Course SEN1531 - Design of Integrated Energy Systems

Embracing uncertainty.

Or how to use uncertainty to strengthen a modelling analysis

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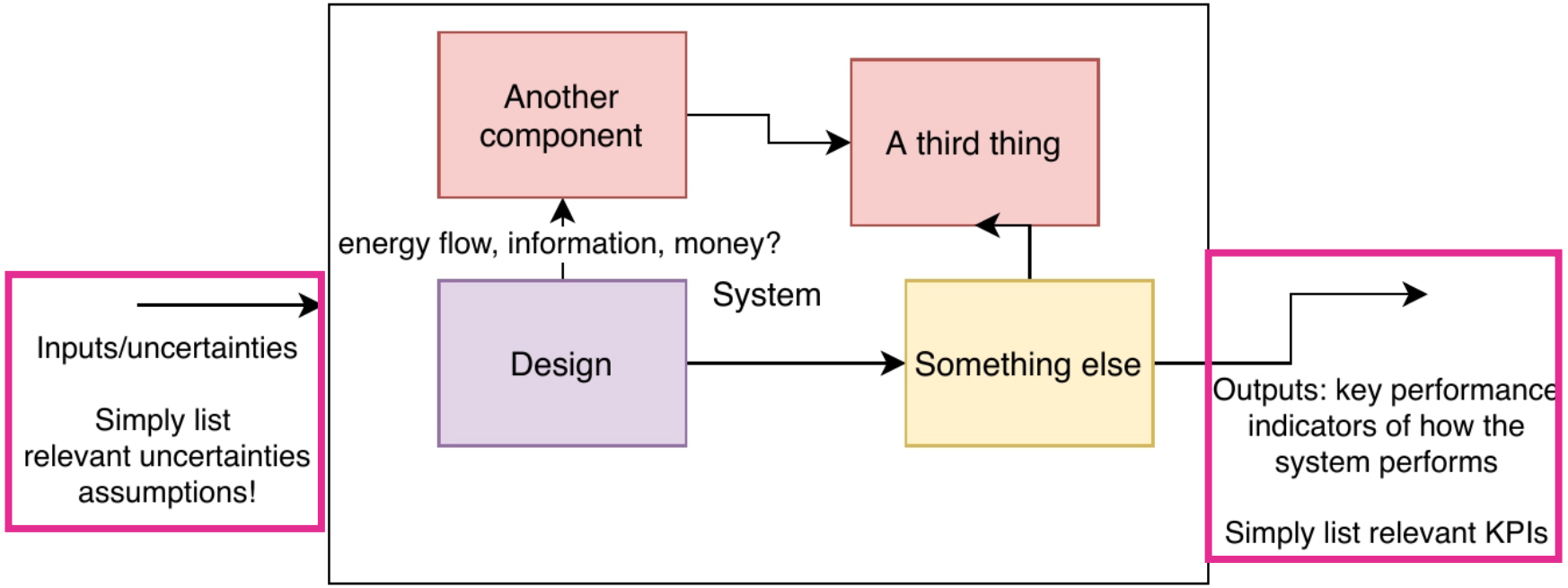
Prelude.

What you learnt so far and how this relates

Prelude.
The problem diagram

You have alredy reflected on uncertainty as part of your **problem diagram**



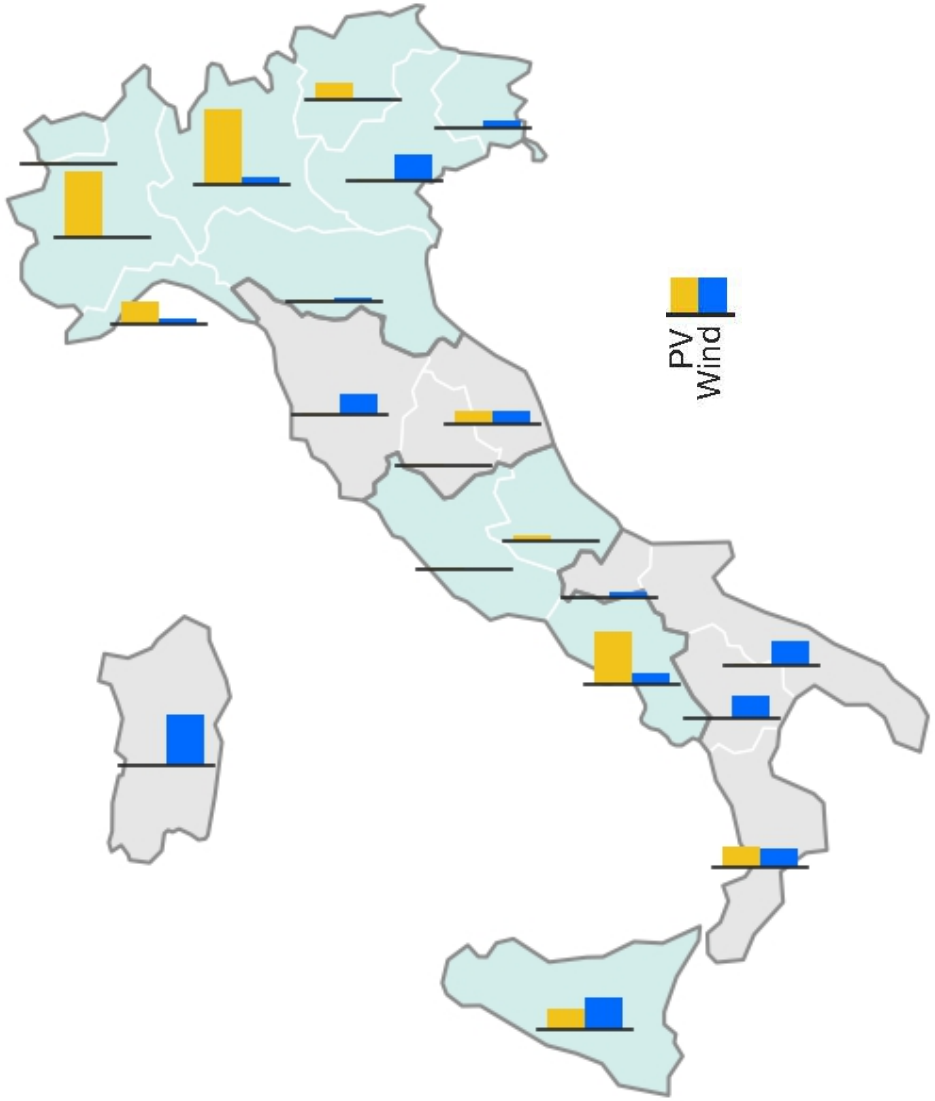
Source: E. Chappin, *How to think and structure your approach*, SEN1531

And you've dealt with how uncertain **inputs** affect your **outputs** for some weeks now, for various models

Prelude.

