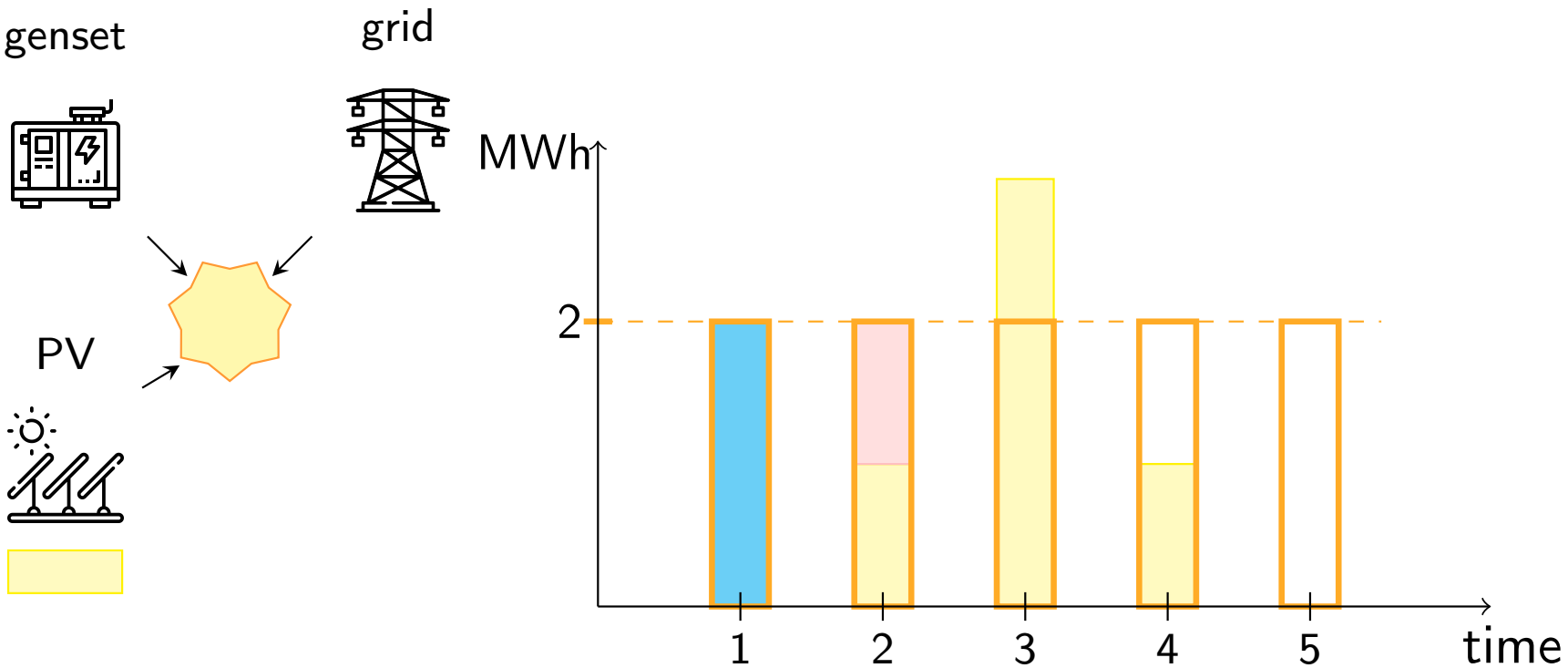

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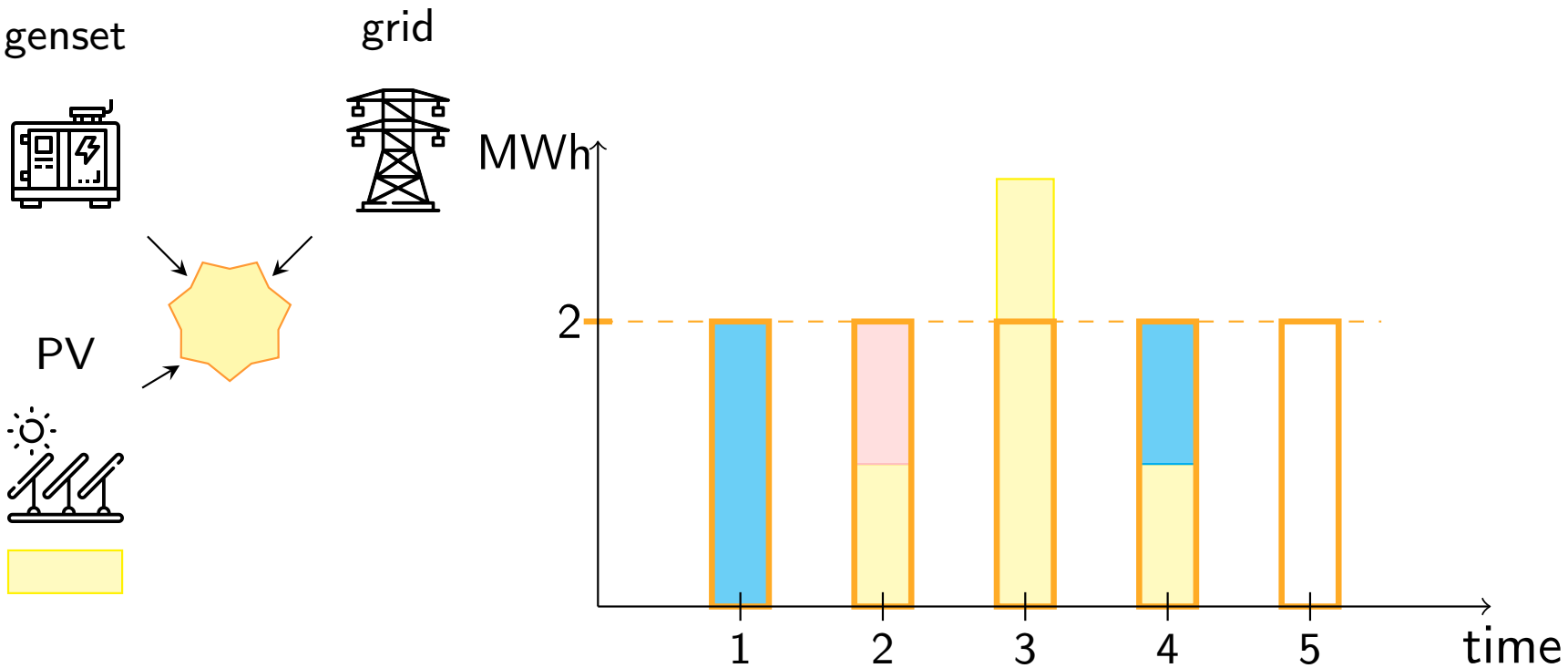

