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Modeling all alternative solutions for highly renewable energy systems

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Presentation by:
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INTRODUCTION

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- Energy system optimization models

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- Complex political agendas

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- Improve on Modelling to Generate Alternatives (MGA) [1]

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- Improve on Modelling to Generate Alternatives (MGA) [1]

Research question:

- How do we explore all near-optimal model solutions?
- What information do the near-optimal solutions provide?

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ENERGY SYSTEM MODEL

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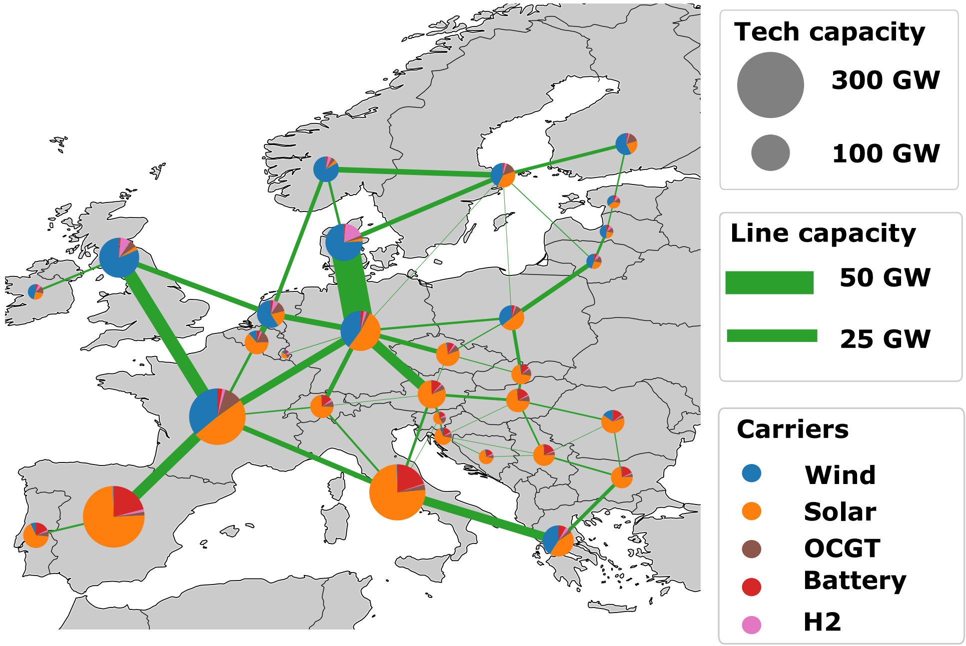
- Model of European power sector [2]



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- Generators: Solar PV, wind and OCGT
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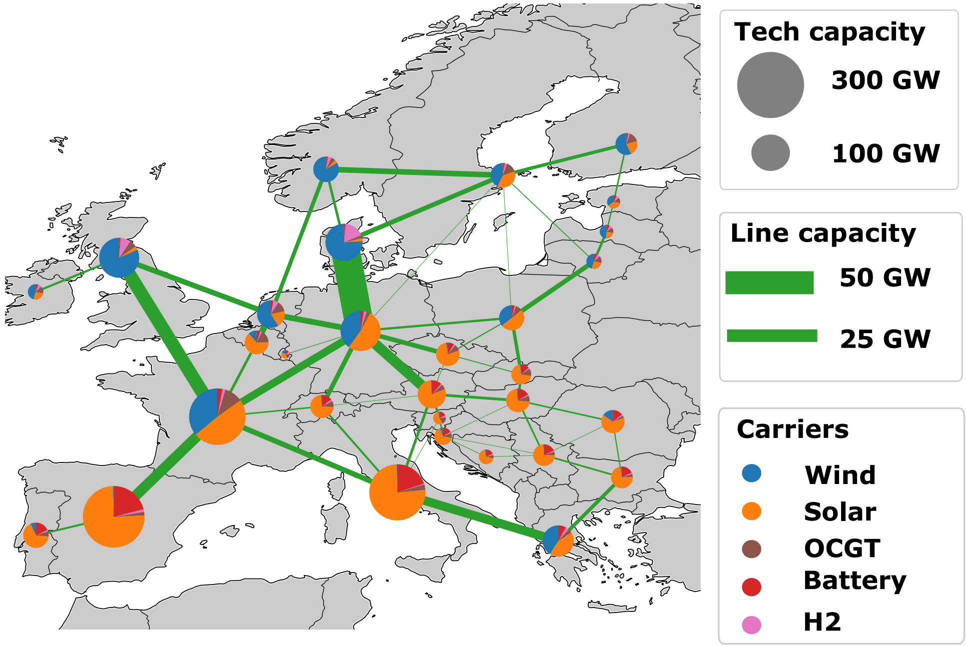

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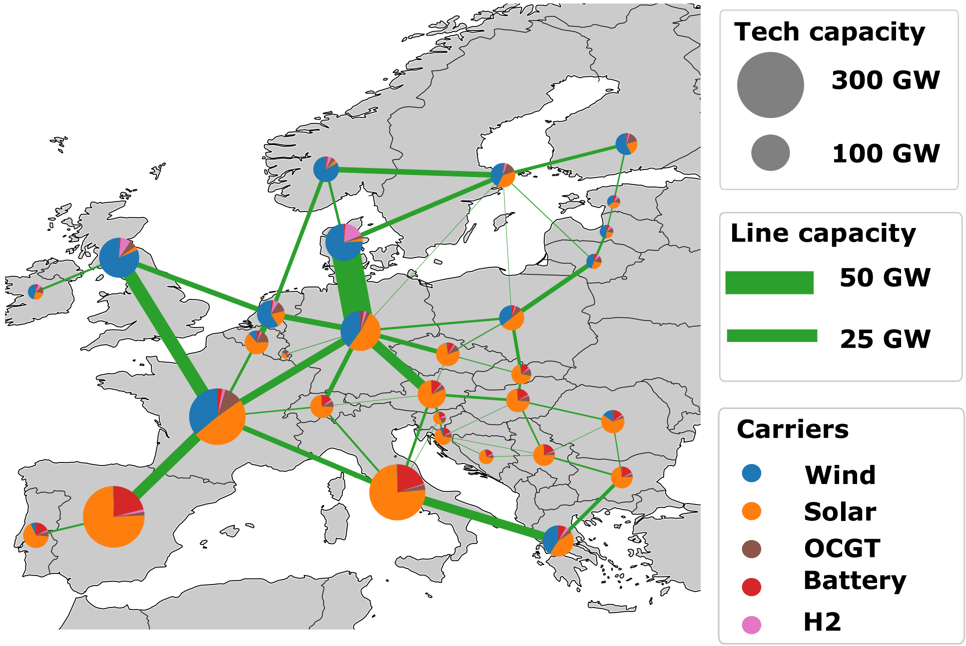

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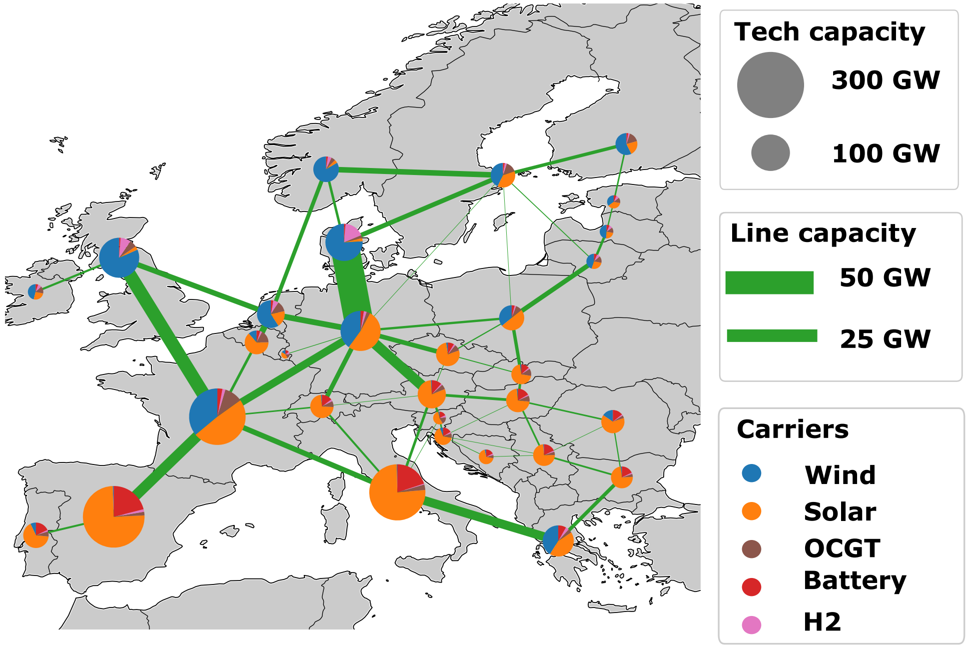

Input

- Weather data
- Energy demand
- Network topology
- Technology costs
- Technical constraints

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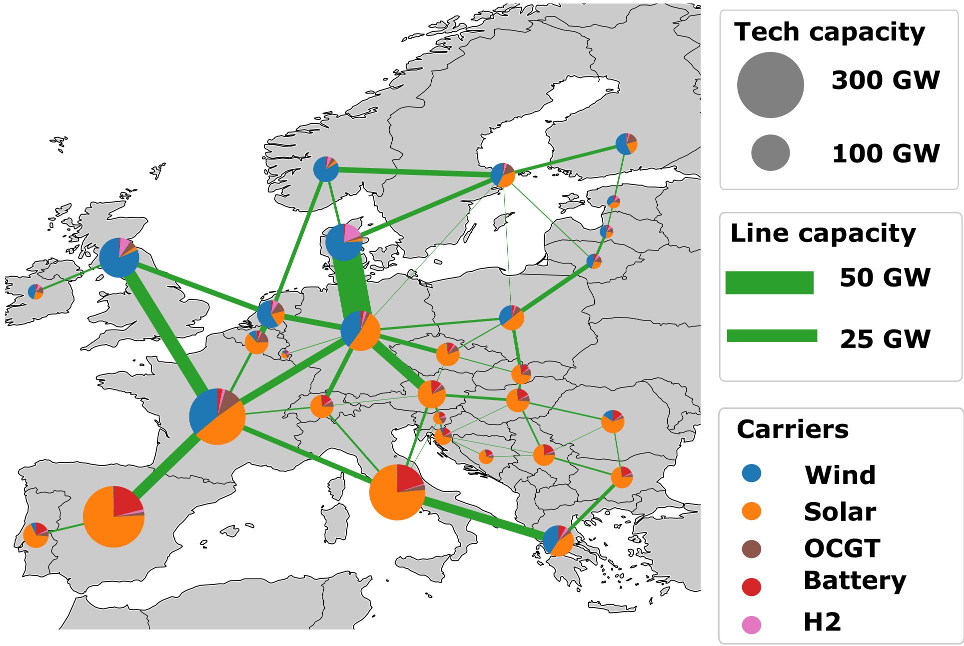

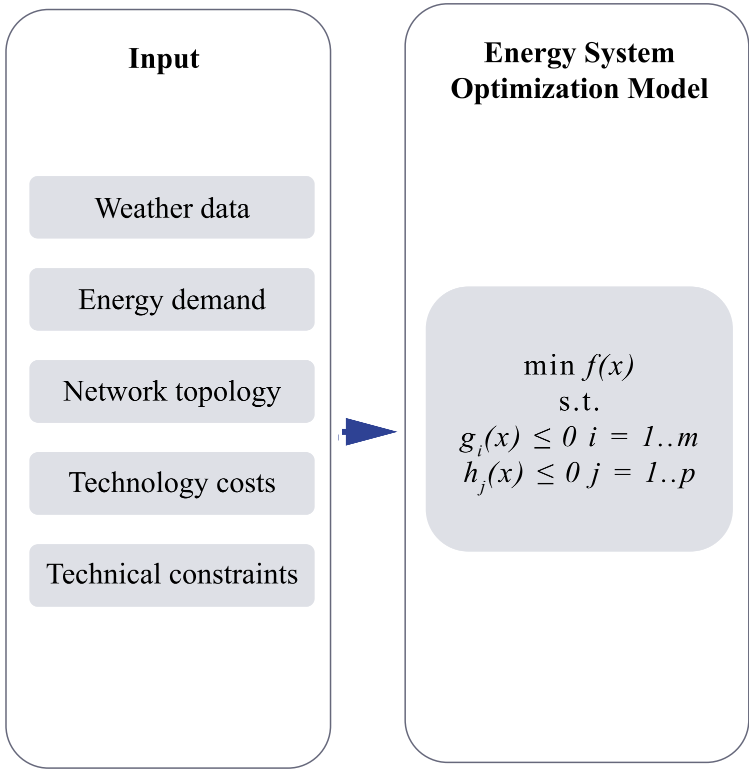

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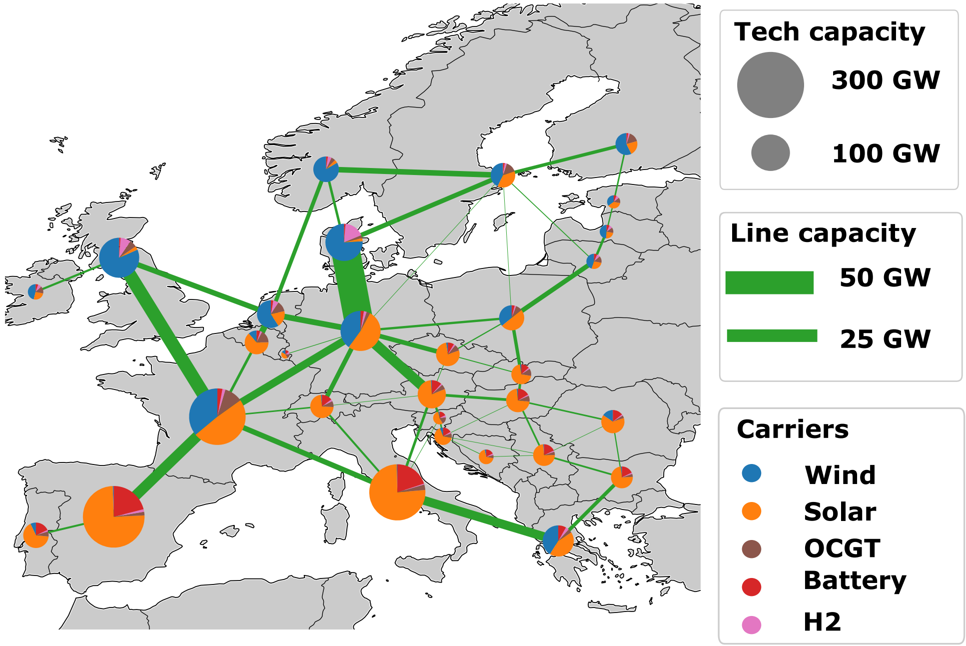