Let's discuss an example model result

Cost-optimal deployment of solar and wind power capacity to fully decarbonise the Italian power system (Calliope-Italy model)



Do you trust this result is solid?

vevox.app
149-444-184

Lombardi, Pickering, Colombo, Pfenninger. *Joule*, 2020. https://doi.org/gg8z6v

Learning objectives.

By the end of today's session, you will be able to

A. **Explain** the different **types of uncertainty** affecting the model-based design of an integrated energy system

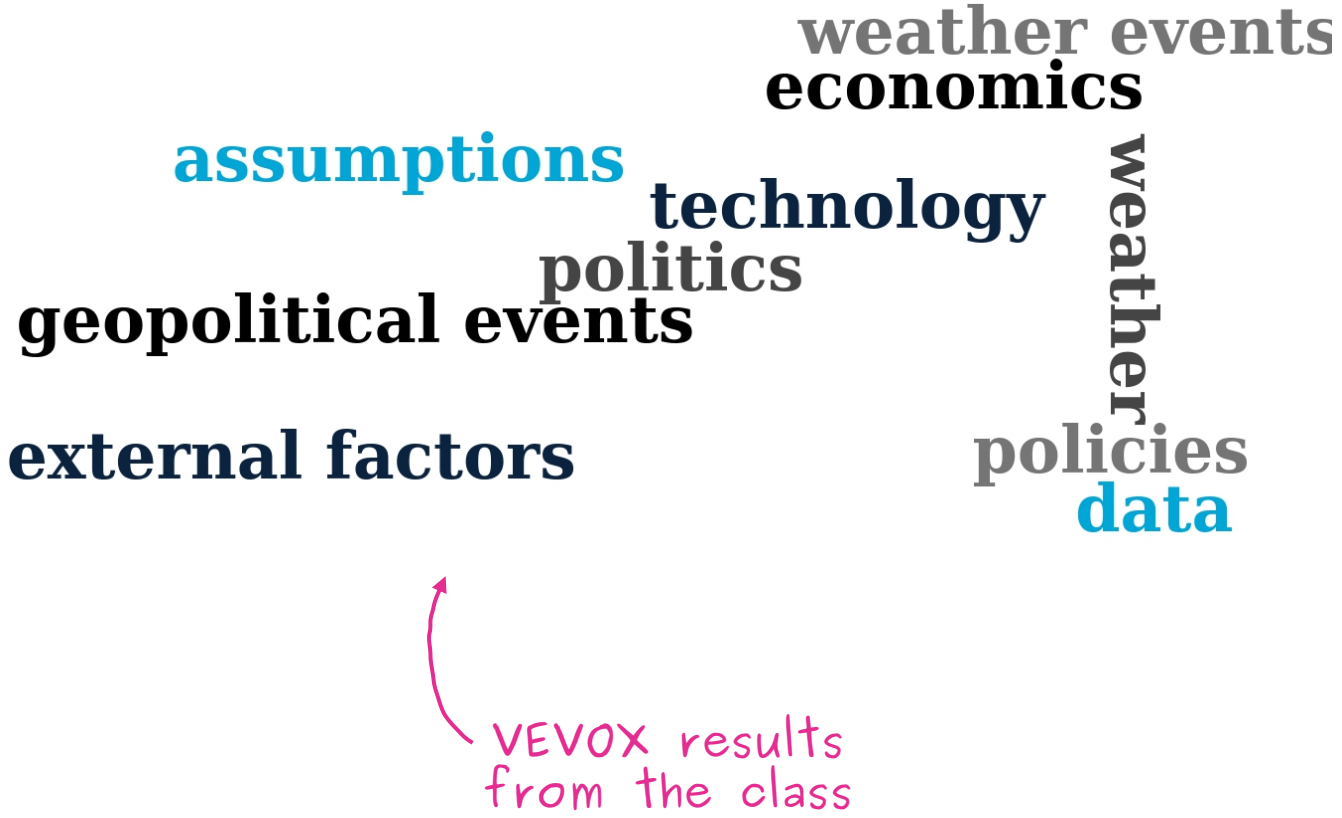
B. **Select methods** to deal with each type of uncertainty

Part A.

What is uncertain in a model?

What could be a source of uncertainty in the shown example model result for the decarbonisation of the Italian power system?

Uncertainty sources.
Brainstorming



What **uncertainty category** would you consider the **most important** to control among those arosen from the in-class discussion?

Uncertainty sources.
Ranking

Discuss with who's sitting next to you (groups of 2-4 people)

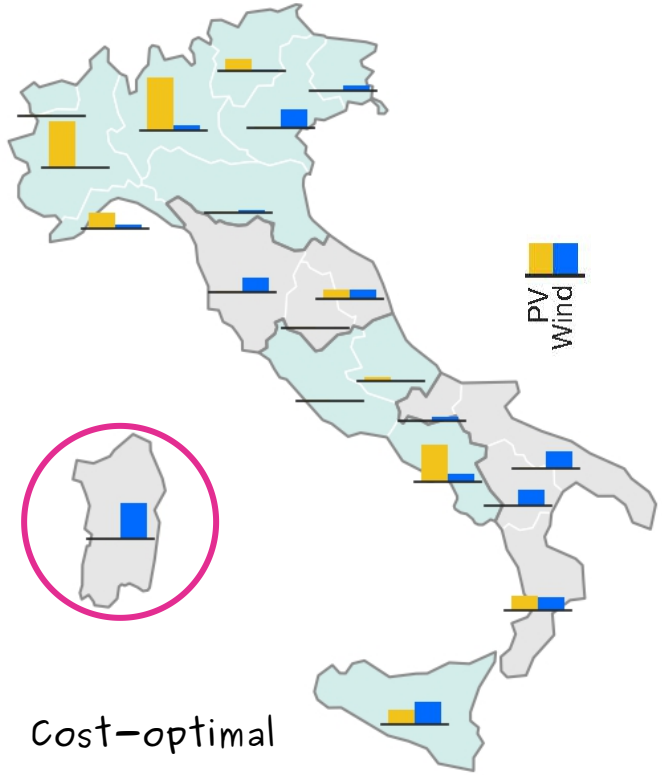
3 minutes!