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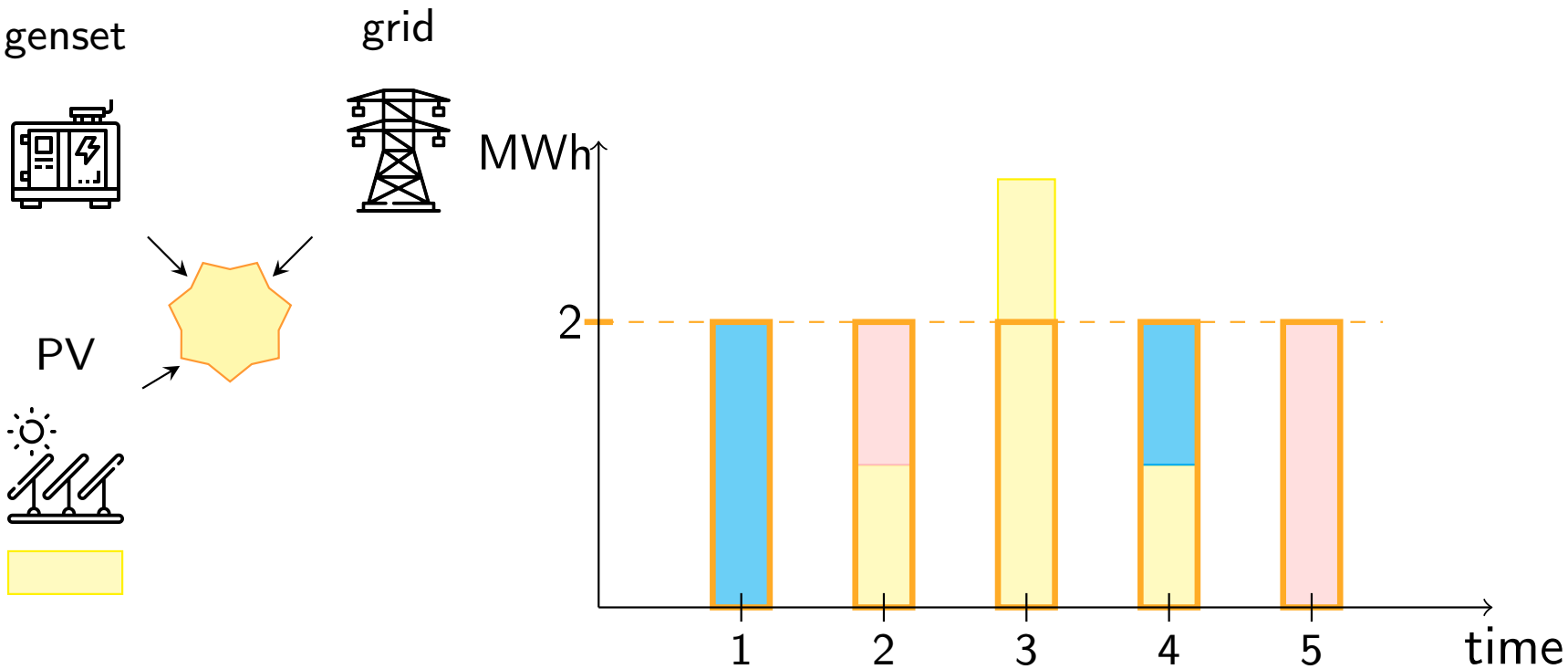

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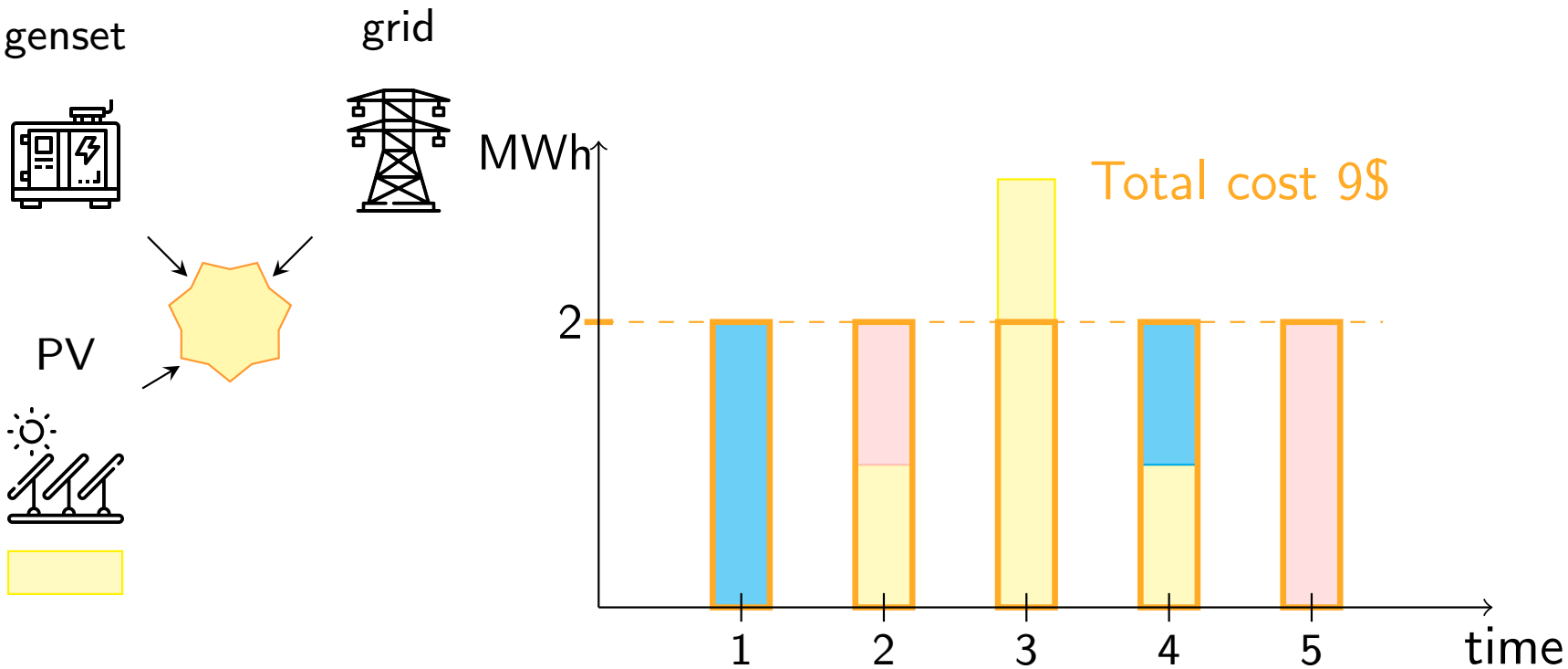

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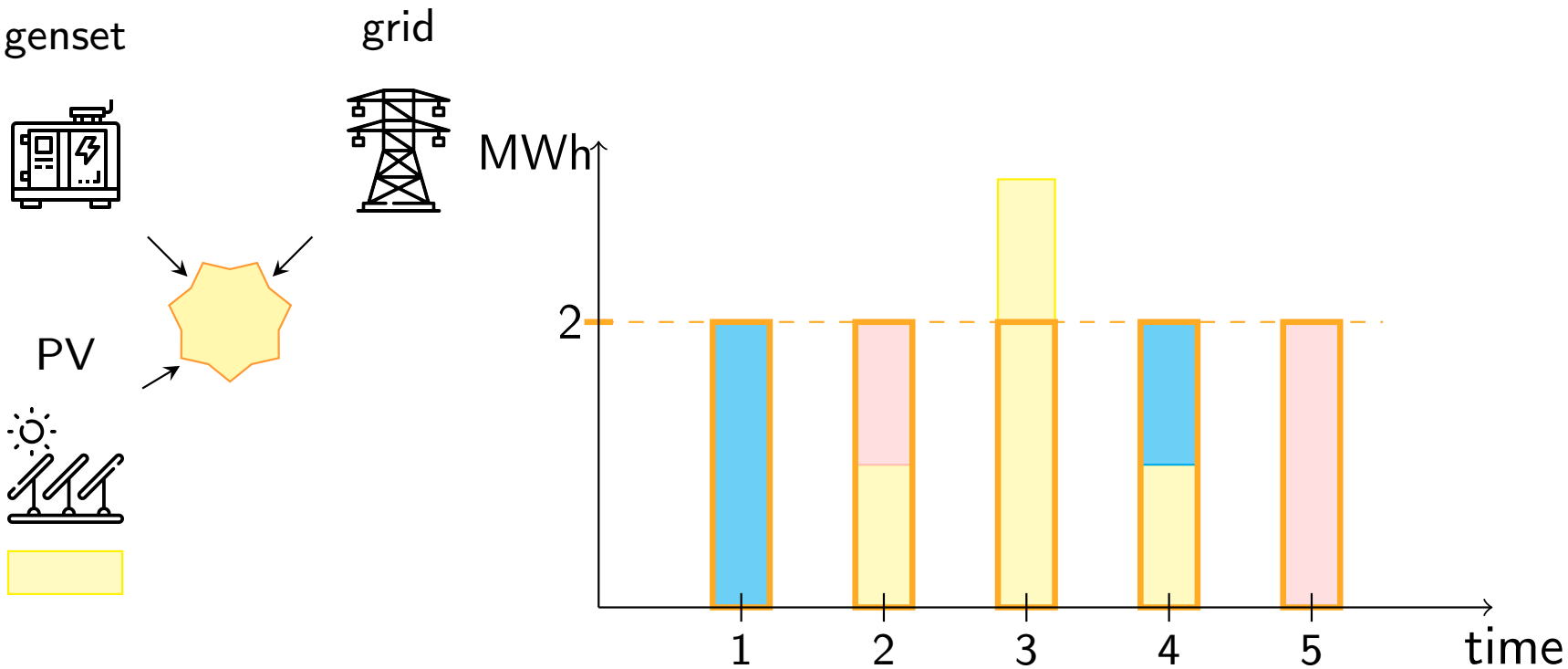

