Energy optimization in drinking water distribution network

DAVID ABERT
ALBA CABRERA
HÈCTOR MONCLÚS

lequia UdG
ECO-INNOVATIVE ENVIRONMENTAL SOLUTIONS

INTRODUCTION

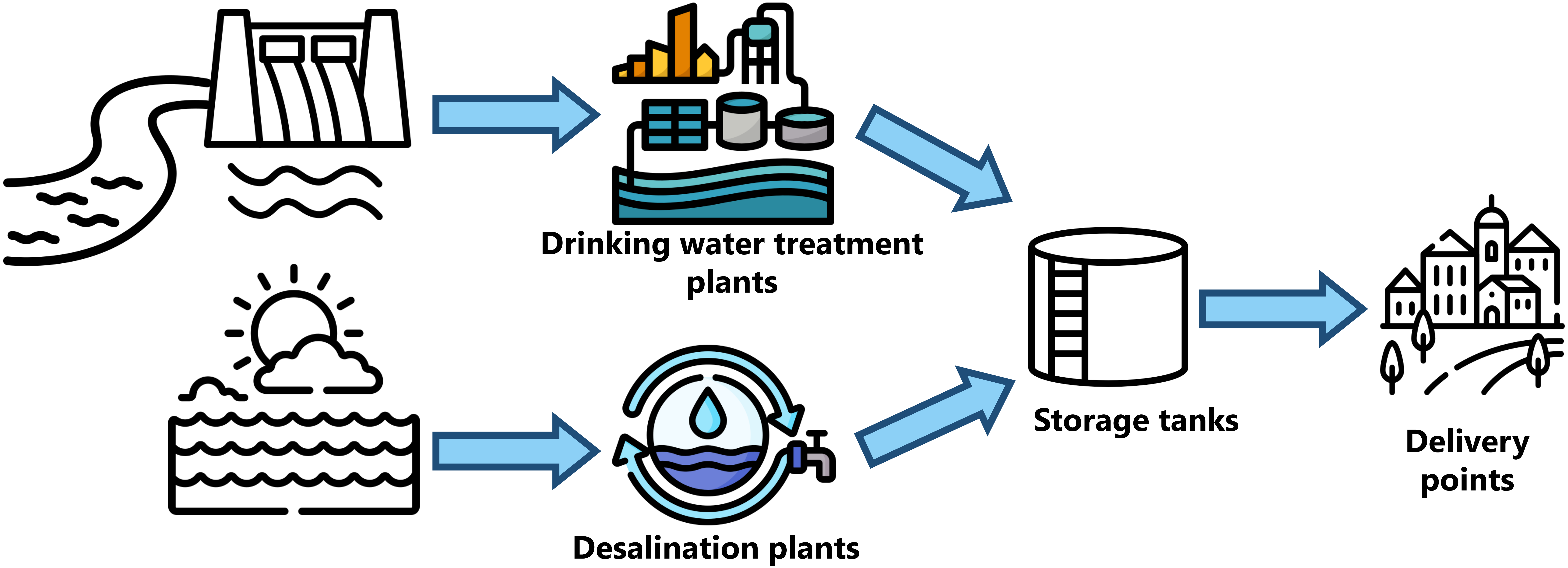
STUDY CASE

SINGLE TANK EXAMPLE

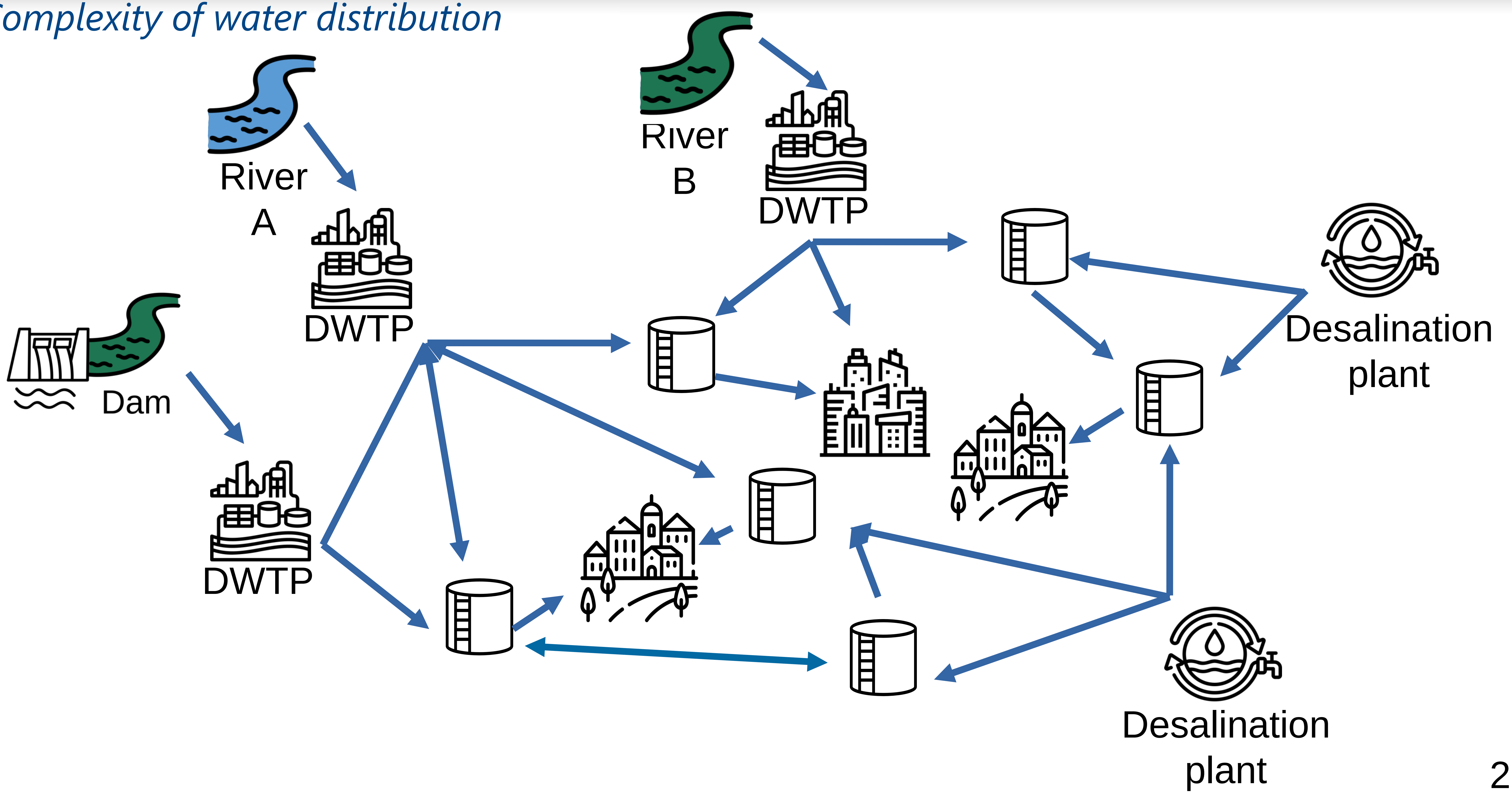
PROBLEM

HYPOTHESIS AND OBJECTIVES

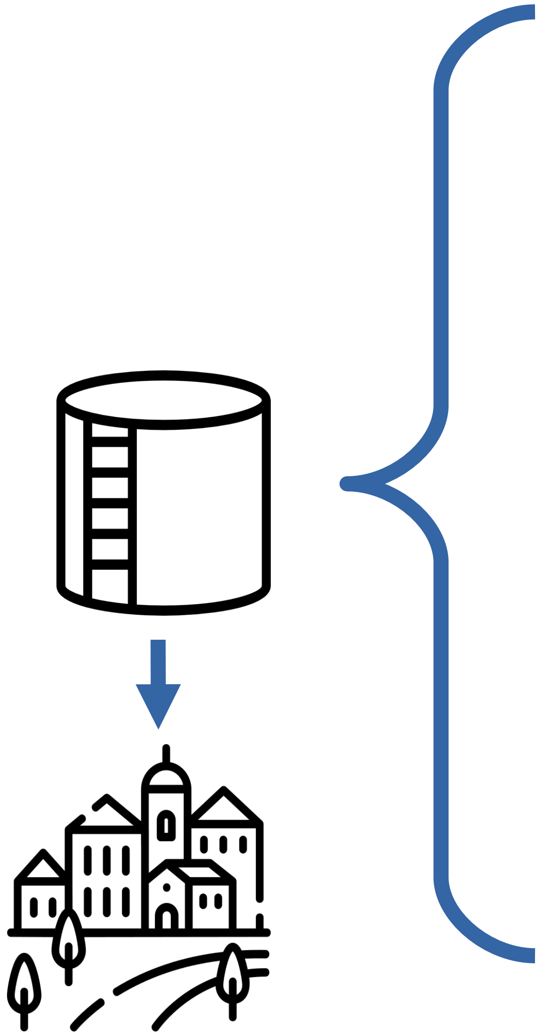
From catchment to tap



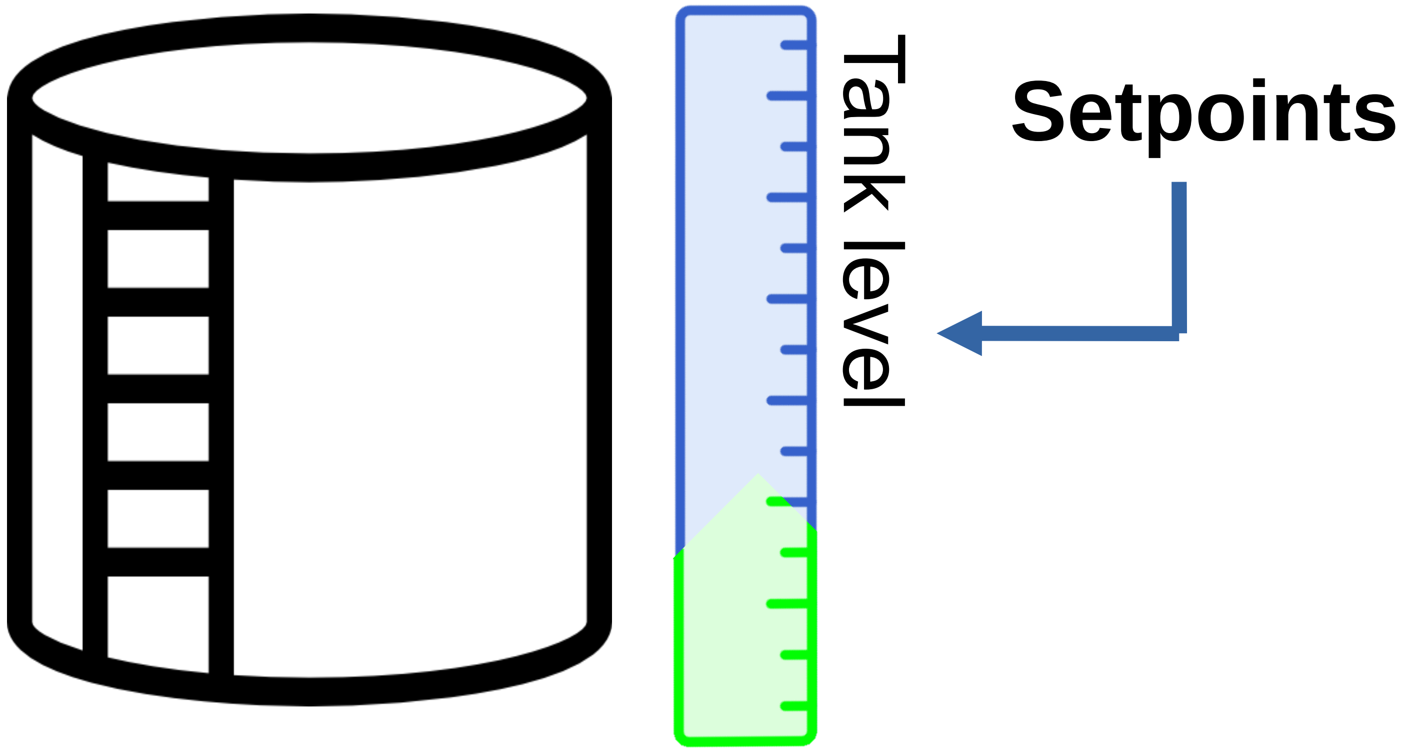
Complexity of water distribution



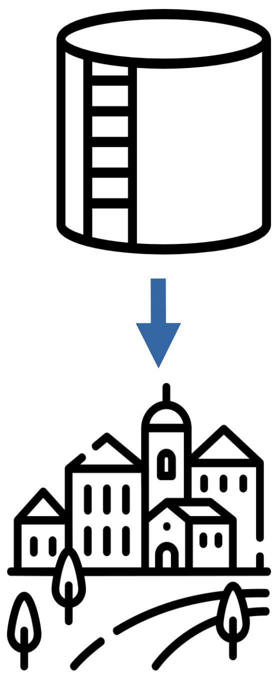
Tank management