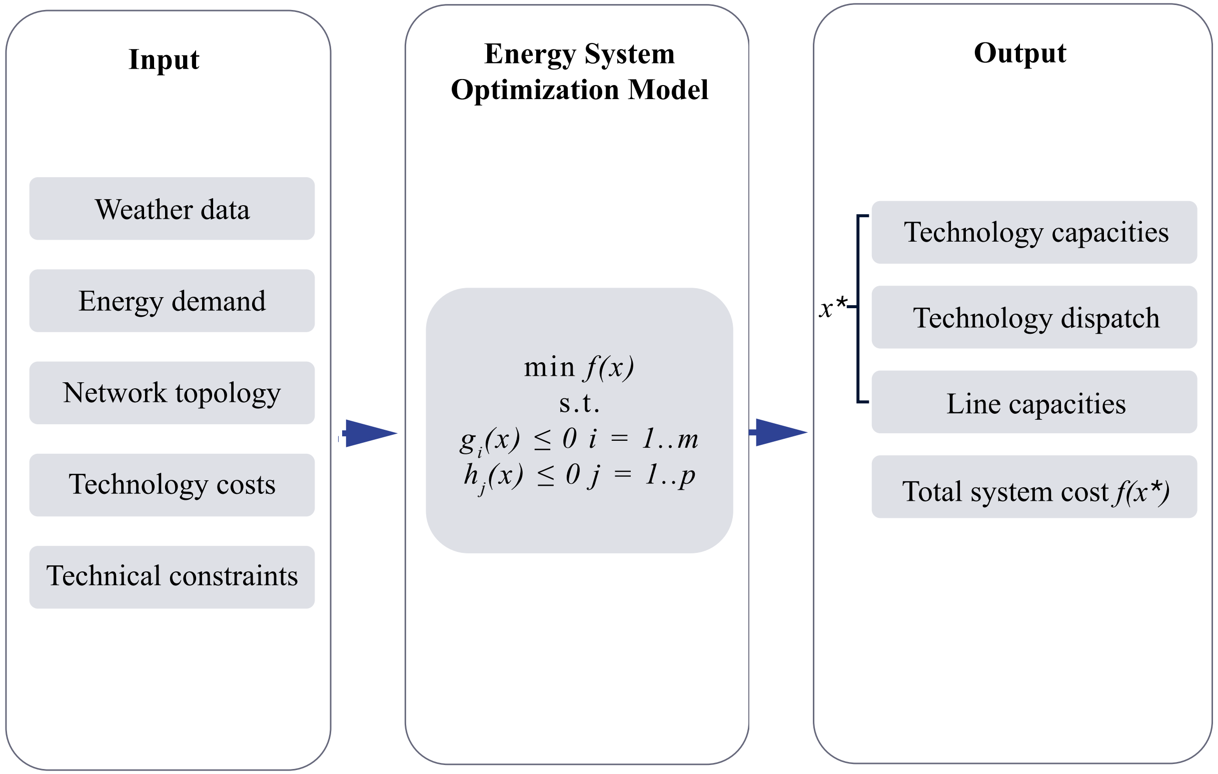

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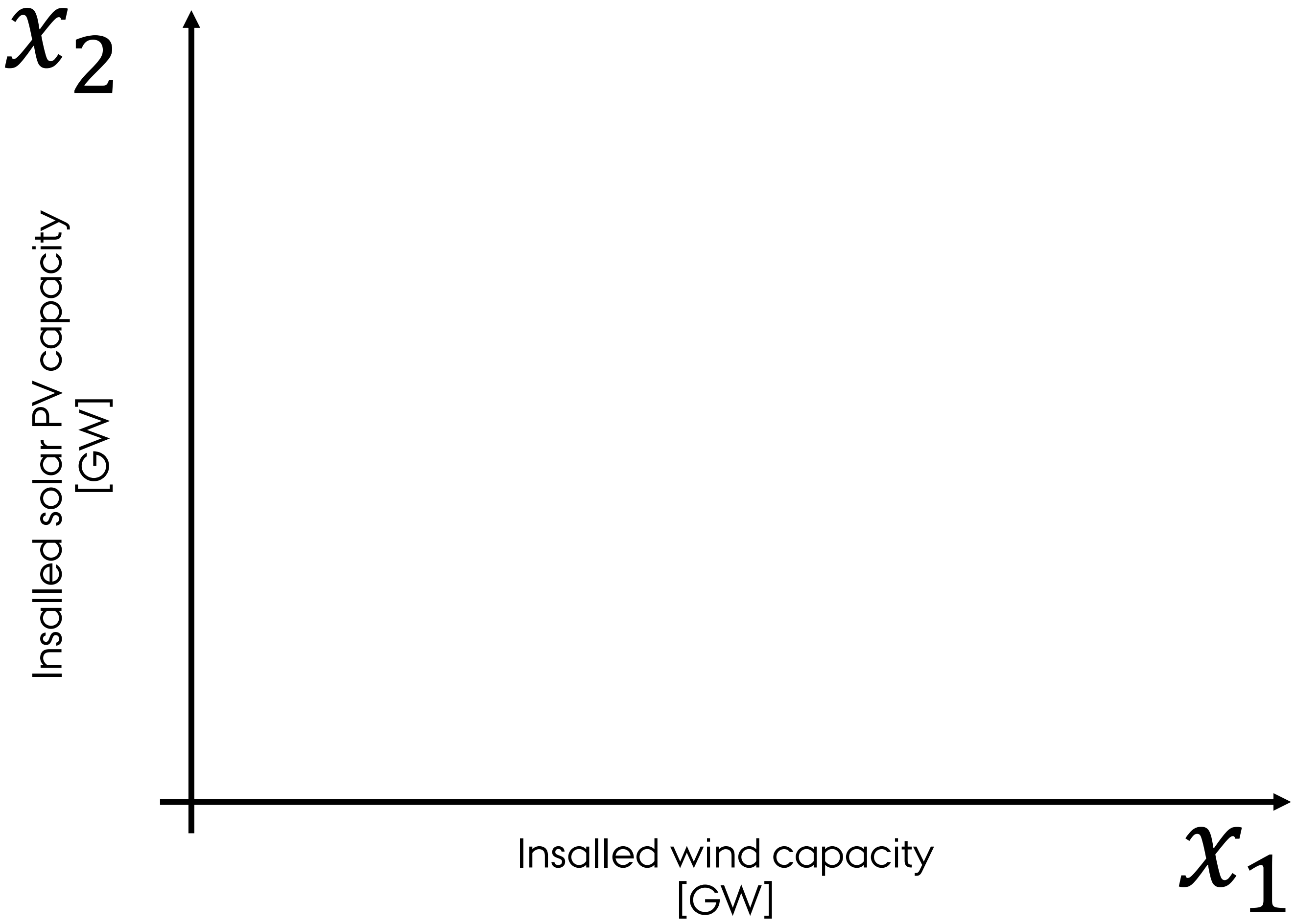
SOLUTION SPACE



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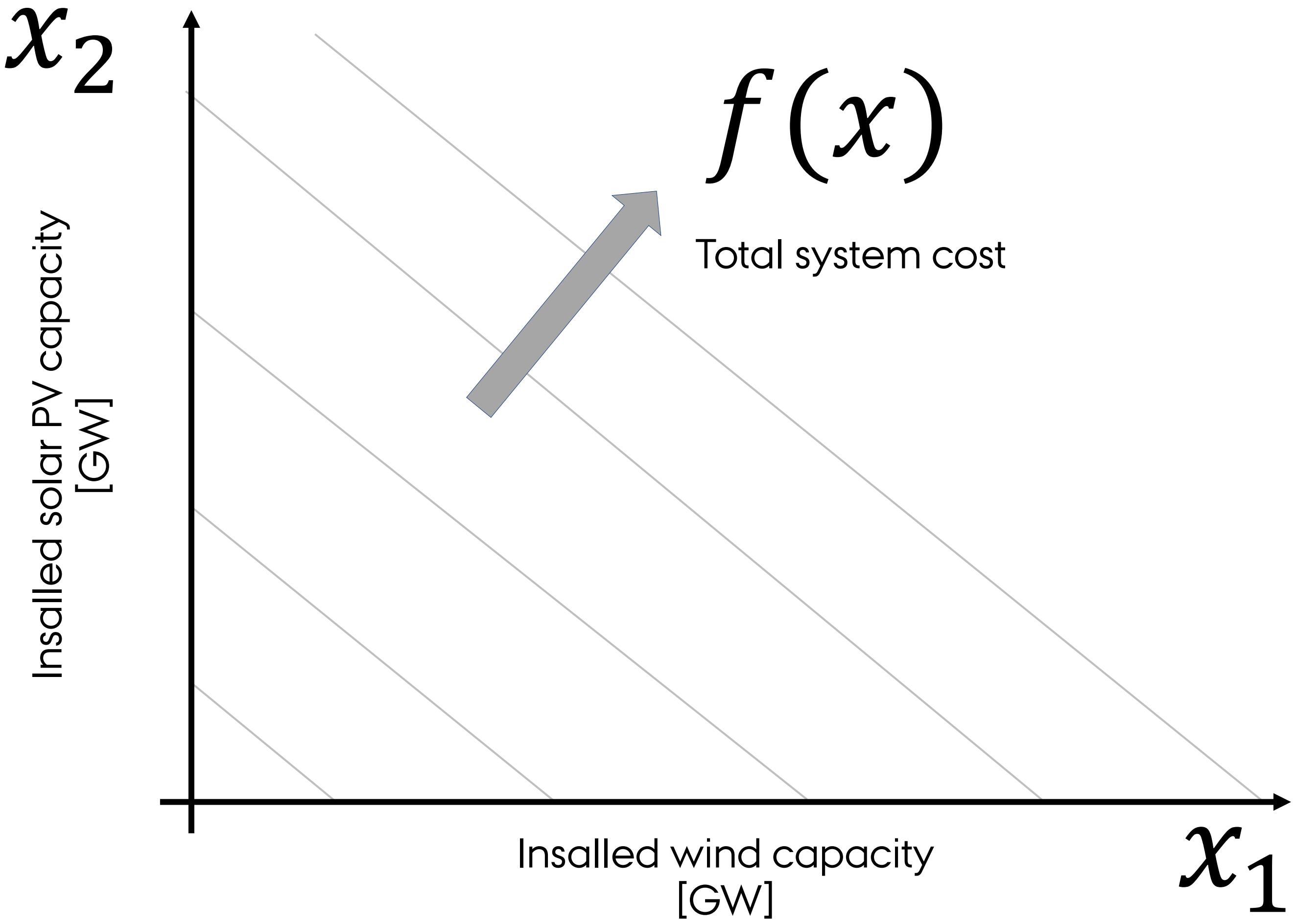

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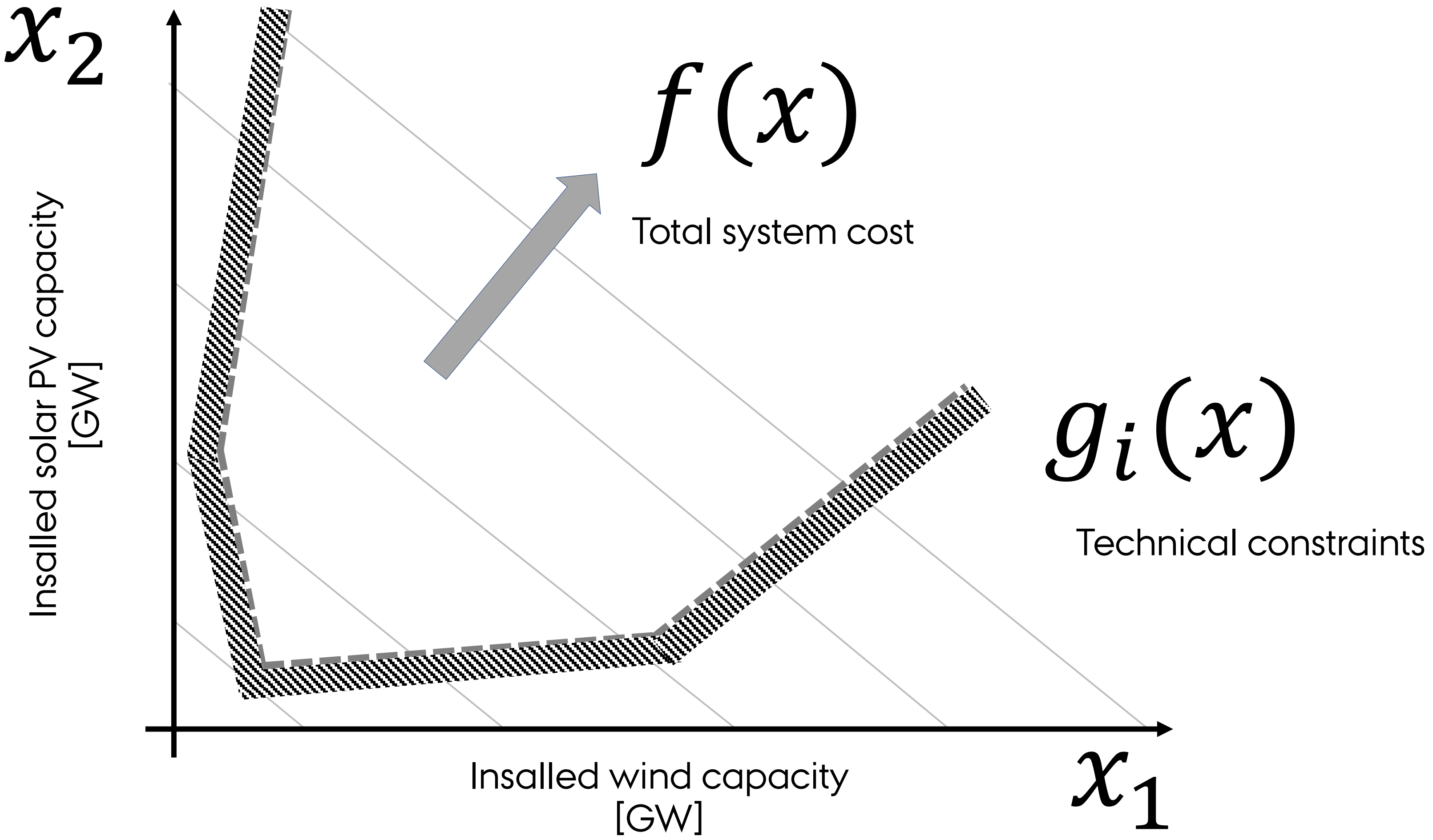