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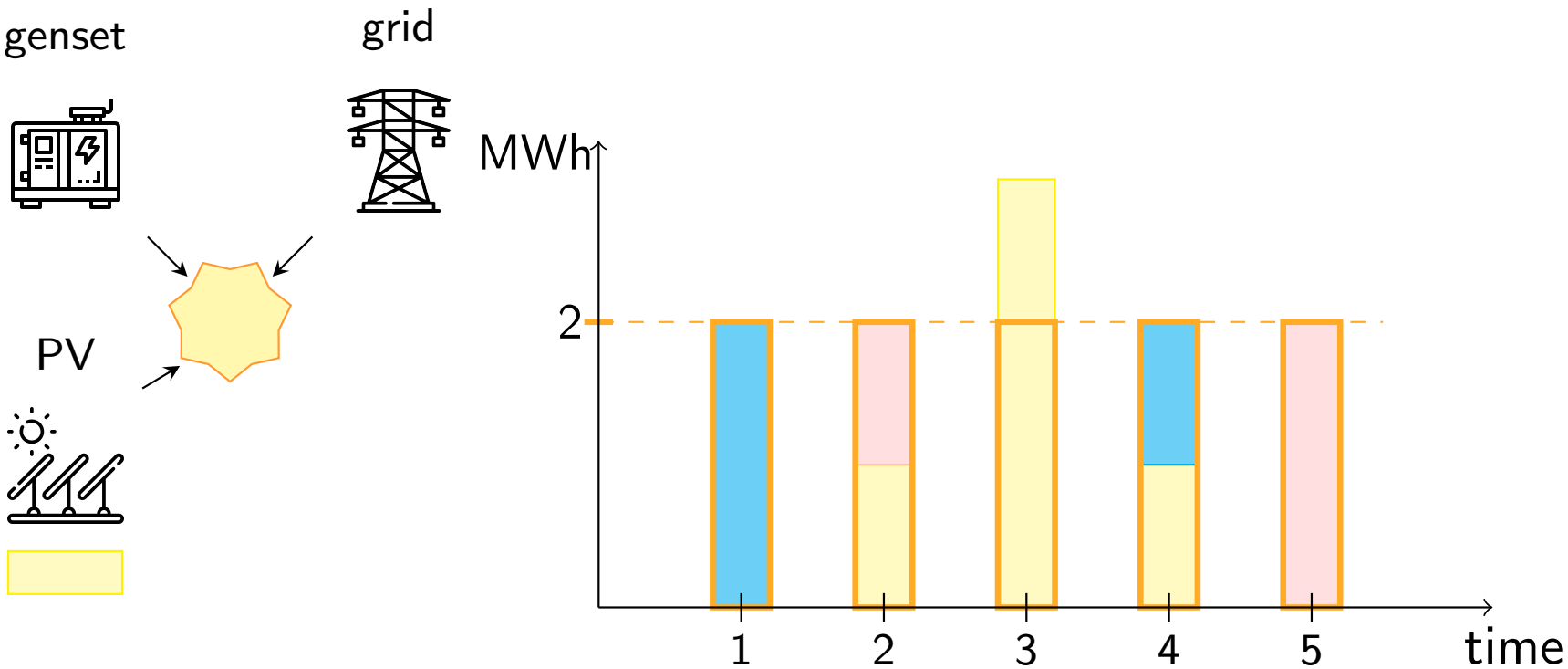
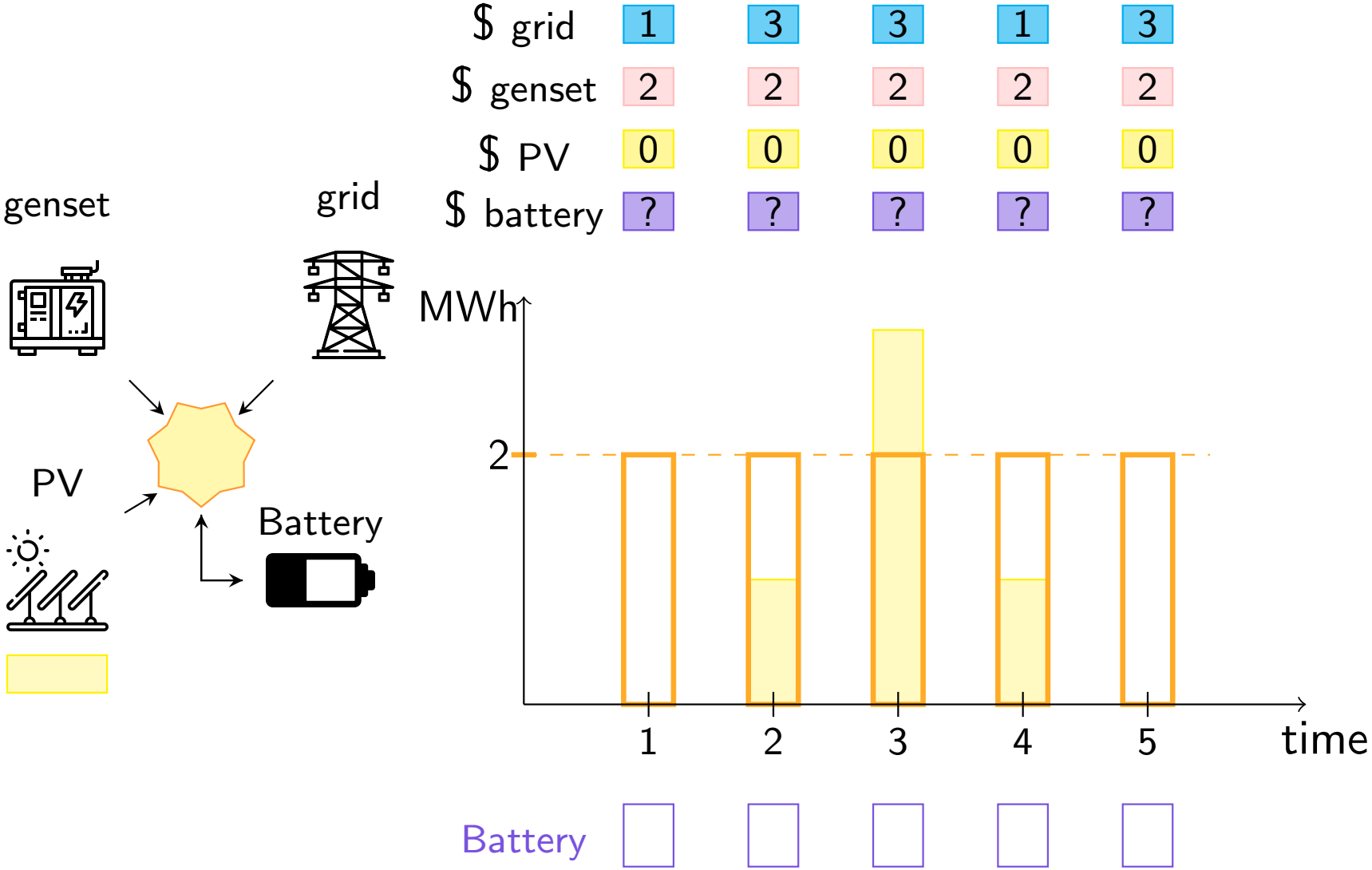


