ESTIMATING MAINTENANCE COSTS OF NEW AIRCRAFT CONCEPTS UNDER UNCERTAINTIES: A FEASIBILITY STUDY

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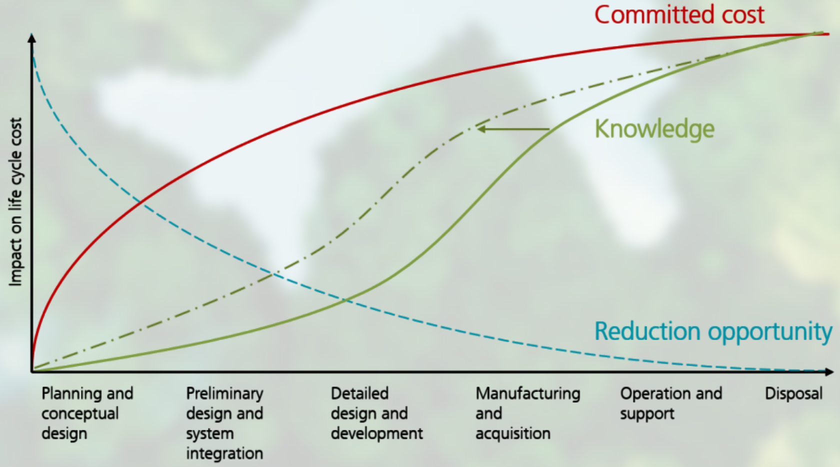
Rising global **climate impact** from **aviation** sector:

Innovative solutions for **low-emission aircraft** concepts

Early estimation of technology potential



→ Impact of maintenance on overall cost?

