Optimising the electrical infrastructure of MTSs to increase energy efficiency: when and where to install reversible substations

Álvaro Jesús López López
Ramón Rodríguez Pecharromán
Antonio Fernández Cardador
Paloma Cucala García

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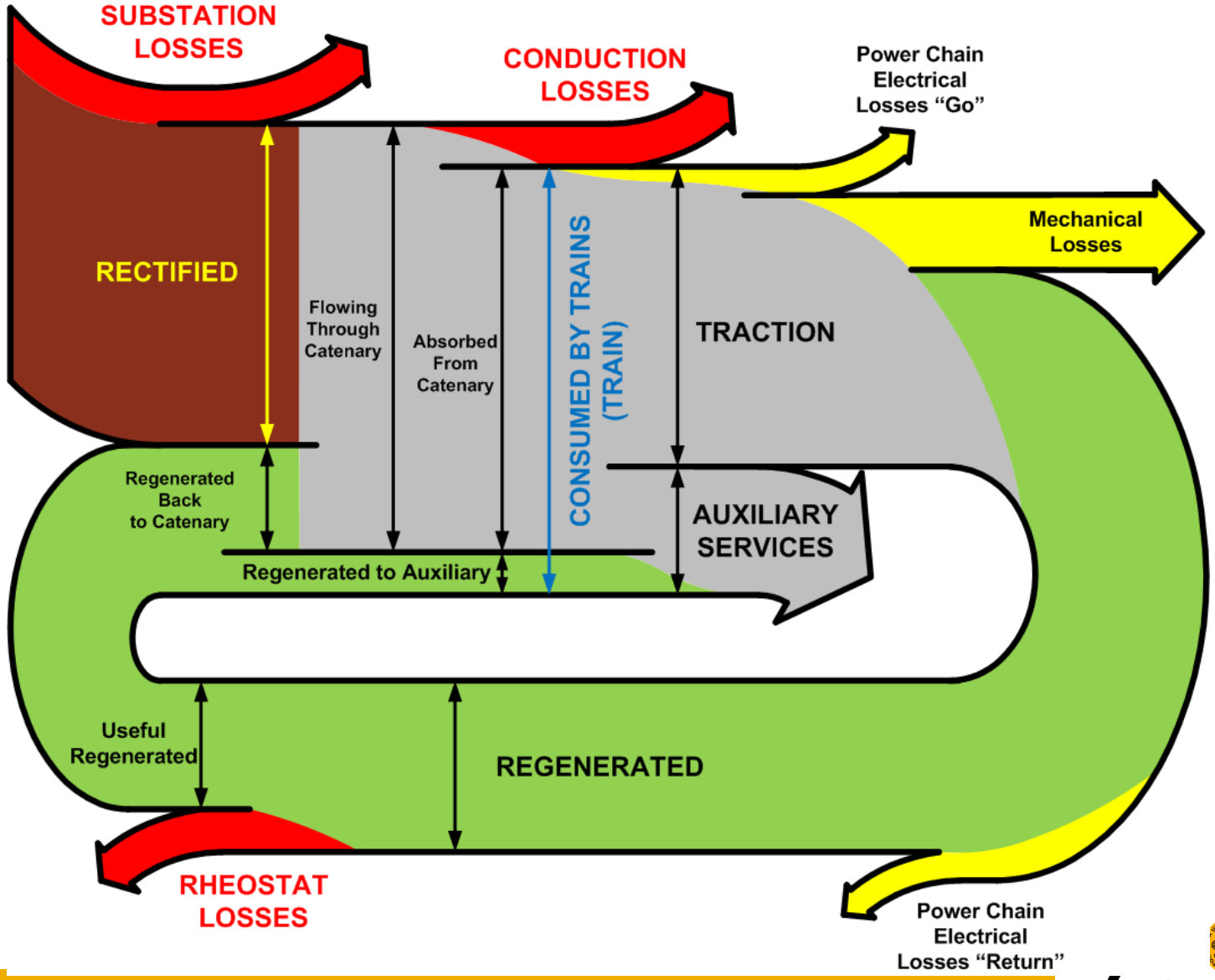
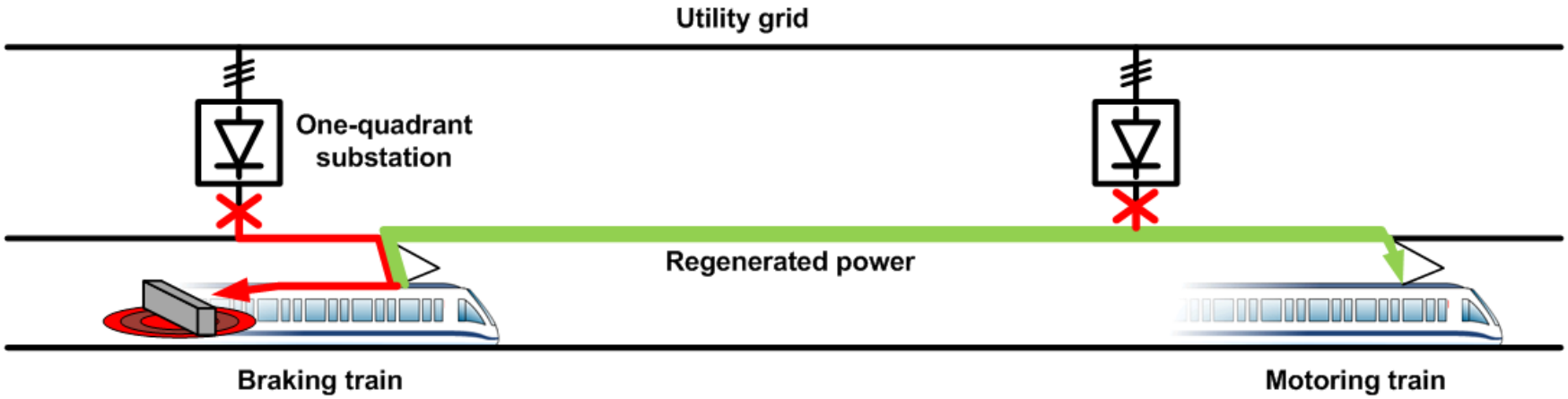
Energy flows in a DC-electrified MTS