DYNAMIC PROGRAMMING: AN EXAMPLE



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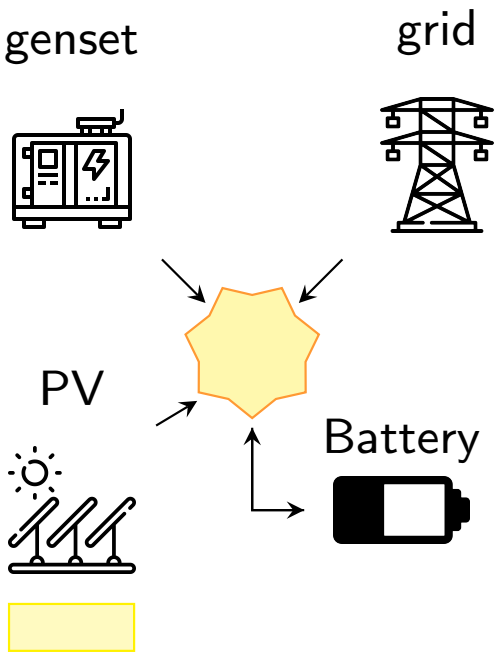
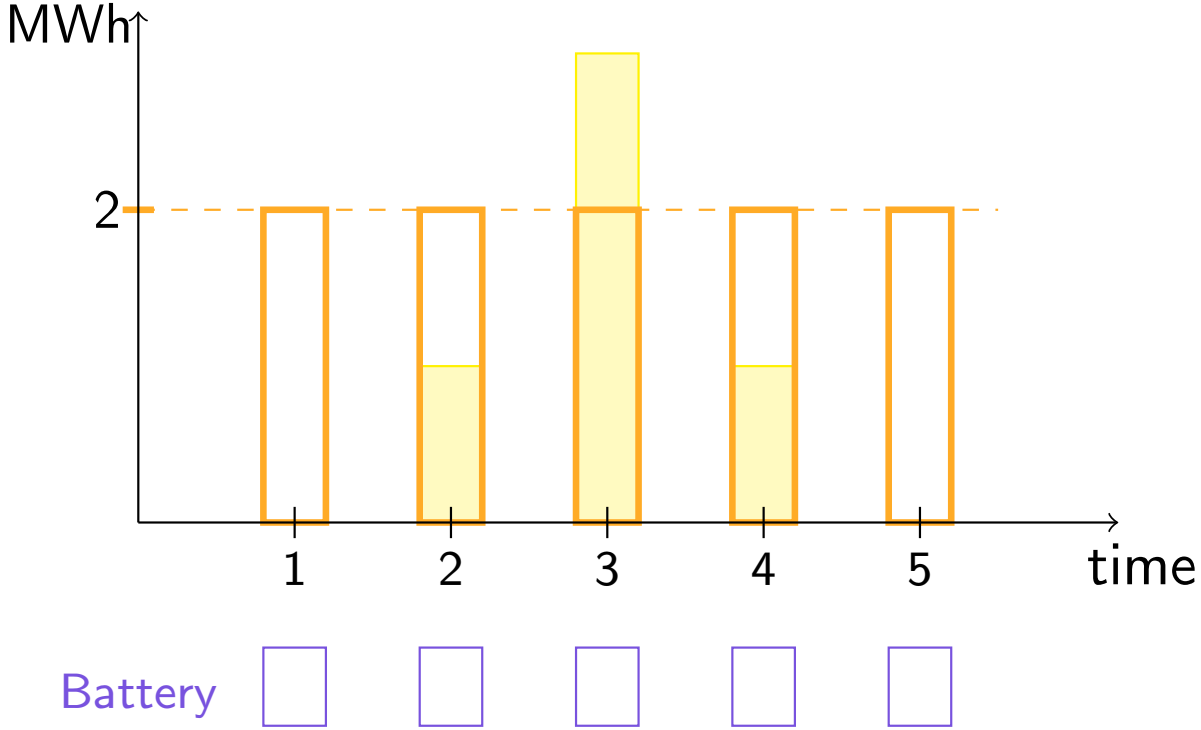
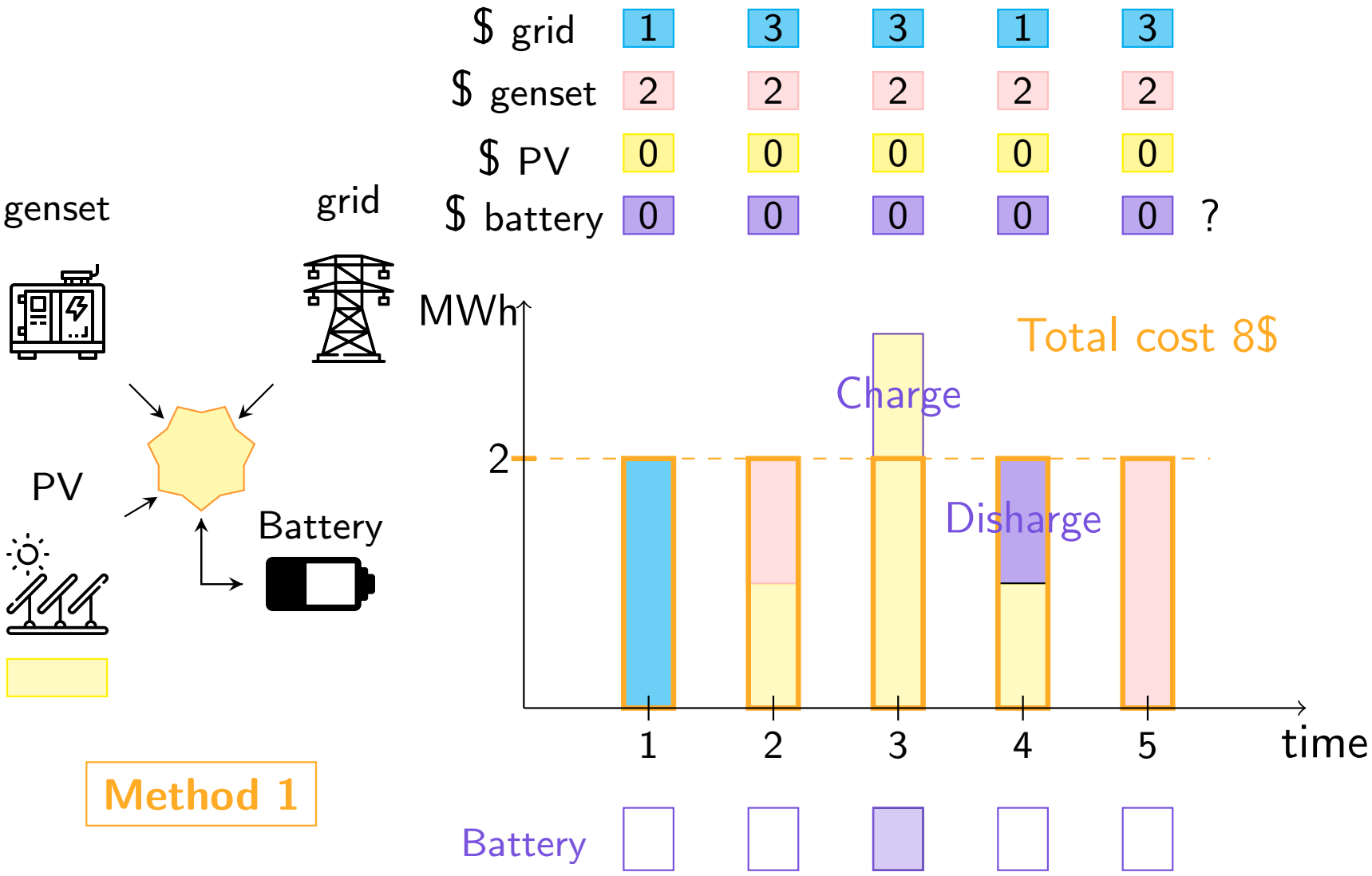


$ grid	1	3	3	1	3	
$ genset	2	2	2	2	2	
$ PV	0	0	0	0	0	
$ battery	0	0	0	0	0	?