Method

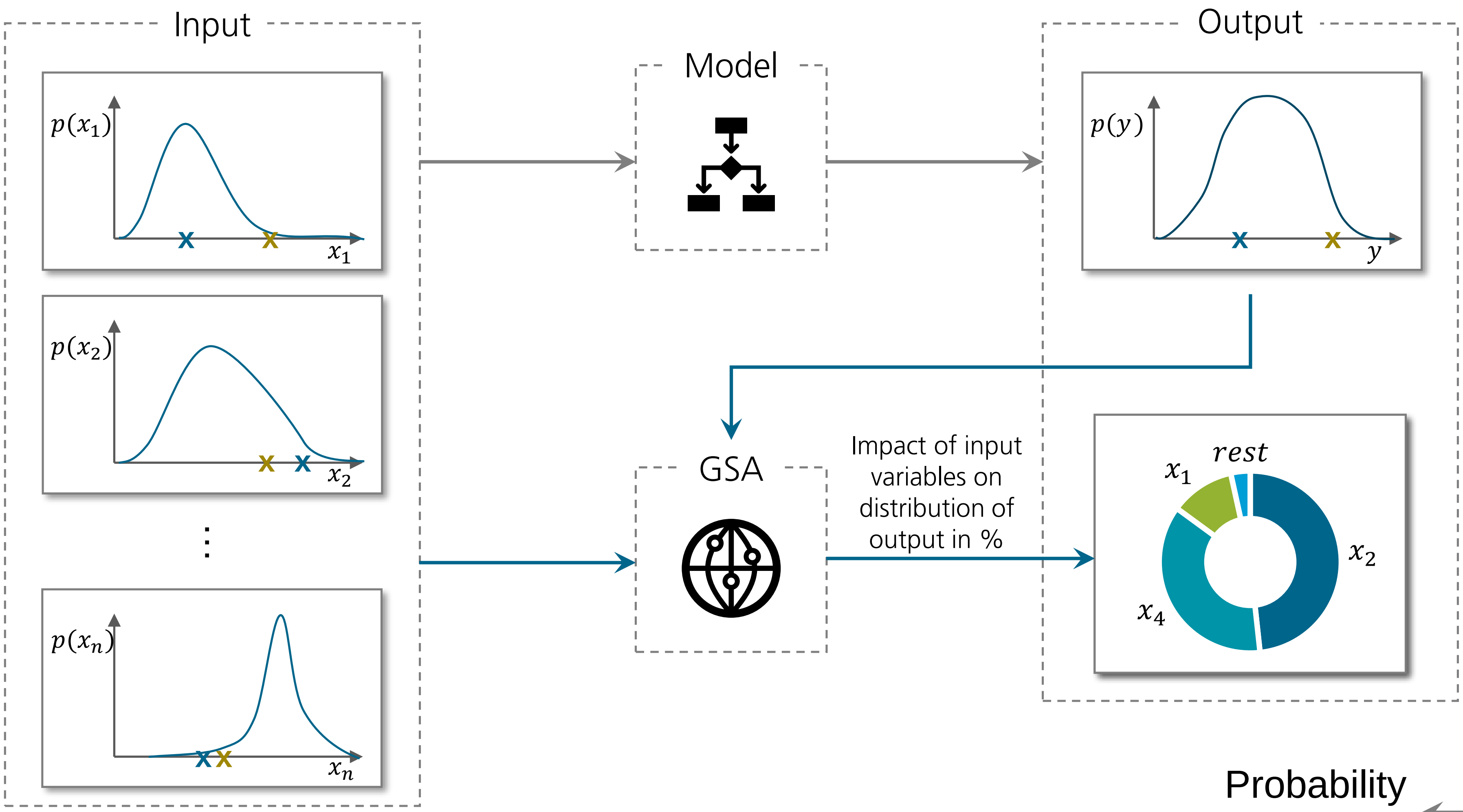
Results

Outlook

METHOD

Method - Overview

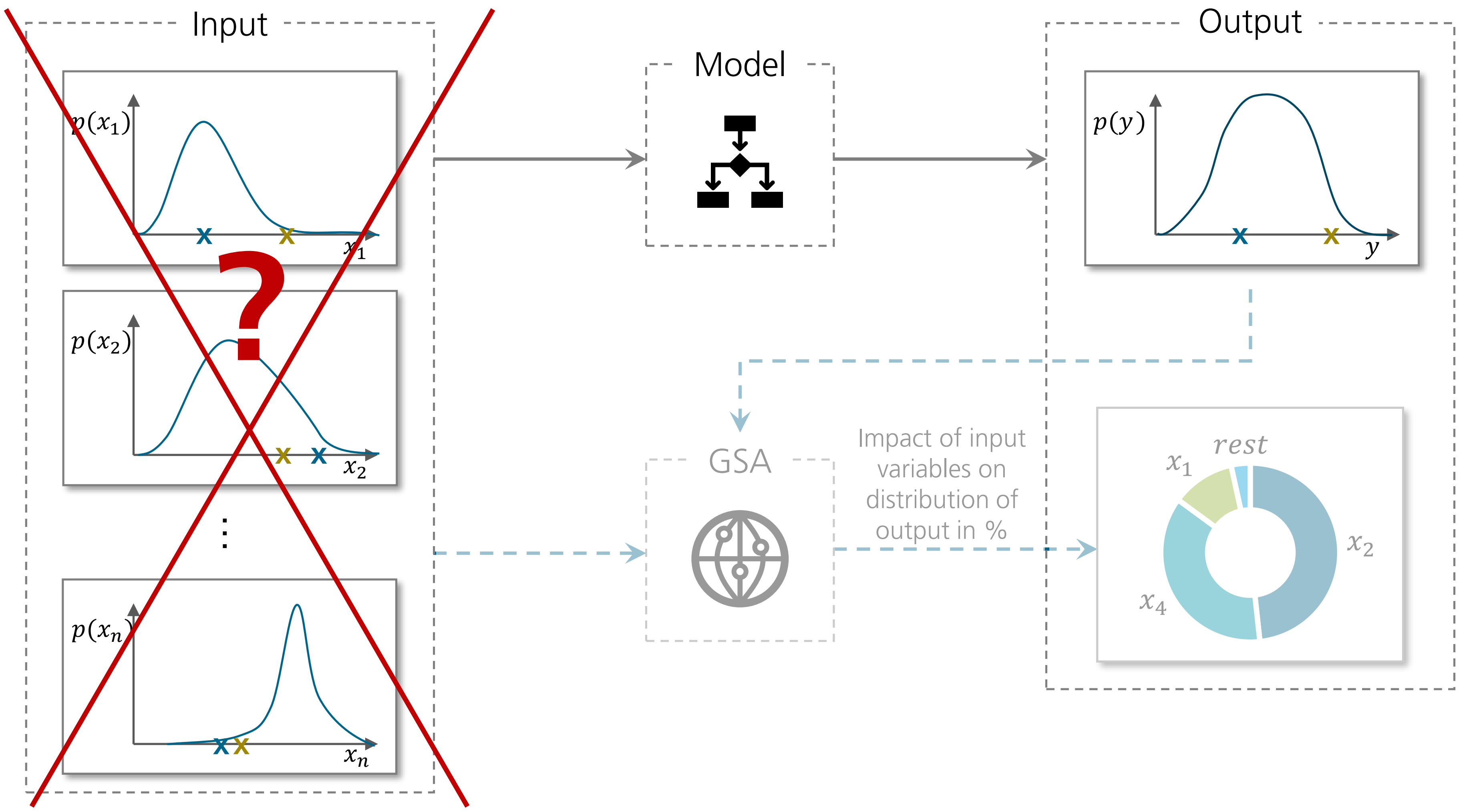
How to integrate uncertainty quantification in assessment within early development phases



Probability Theory ← Lots of data available

Method - Overview

How to integrate uncertainty quantification in assessment within early development phases



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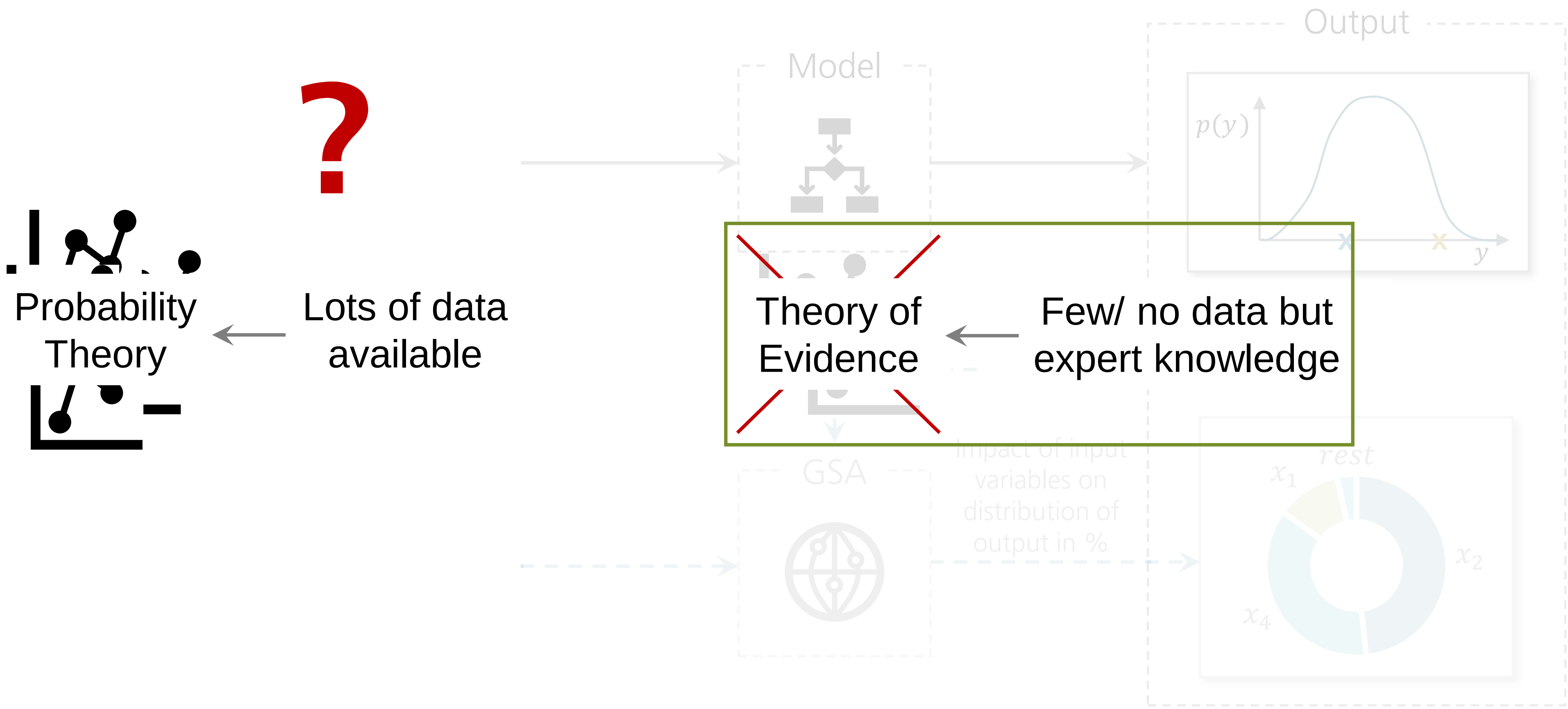