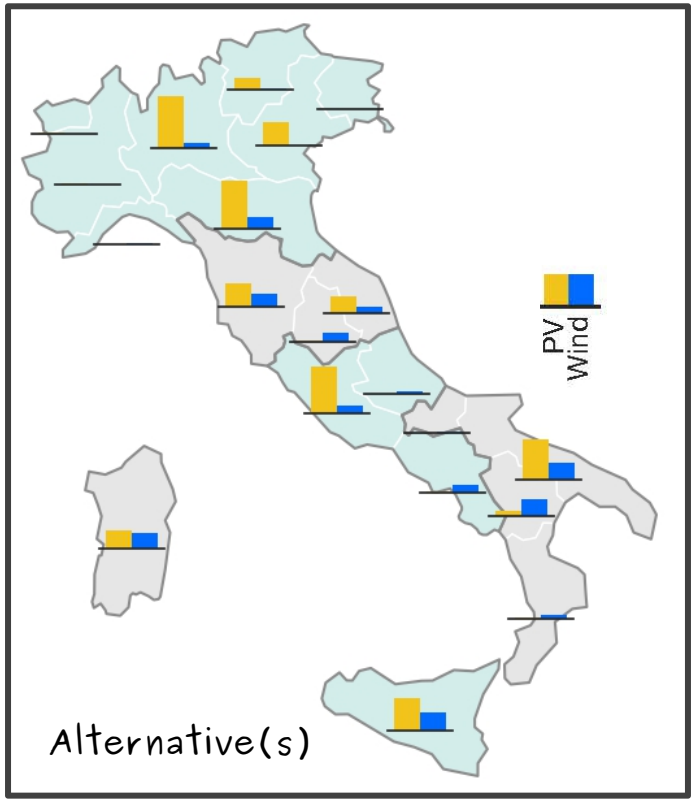
Results from the class:

1. Weather data
2. Technology data
3. Economic and political factors

Uncertainty lies not only with data but also with a **model's structure.**
For instance, with the chosen **objective** for an optimisation model

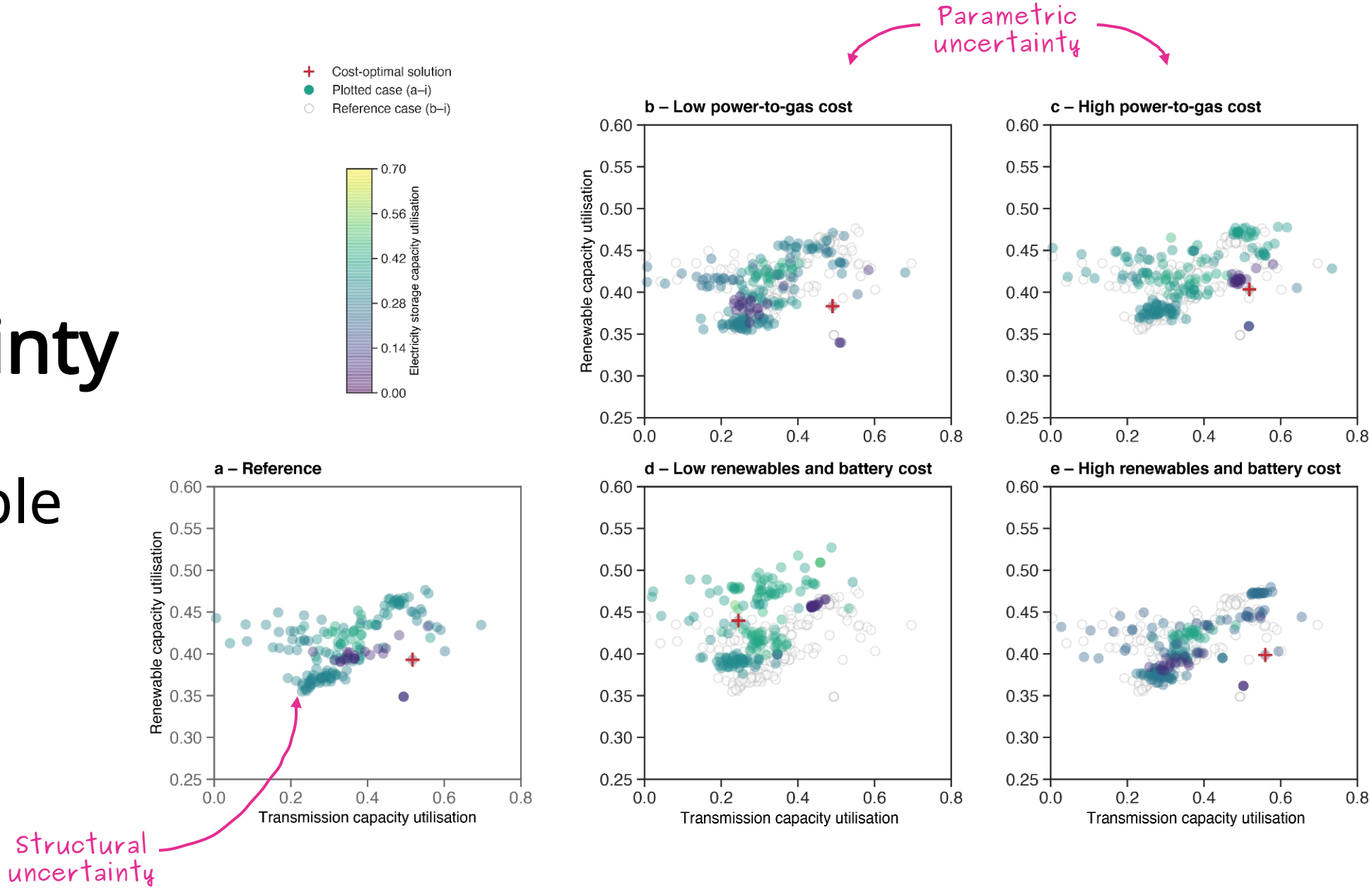
Uncertainty sources.
A second look at the example





Uncertainty sources.