Method 1

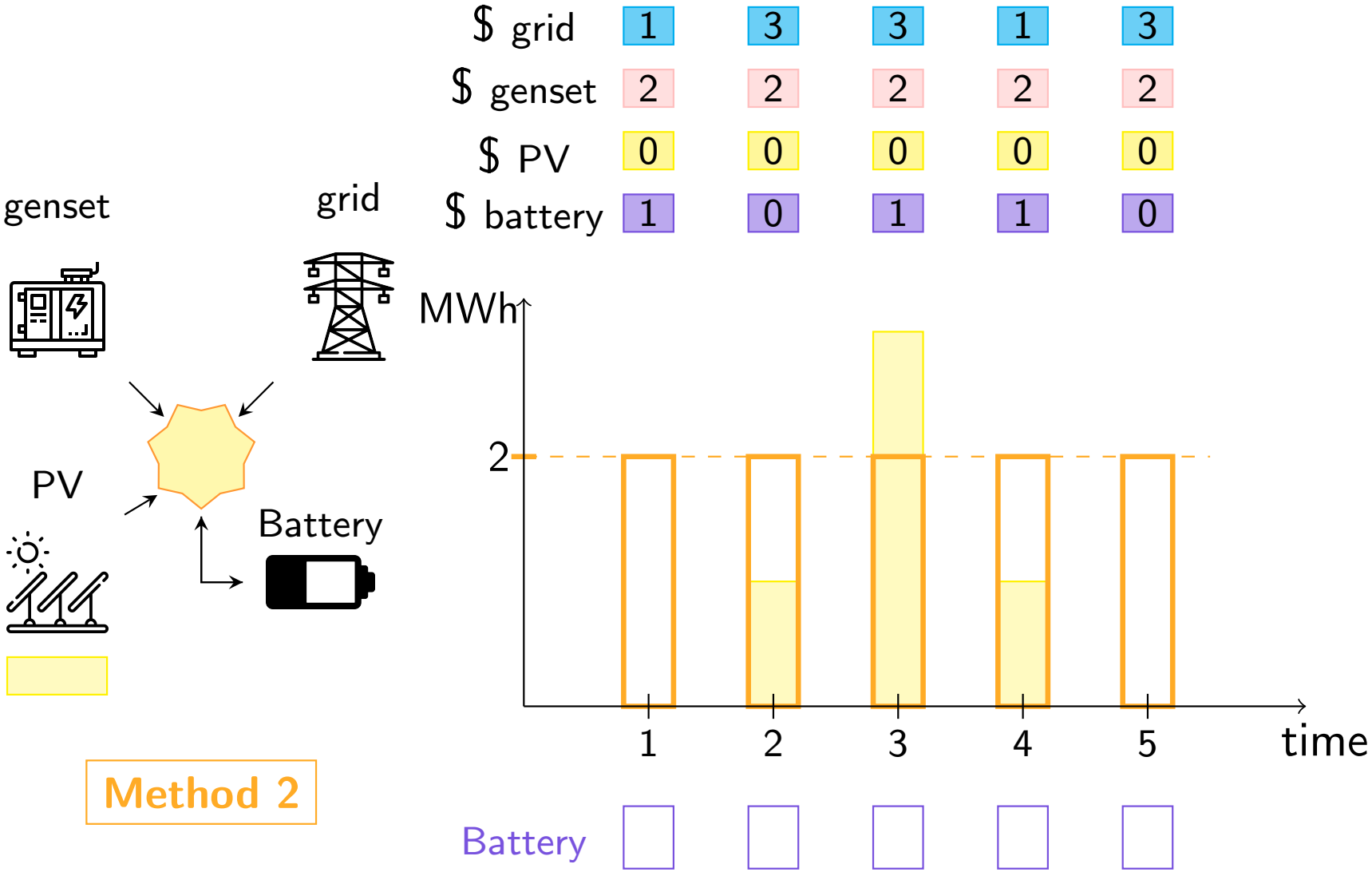
DYNAMIC PROGRAMMING: AN EXAMPLE



Method 1

➥ **The energy stored has a marginal value depending on time.**

DYNAMIC PROGRAMMING: AN EXAMPLE