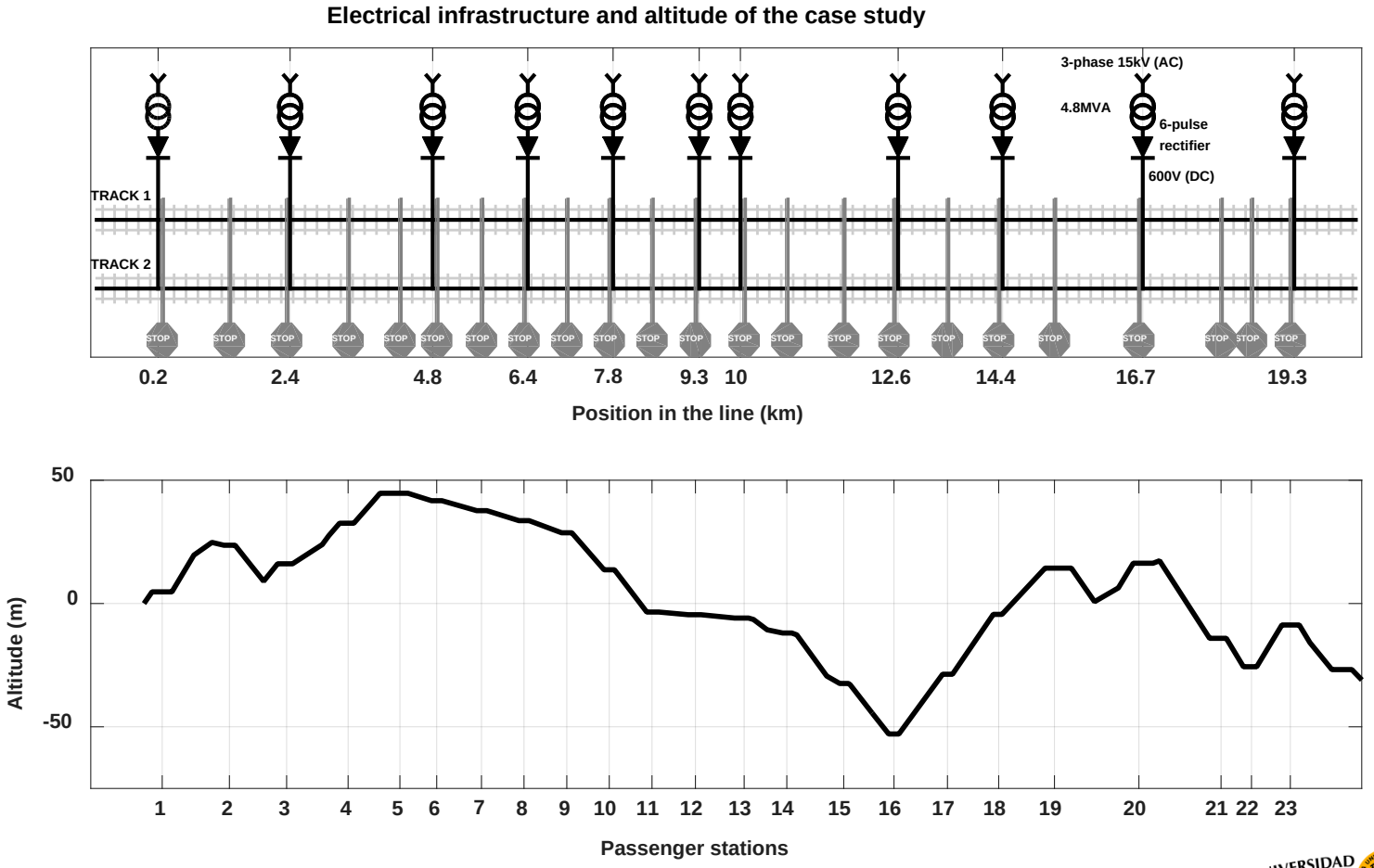
The problem of limited receptivity



- **How could this be fixed?**
  - Improving or optimally operating the **electrical infrastructure**