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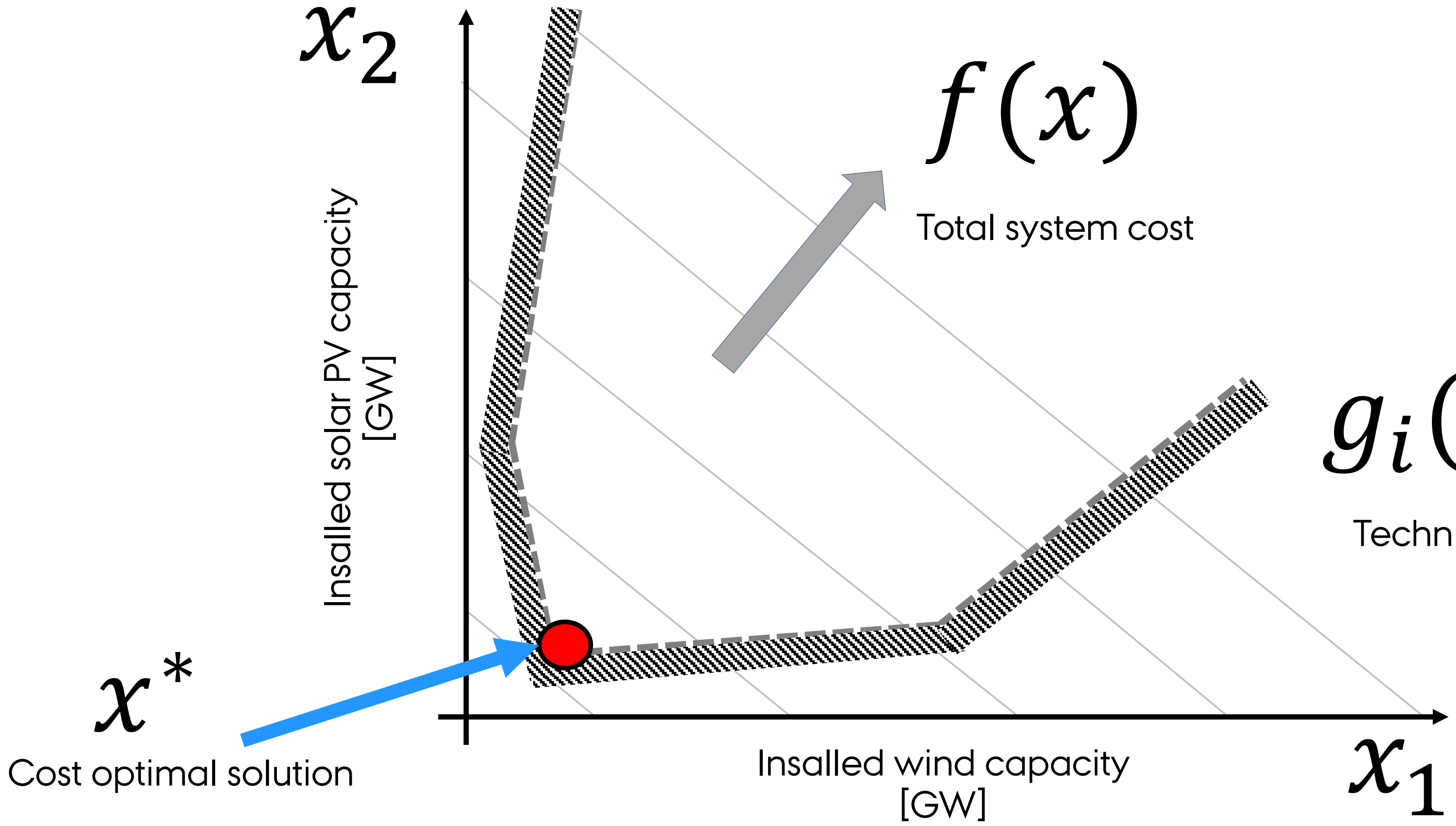

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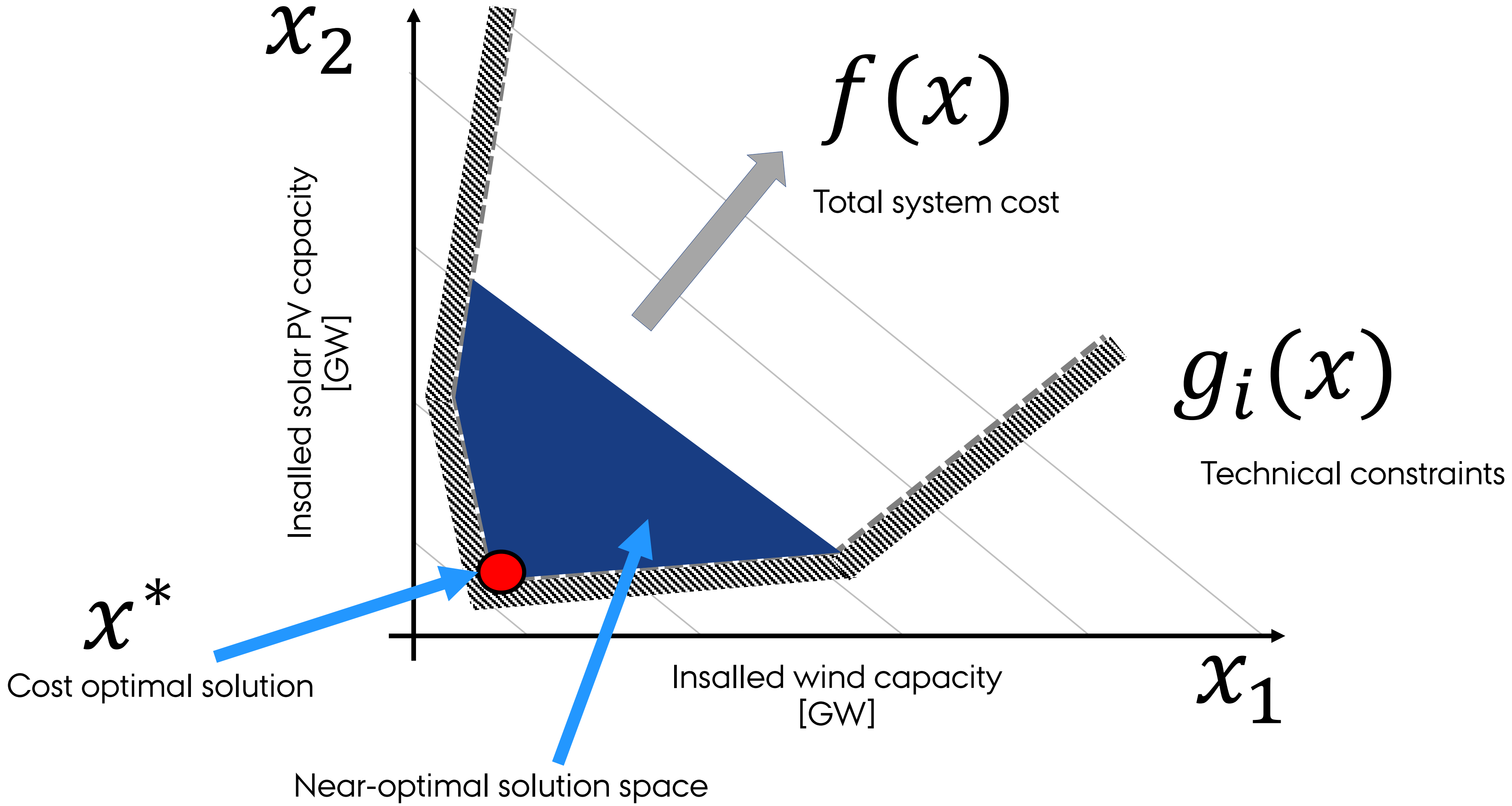
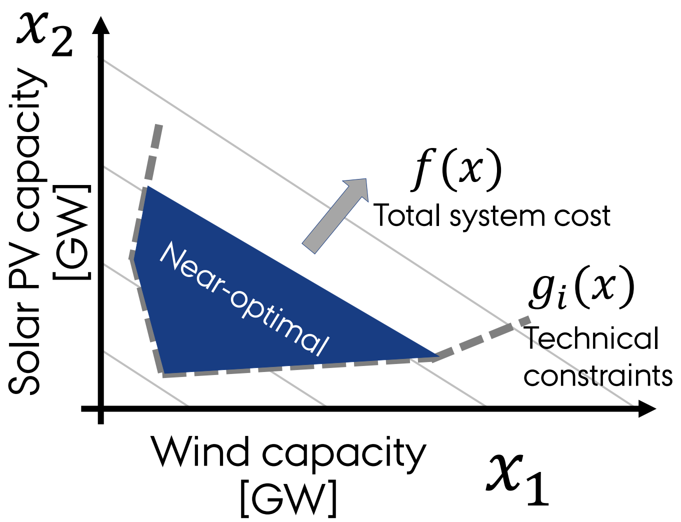


NEAR-OPTIMAL SOLUTIONS



Carriers
- Wind
- Solar
- OCGT
- Battery
- H2

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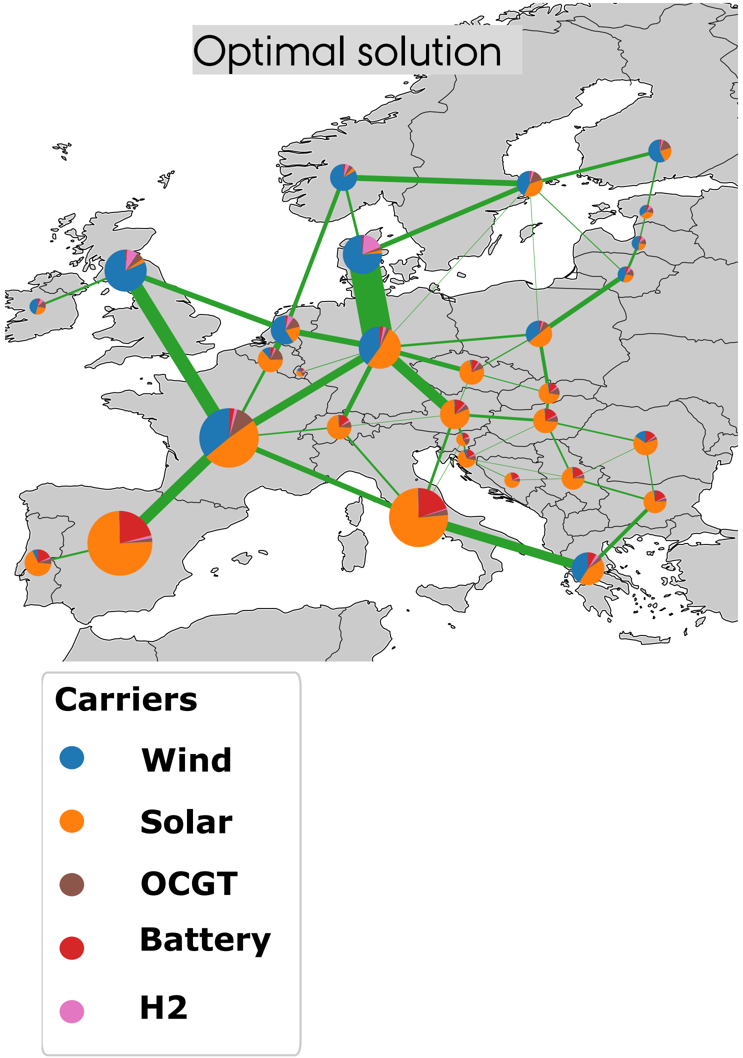

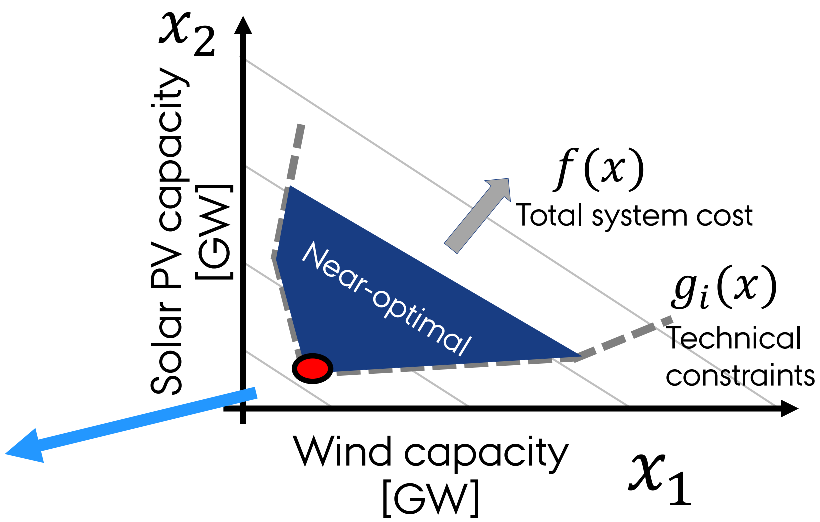

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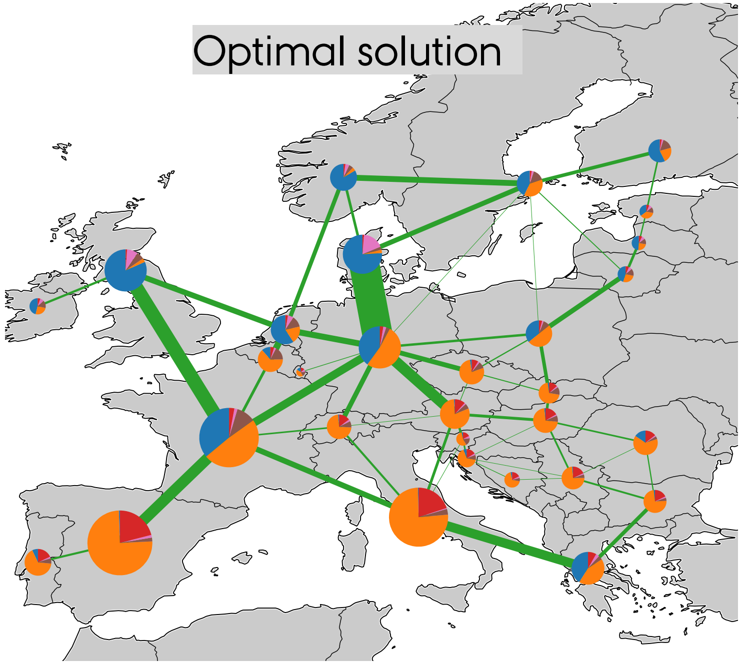

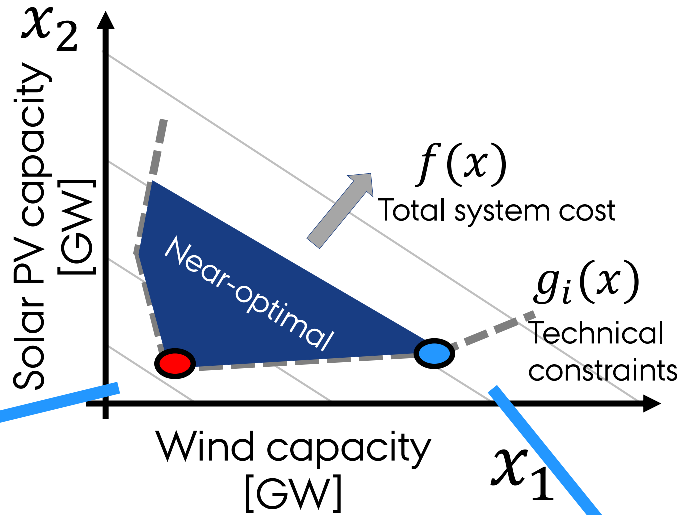

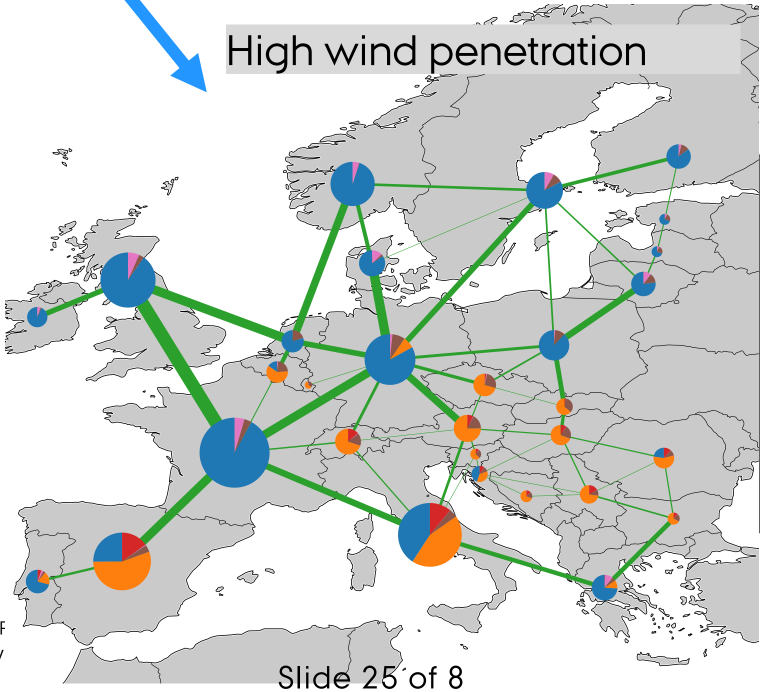

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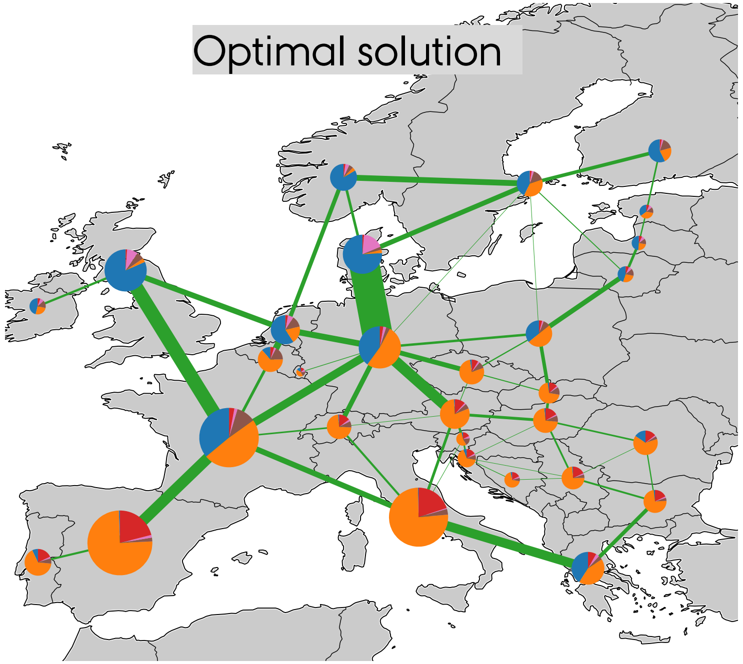