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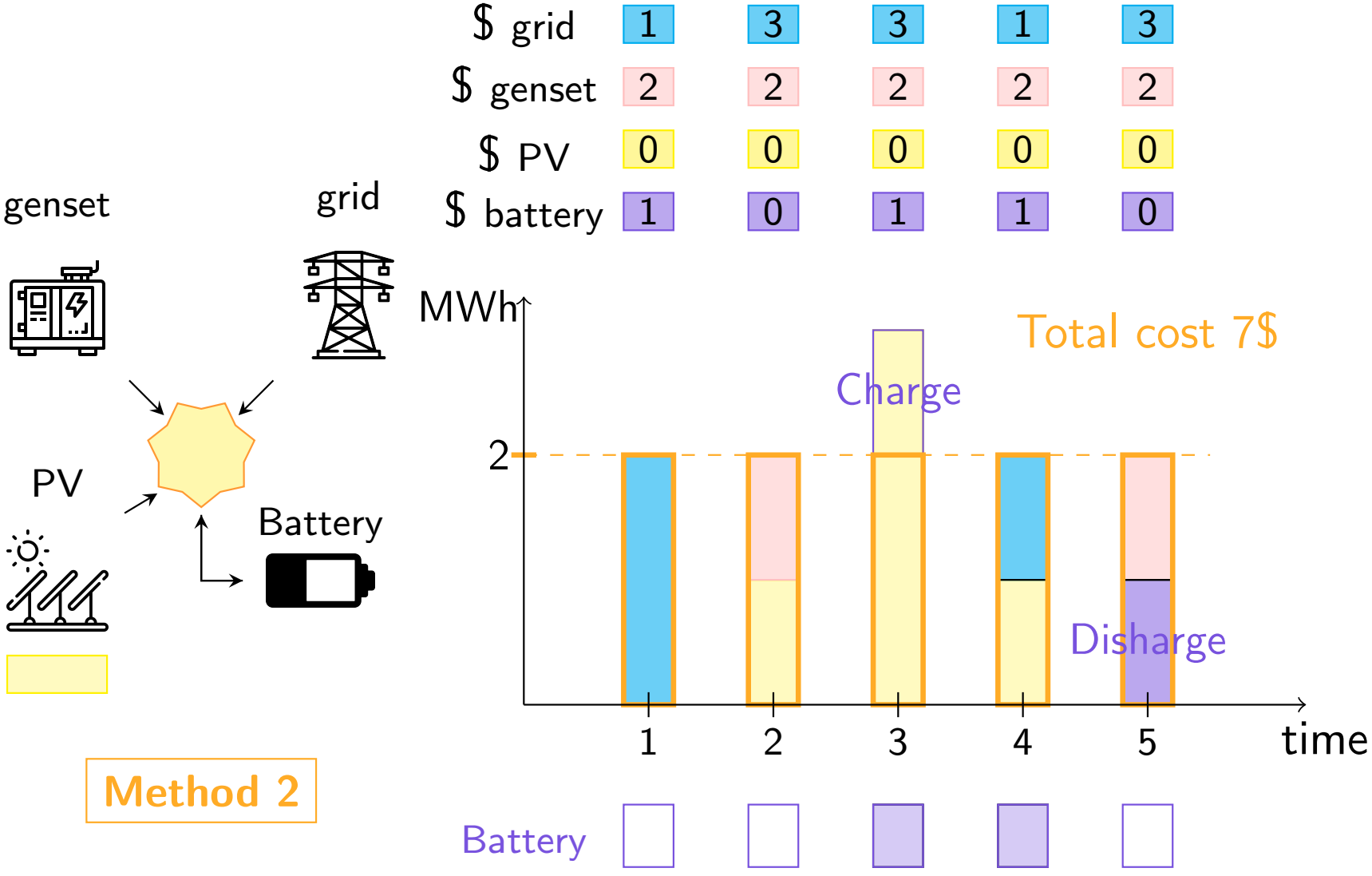
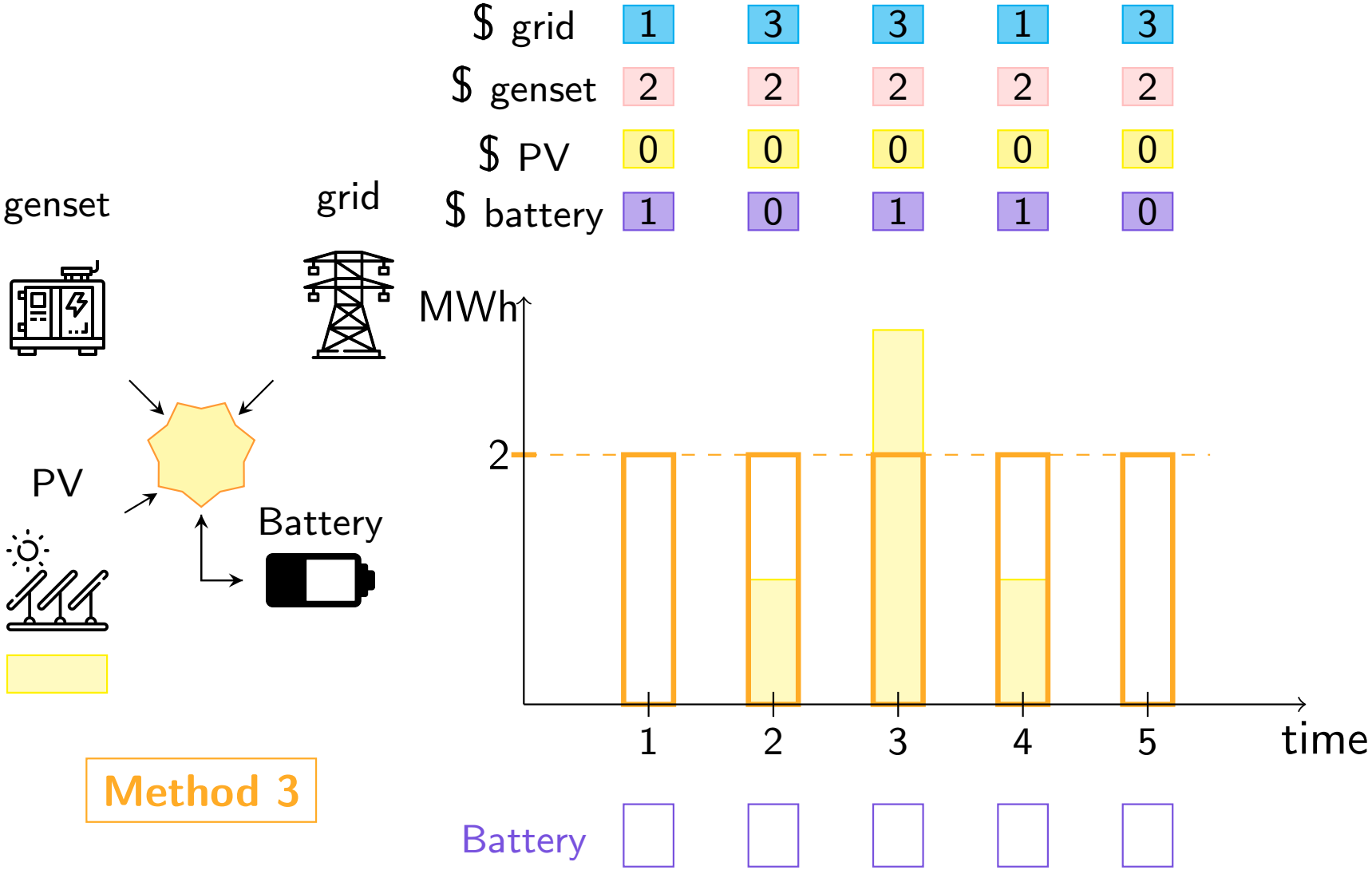
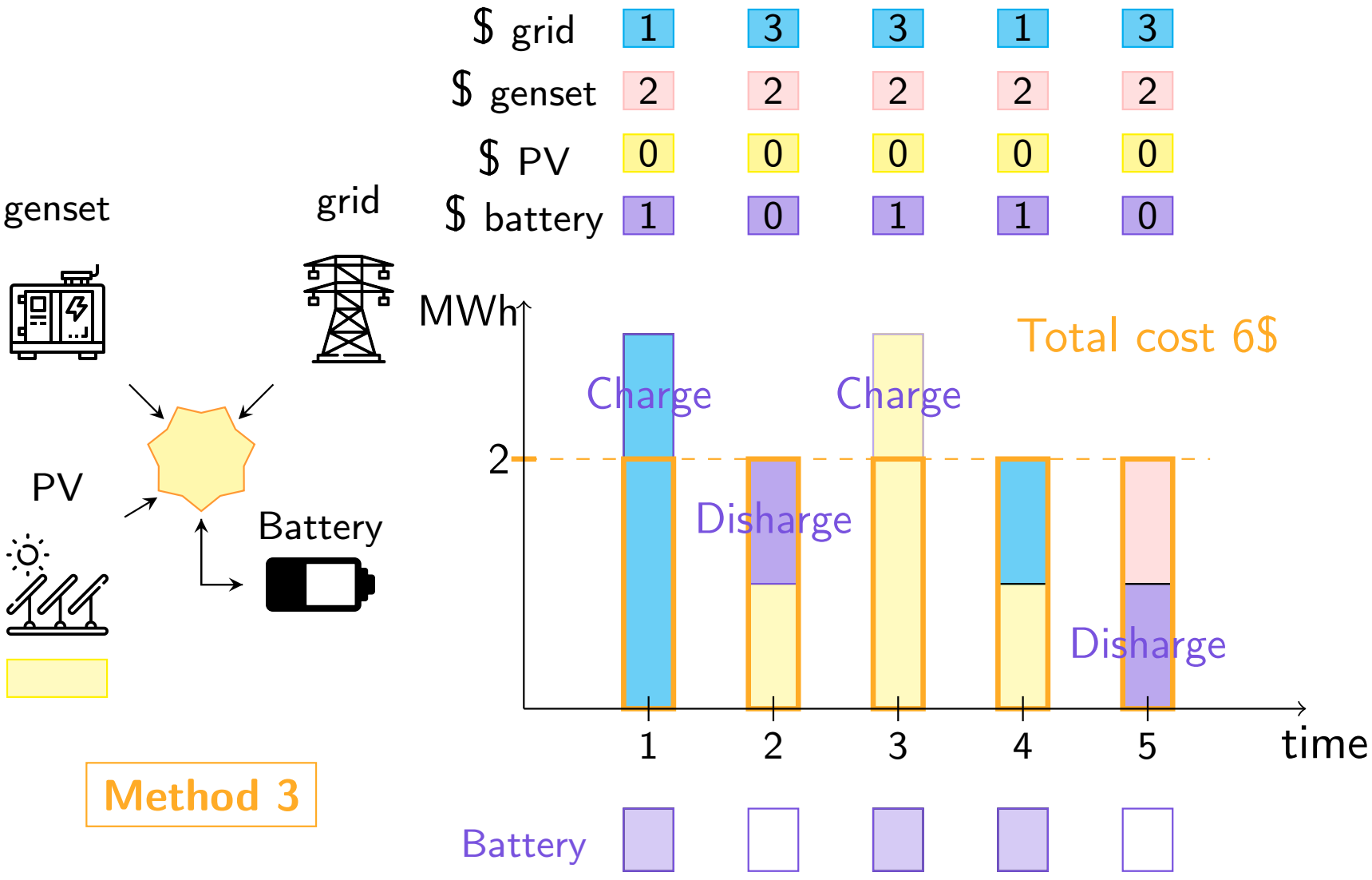