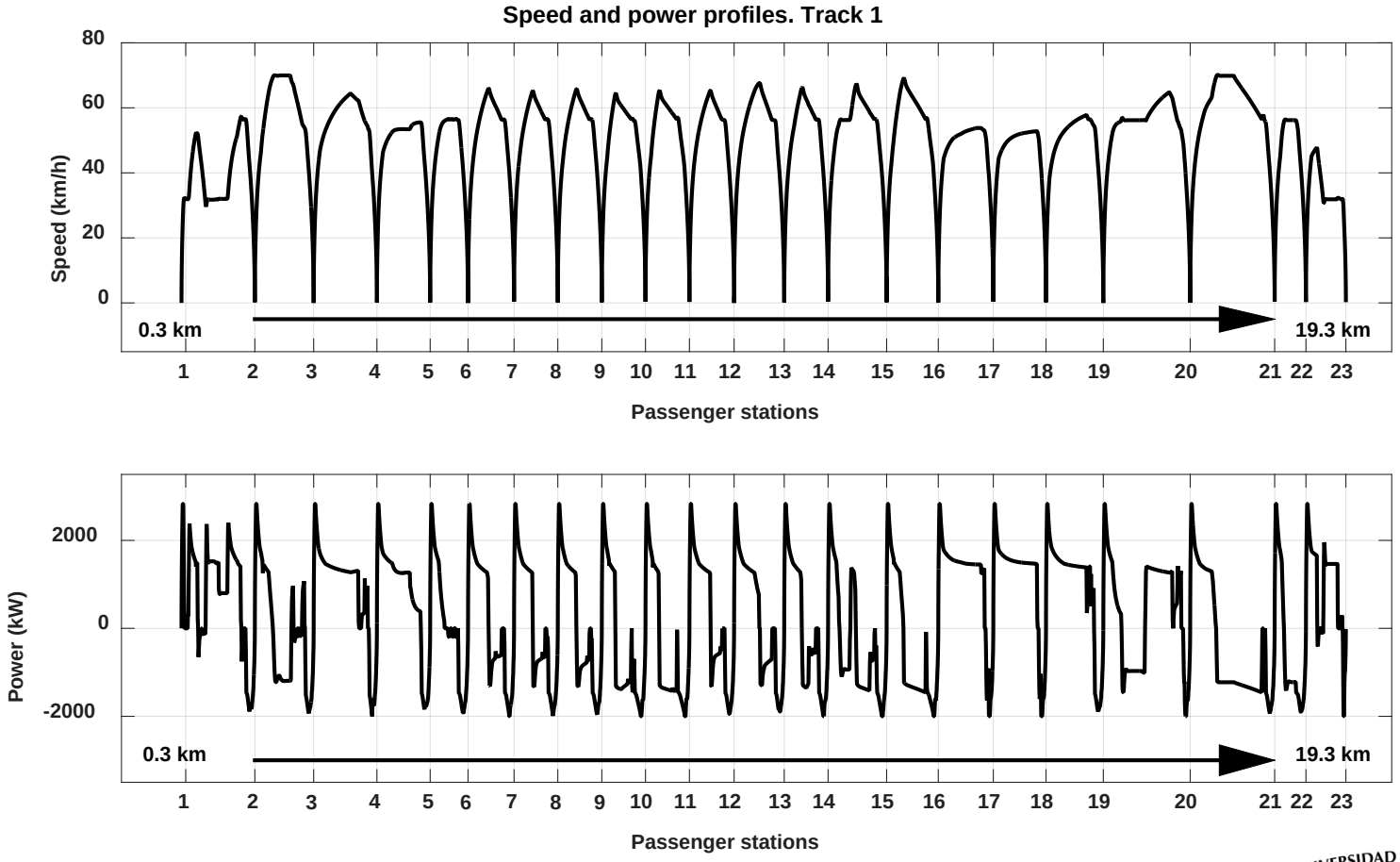
Let's put some numbers to the problem…

- 19 km **double-track** line
- **23 stations** ➔ 860 m average inter-station



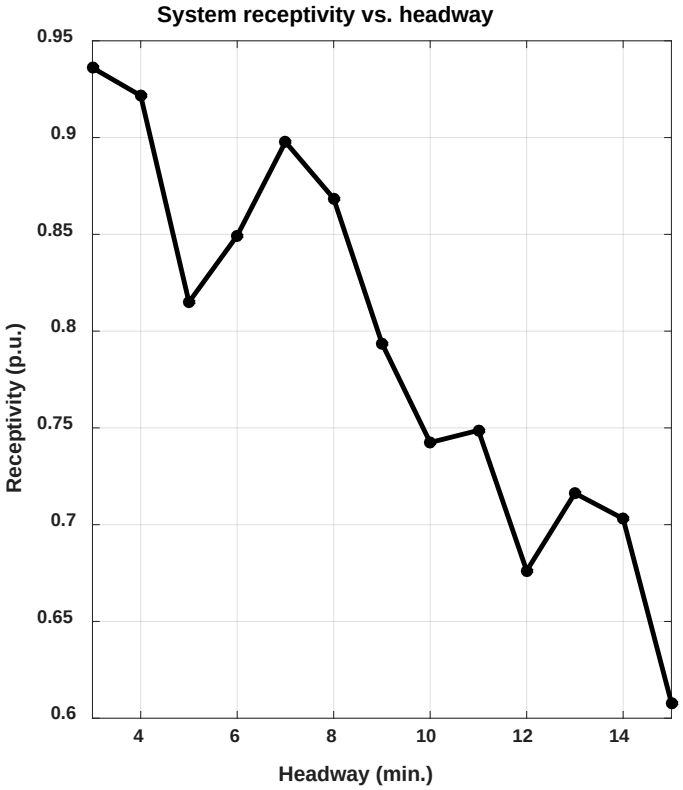
Let’s put some numbers to the problem…

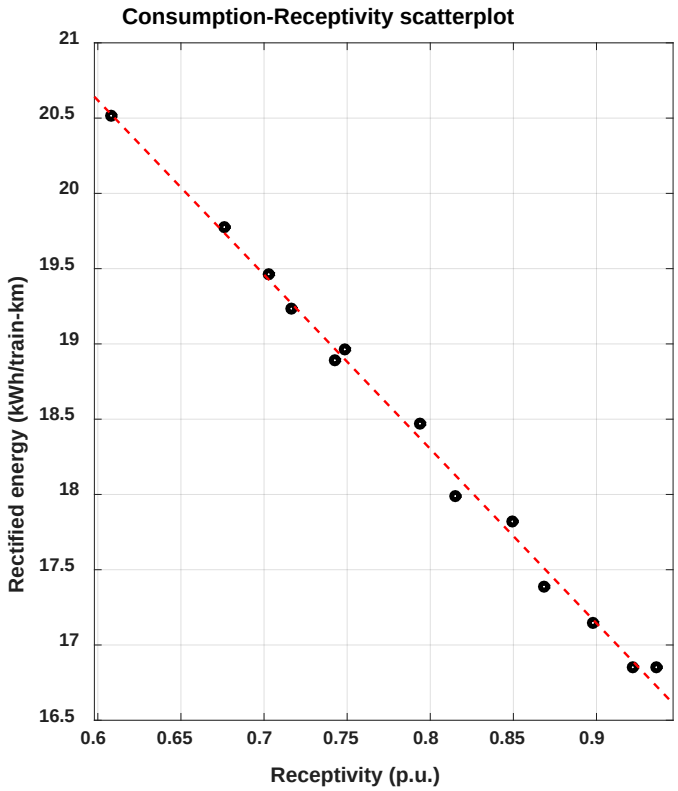
- ATO speed profiles (flat-out)
- Speed limitations (max. line speed = 70 km/h)



Preliminary analysis results