Autonomy management

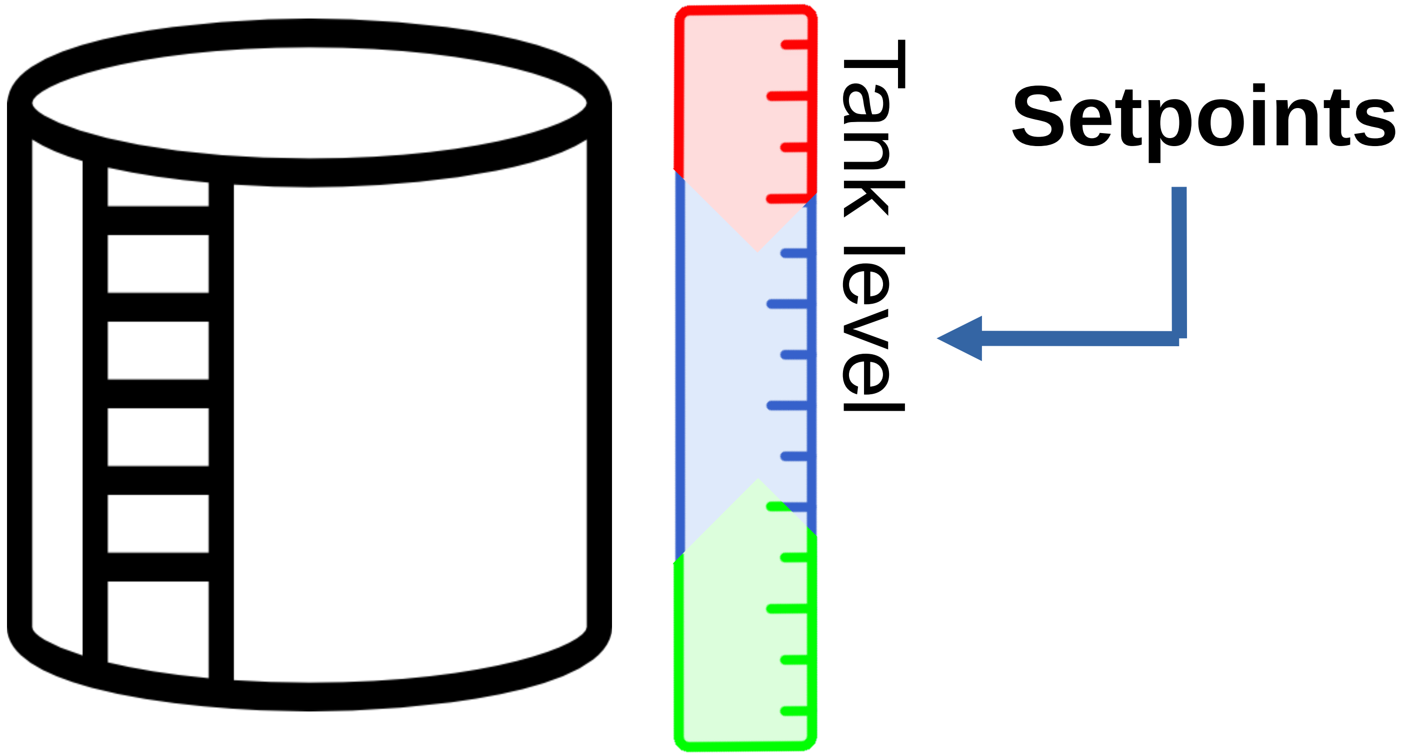


Tank management



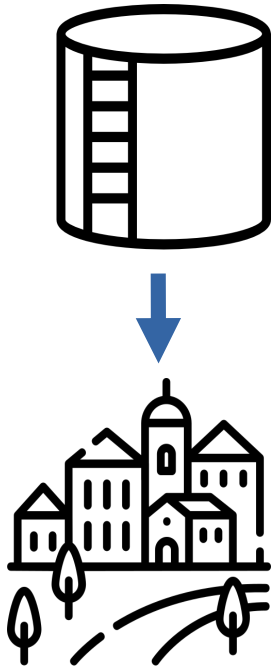
Autonomy management

Quality management ⚠



de Castro Medeiros et al., (2019). Toxicological aspects of trihalomethanes: A systematic review

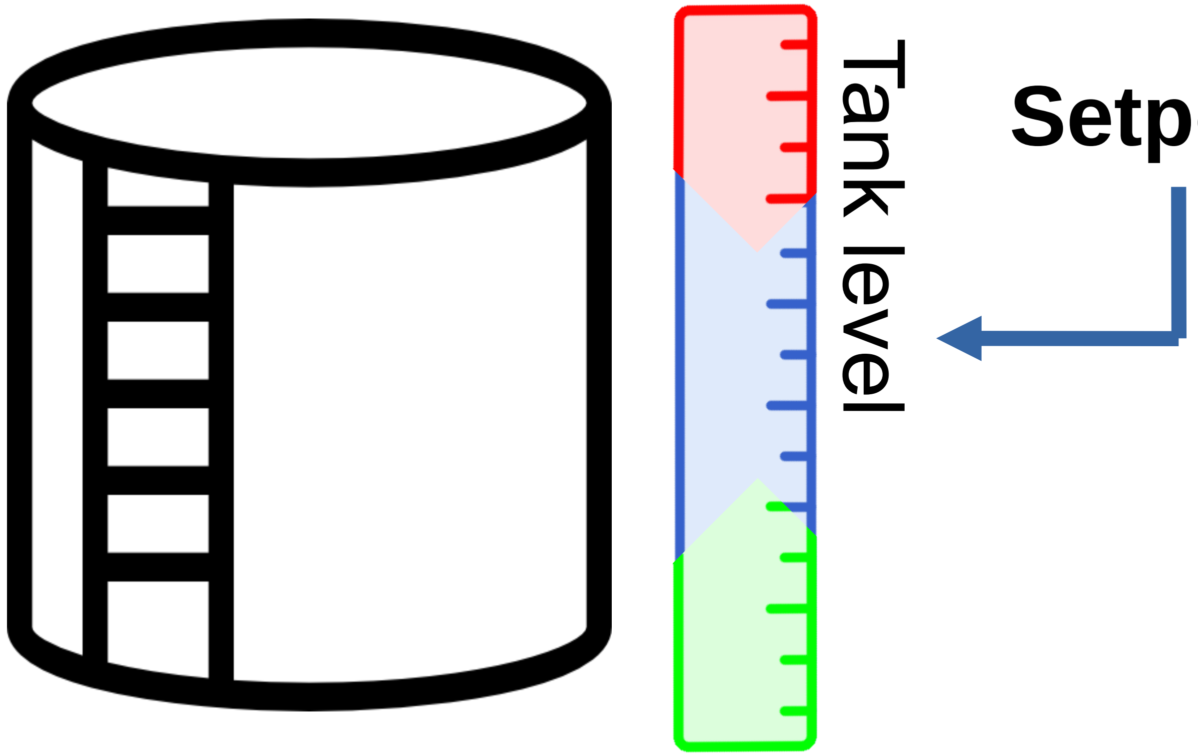
Tank management



Autonomy management

Quality management ⚠

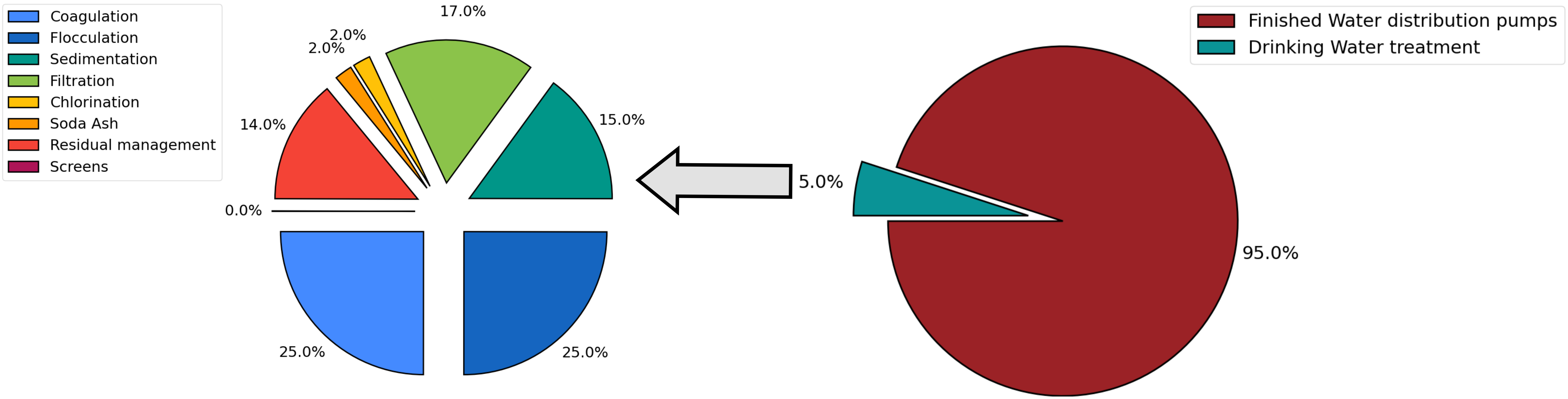
Energy management



de Castro Medeiros et al., (2019). Toxicological aspects of trihalomethanes: A systematic review