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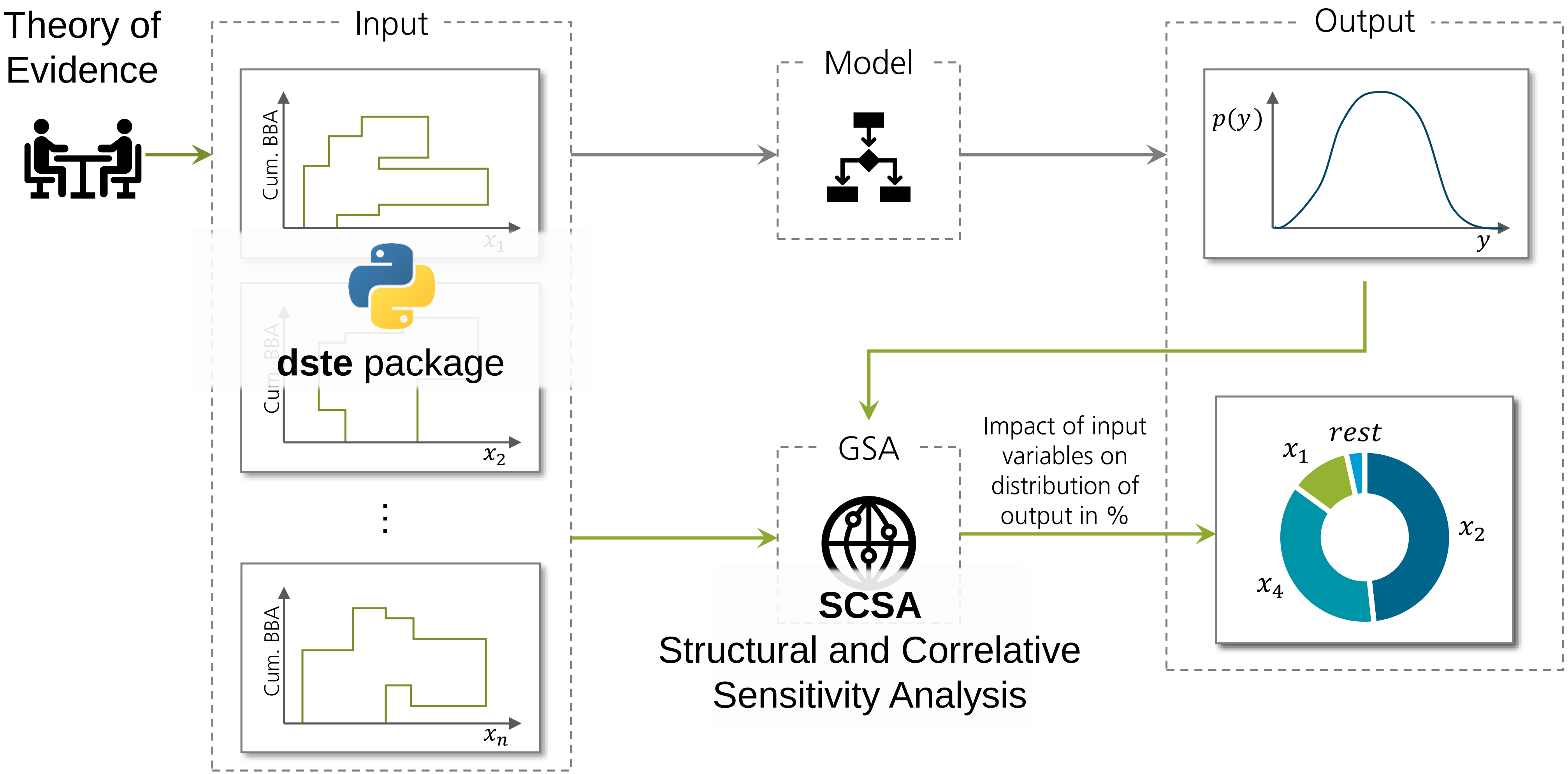
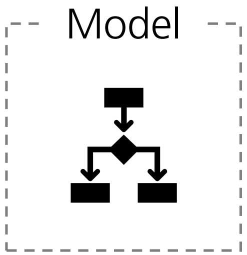
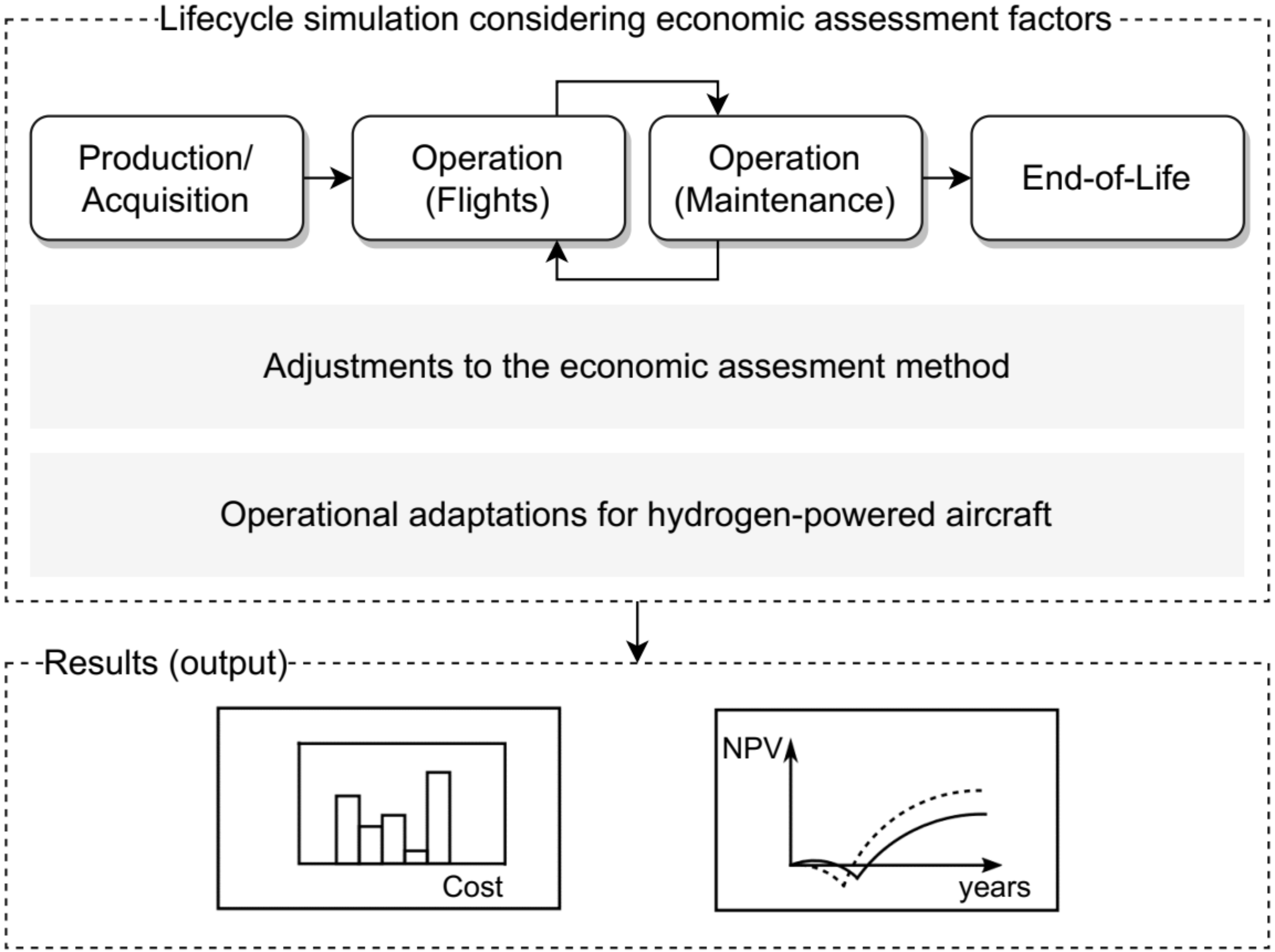