Regenerative braking ➔ large **efficiency** increase (40 %)





Infrastructure **improvements welcome!**

Preliminary analysis. Improvement techniques

IMPROVEMENT TECHNIQUES

LOW INVESTMENT

- No-load voltage
- SS shutdown

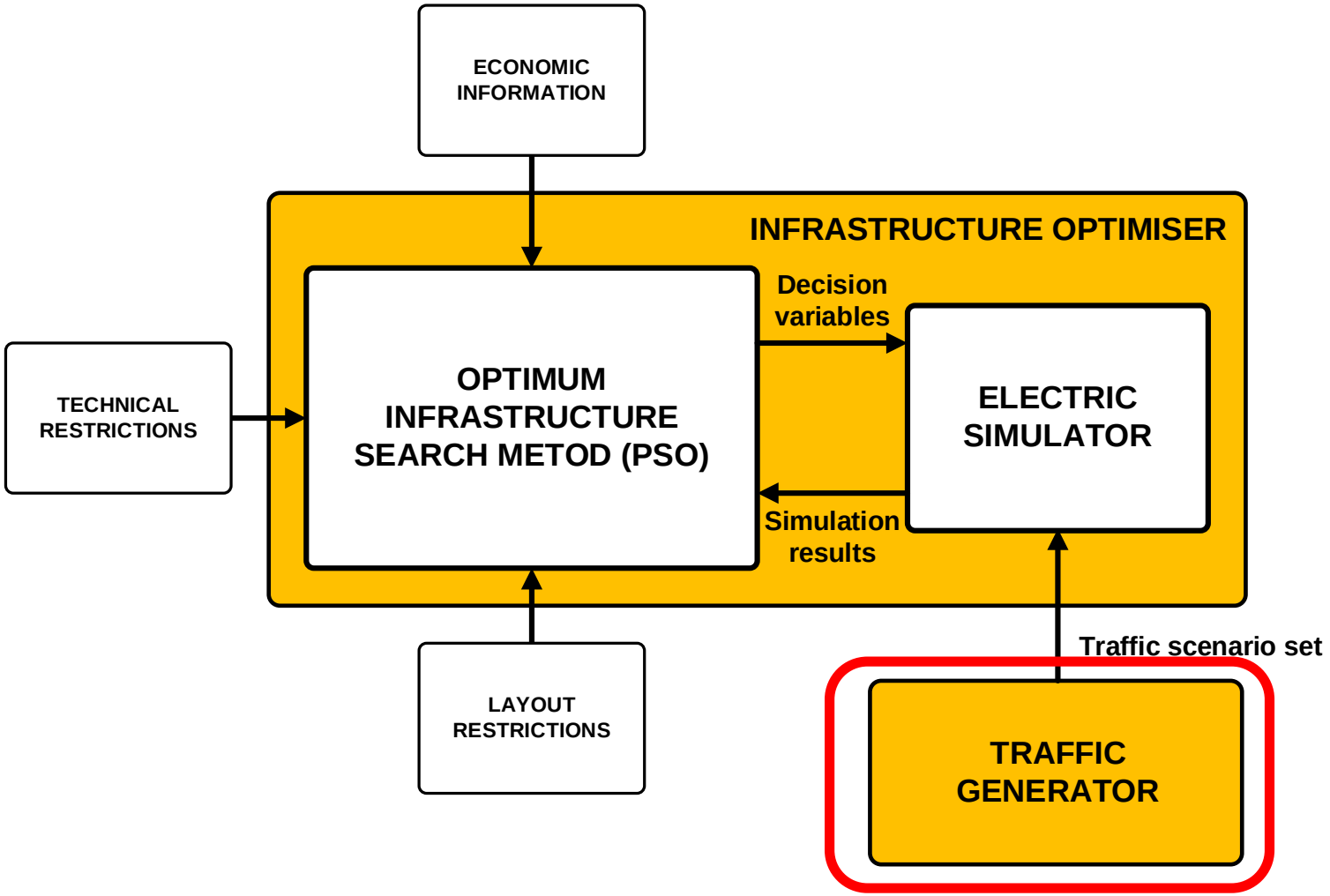
HIGH INVESTMENT

- Nominal voltage level
- Improve conductors
- Rev. Substations (RSs)
- Energy Storage (ESSs)
- Others