Energy costs

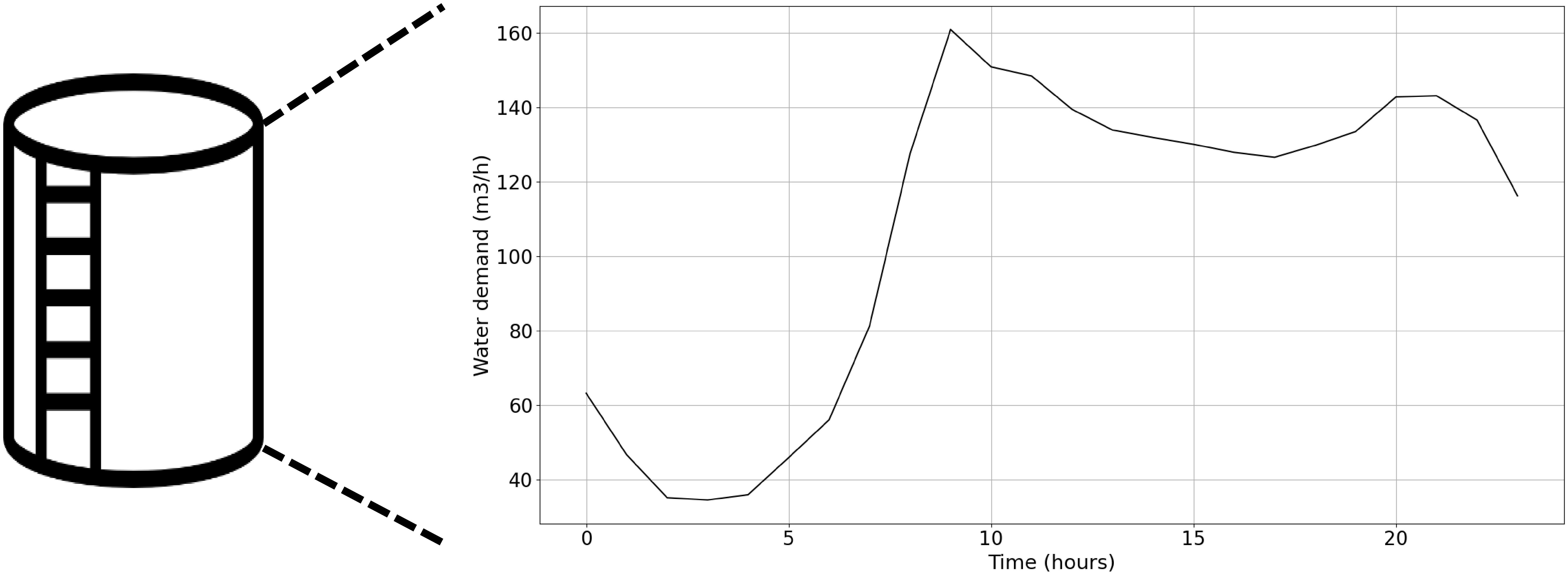
- Water treatment and distribution represent between 4 and 10% of all consumed energy



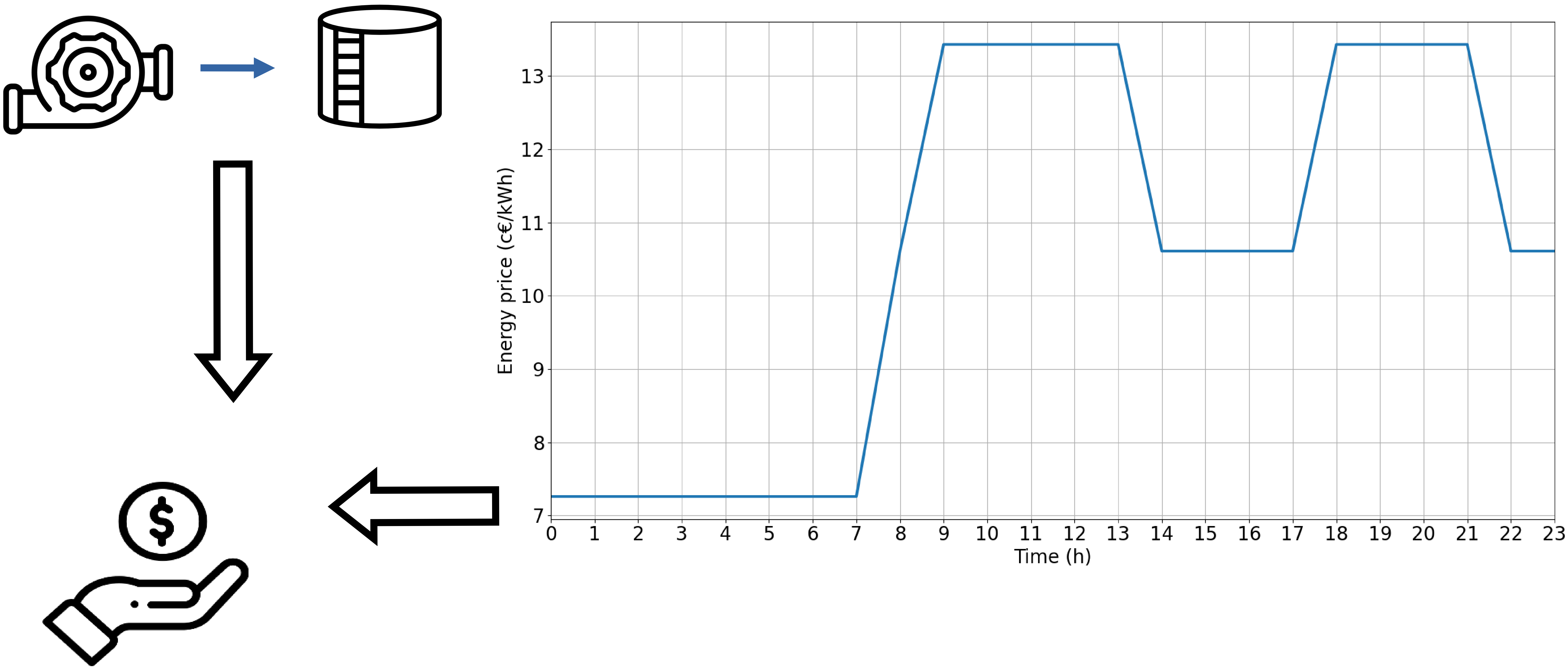
Bukhary, S., Batista, J., & Ahmad, S. (2020). Design Aspects, Energy Consumption Evaluation, and Offset for Drinking Water Treatment Operation.