* PhD Pohya - unpublished

Model for life cycle cost estimation - LYFE

General method - Overview

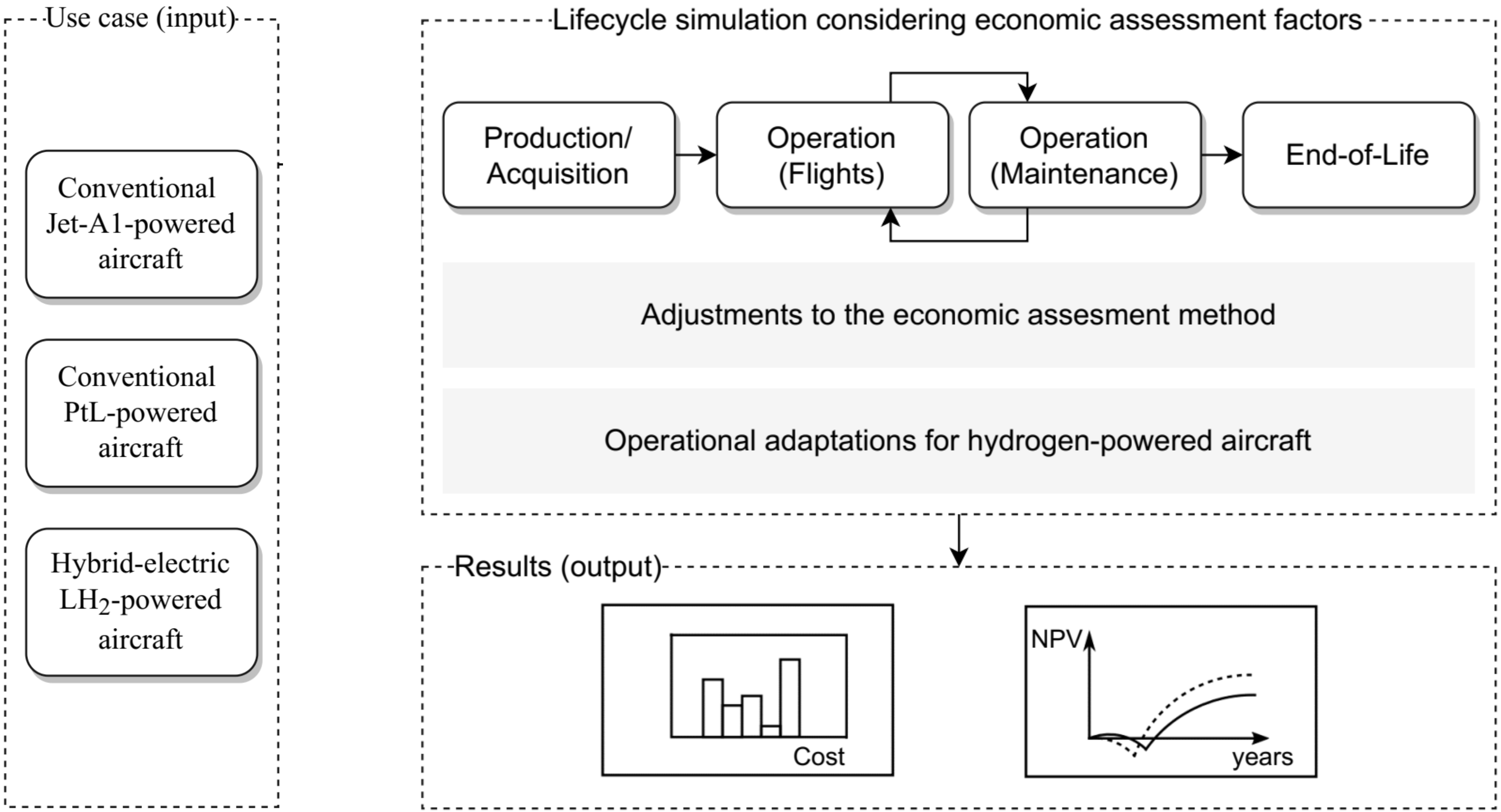




* According to: https://doi.org/10.2514/6.2022-3882

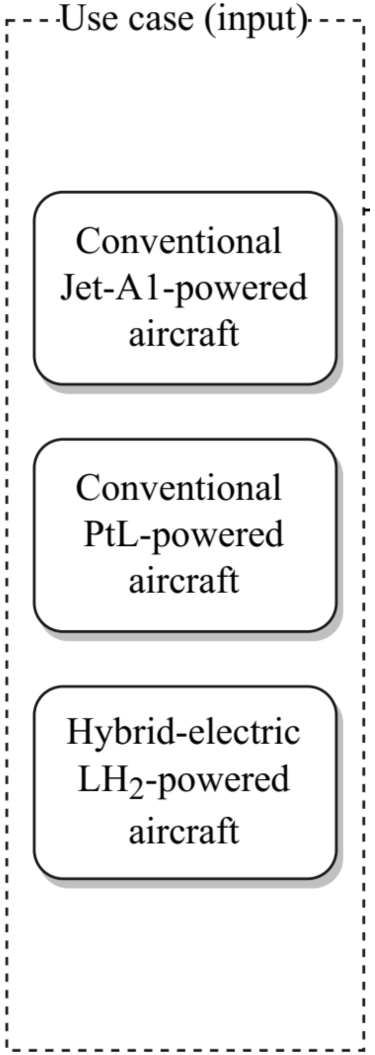
Model for life cycle cost estimation - LYFE

General method - Overview

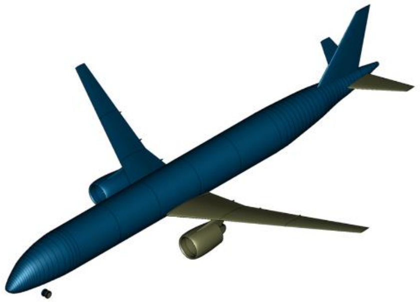


Model for life cycle cost estimation – Use Cases

Developed within the DLR project EXACT (Exploration of Electric Aircraft Concepts and Technologies)



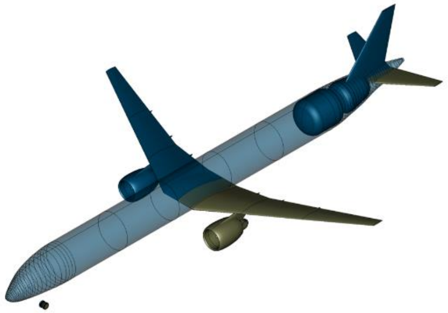
Conventional Reference



- Based on the recalculated A321neo
- Advanced wing design
- Turbofan engine improvements
- 250 PAX design
- Lifetime 20 years

- Powered by Jet-A1 or PtL*

Hydrogen-powered MHEP** concept



- Same technological assumptions as Baseline
- Hydrogen combustion engines
- Combination with PEM fuel cell system for different purposes:
  - Replacement of APU
  - Provides power for on-board systems, e-taxi system, assisted idle system

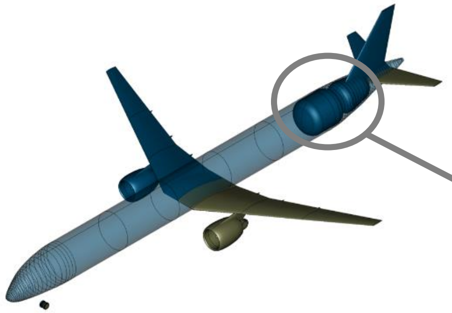
For more information see: https://doi.org/10.2514/6.2022-3882

* Power-to-Liquid
** Mild-Hybrid Electric Propulsion

Model for life cycle cost estimation – Use Cases

Uncertain input values

Hydrogen-powered MHEP** concept



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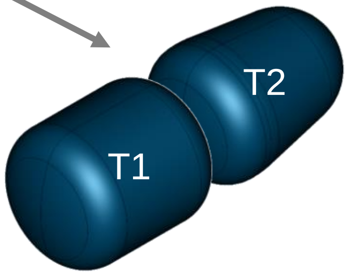


Assumption:

- All values for MHEP fixed
    - Fuel cell system
    - Distribution
    - Inspection of hydrogen tank
- Only hydrogen tank exchange uncertain

Tank exchange with the following uncertain input values:

- Production price of hydrogen tank
- Maintenance of hydrogen tank
    - Interval
    - Downtime
    - Man hour effort