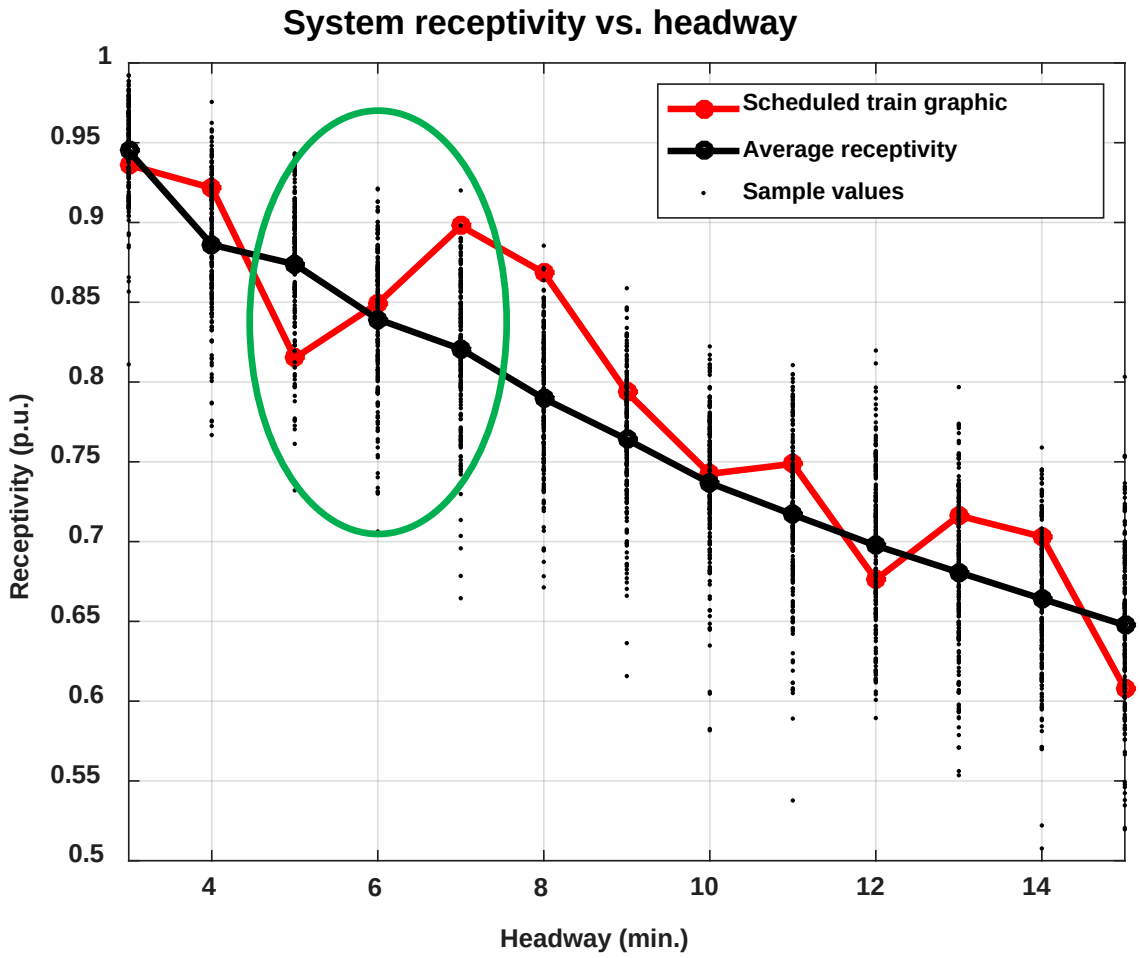
Large rheostat **losses** → **investment** required → **RISK**

Important: **tools and models** to take **right decisions**

Our tool to assist decision taking



High sensitivity to the traffic model



Necessary to include more scenarios

Traffic model concept and concerns

Single traffic scenario

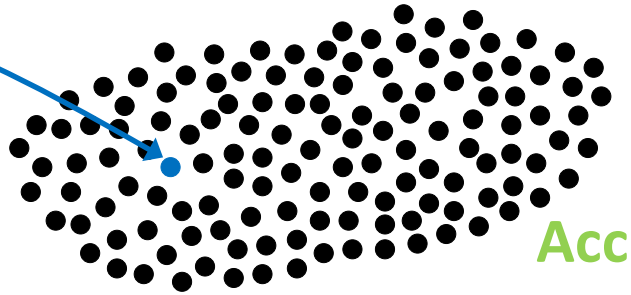
Perfect schedule

Inaccurate

Comp. burden

Traffic space

Enough samples of stochastic traffic scenarios

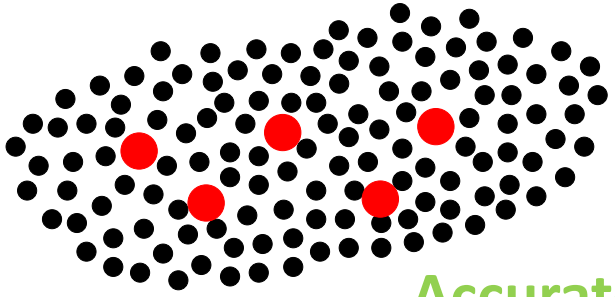


Accurate

Comp. burden

Representative traffic scenarios

A representative subset

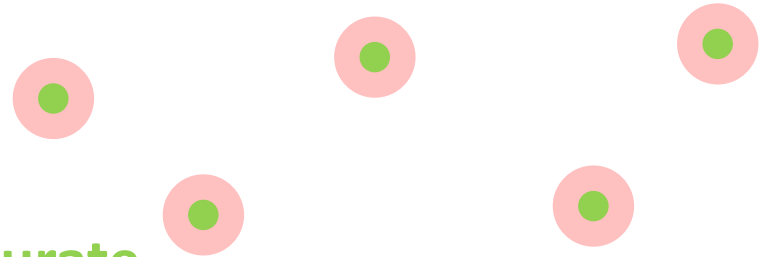


Accurate

Comp. burden

Compressed traffic scenarios

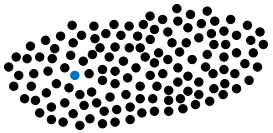
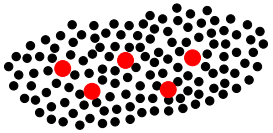
The representative subset, compressed