DYNAMIC PROGRAMMING: AN EXAMPLE

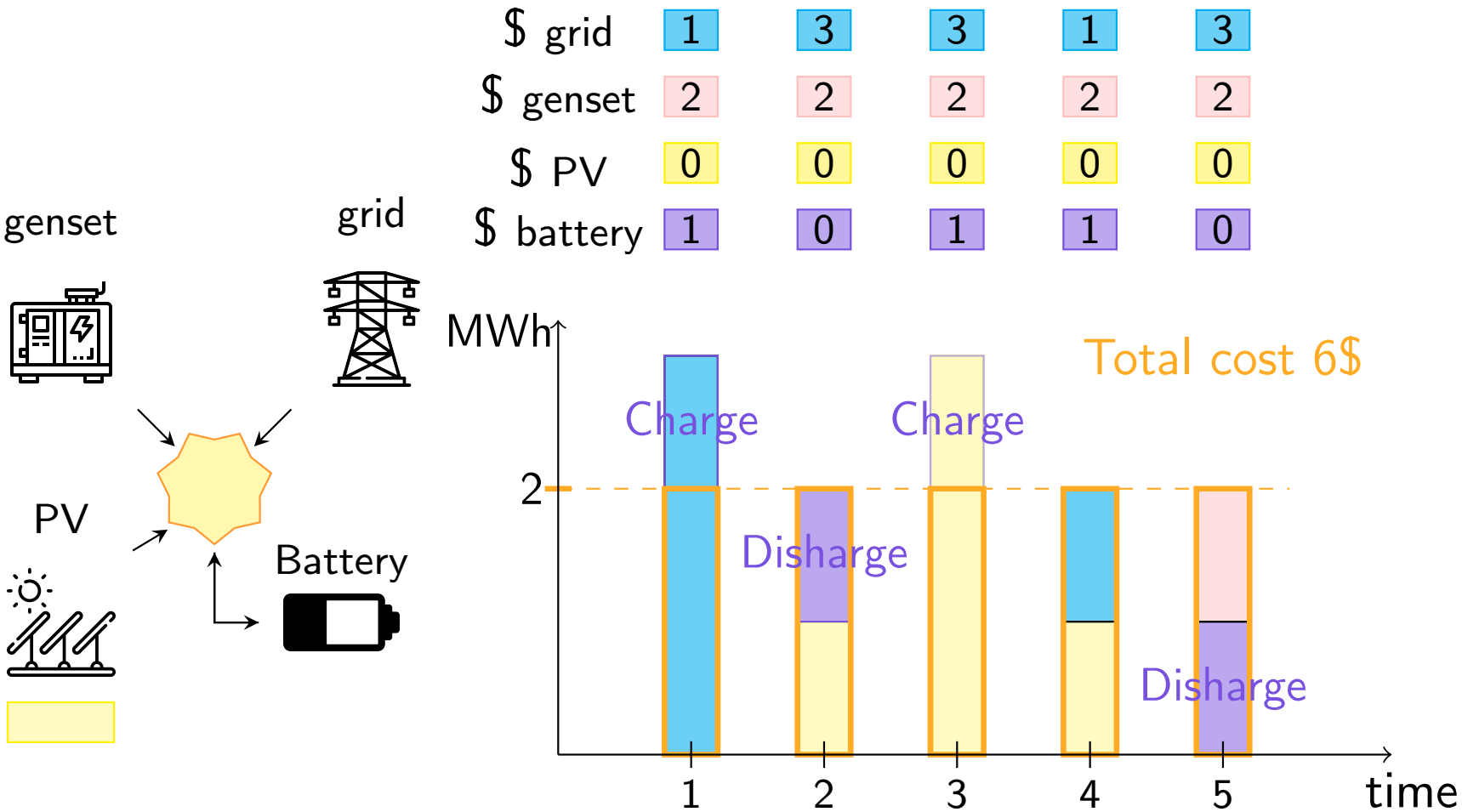


DYNAMIC PROGRAMMING: AN EXAMPLE



Method 3

DYNAMIC PROGRAMMING: AN EXAMPLE



➥ **We want to evaluate the value $V_t(x)$ of x MWh at t.**

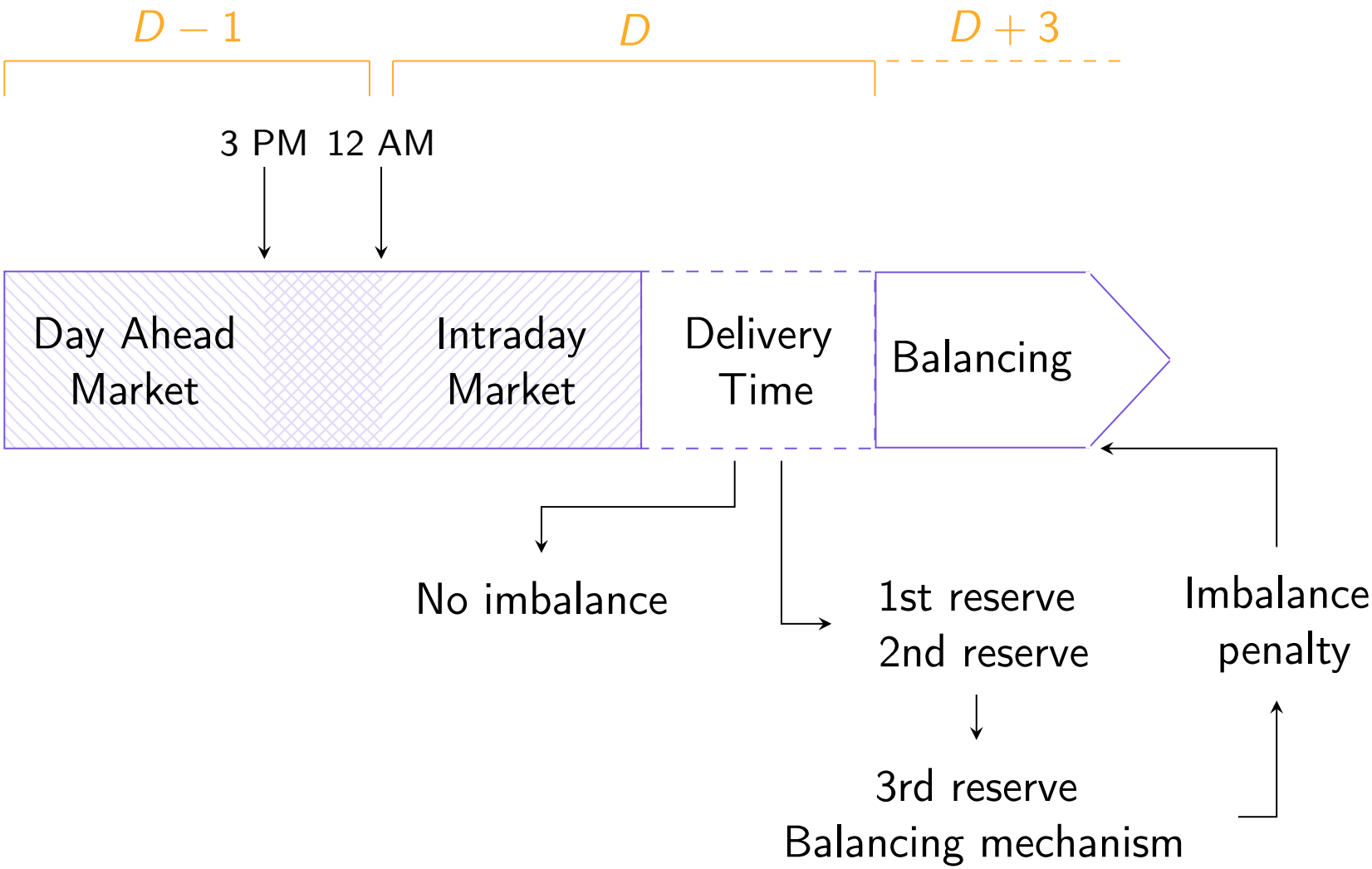
$$V_t(x) = \min_{\text{decisions}} \text{cost of decisions at } t + V_{t+1}(y)$$