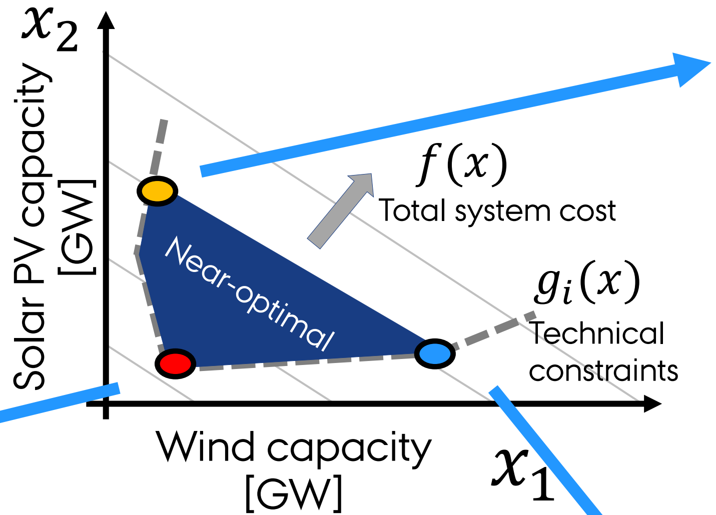

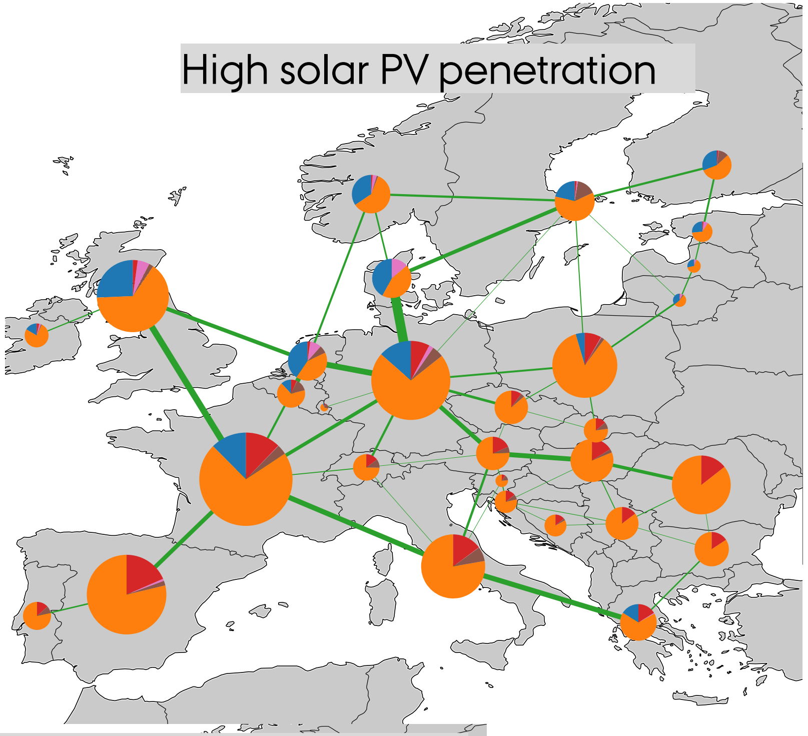

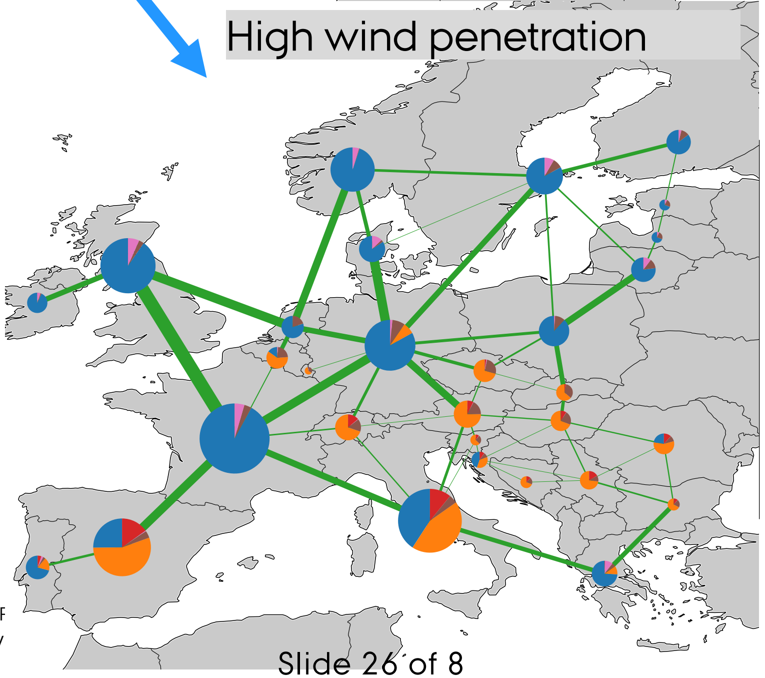

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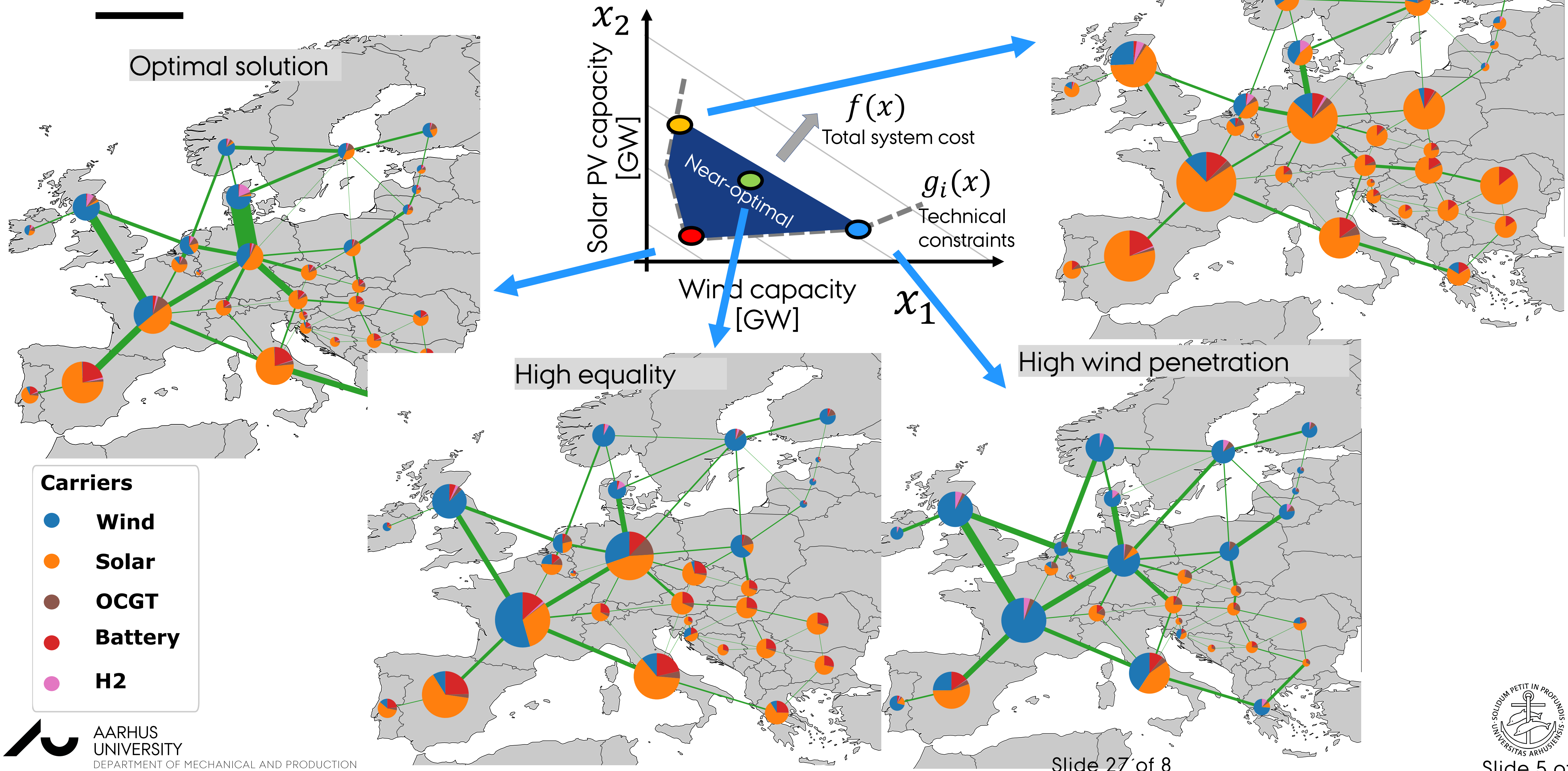

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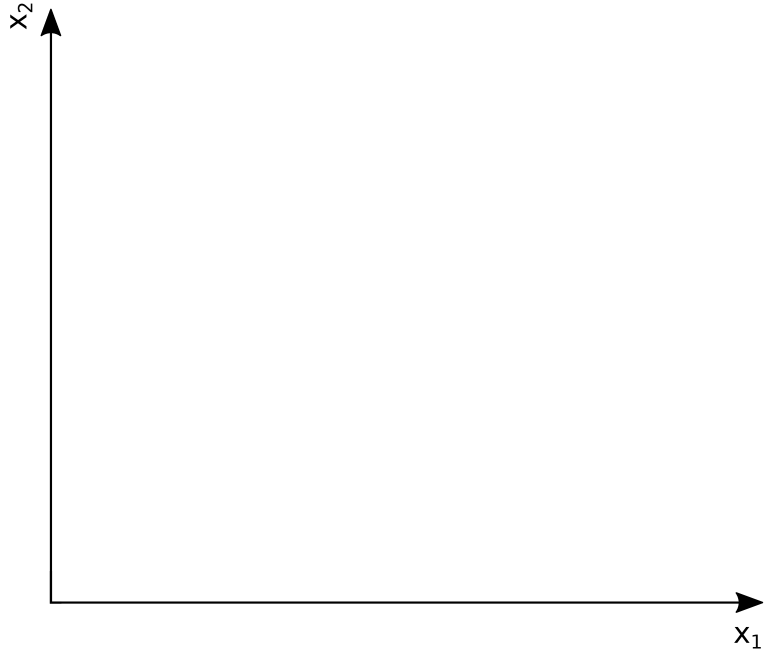
MAPPING ALL ALTERNATIVES



- Optimal solution
- Sample point
- Optimization direction
- Intermediate solution boundary
- Full solution boundary

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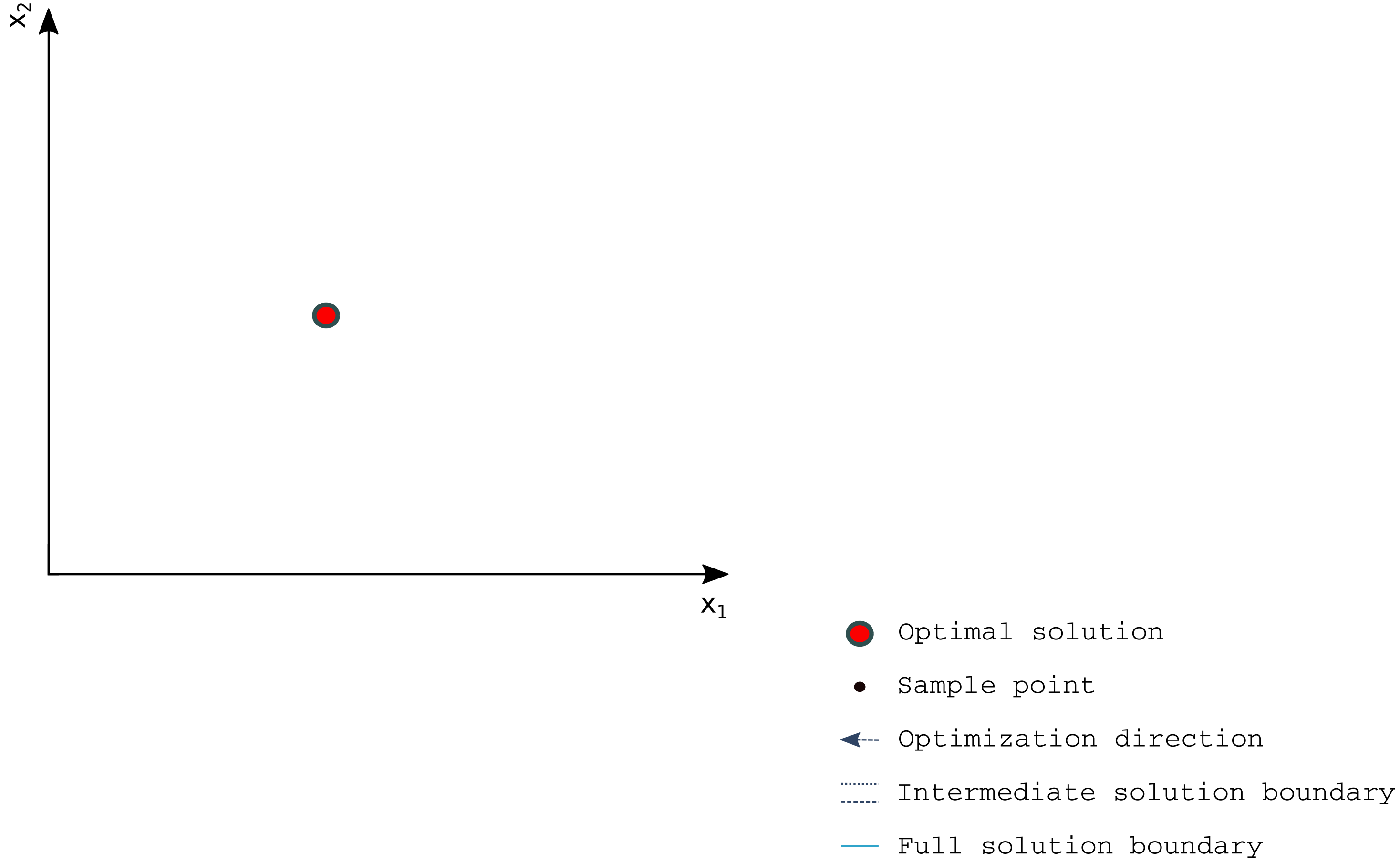
1) Find optimum