For more information see: https://doi.org/10.2514/6.2022-3882

* Power-to-Liquid
** Mild-Hybrid Electric Propulsion

RESULTS

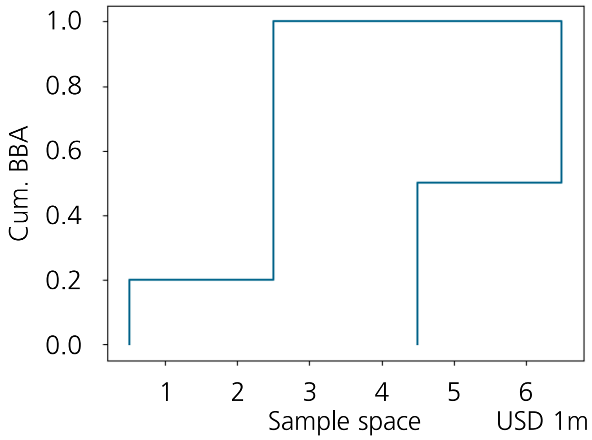
Representation of Uncertainties

Using Dempster-Shafer Theory of Evidence

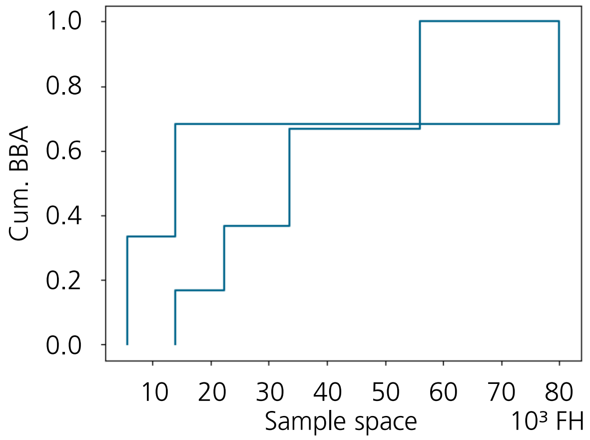
Description of uncertainty by means of Basic Belief Assignments (BBA)

Conducting systematic expert interviews to derive the evidences

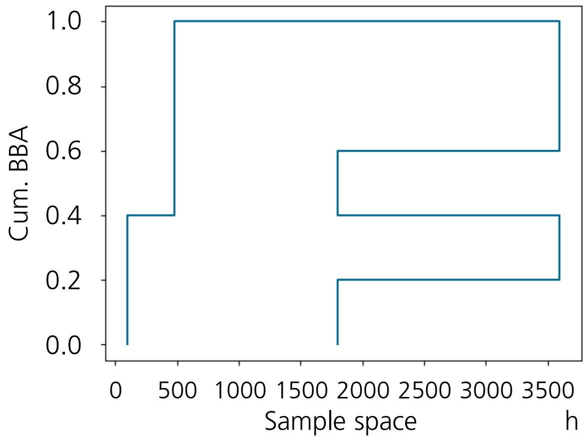
Evidence of acquisition cost



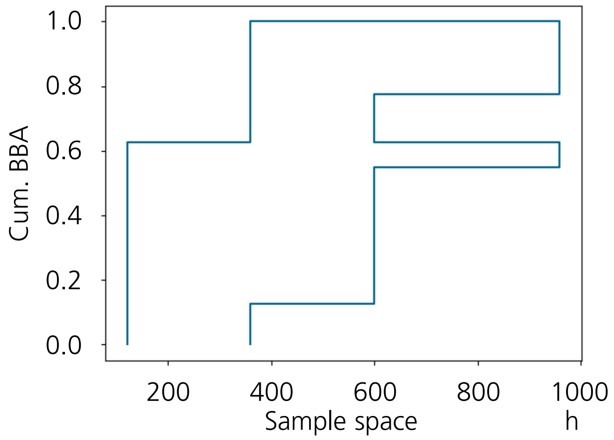
Evidence of maintenance interval



Evidence of maintenance man hours



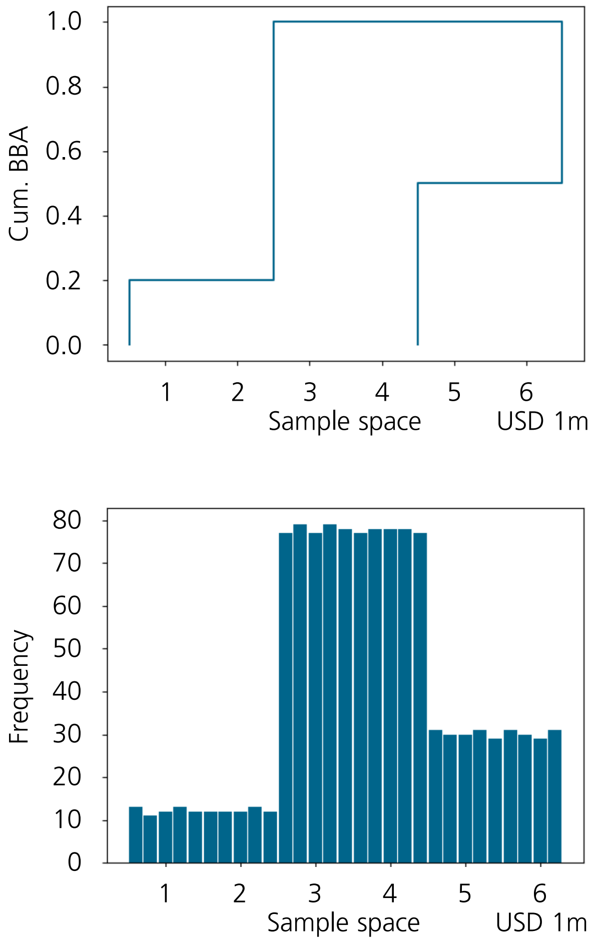
Evidence of maintenance downtime



Representation of Uncertainties

Using Dempster-Shafer Theory of Evidence

Evidence of acquisition cost



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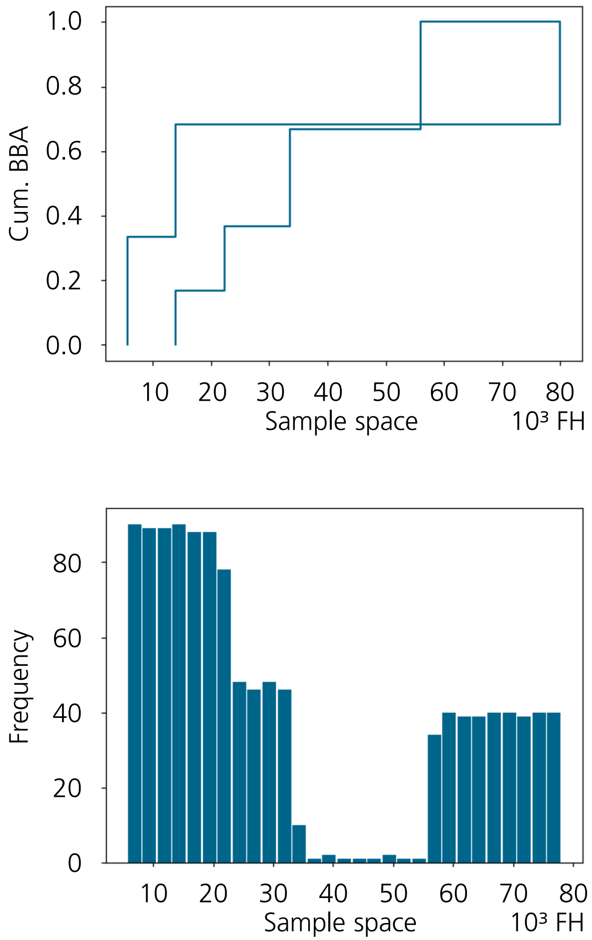