$\longrightarrow$ y MWh at $t+1$

PRESENTATION OUTLINE

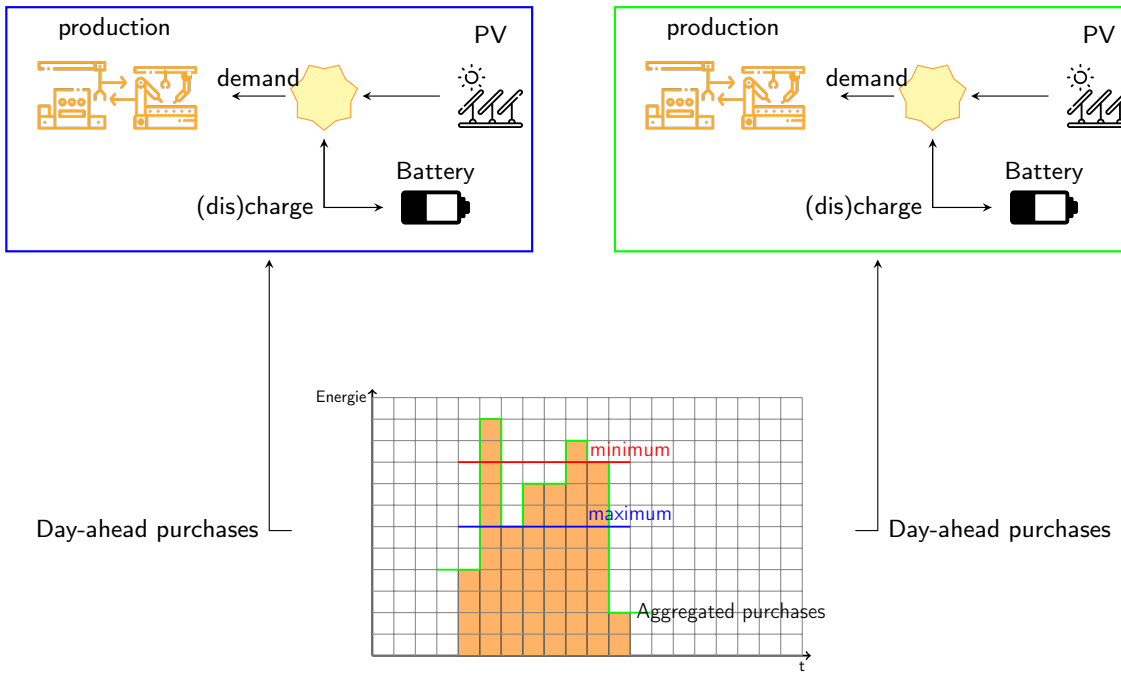
1. Operation Research
2. My PHD Subject
   - PHD Organization
   - General problem
3. Technical Challenges
   - Challenges Overview
   - Binary variables
   - Uncertainties
4. Toy example
5. Energy Markets

ENERGY MARKETS



CONTEXT

Interest: day ahead cheaper prices, reserve participation . . .



Problem: too small to enter those markets.

➥ aggregate multiple industrial sites (increase model complexity)

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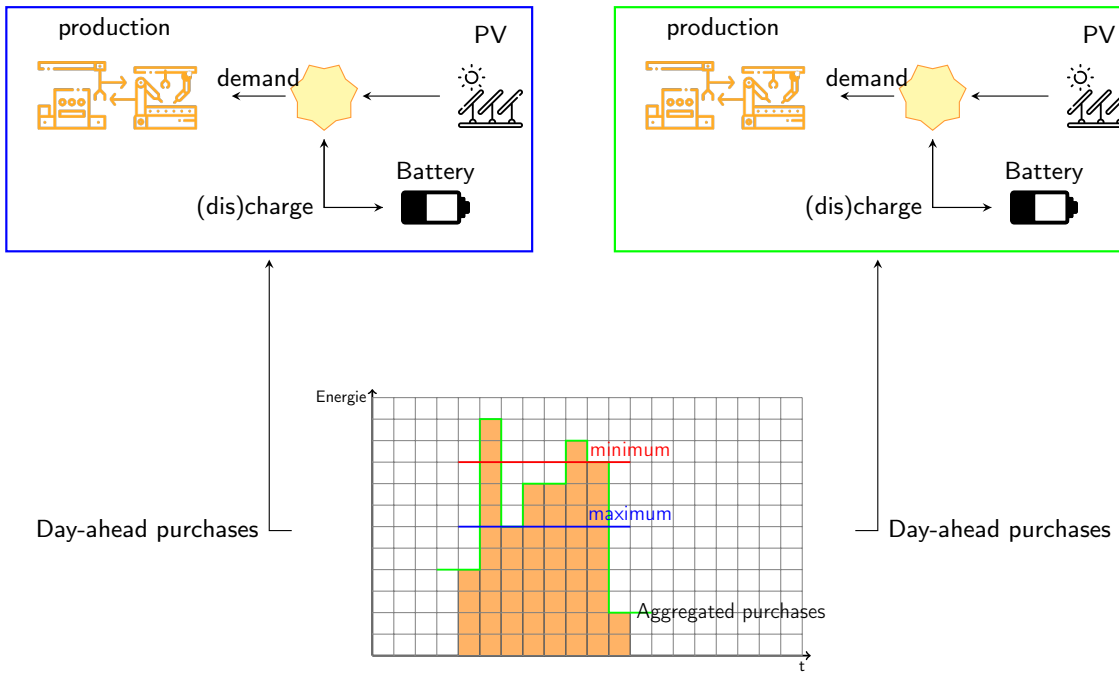

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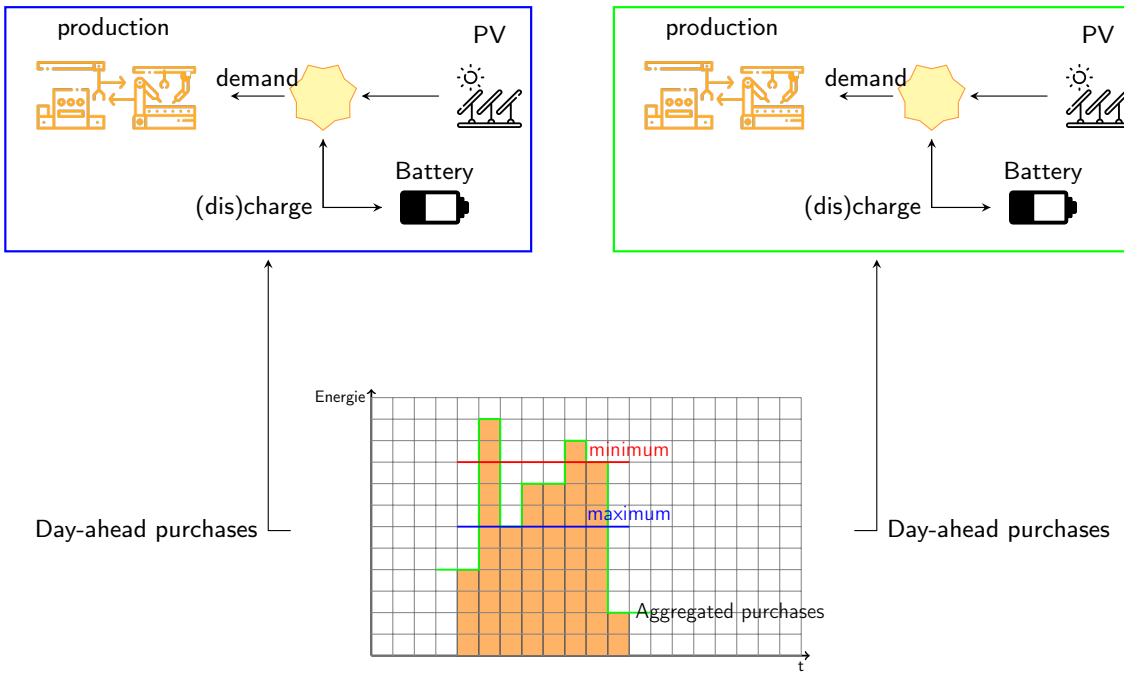

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FAIRNESS ISSUES

1. An aggregator groups different clients to enter the market and buy energy.

2. The energy cost of the group is better than the sum of each individual costs.

➥ How to share the benefit?

➥ How to share the energy?

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IN A NUTSHELL

- We want to evaluate opportunity in investing in EnR + EMS.
- To do so we need to find optimal control strategies (evaluating value of energy stored).
- Technological roadblock: dealing with binary constraints and uncertainties.
- To access market, discuss aggregation opportunities.

We need you for use case and data for:

1. Counter, or minimal up / down time
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