Study case

Daily water demand example

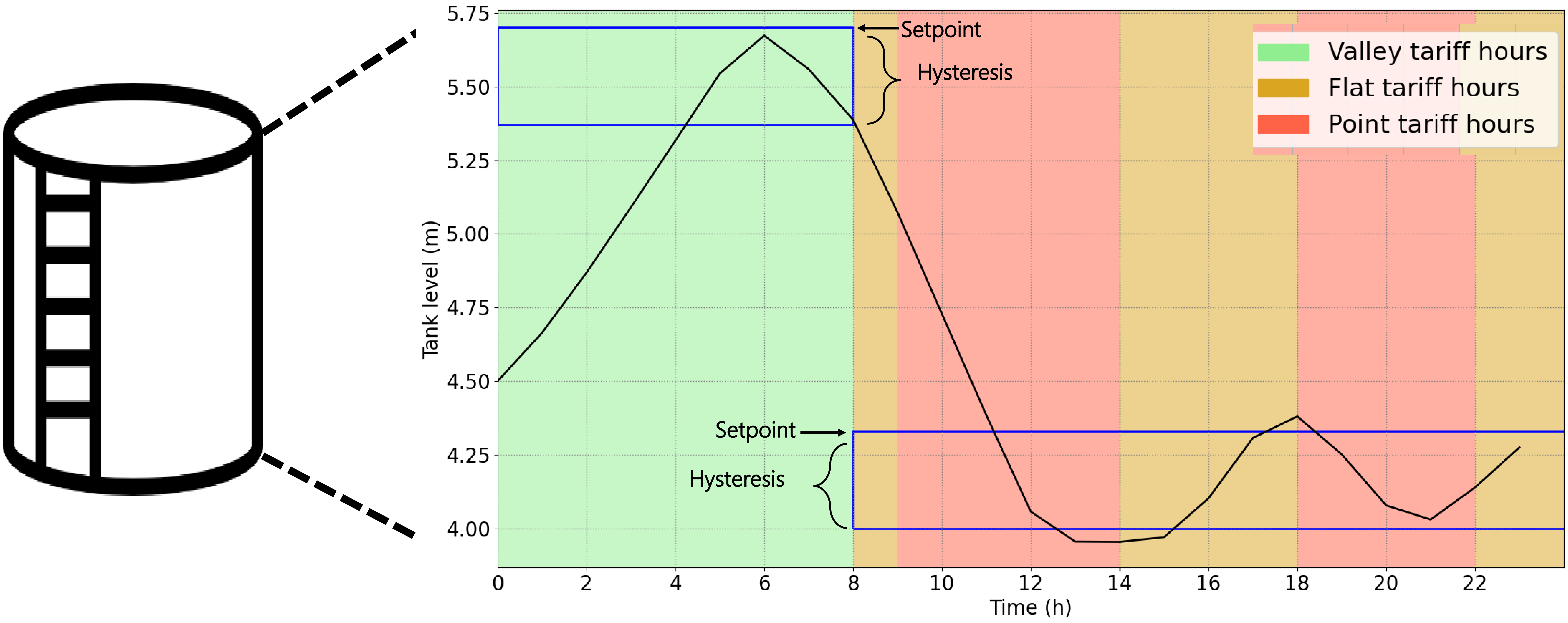


Energy costs



Study case

Green hours: 5.7m || Orange hours: 4.3m || Red hours: 4.3m || Hysteresis: 0.3m



INTRODUCTION

STUDY CASE

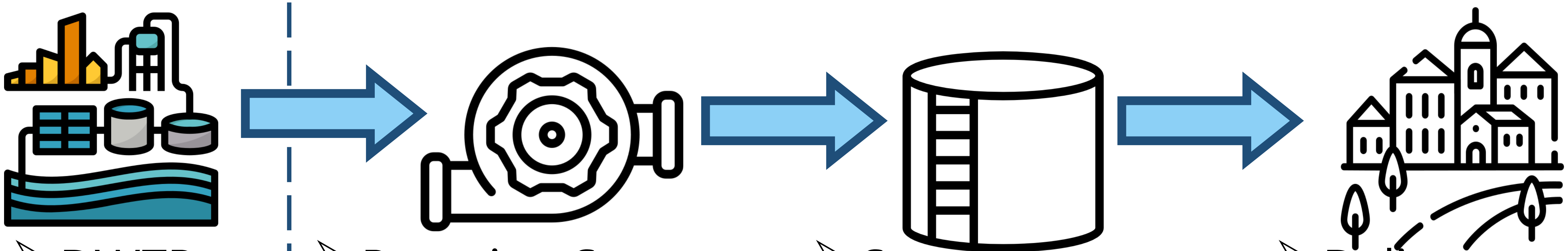
SINGLE TANK EXAMPLE

PROBLEM

HYPOTHESIS AND OBJECTIVES

Single-tank optimization example

Water management simulation



- DWTP
- Pumping System
- Storage system
- Delivery points

- Pump flow
- Pump kWh consumption
- Energy tariff
- Historical pump data

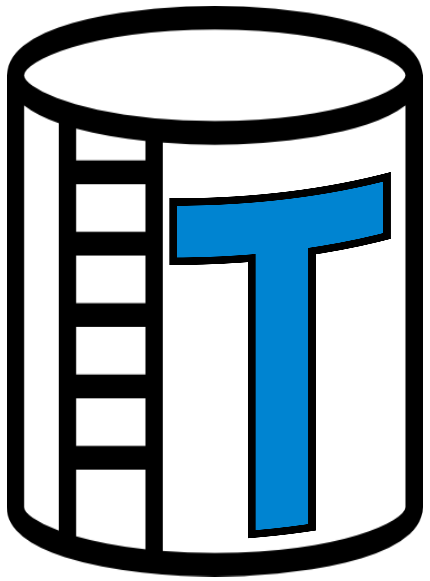
- Tank capacity
- Tank max level
- Tank min level
- Tank setpoints
- Tank hysteresis
- Historical level data

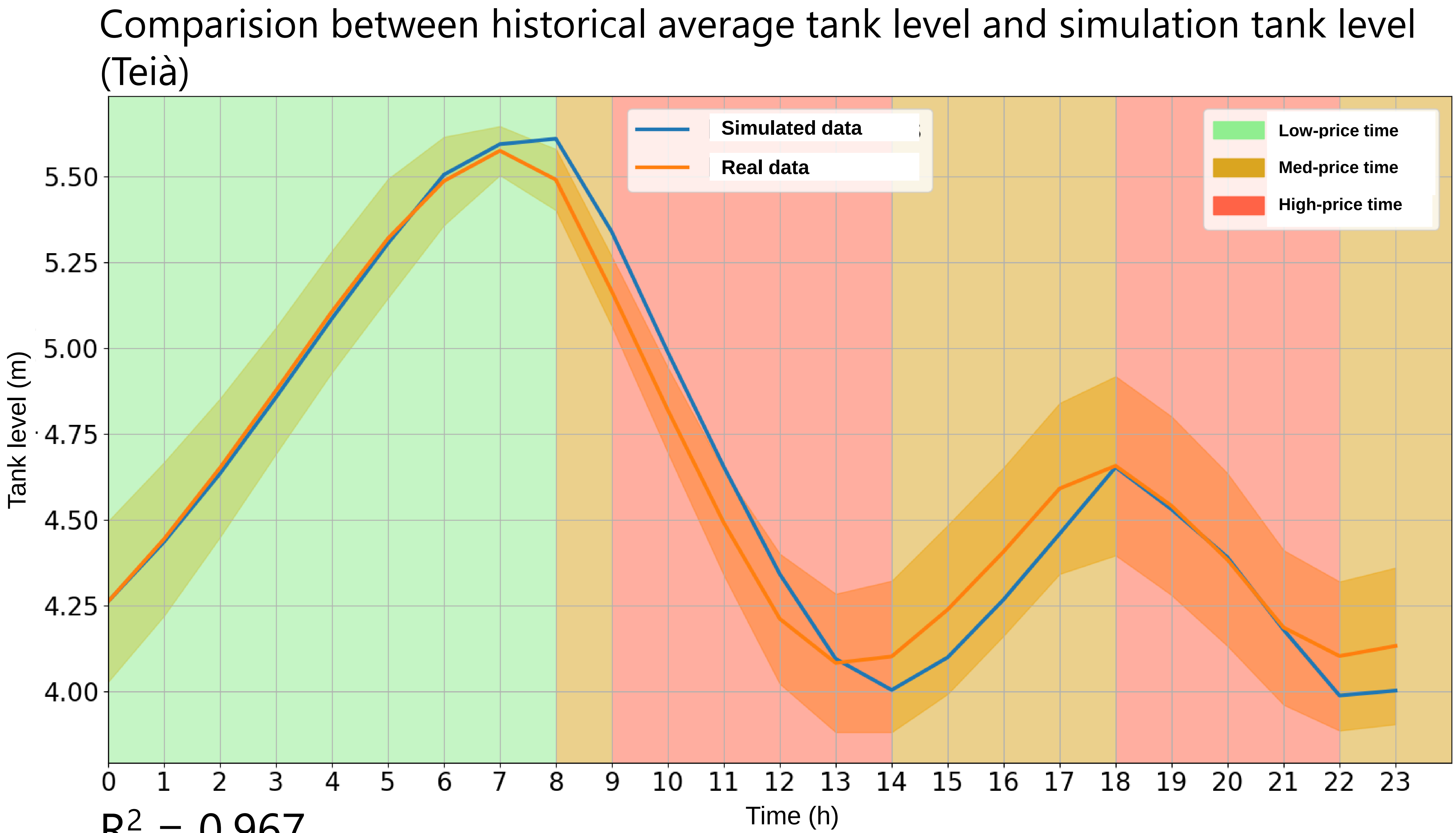
- Average demand curve

- Simulations algorithm

Single-tank optimization example

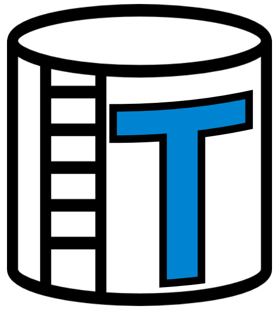
Hydric management simulation





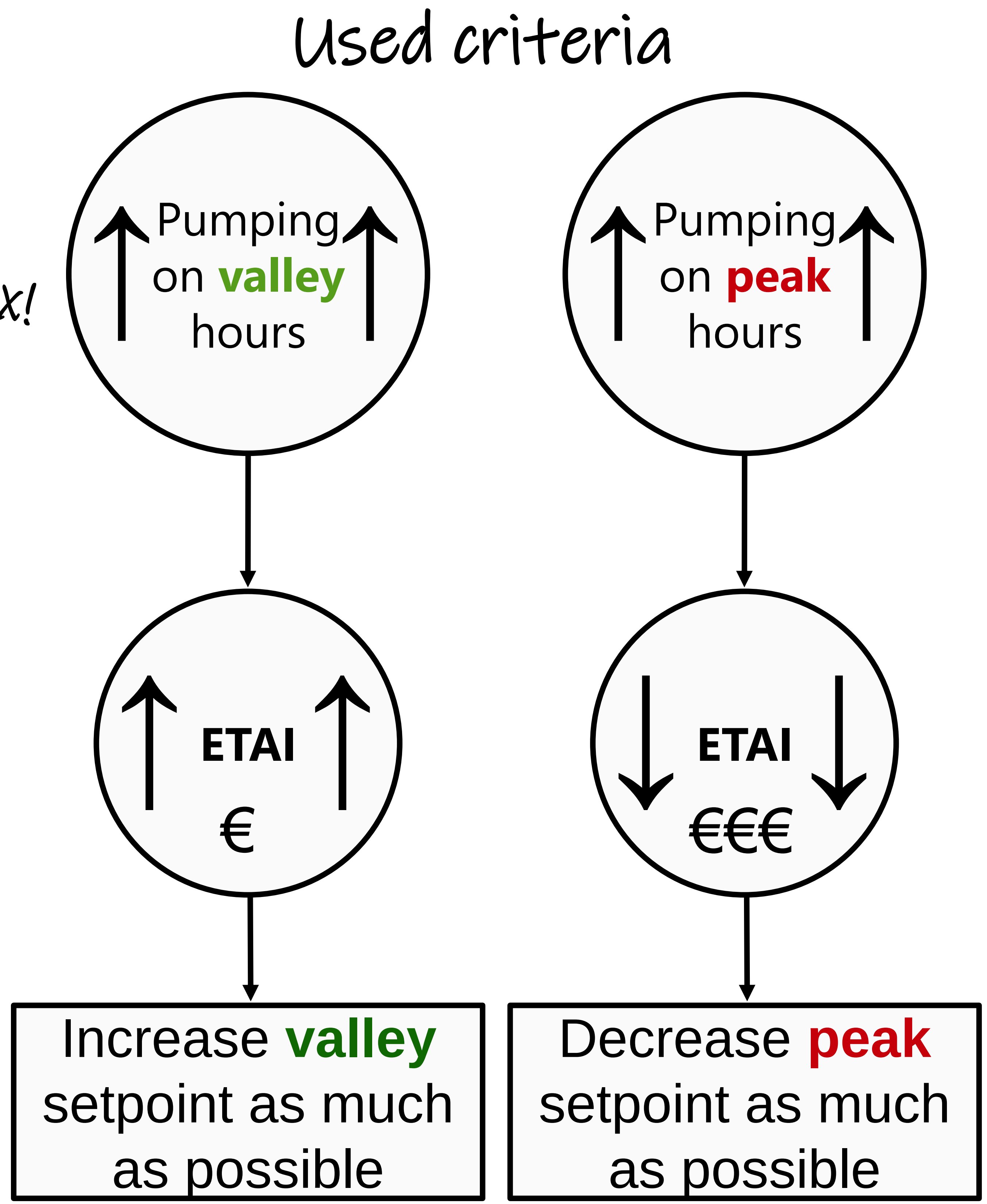
$R^2 = 0.967$

Setpoint optimization



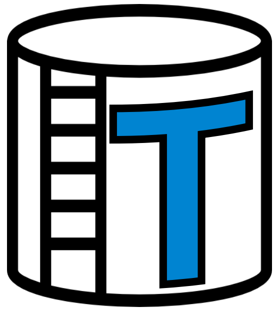
Economic pumping index!