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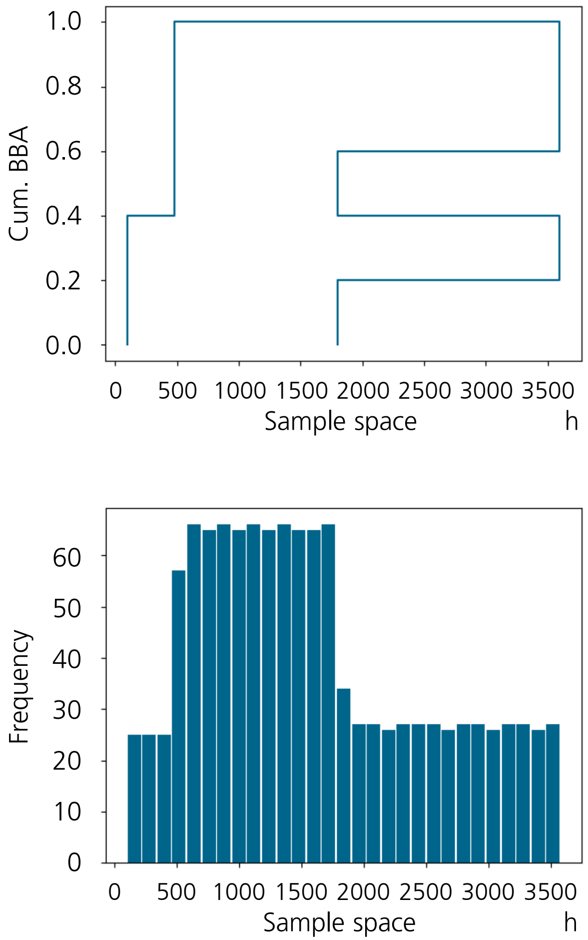

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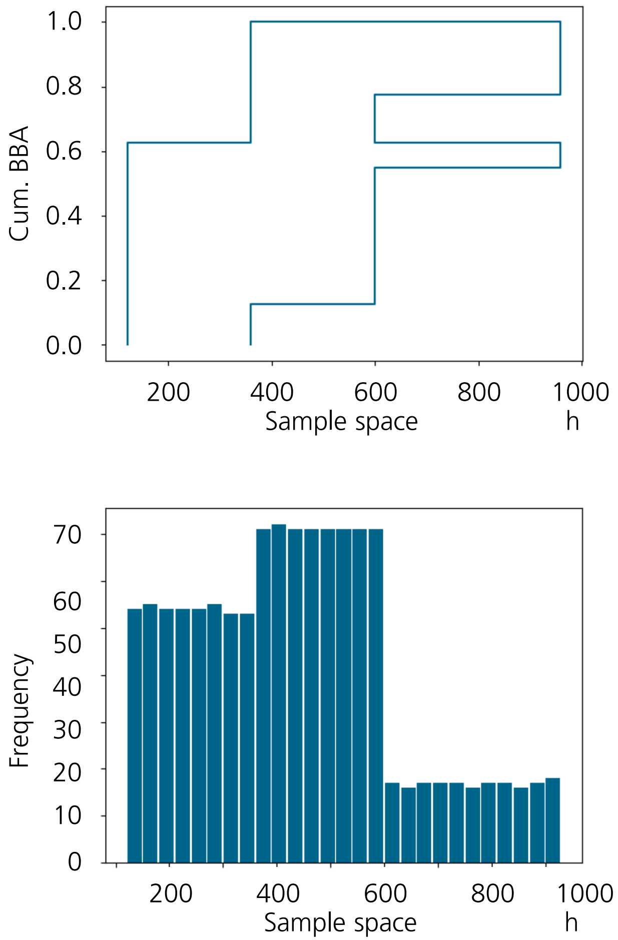
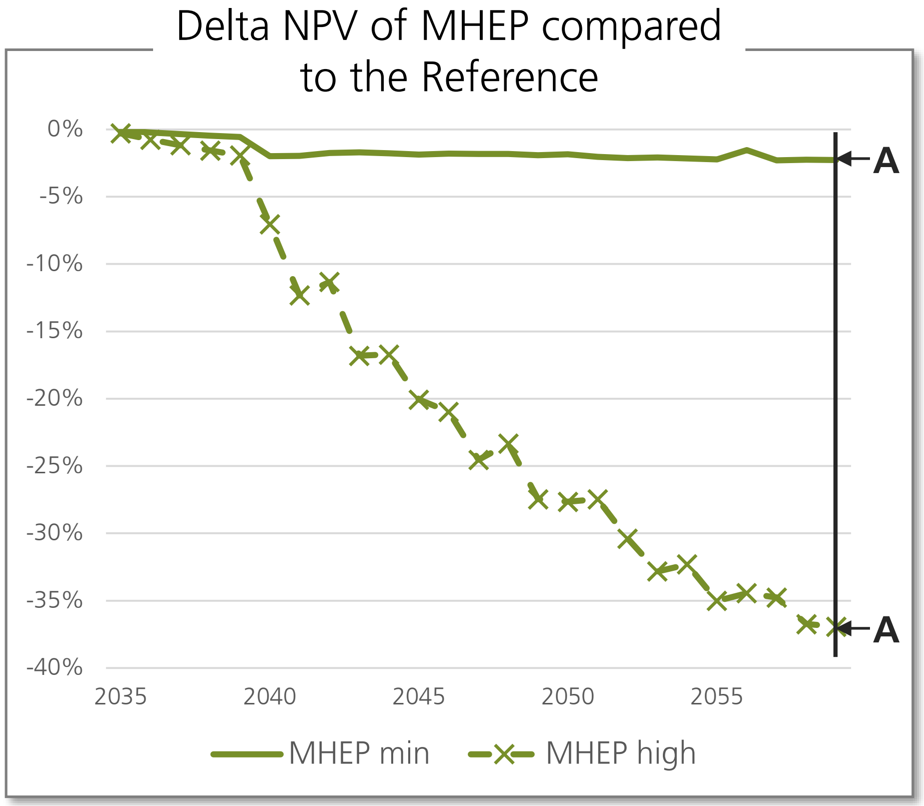
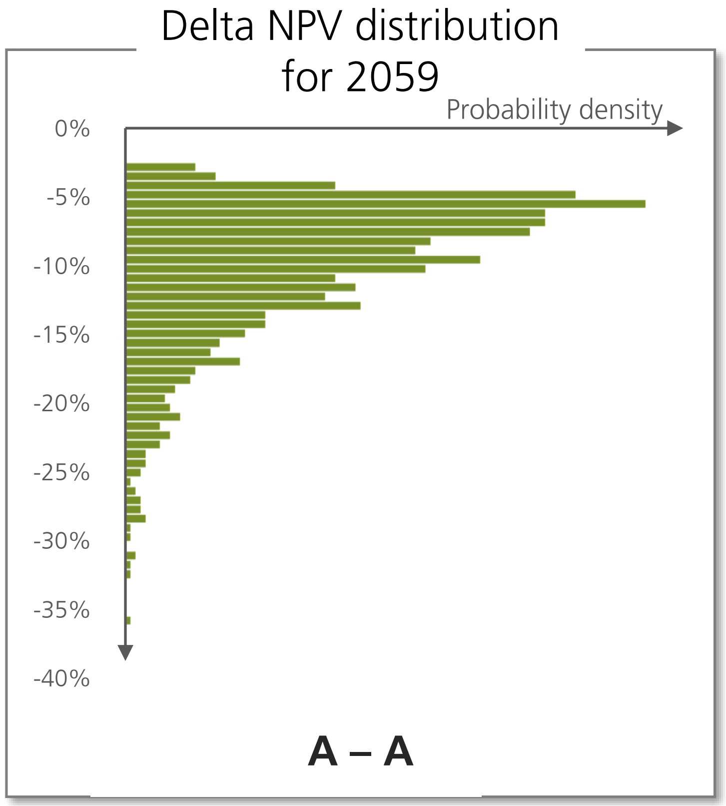
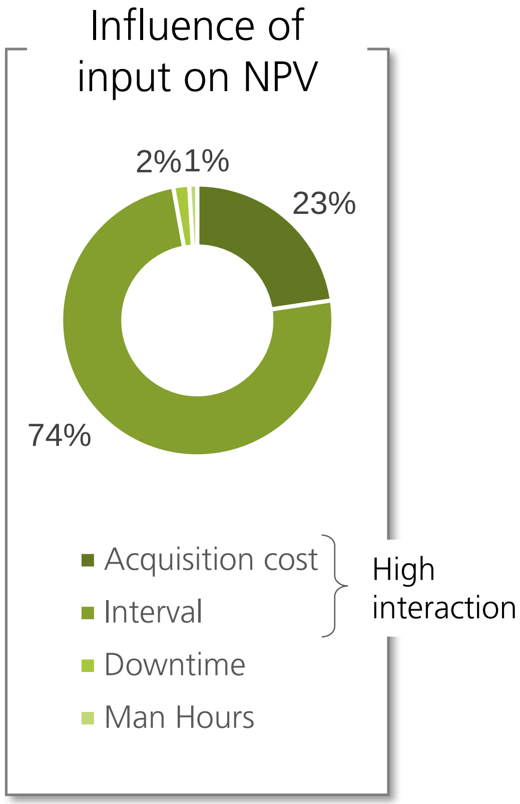