Full example overview



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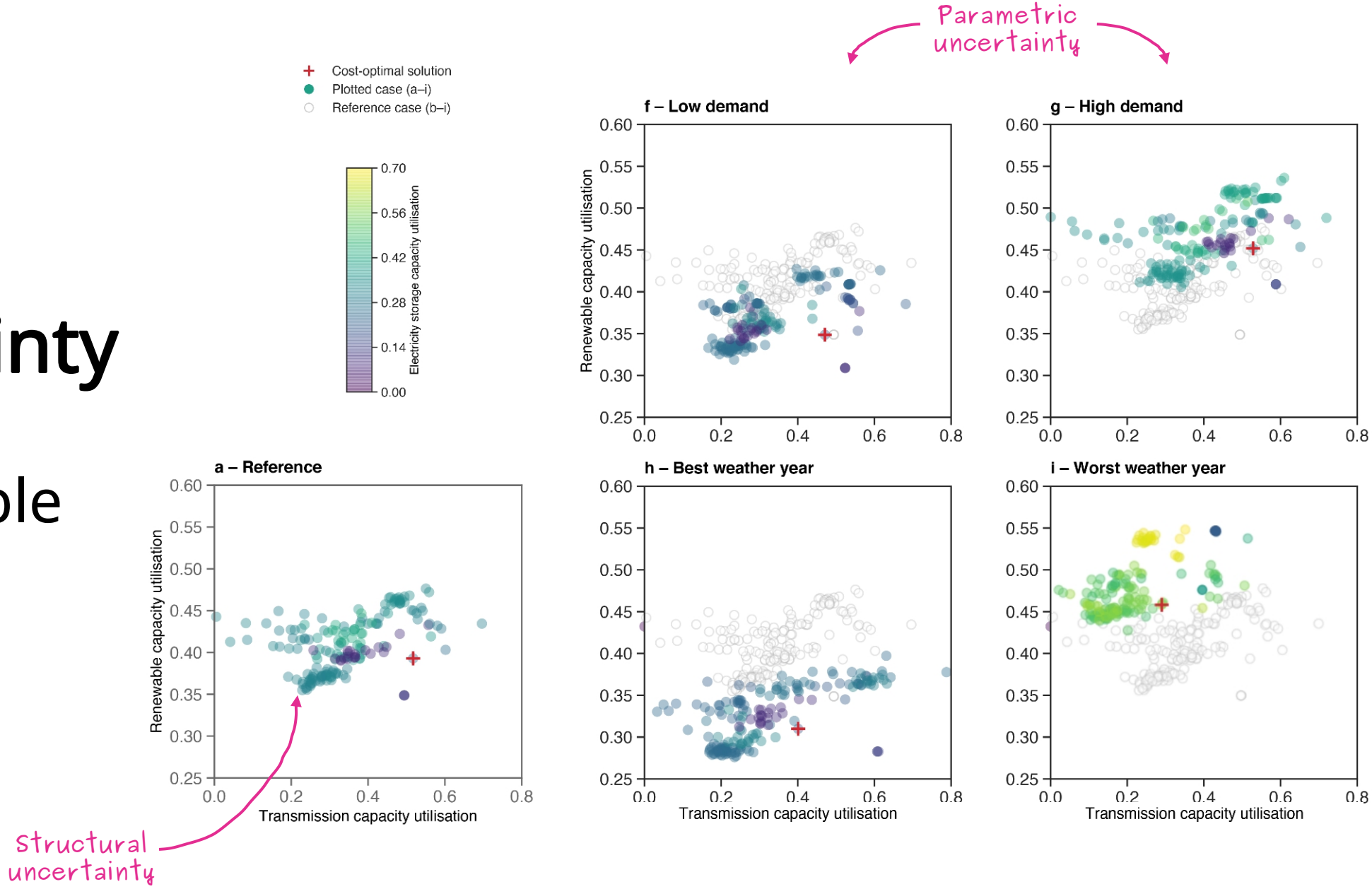
Uncertainty sources.

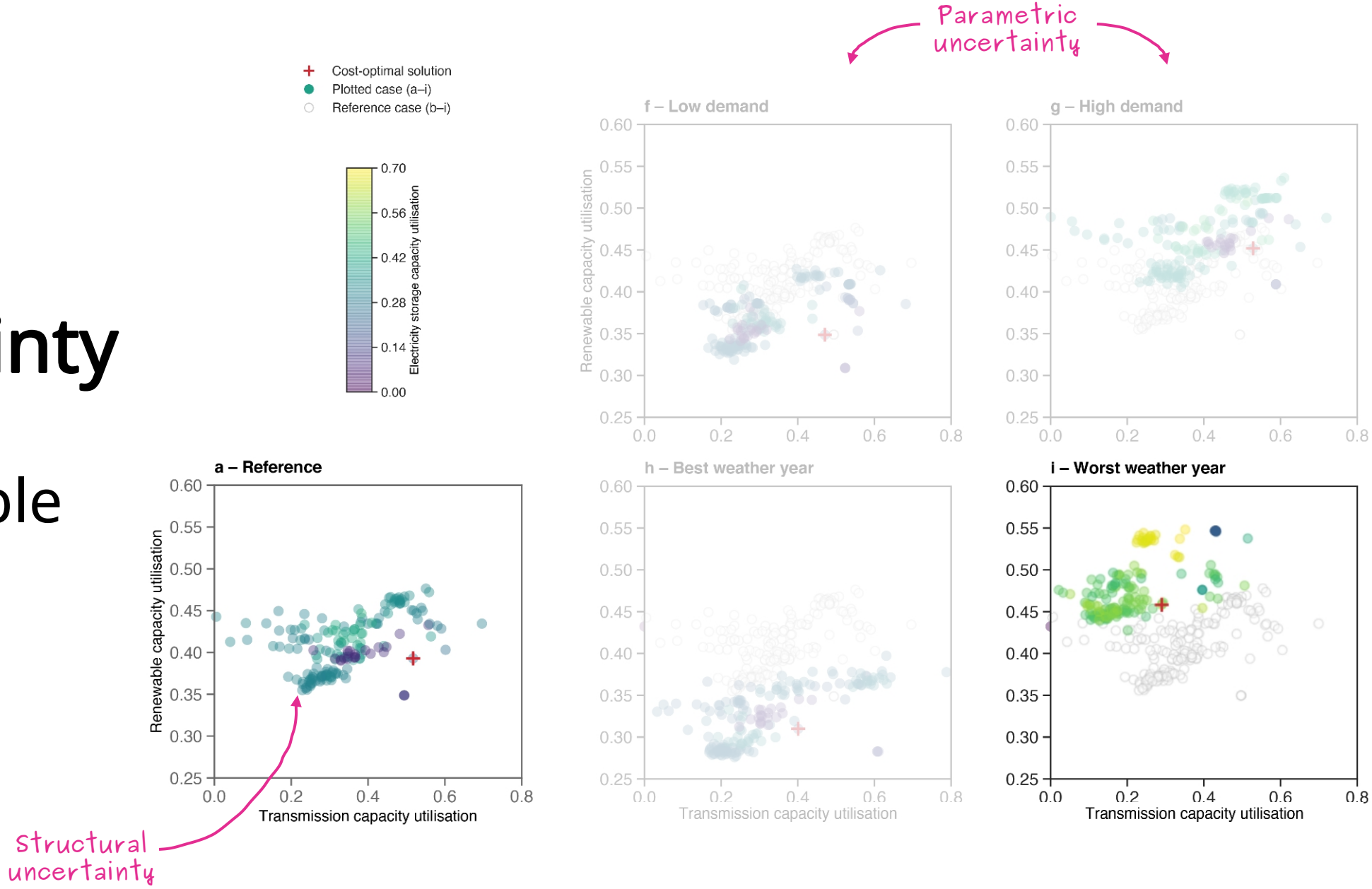
Full example overview



Lombardi, Pickering, Colombo, Pfenninger. *Joule*, 2020. https://doi.org/gg8z6v

Uncertainty sources.