$$\text{INDEX} = \frac{(-10)\cdot\sum\left(kWh_{\text{High-\$}}\right) + 10\cdot\sum\left(kWh_{\text{Low \$}}\right)}{\sum\left(kWh_{totals}\right)}\cdot\frac{1}{2}+0.5$$

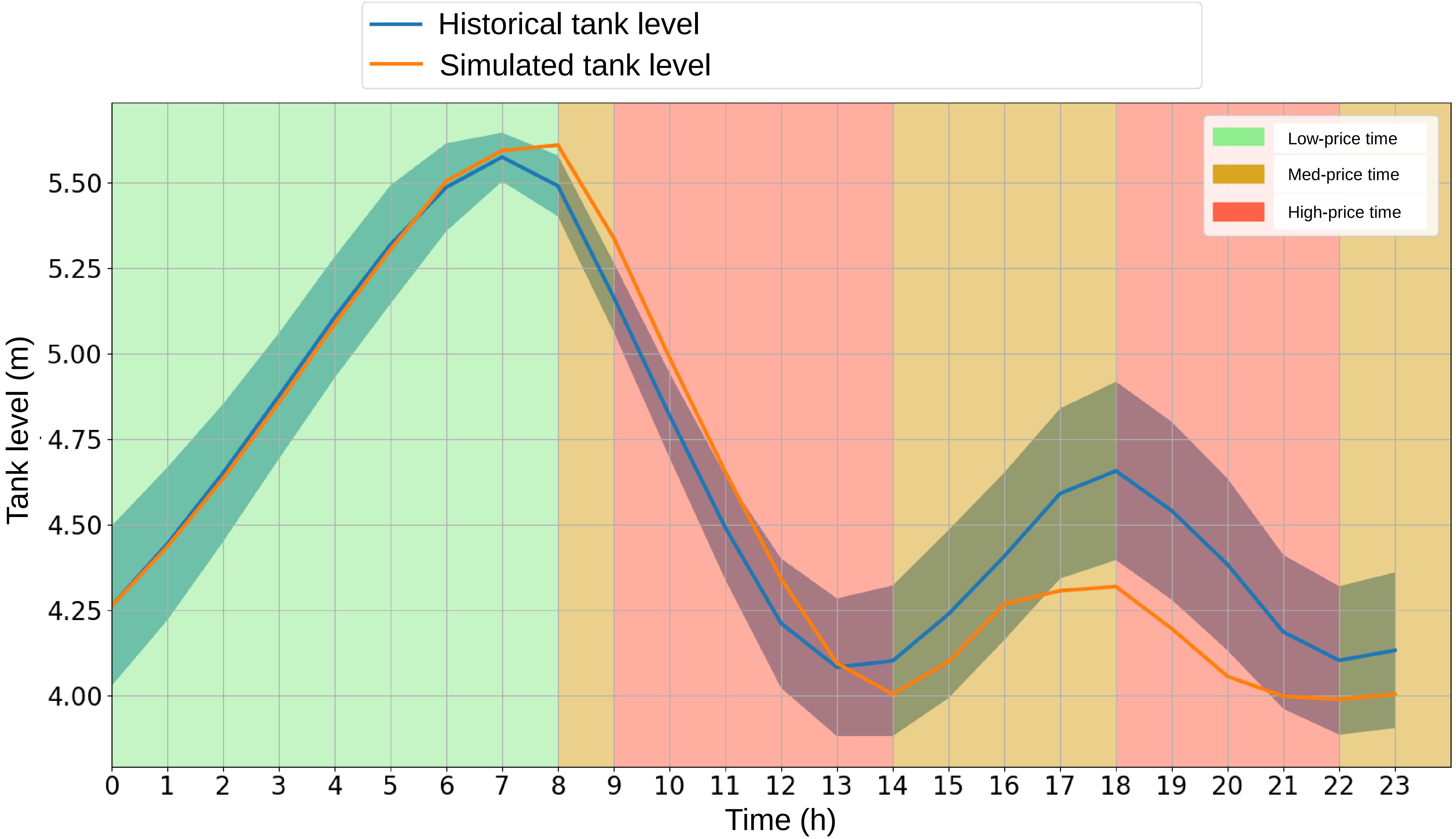


Single-tank optimization example

Comparison of the proposal with the current management

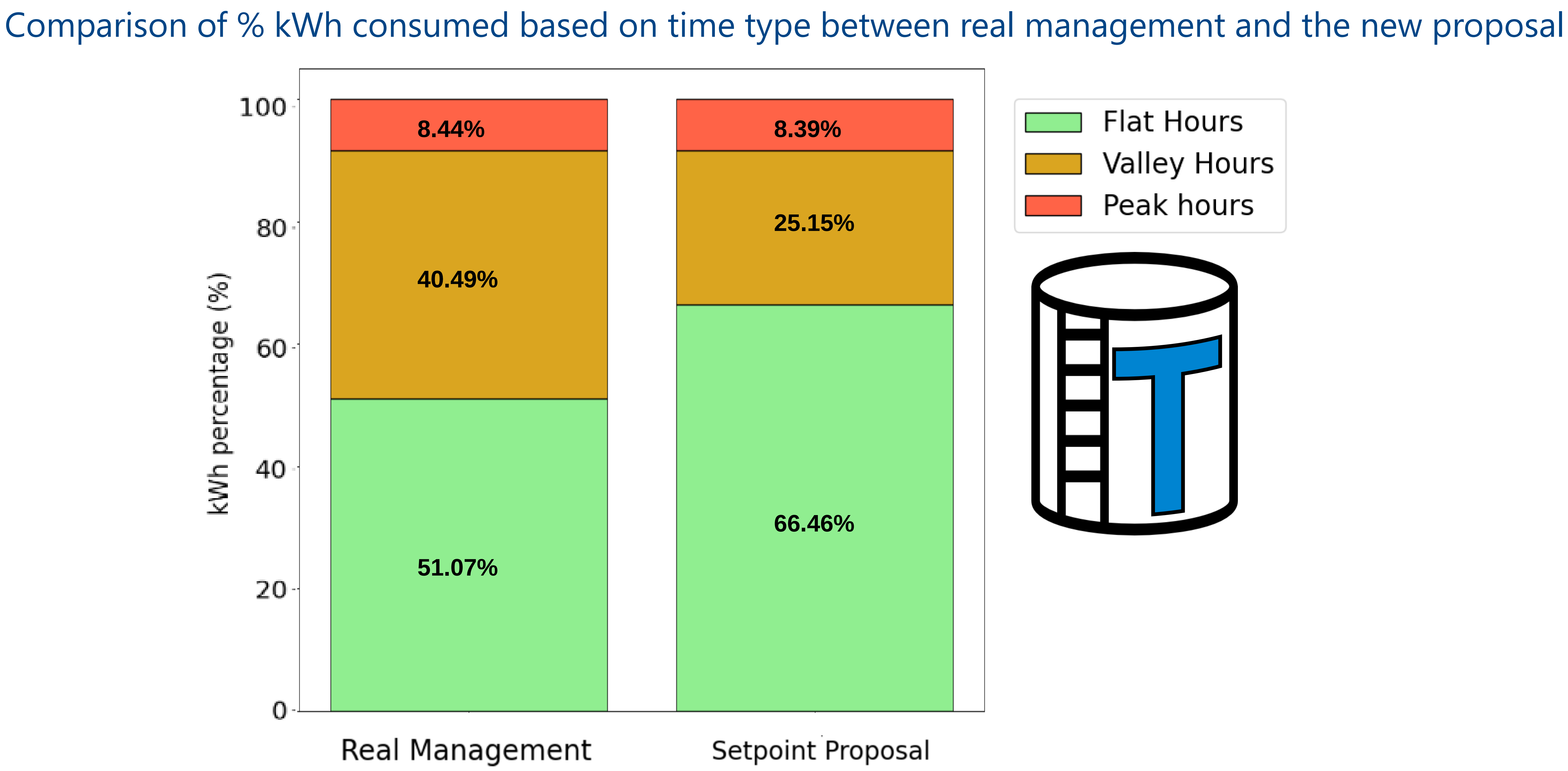


Teià		
Setpoints	**Current management**	**Management proposal**
Cheap hours	5.7 m	5.7 m
Medium hours	5 m	4.3 m
Expensive hours	4.3 m	4.3 m
PUMPING INDEX	**8.32**	**8.62**