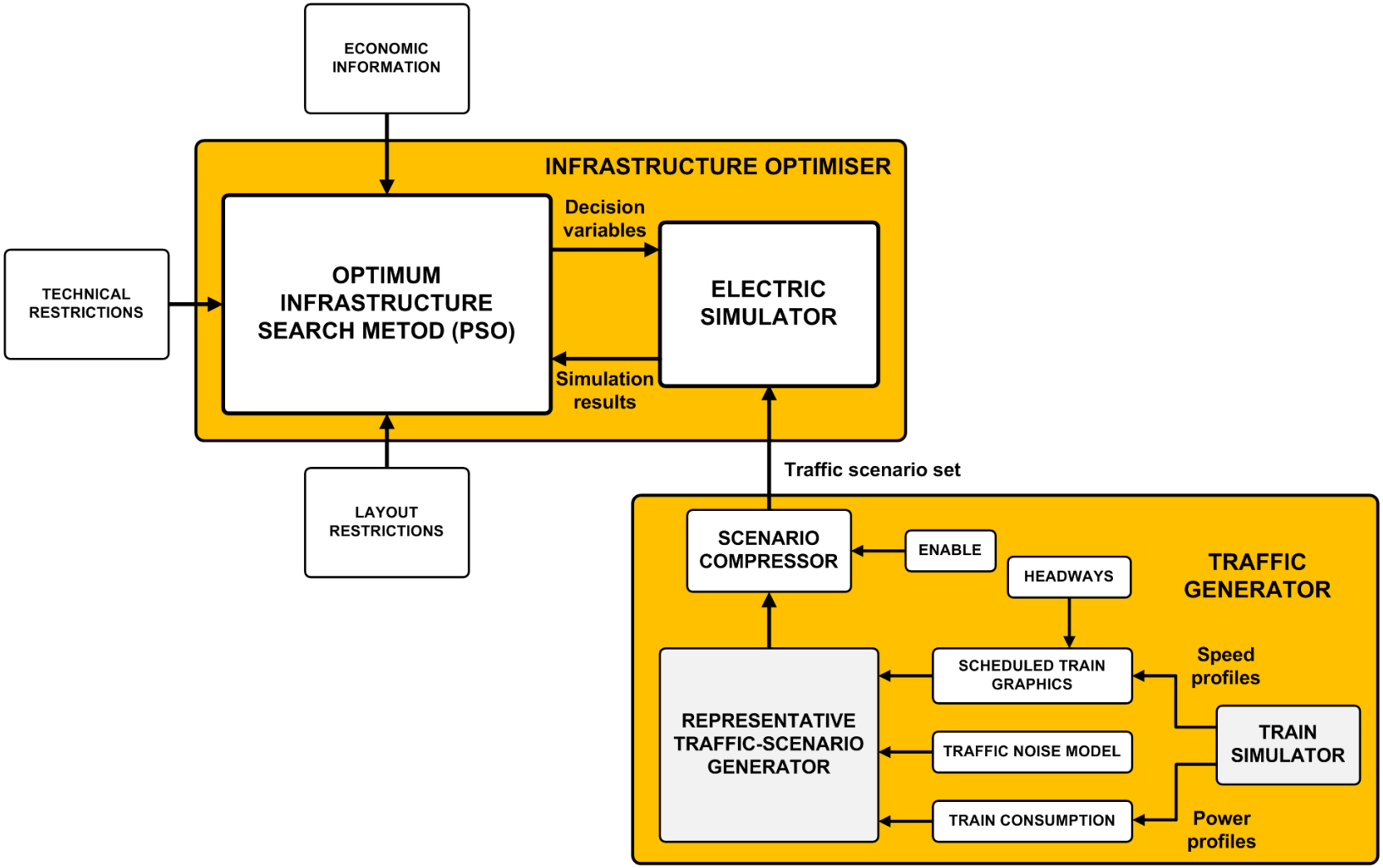
Accurate

Comp. burden

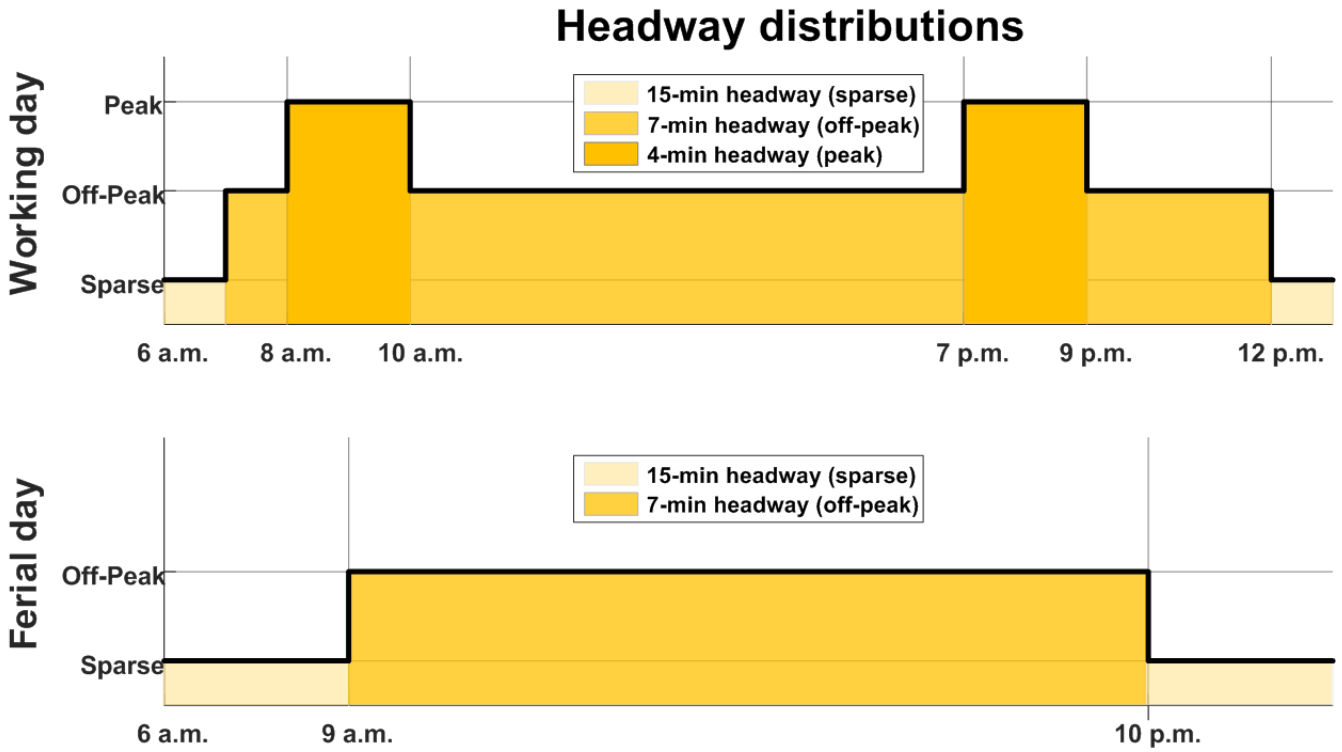
Some figures in a typical optimisation process

	Nº scenarios	Accuracy	Optimisation time (rough estimation)
Single-scenario		POOR!	13 hours
Traffic space		The highest	9.3 MONTHS
Representative scenarios		Good!	93 hours
Compressed Repr. Scen.		Still good!	18.6 hours

Optimiser details



Headway weekly composition



	Working day	Ferial day	Weekly total
Sparse headway (hours)	2	6	22
Off-peak headway (hours)	13	13	91
Peak headway (hours)	4	0	20