Results - NPV

Delta NPV compared to the Reference, delta NPV distribution and results of the GSA

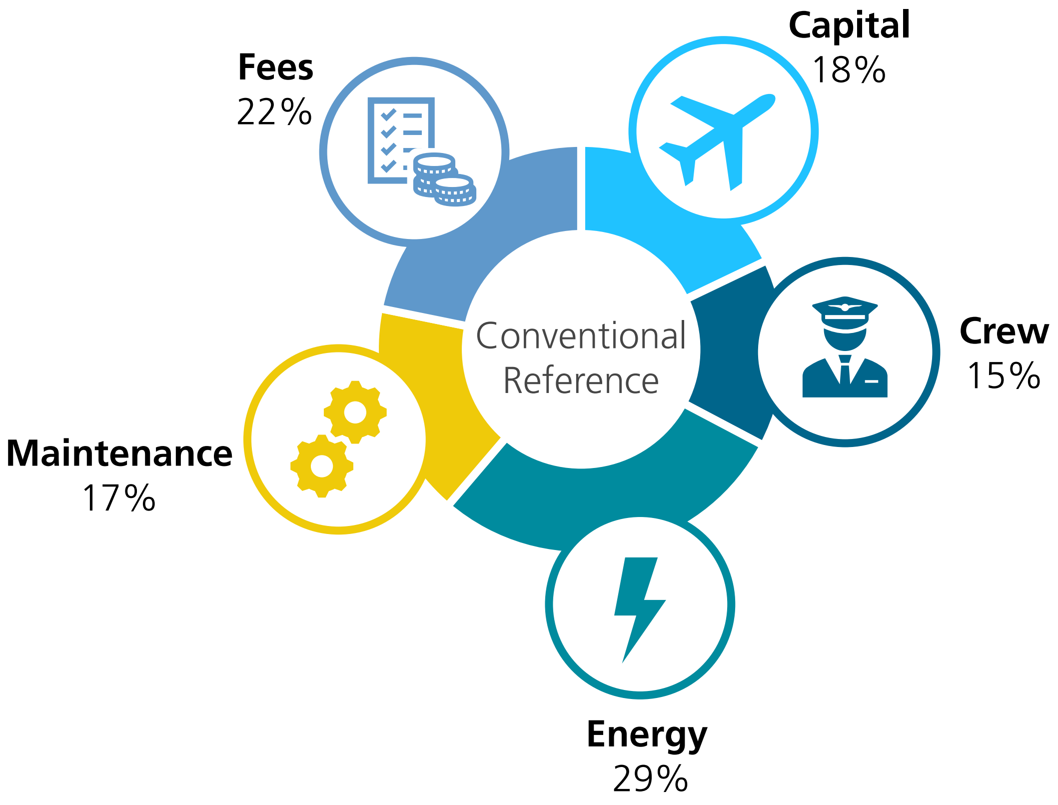


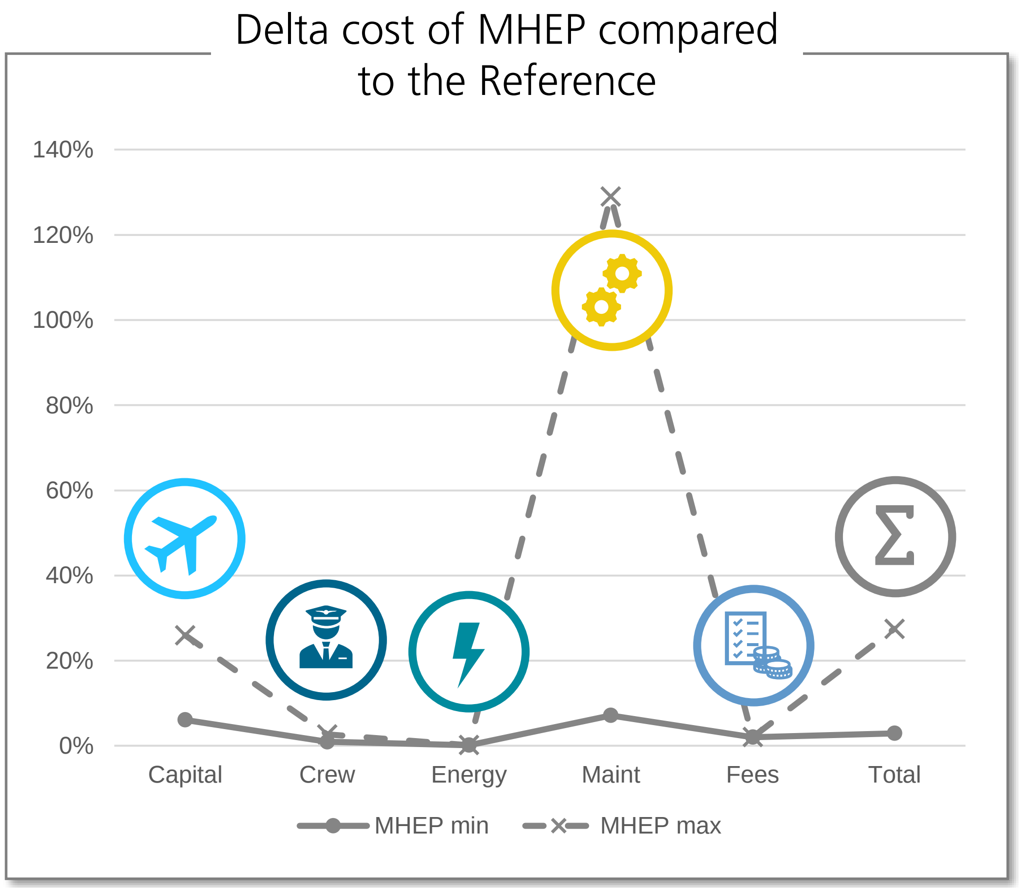




Results - Cost

Cost distribution for the Reference and variability of the costs compared to the baseline