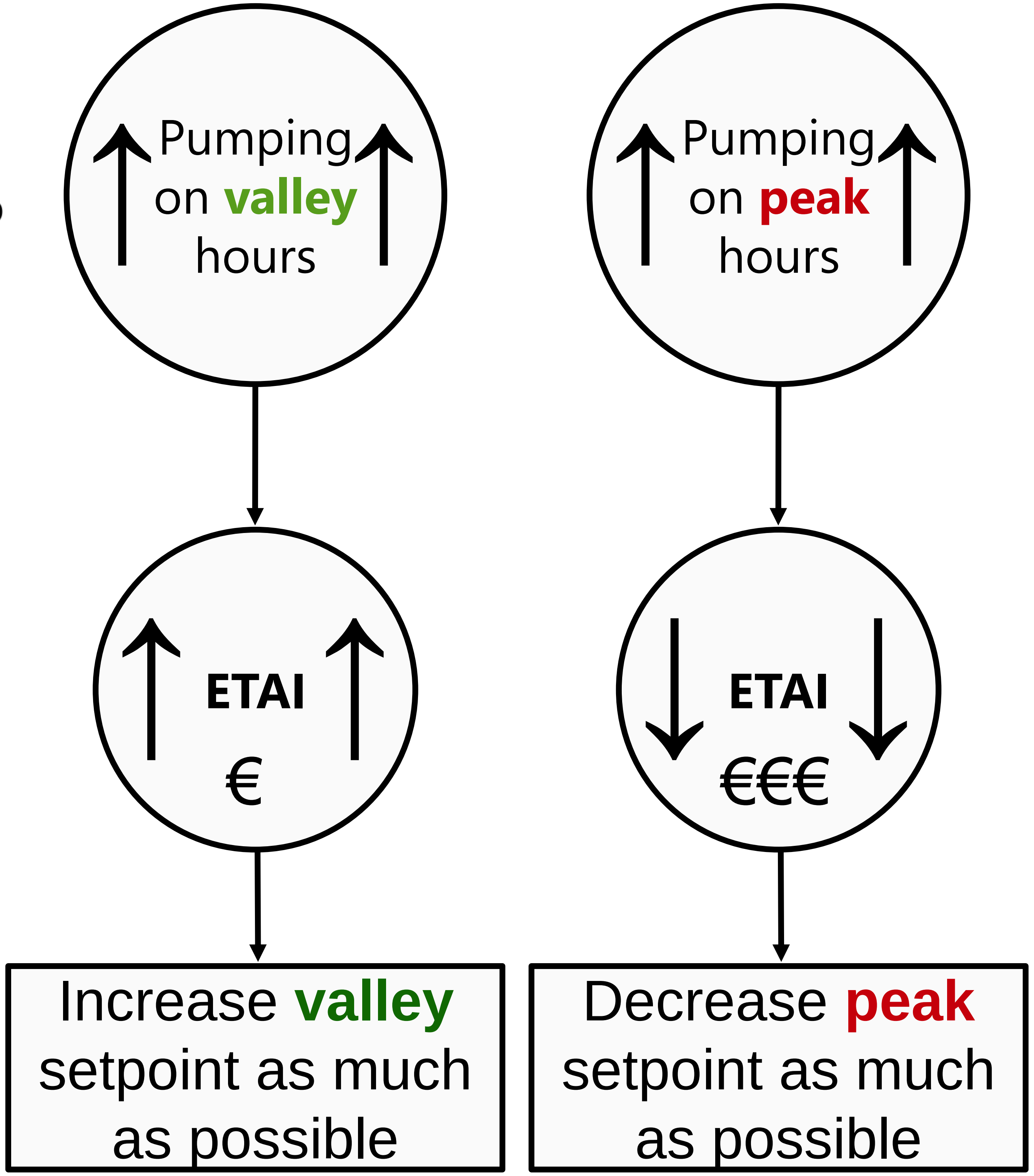
Comparison between historical average tank level and tank level based on the proposed setpoints

Comparison of the proposal with the current management



Setpoint optimization

$$ETAI = \frac{(-10)\cdot\sum(kWh_{punta}) + 10\cdot\sum(kWh_{vall})}{\sum(kWh_{totals})}\cdot\frac{1}{2}+0.5$$

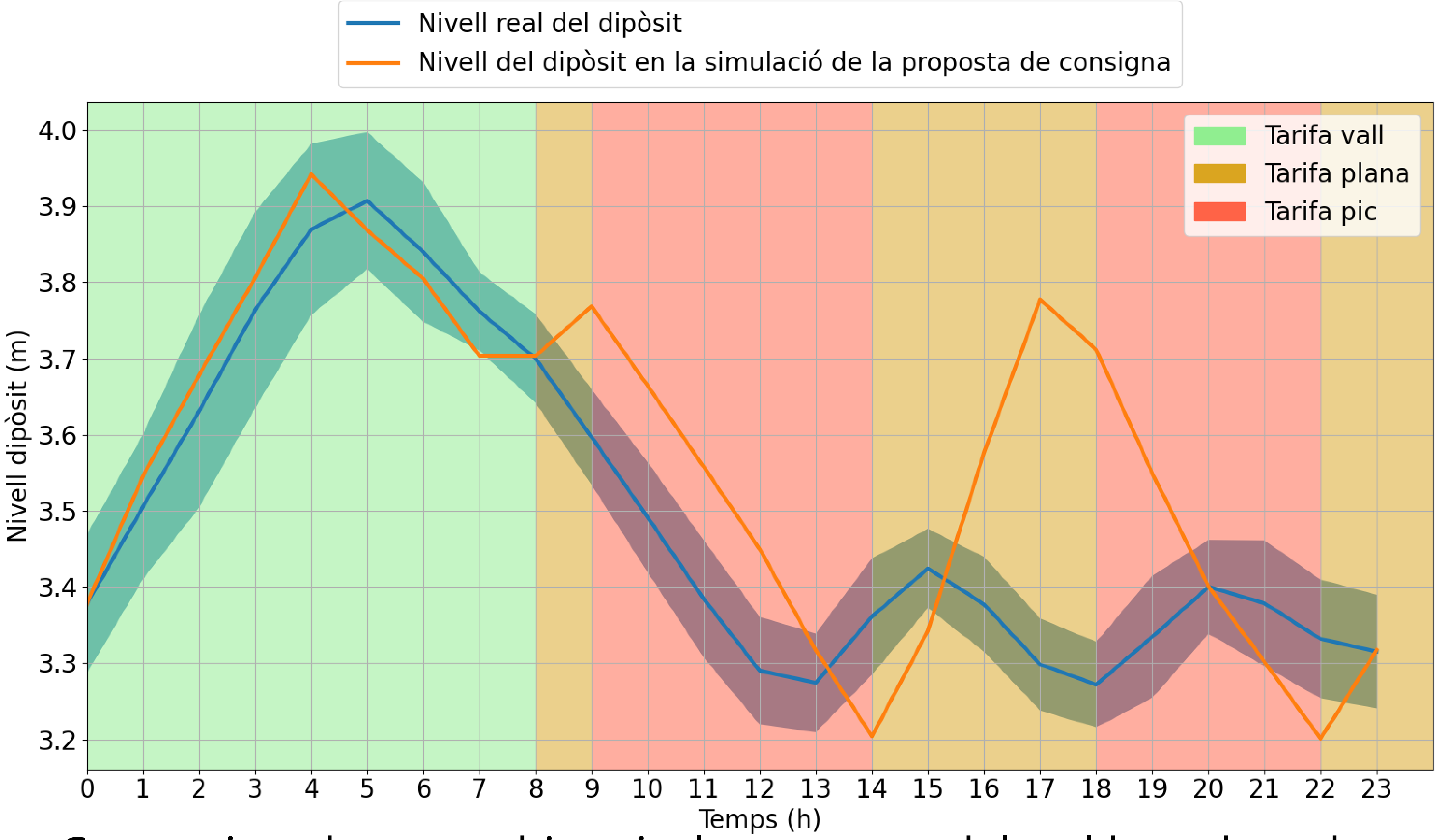


Best flat setpoint optimization results for Sentmenat

Sentmenat			
Algorithm	Flat setpoint (m)	Maximum ETAI	Time (seconds)
Every setpoint computation	3.8	7.27	0.09
Nelder-Mead	3.7	6.66	0.4
Basinhopping	3.7	6.66	1.02
Evolució diferencial	3.8	7.27	1.06
Current management	3.5	6.36	-

Comparison of the proposal with the current management

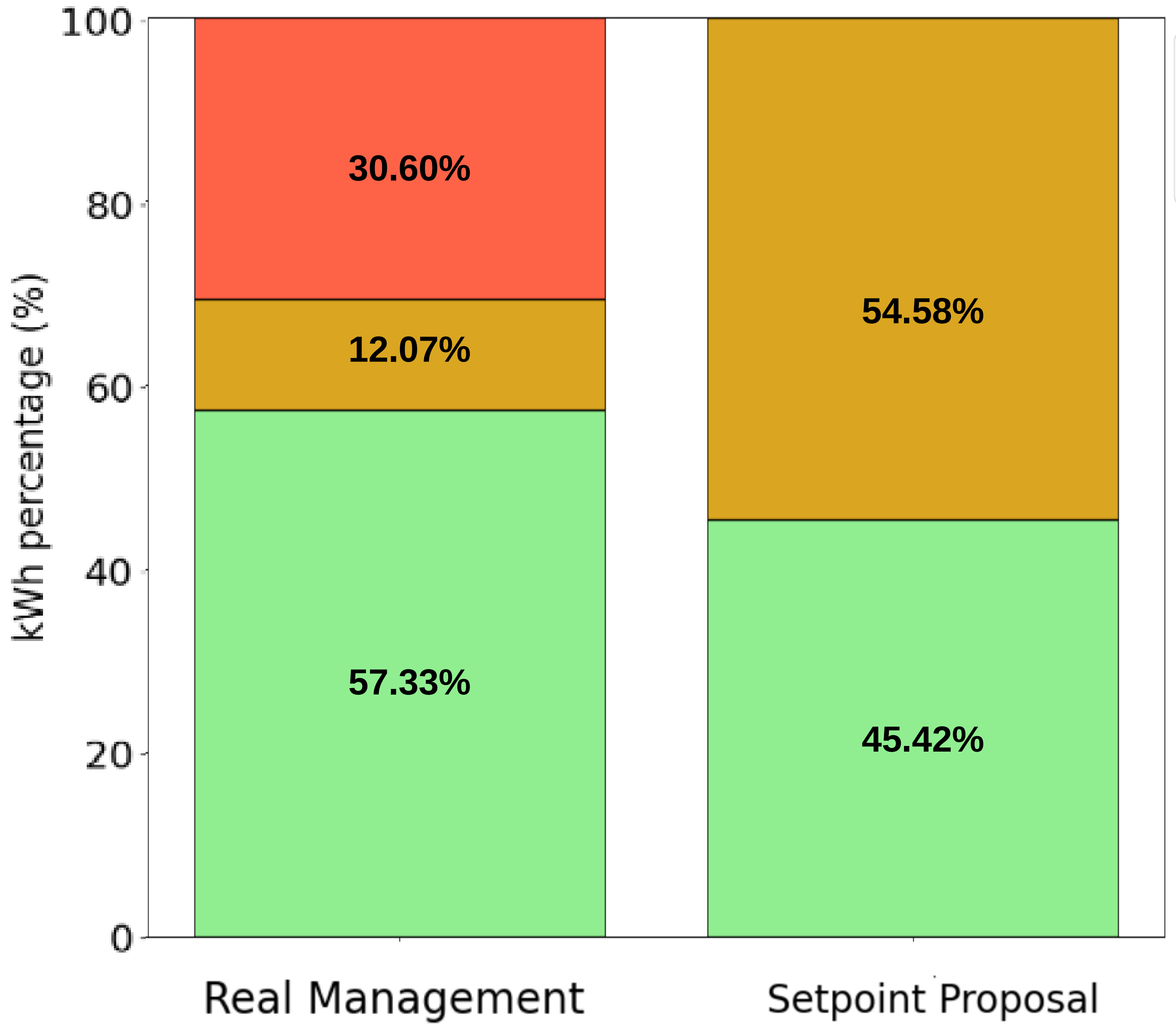
Sentmenat		
Setpoints	Current management	Management proposal
Valley hours	4 m	4 m
Flat hours	3.5 m	3.8 m
Peak hours	3.5 m	3.5 m
ETAI	6.36	7.27