Economic concerns

RS cost

$$C_{RS} = C_{Fixed} + \alpha_{PWR} \cdot P_{RS}$$

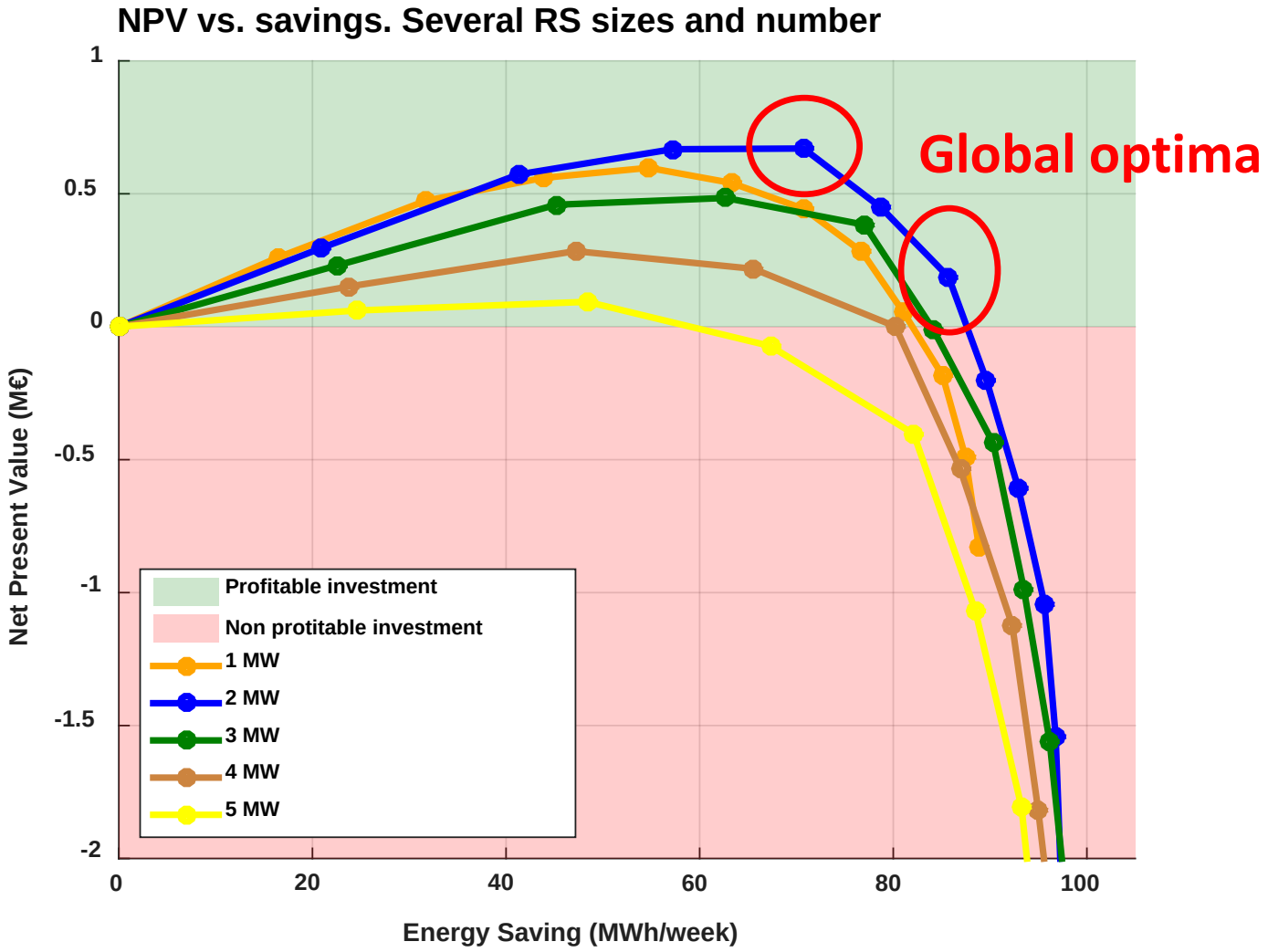
E.g.: 2-MW RS ➔ 0.55 M€

Investment feasibility: Net Present Value

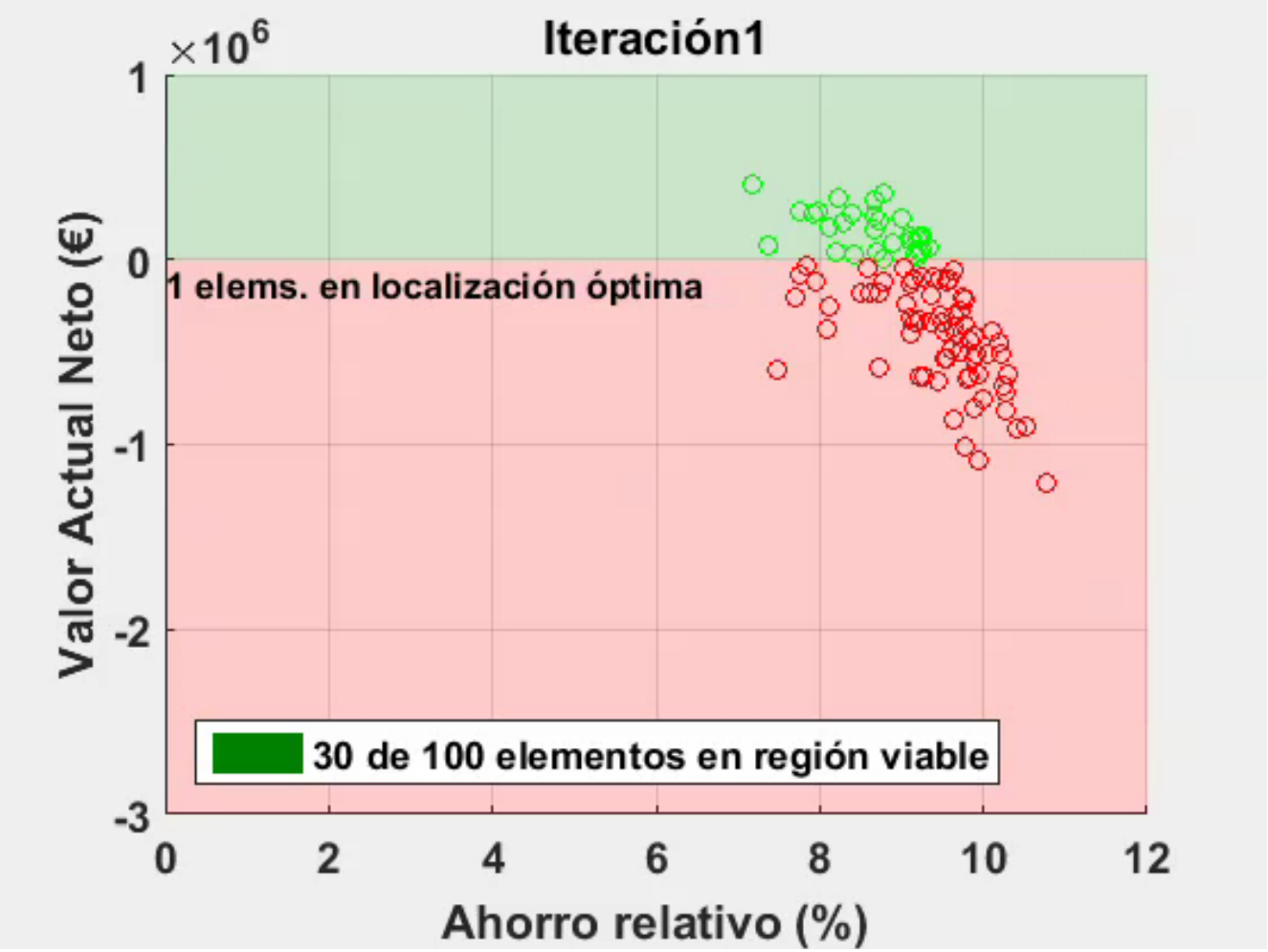
$$NPV = \sum_{t=1}^{T} \frac{ES_t}{(1+r)^t} - C_0$$

NPV ≥ 0 ➔ Feasible investment

Search space analysis. Some savings curves



The optimiser in action!



Useful outcomes for operators

- Insights on the **effect of traffic in receptivity**
  - and thus in **achievable savings**
- **Methods and models** to represent the traffic in any system
- **Modular** concept design
  - Optimiser, simulator & traffic model **can be plugged into other concepts**
- **Uncertainty** on investment return (and so **risks**) **reduced**

Thank you for your attention!
Questions?

Instituto de Investigación Tecnológica
C/ Santa Cruz de Marcenado, nº 26
28015 Madrid
Tel +34 91 542 28 00
Fax + 34 91 542 31 76
info@iit.upcomillas.es