Full example overview



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Uncertainty sources.
Learning check.
True or false?

Q1 “When designing highly-renewable energy systems, weather can be the leading source of parametric uncertainty”

Q2 “Structural uncertainty can arise due to excessively simplistic representations of complex real-world phenomena”

Q3 “For optimisation models, structural uncertainty is typically less important than parametric uncertainty”

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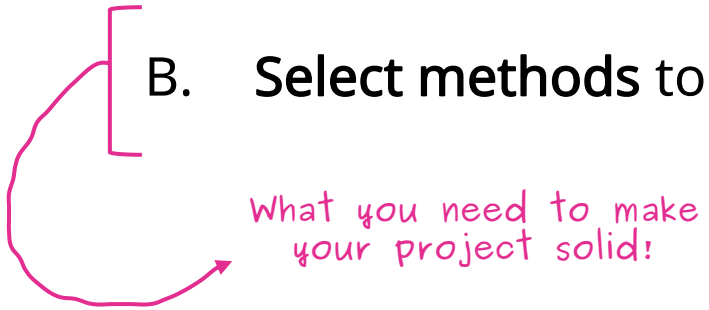
B. **Select methods** to deal with each type of uncertainty



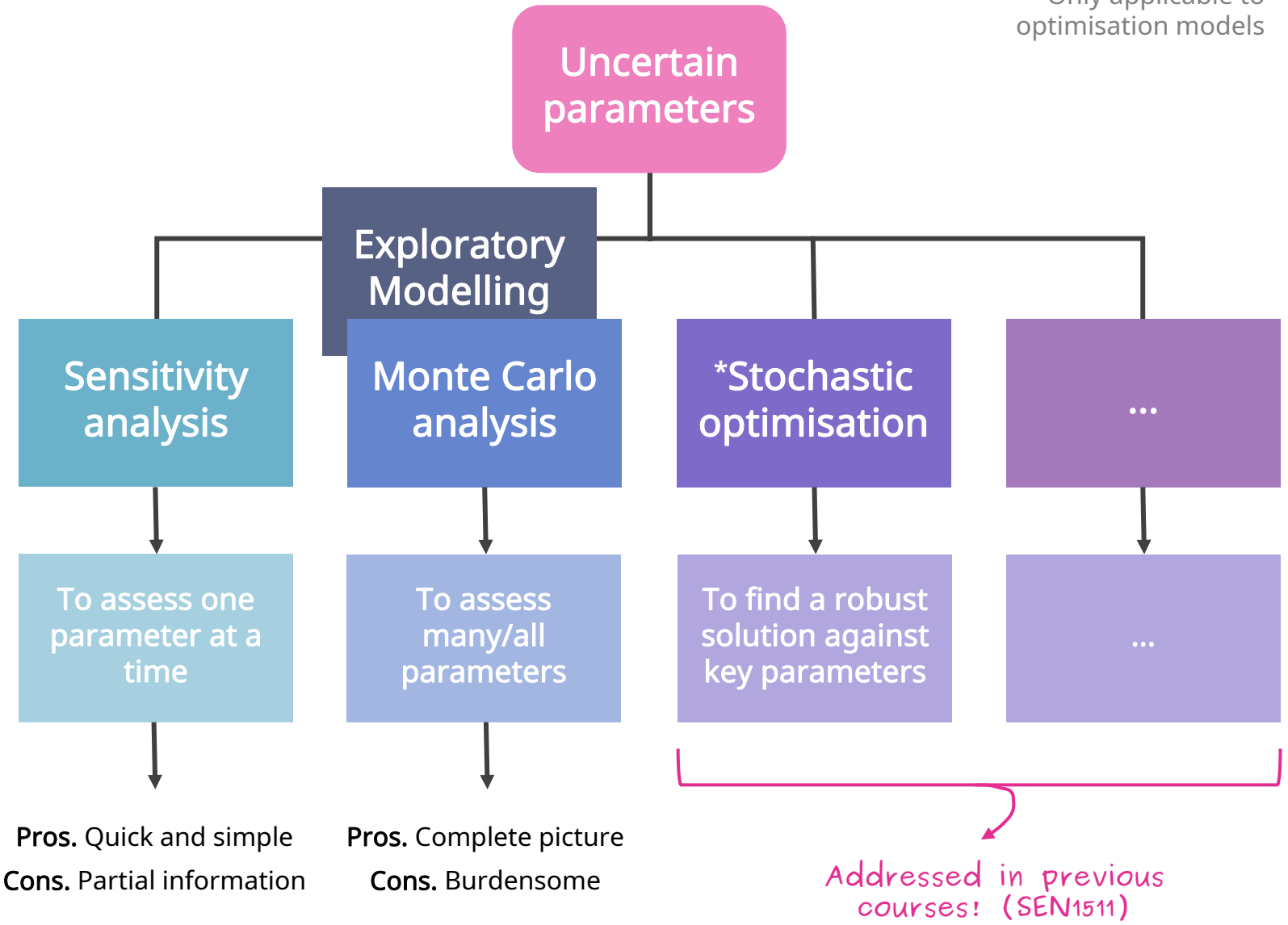
Part B.

How can you use uncertainty productively?

Handling uncertainty.