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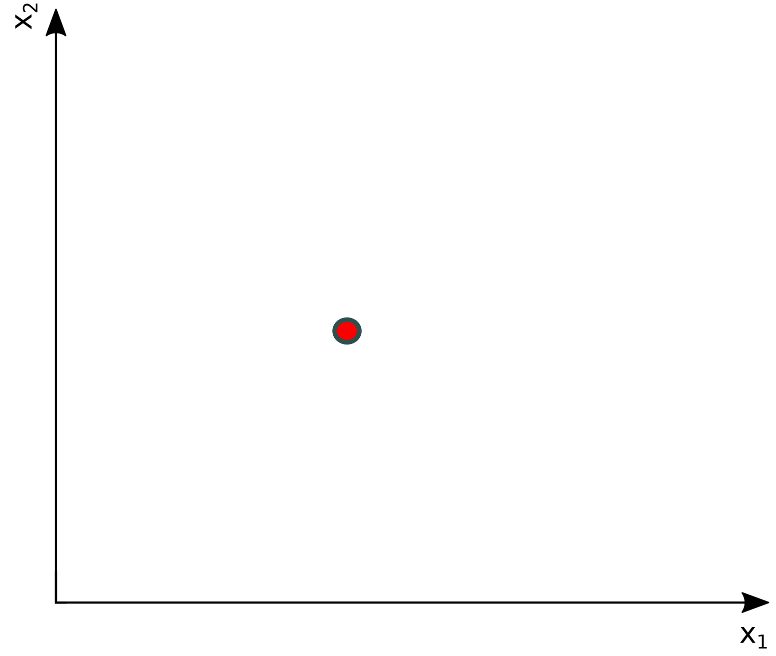
MAPPING ALL ALTERNATIVES

1) Find optimum
2) Add constraint on maximum total system cost

$f(\mathbf{x}) \leq f(\mathbf{x}^*)(1+\epsilon)$



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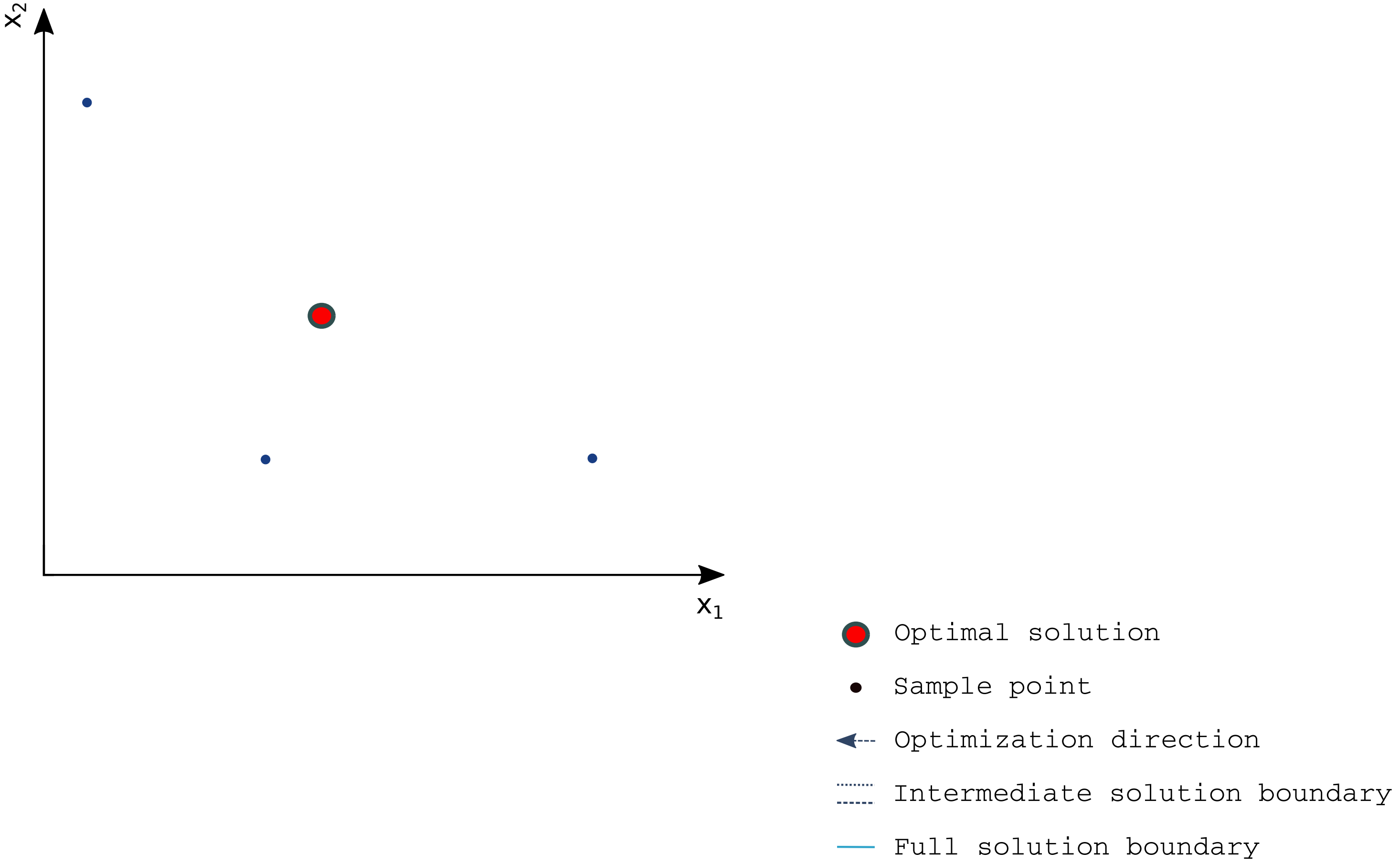
3) Maximize and minimize all variables



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1) Find optimum
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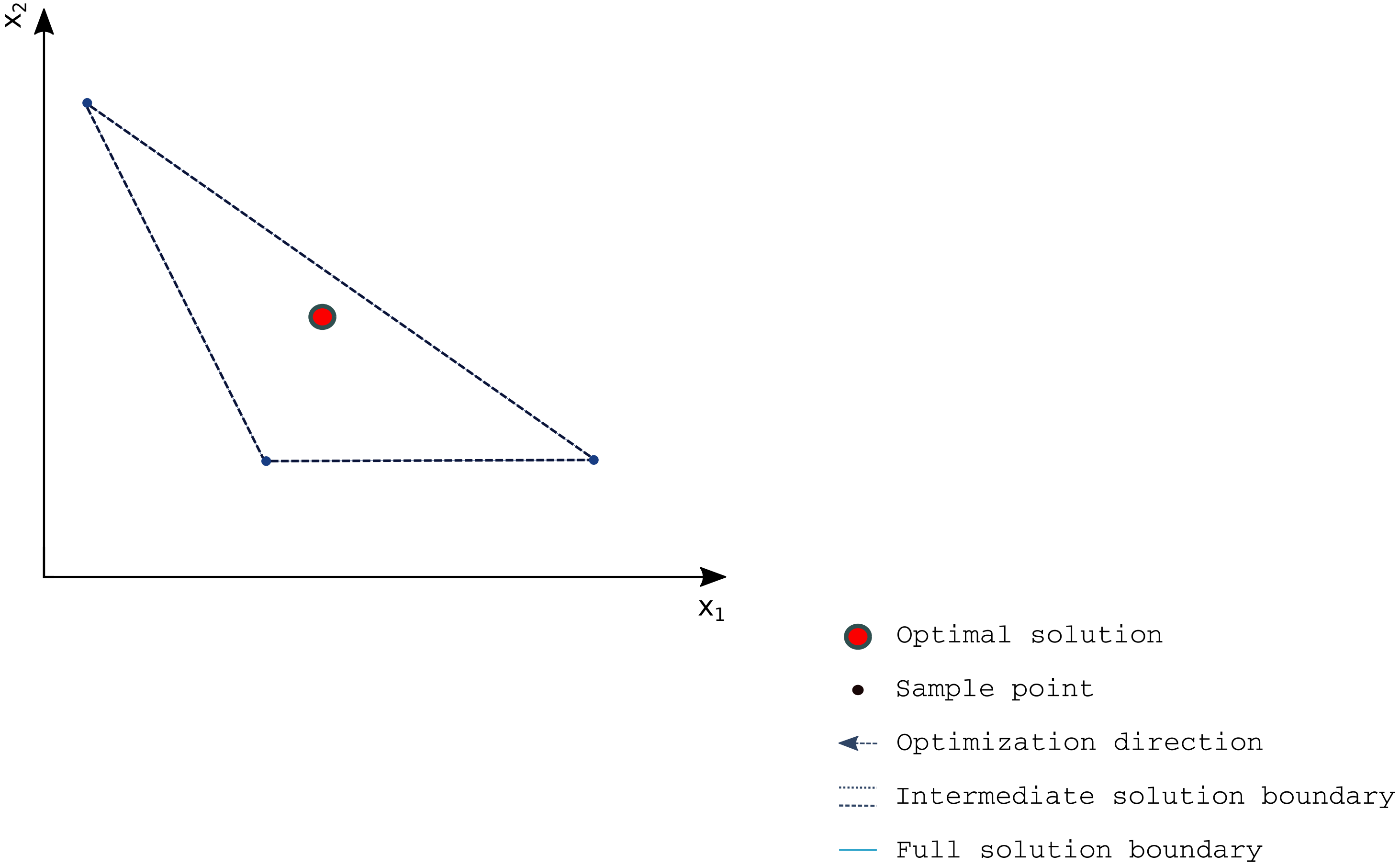
4) Define convex hull containing known solutions



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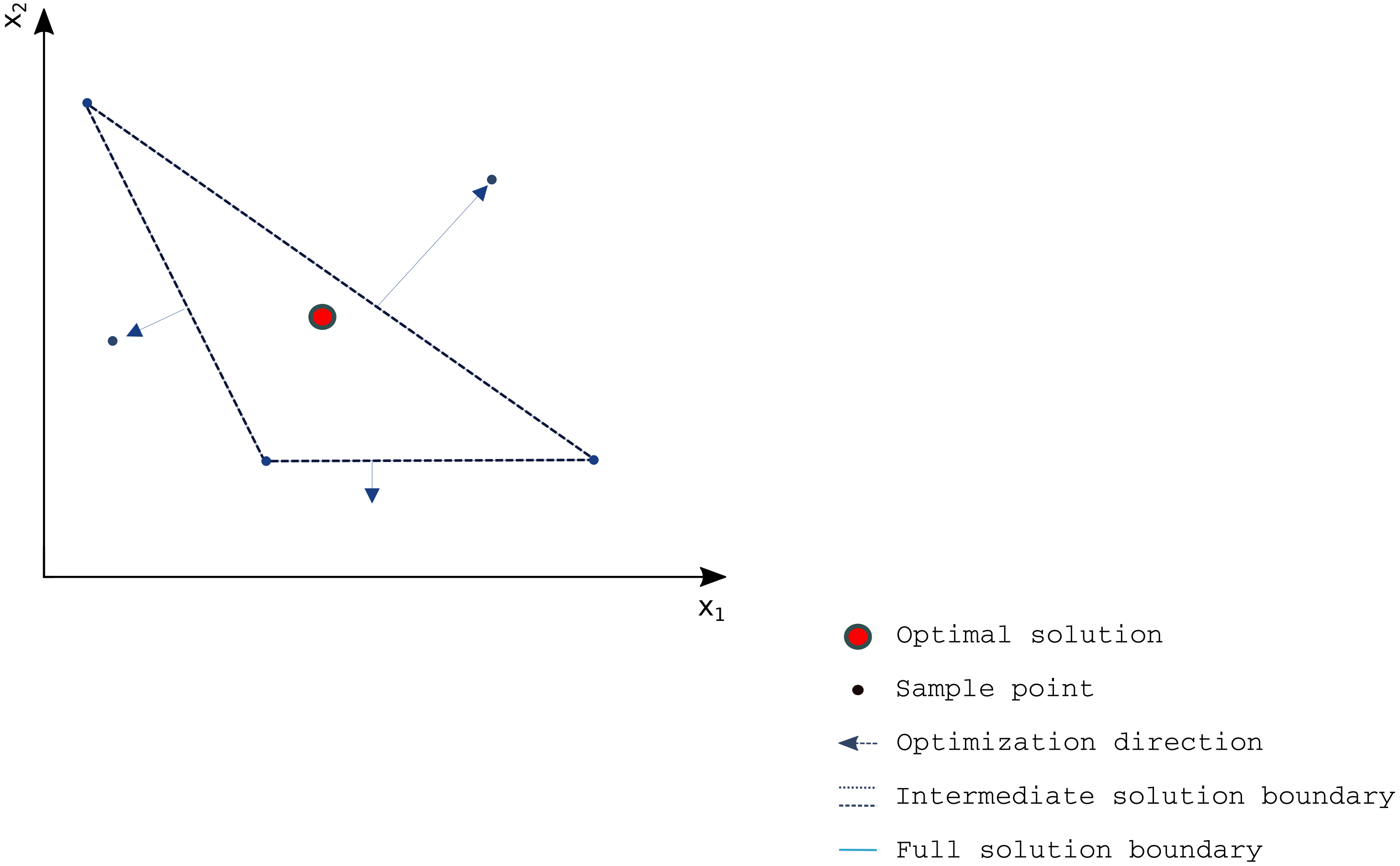