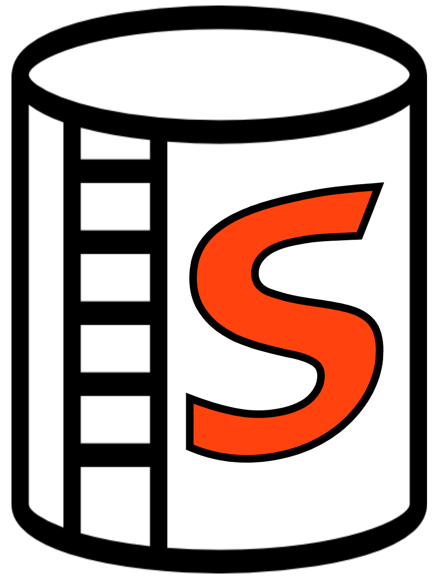


Comparison between historical average tank level based on the proposed setpoints

Comparison of the proposal with the current management

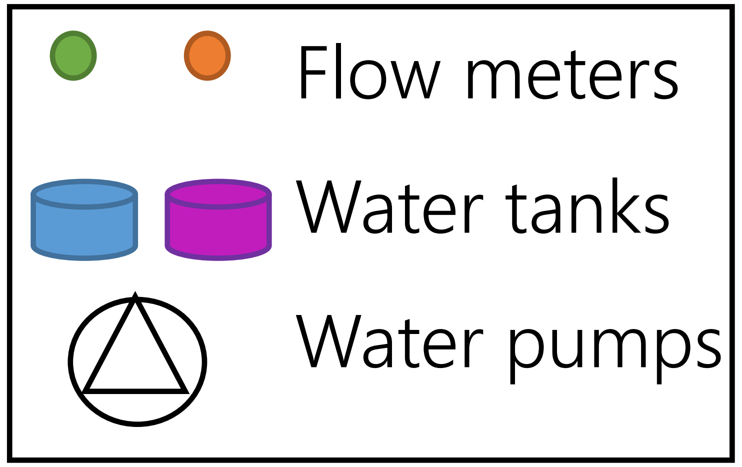
Comparison of % kWh consumed based on time type between real management and the new proposal