Parametric

*Only applicable to optimisation models

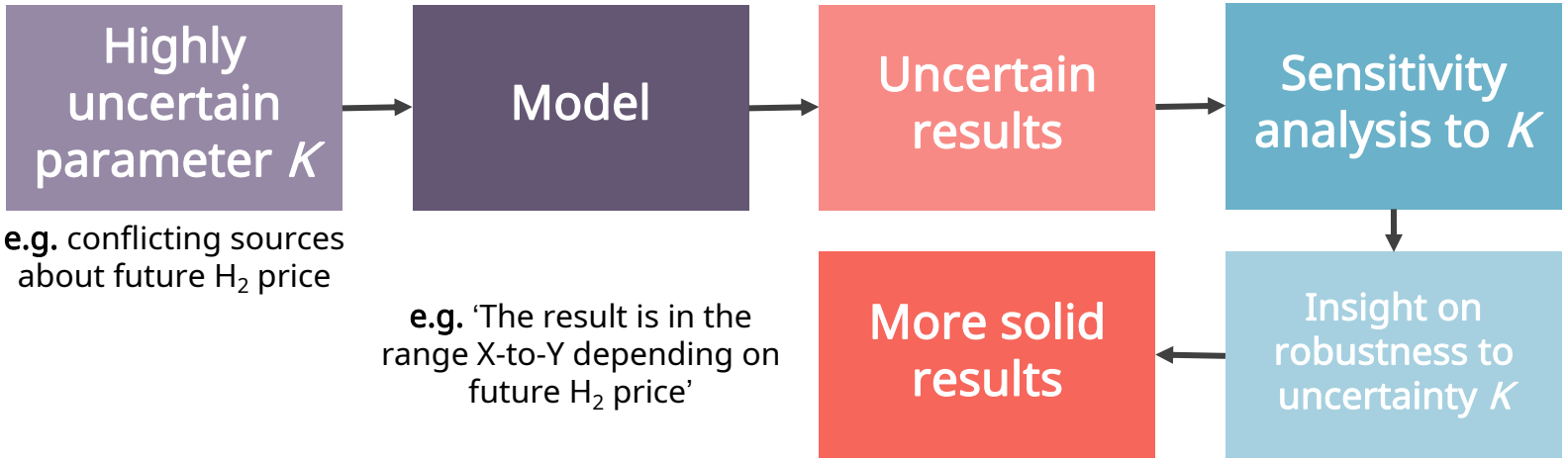


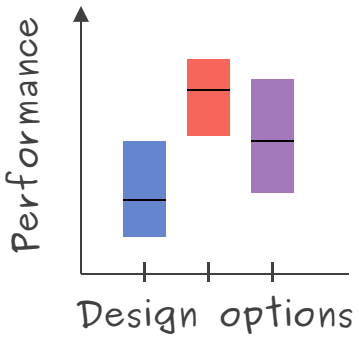
Adapted and expanded from: Yue, Pye, DeCarolis, Li, Rogan. *Energy Strategy Reviews*, 2018. https://doi.org/gf75x4

What can you do for a **time- and resource-constrained analysis**?

Handling uncertainty.

Simple sensitivity example 1

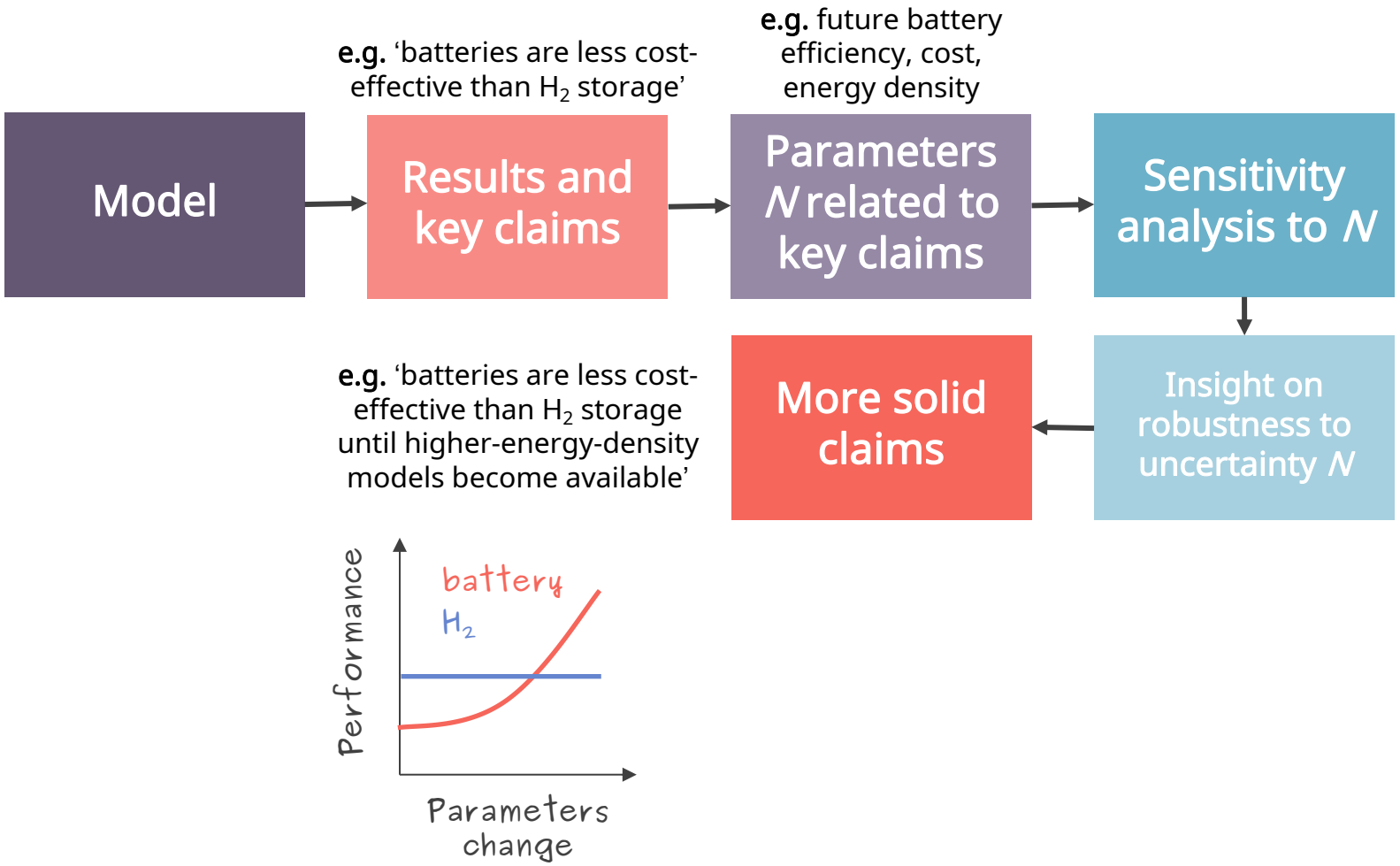




Handling uncertainty.