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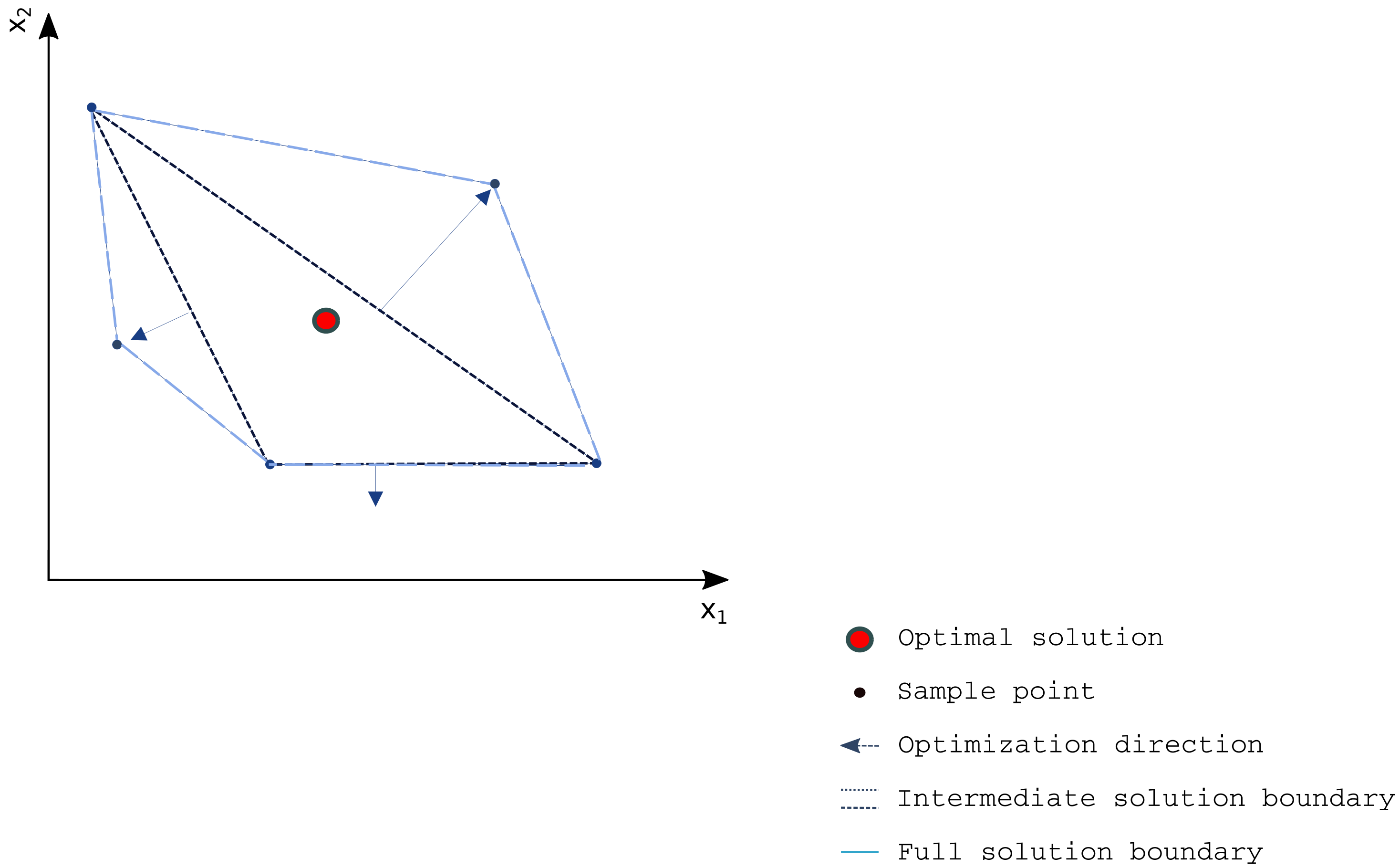

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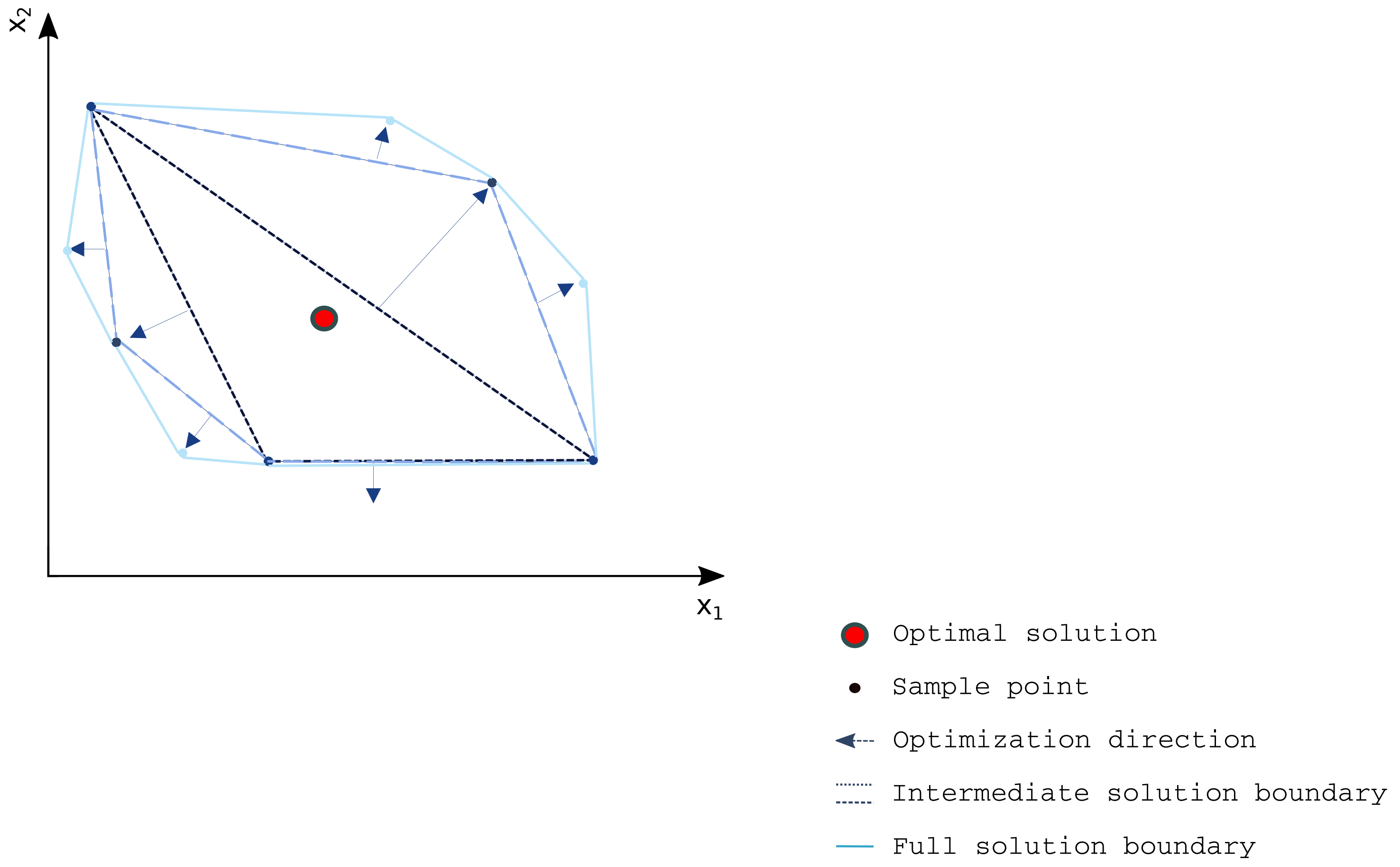

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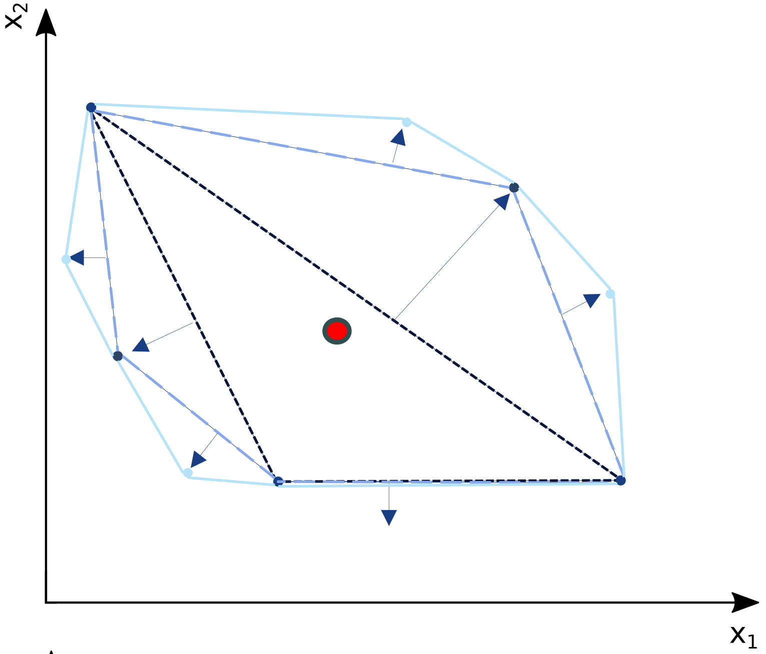

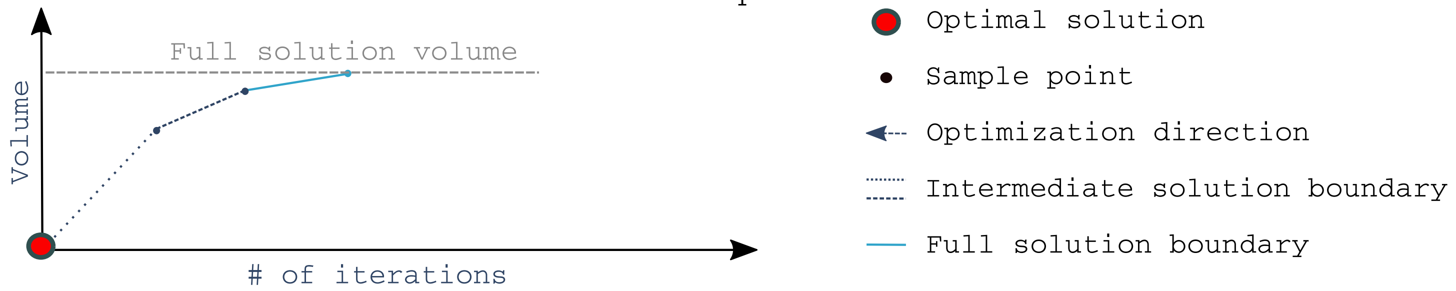

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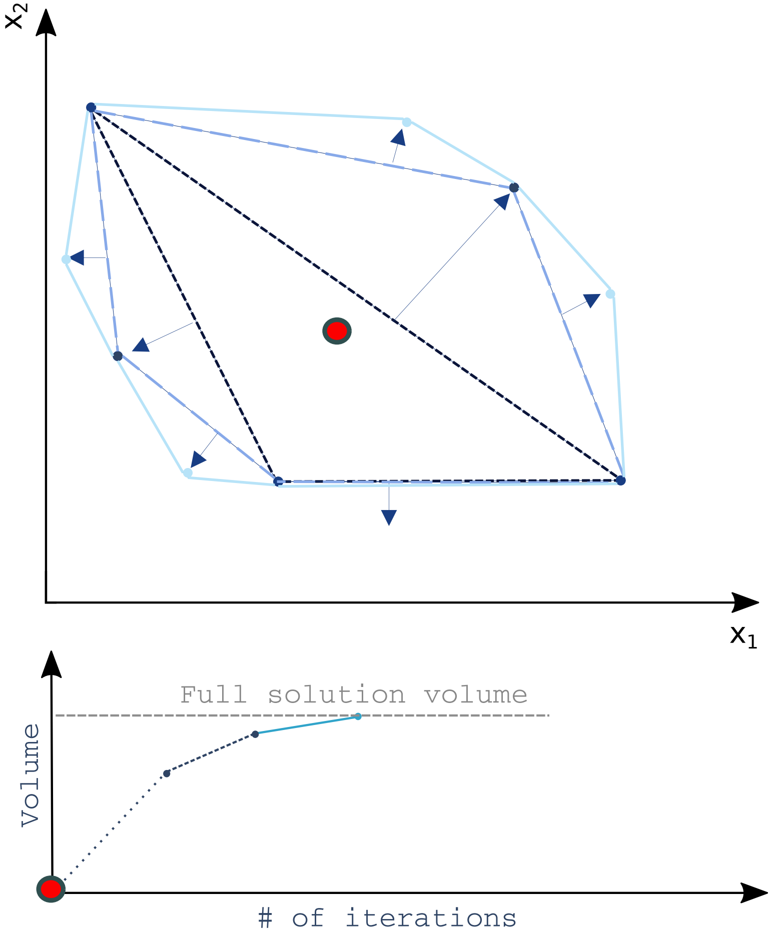
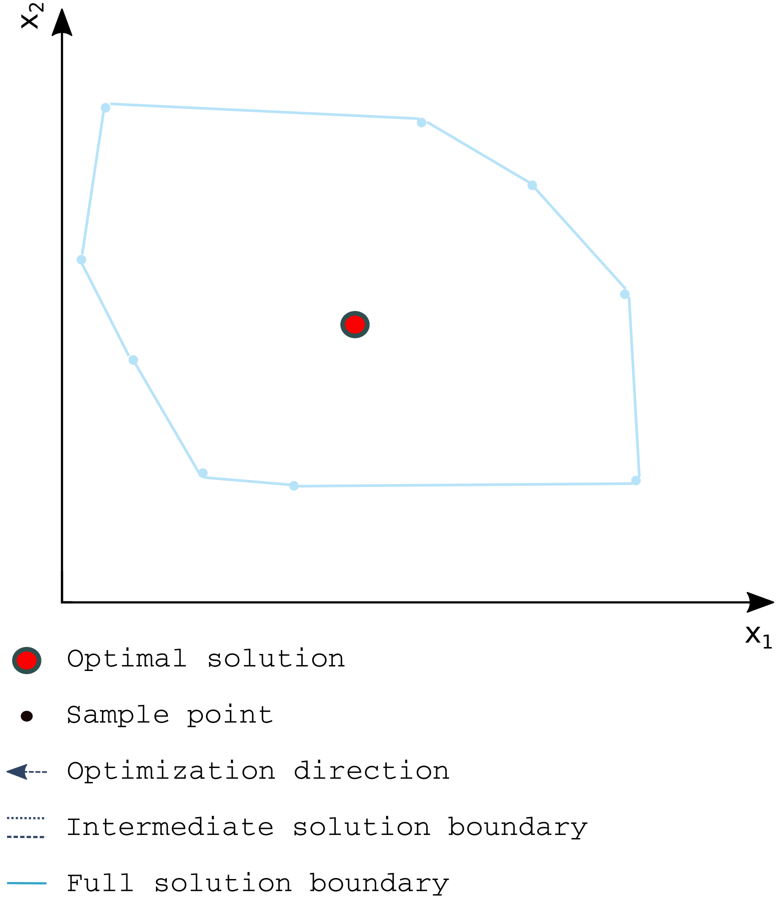
$$\mathbf{p}_{\text{new}} = \sum_{i=1}^{m} \mathbf{p}^i s_i$$





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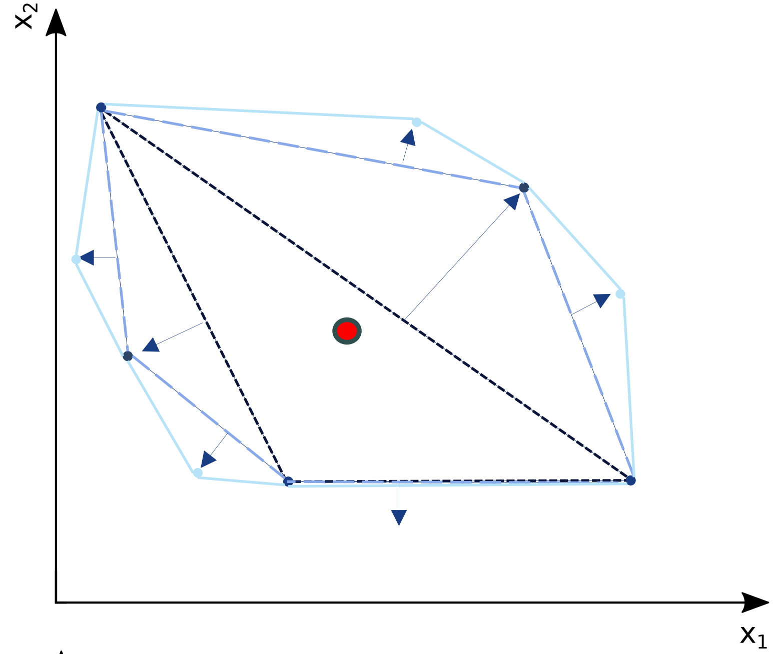