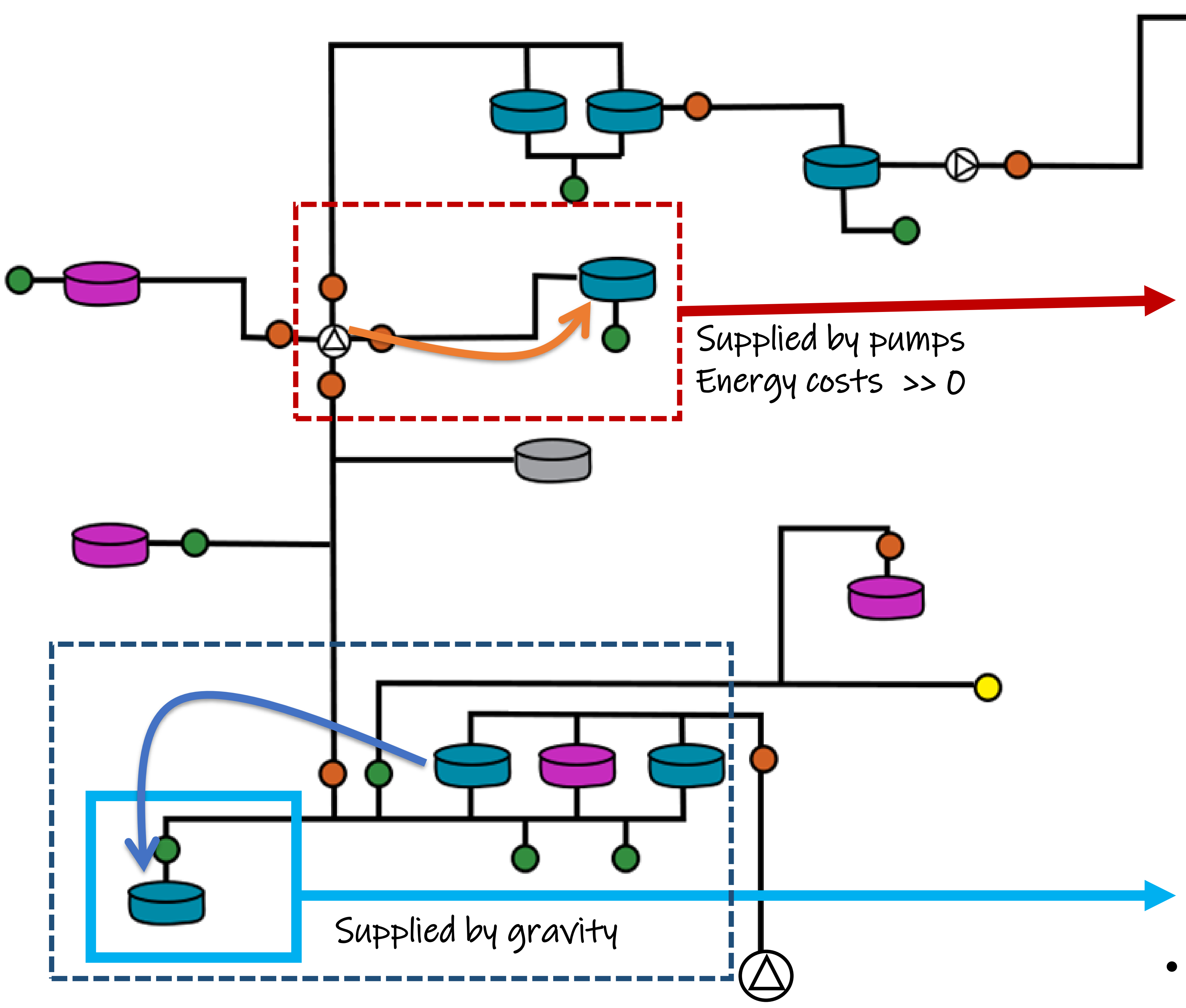




- INTRODUCTION
- STUDY CASE
- SINGLE TANK EXAMPLE
- PROBLEM
- HYPOTHESIS AND OBJECTIVES

Water supplying sources





Opening inlet valve forces water pumping

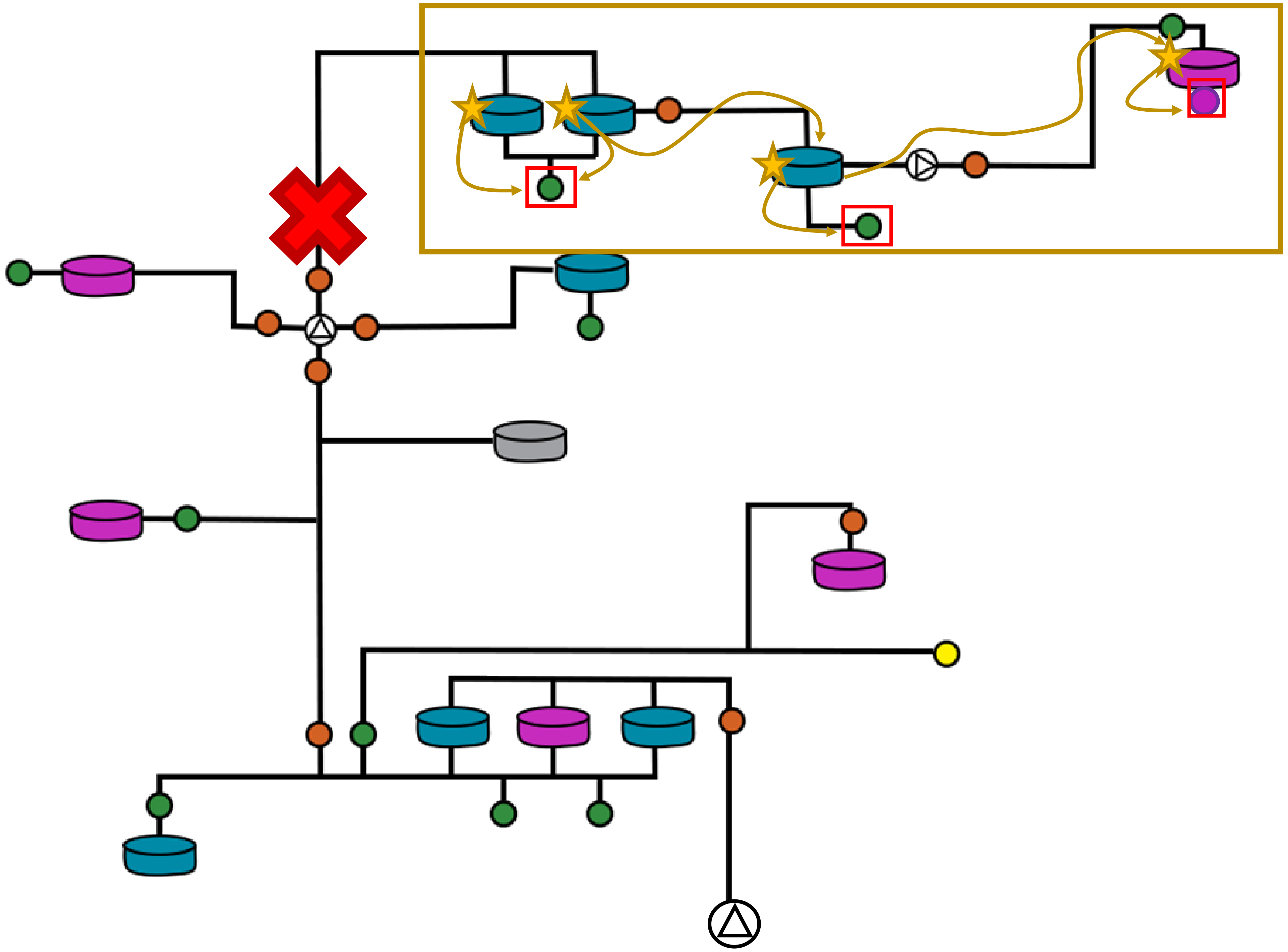
- Direct energy consumption

Opening inlet valve **does not** force water pumping

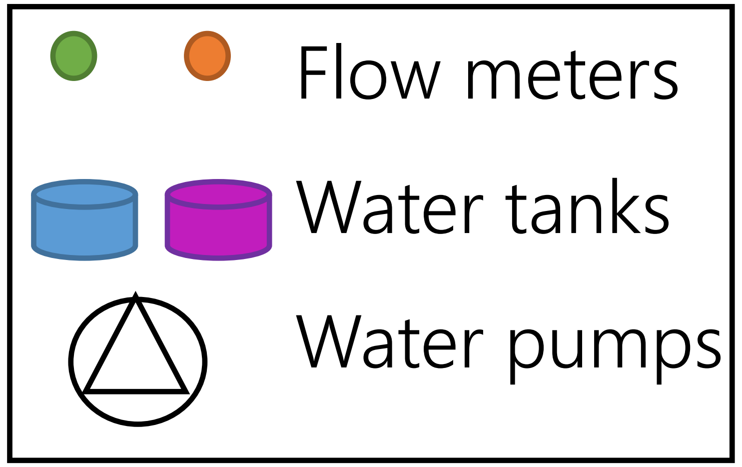
- Indirect energy consumption

Assumptions

Network autonomy



Capacity to supply for 20 hours!



INTRODUCTION

STUDY CASE

SINGLE TANK EXAMPLE

PROBLEM

HYPOTHESIS AND OBJECTIVES

Hypothesis and objective

- **Hypothesis**: changing storage tanks setpoints can be usefull to reduce energy pumping costs.

Hypotesis and objective

- Hypothesis: changing storage tanks setpoints can be usefull to reduce energy pumping costs.
- Objective: To develop a methodology, an algorithm or a set of criteria[1] to change setpoints and hysteresis in order to reduce the **energy pumping costs**.

[1] Example: increasing cheap energy hours setpoint to pump more water on cheap energy hours in order to supply it during expensive energy hours.

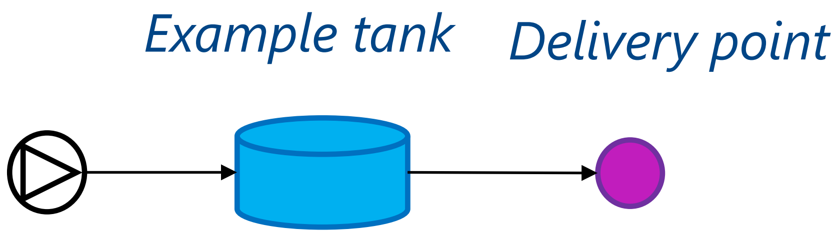
Hypotesis and objective

- **Hypothesis**: changing storage tanks setpoints can be usefull to reduce energy pumping costs.
- **Objective:** To develop a methodology, an algorithm or a set of criteria[1] to change setpoints and hysteresis in order to reduce the **energy pumping costs**.
  - The obtained results have to be extrapolated to any study case

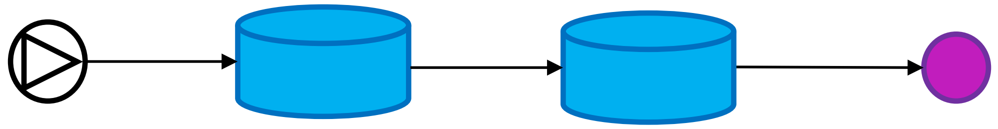
[1] Example: increasing cheap energy hours setpoint to pump more water on cheap energy hours in order to supply it during expensive energy hours.

Hypotesis and objective

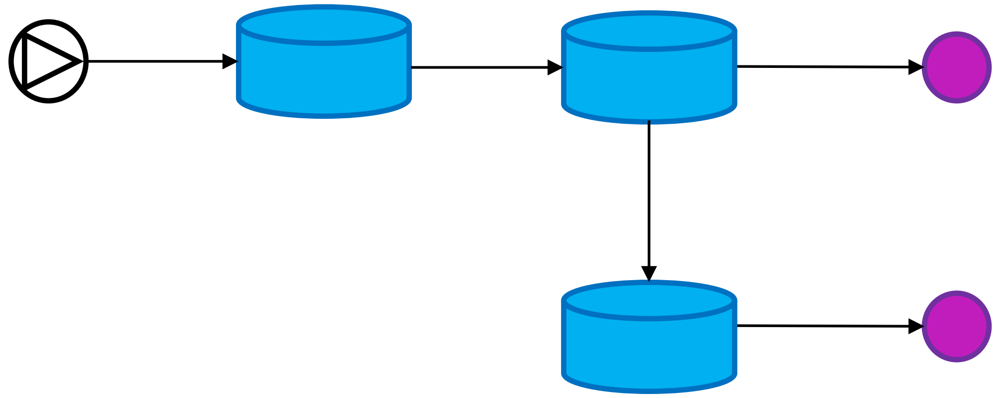
Cases variability



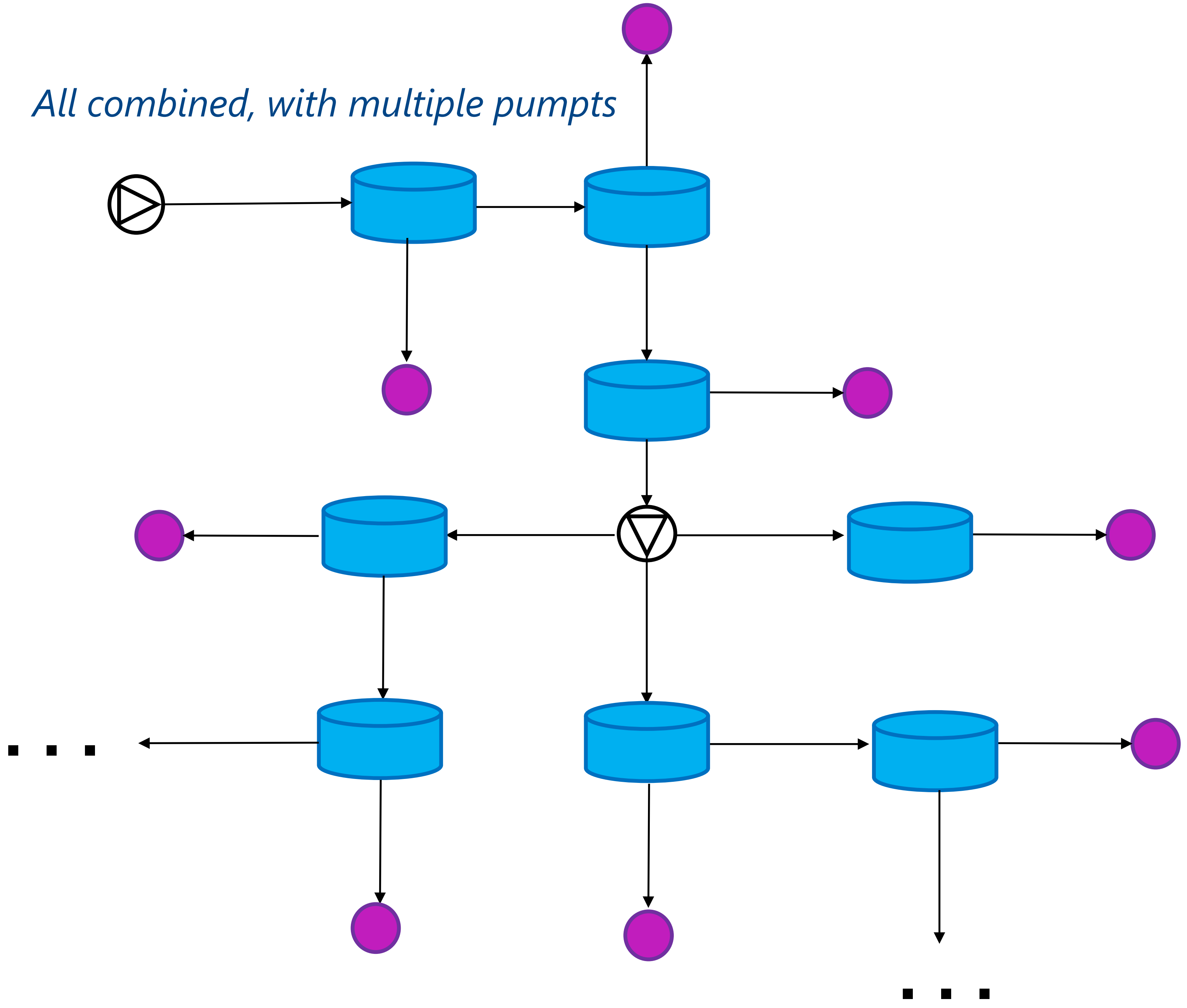
Serial tanks



Parallel and serial tanks



All combined, with multiple pumpts



Hypotesis and objective

- Hypothesis: changing storage tanks setpoints can be usefull to reduce energy pumping costs.
- Objective: To develop a methodology, an algorithm or a set of criteria[1] to change setpoints and hysteresis in order to reduce the **energy pumping costs**.
  - The obtained results have to be extrapolated to any study case
  - The energy costs optimization can **only** be done by changing the values of:
    - **Cheap energy hours setpoint**
    - **Medium energy hours setpoint**
    - **Expensive energy hours setpoint**
    - **Hysteresis level**

---

[1] Example: increasing cheap energy hours setpoint to pump more water on cheap energy hours in order to supply it during expensive energy hours.

Assumptions

- Autonomy level: All tanks must have a minimum level from which water cannot fall: this level is defined as the volume of water that allows supplying the demand for 20 hours[1].
- Distribution network water can only flow in one direction
- The flow rate of the pumps is not variable: they can only be on at full power or off.
- It is assumed that the speed of distribution of the water is instantaneous.
- It can be assumed that for a given tank, the water demand along the day is the same every day.
- Water inlet flow to a given tank is higher than its highest demand peak flow.

[1]In emergency cases where water can not be pumped, the tanks in water distribution network must have enough autonomy to supply domestic water consumption during a defined time

Questions?

Feel free to ask me anything whenever you want!

DAVID ABERT || e-mail: david.abert@udg.edu

® lequia UdG ECO-INNOVATIVE ENVIRONMENTAL SOLUTIONS