Simple sensitivity example 1

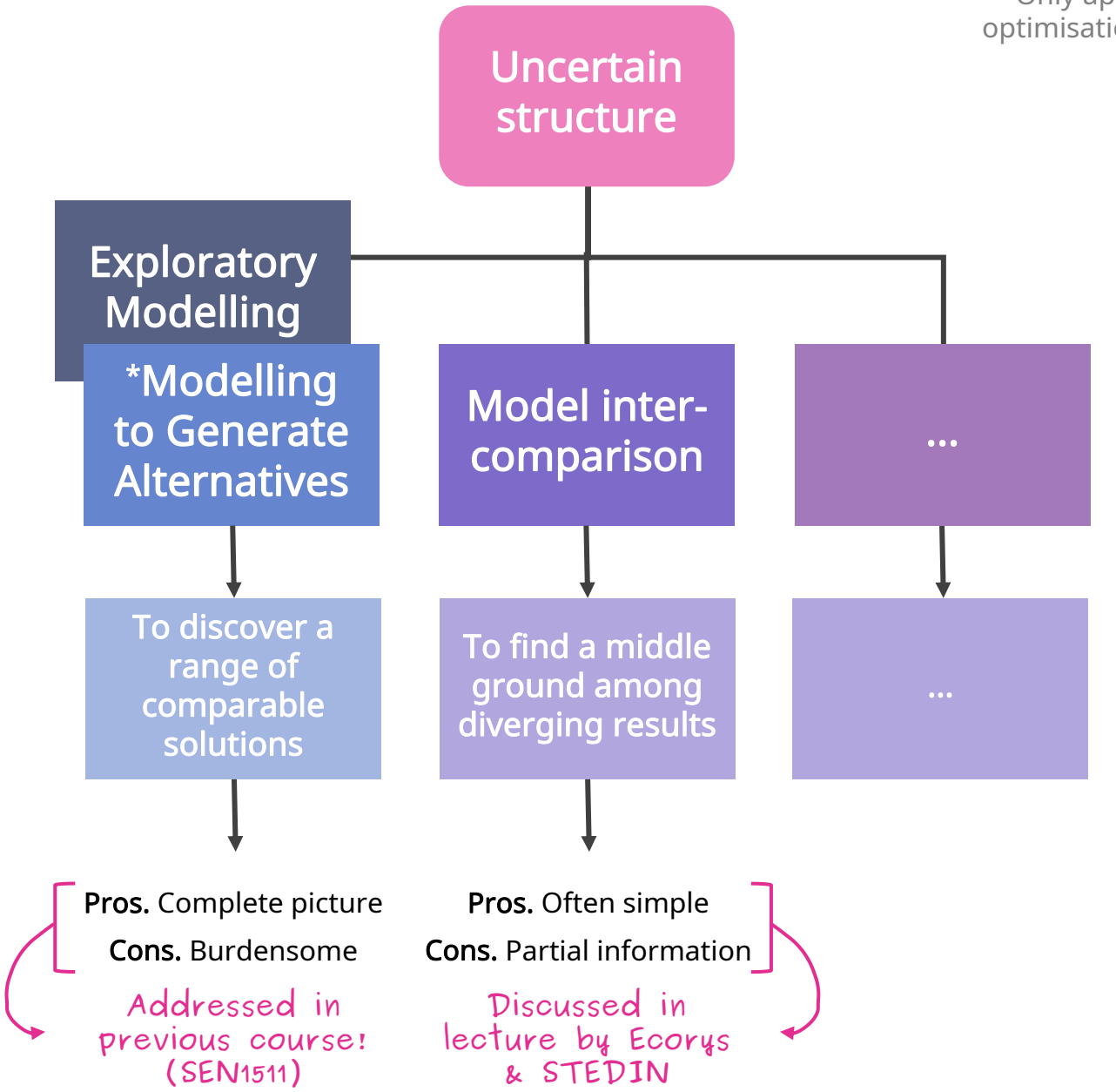
What can you do for a **time- and resource-constrained analysis**?



Handling uncertainty.

Structural

*Only applicable to optimisation models



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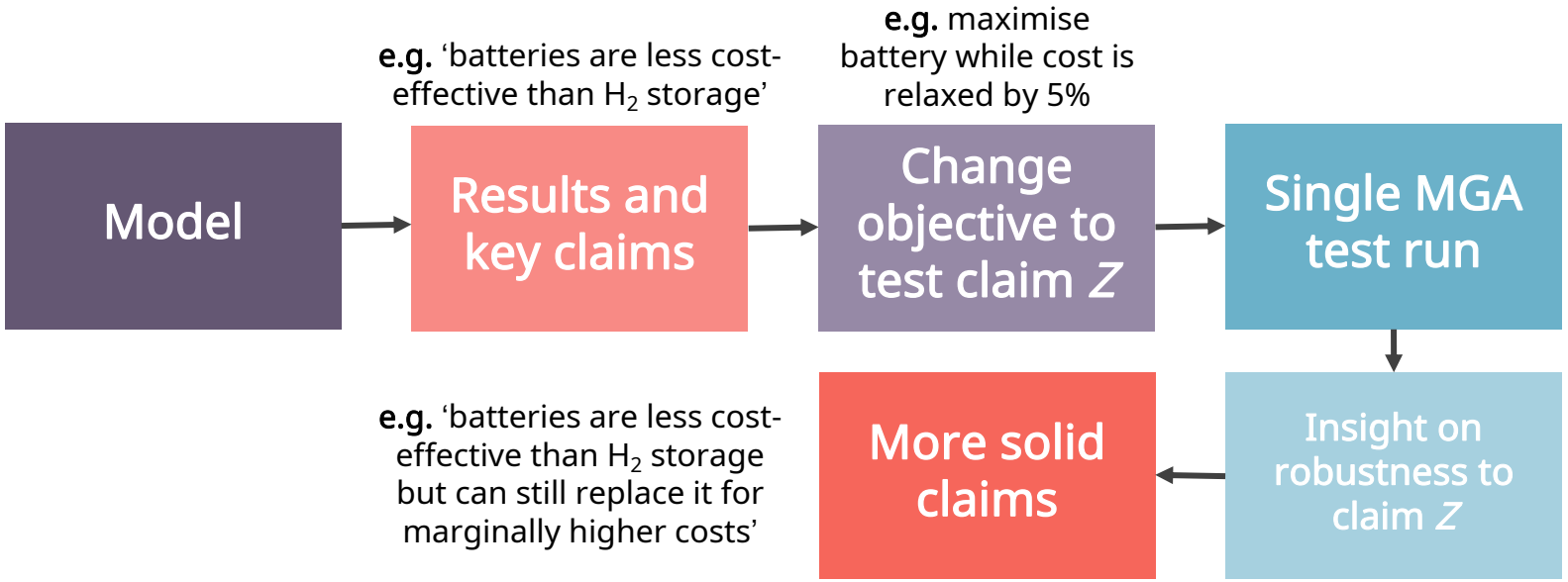
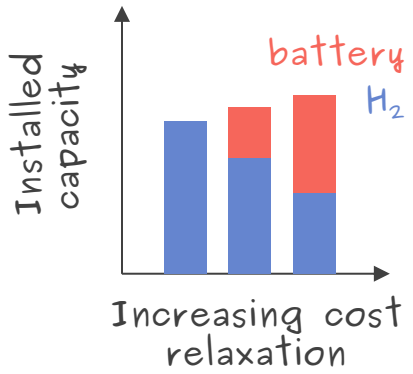
Handling uncertainty.
Simplified MGA example

What can you do for a **time- and resource-constrained analysis**?