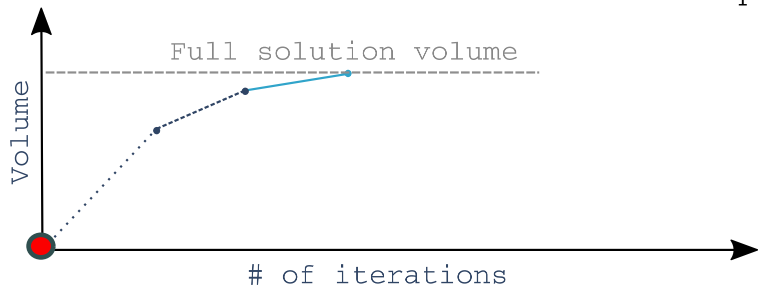

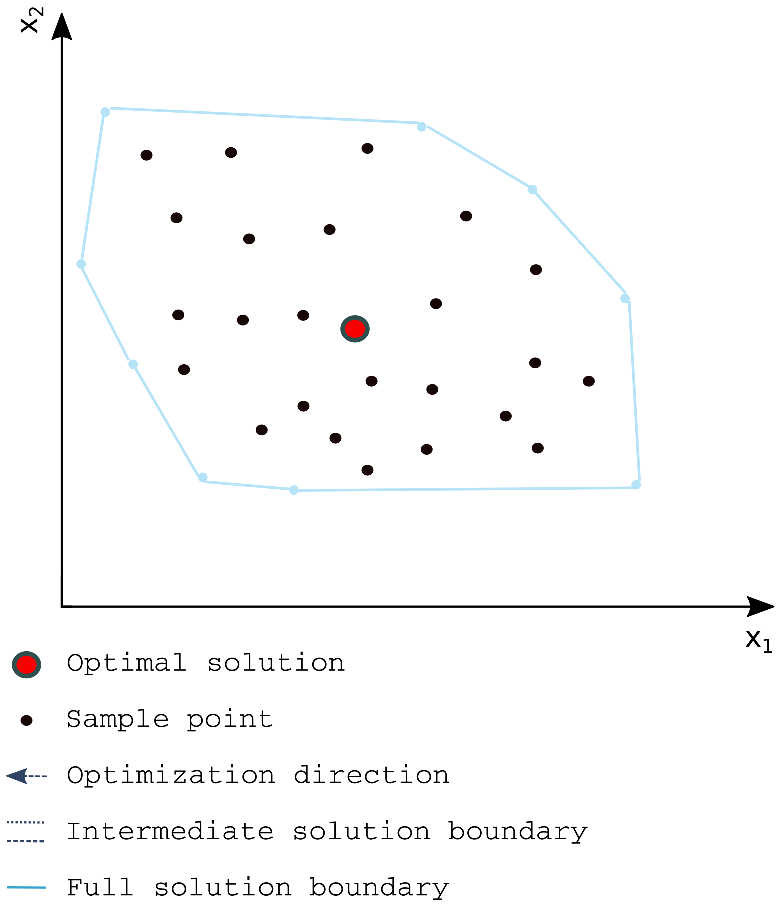

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RESULTS

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- Solutions different in technology mix

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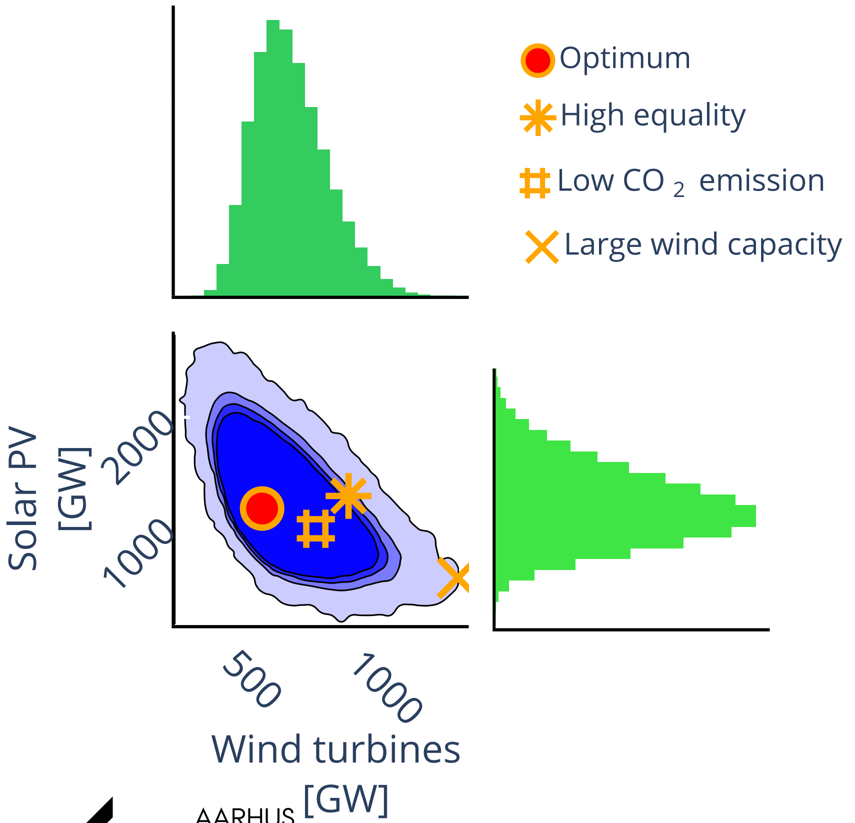

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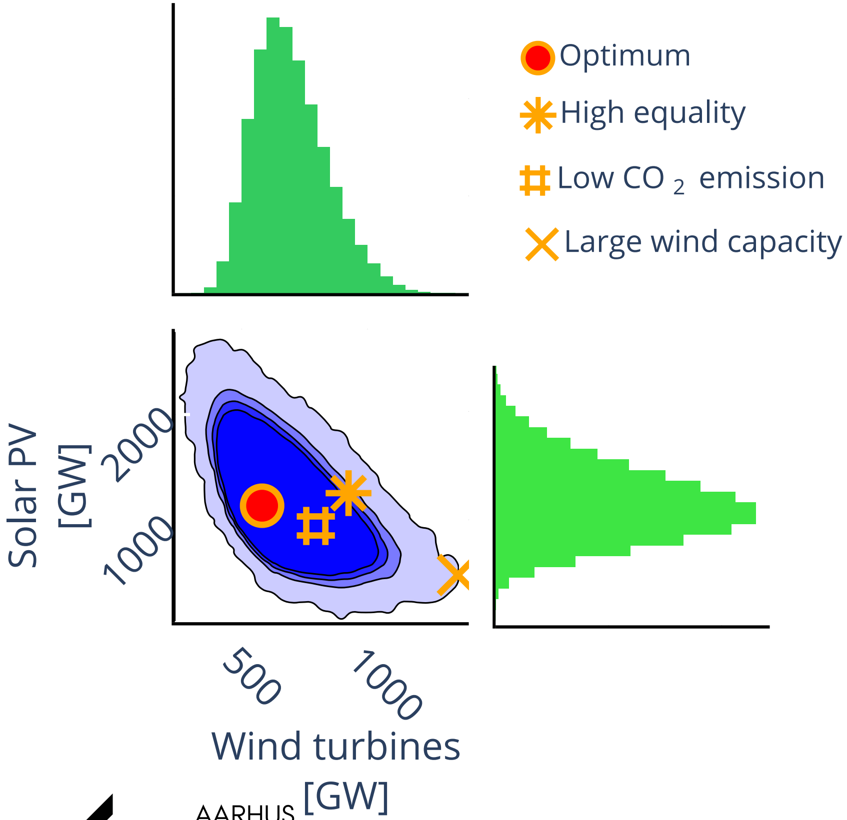

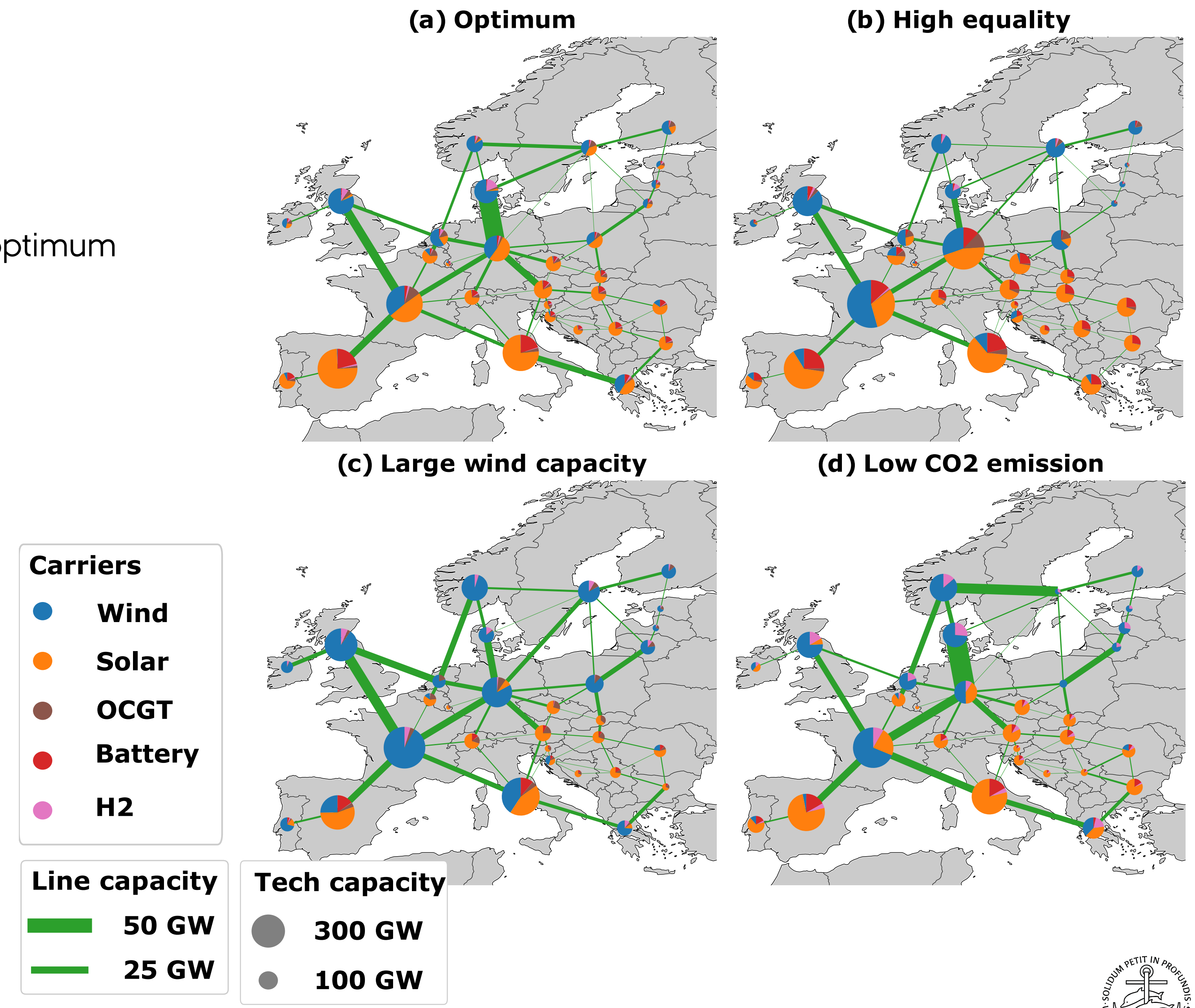

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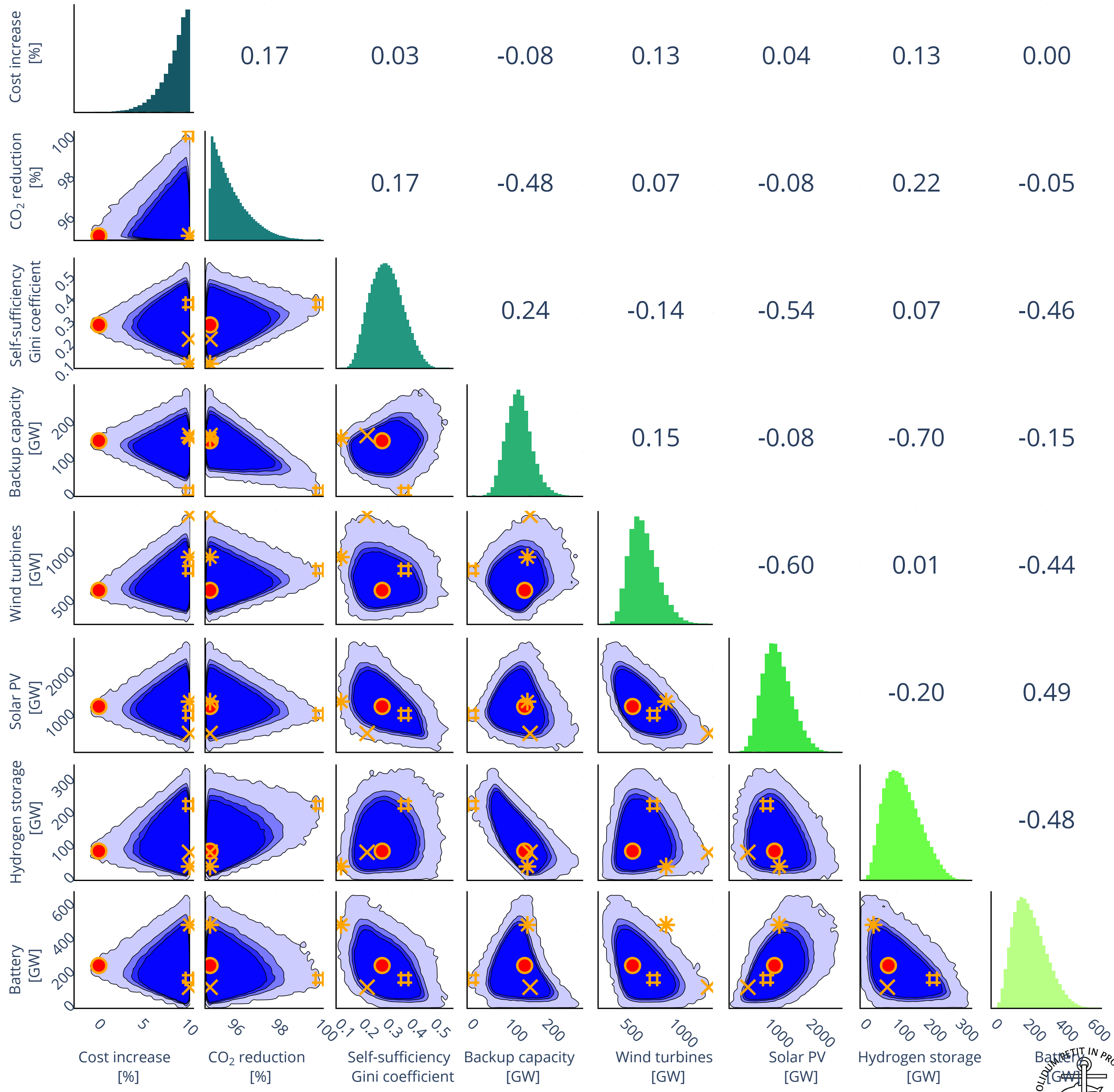

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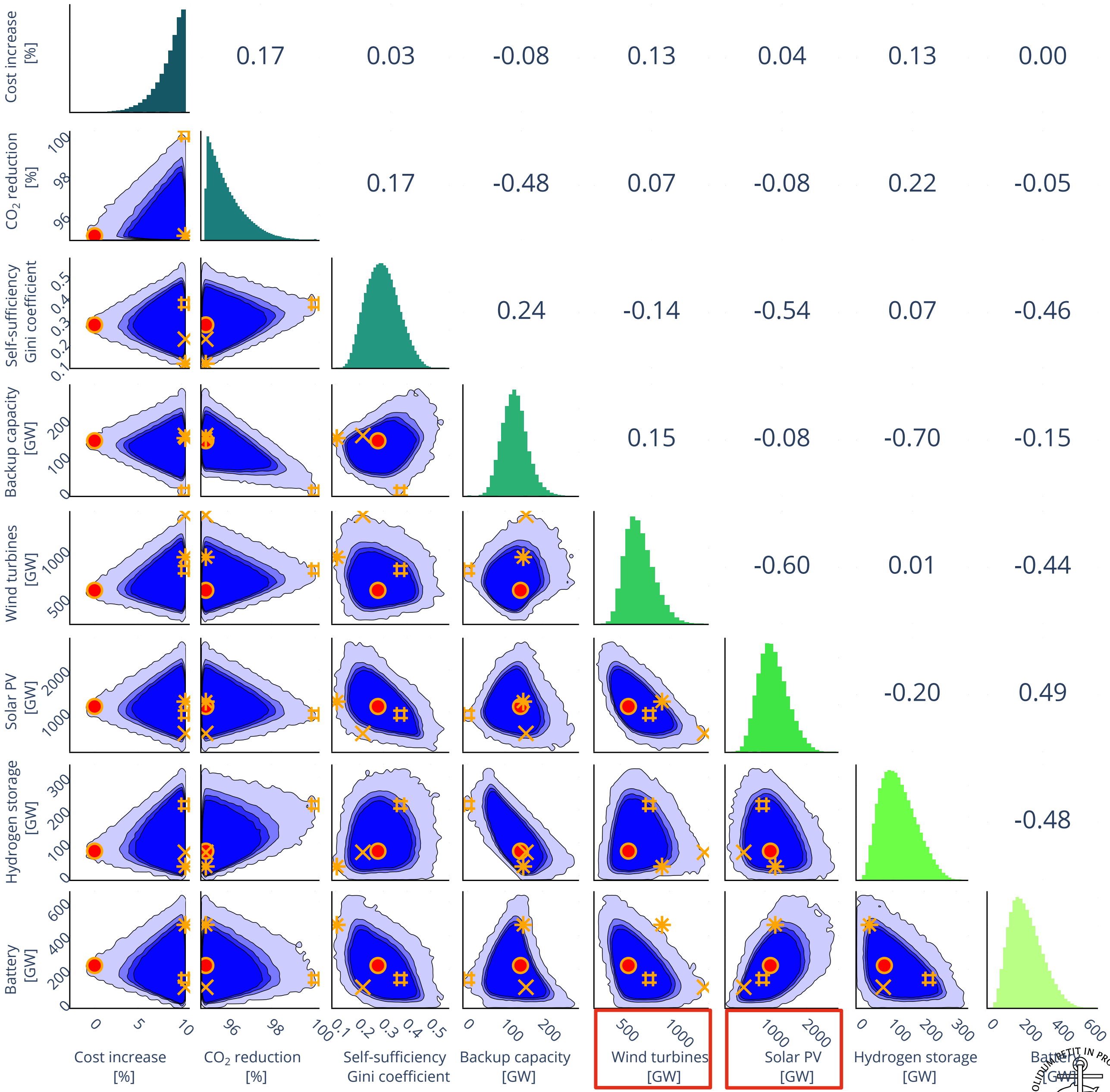
Findings

- Large variation in solutions at small changes in total system cost



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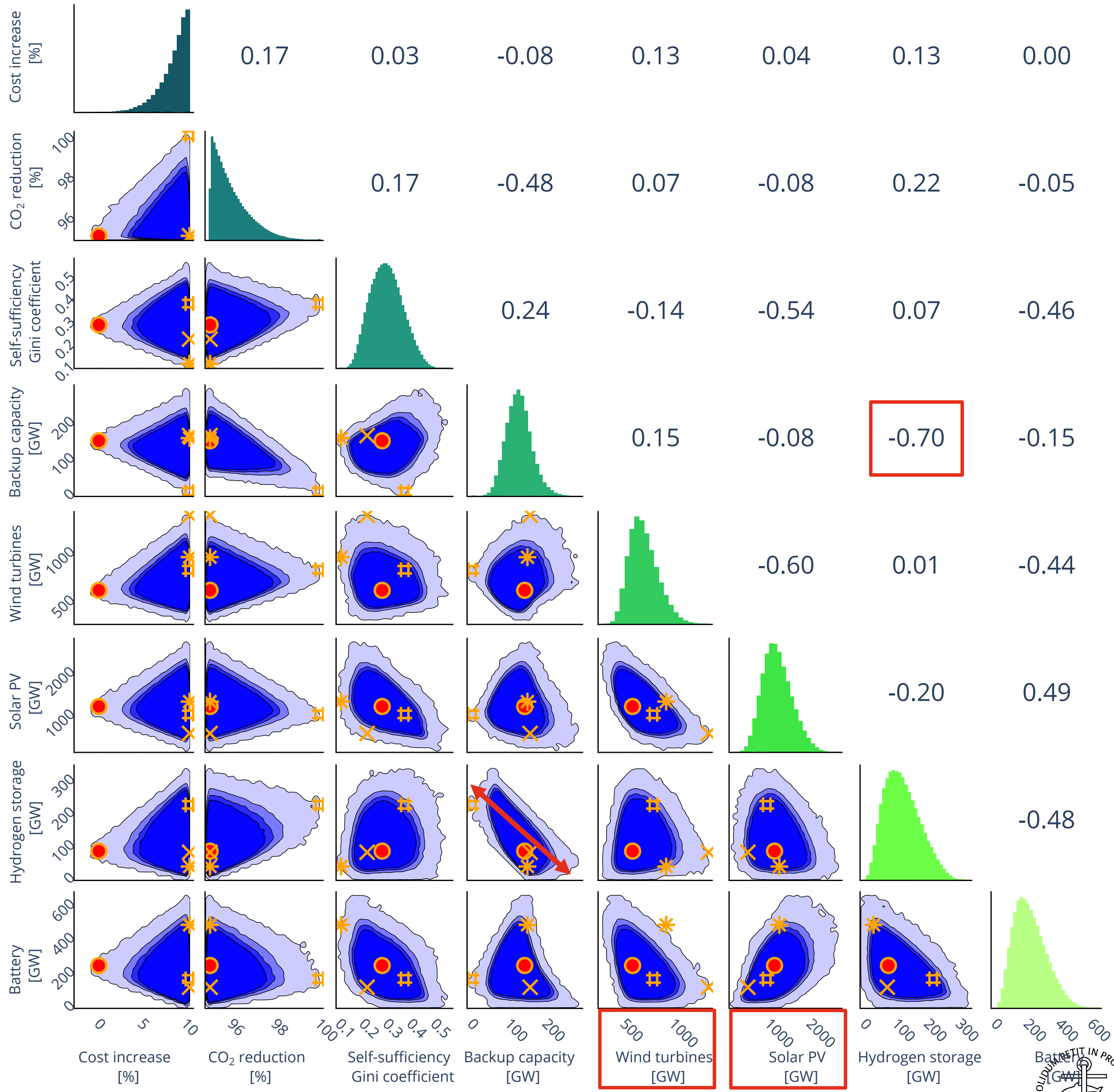
- Negative correlation between hydrogen storage and OCGT



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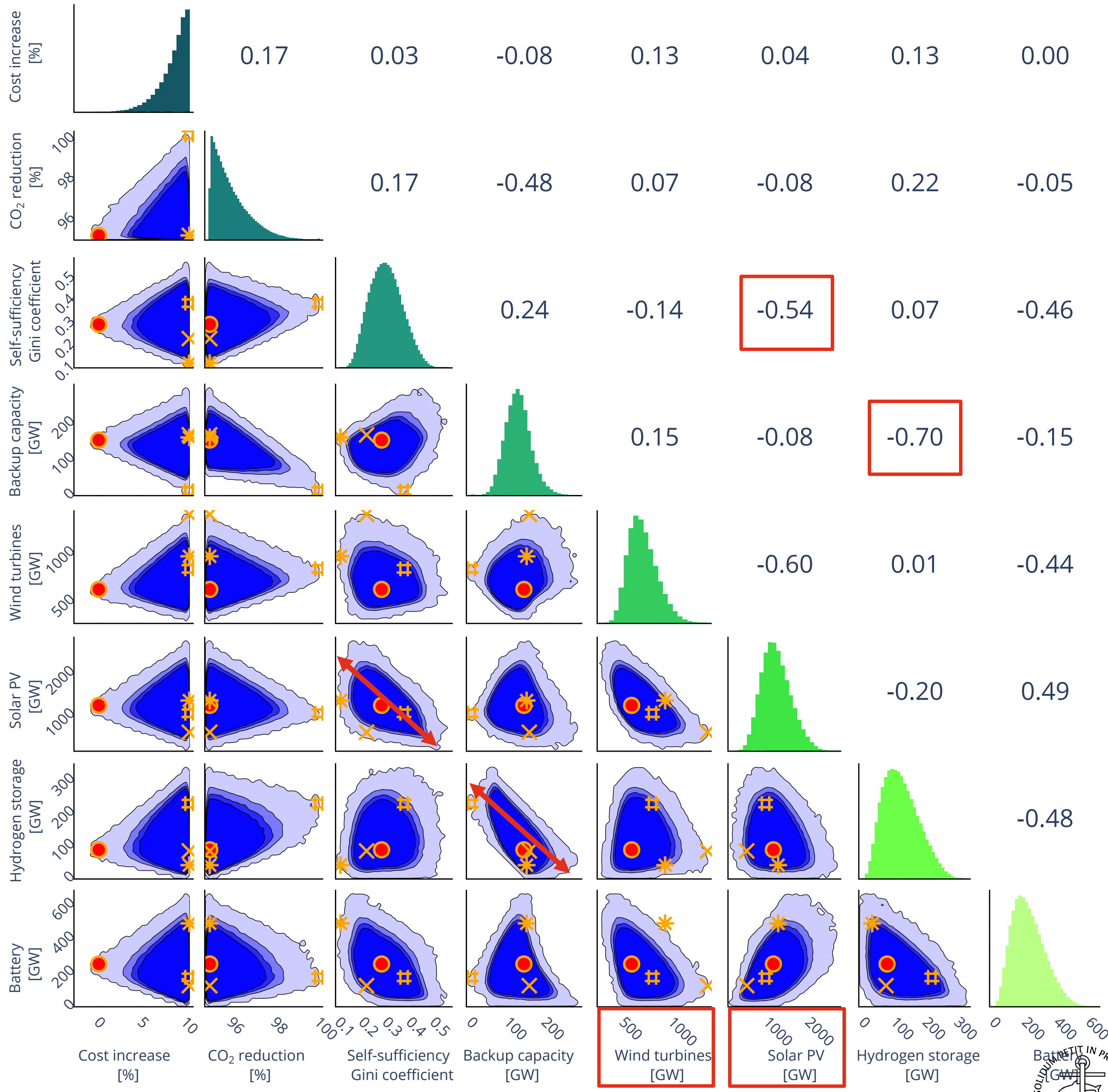
RESULTS

Findings

- Large variation in solutions at small changes in total system cost
- Negative correlation between hydrogen storage and OCGT
- Strong correlation between solar PV and equality in energy production



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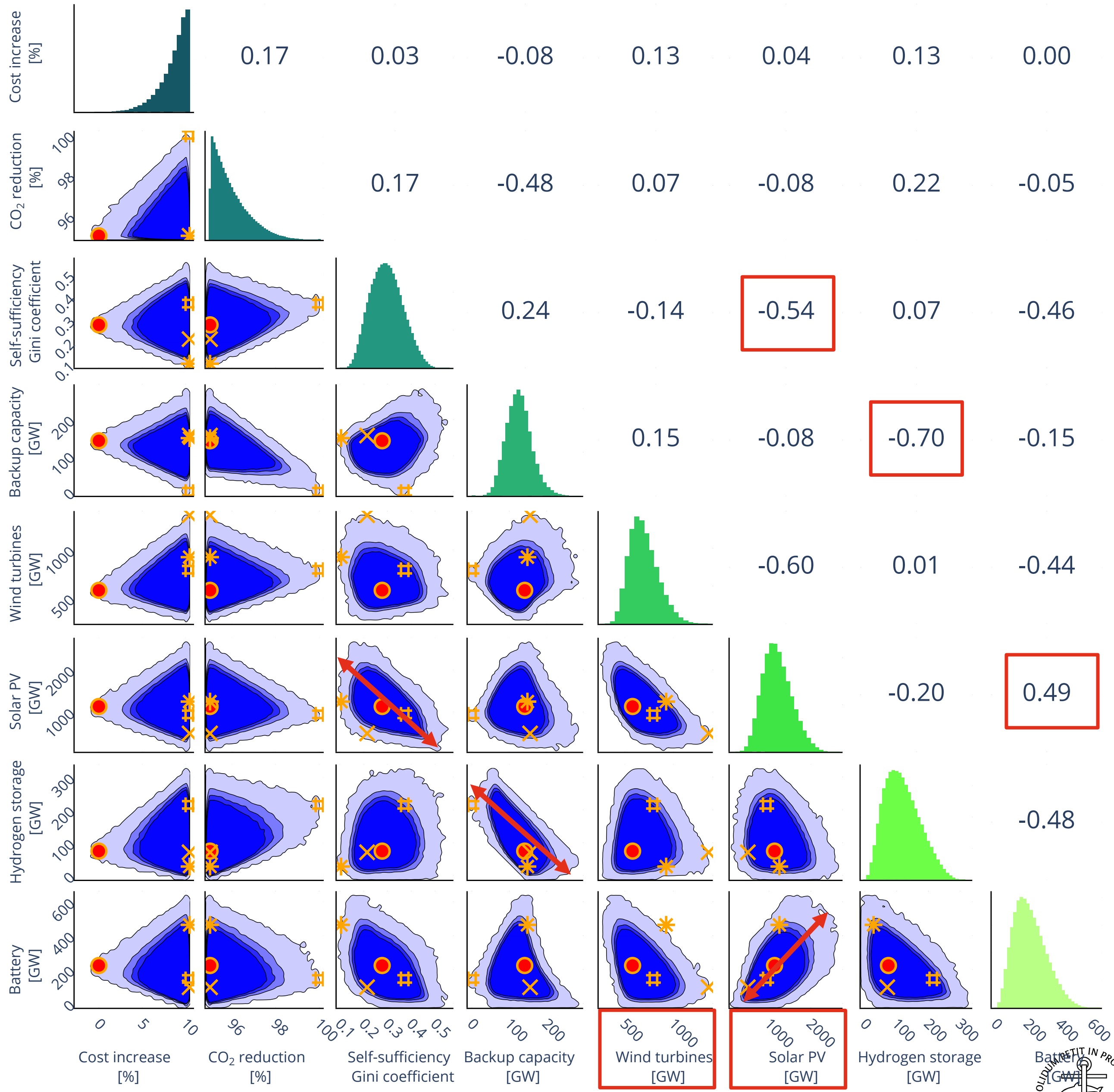
- Large variation in solutions at small changes in total system cost
- Negative correlation between hydrogen storage and OCGT
- Strong correlation between solar PV and equality in energy production
- Strong correlation between solar PV and battery



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