You don't get a complete picture of all the options, but you can at least **test** whether your **key claims** are solid

Recent idea just proposed in the literature: Lombardi, Pickering, Pfenninger. *Applied Energy*, 2023. https://doi.org/j457

Handling uncertainty.
Learning check

Design problem.

Renewables increase by +50% by 2030 in the Dutch power system. Is it more cost-effective to expand transmission capacity or deploy storage?

Inputs.

1. H_2 storage cost and efficiency
2. Battery storage cost and efficiency
3. Transmission expansion cost
4. Weather patterns

→ **Model of the NL power system** →

Outputs.

Cost-optimal mix of transmission and storage capacity

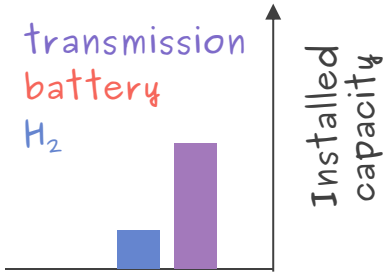
Uncertainty.

1. Source A and B have different outlooks
2. Current values known, but could improve by 2030
3. None
4. Many possible weather years

Key claim.

'It is more cost-effective to expand transmission, complemented by little H_2 storage'

Results.



How can we use uncertainty to make our claim more solid?

Discuss with who's sitting next to you (groups of 4+ people)

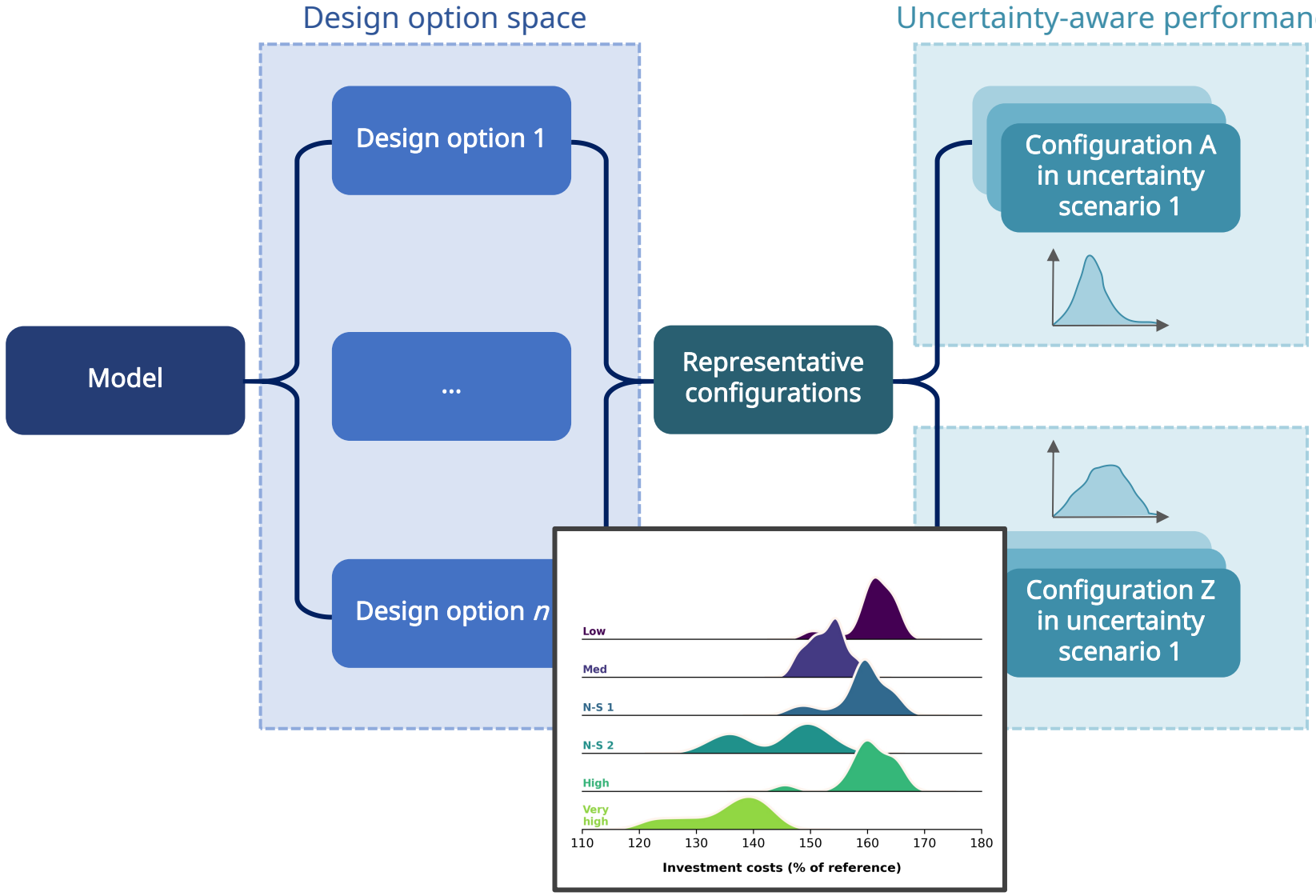
5 minutes!

Bonus part for inspiration.

Can we handle both types of uncertainty at once?

Handling uncertainty.
Research frontiers

Out-of-sample testing of MGA design options is a possible approach



Adapted from: Lombardi, Pickering, Pfenninger. *WindSPORES final report.* 2023
And originally piloted in: Van Til (*supervisor*: Lombardi), *TU Delft MSc Thesis*. 2021

Next steps.

- Ideally, **wrap up** your modelling work by end of this week
- Use what you learnt today to **make your claims solid**
- **Discuss** the uncertainties that you cannot address