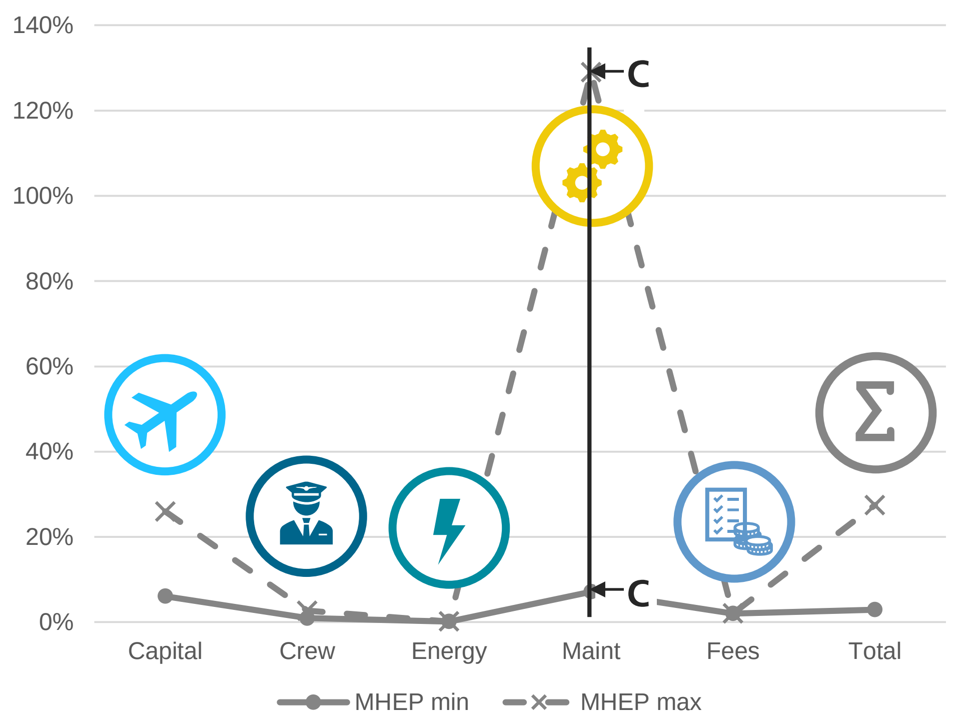




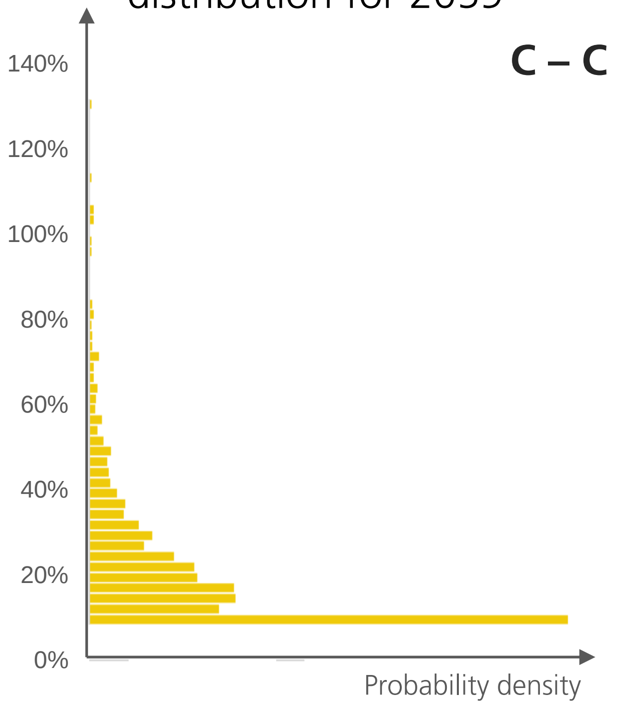
Results – Maintenance Cost

Cost distribution and results of the GSA

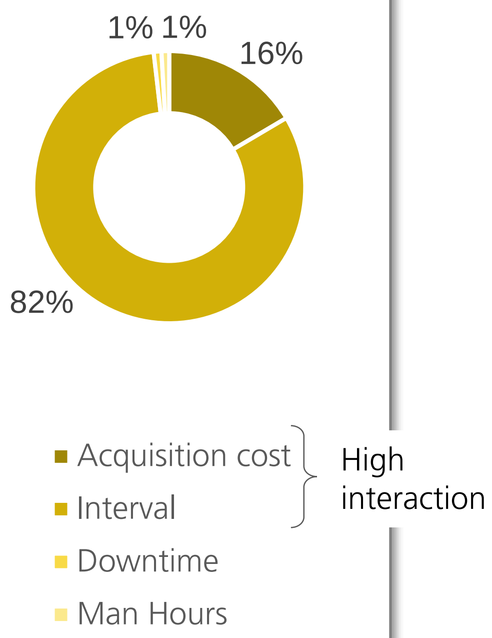
Delta cost of MHEP compared to the Reference



Delta maint cost distribution for 2059

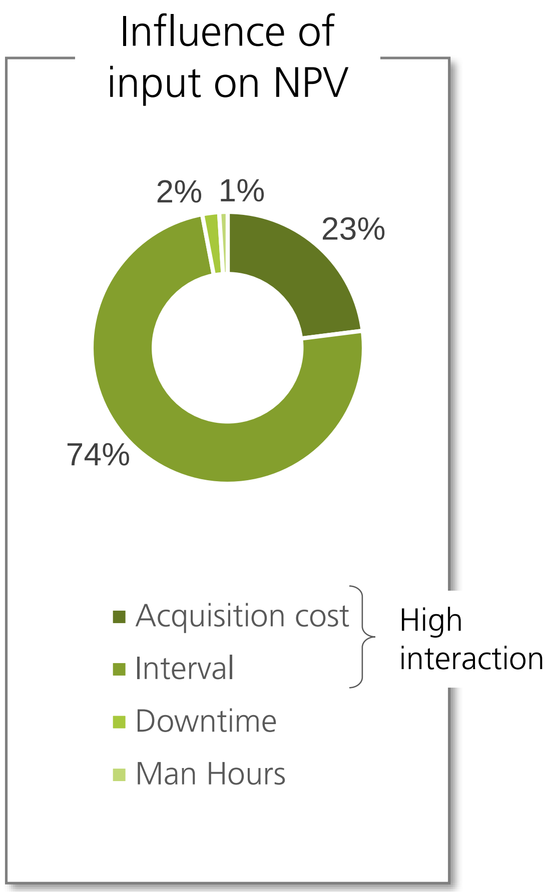


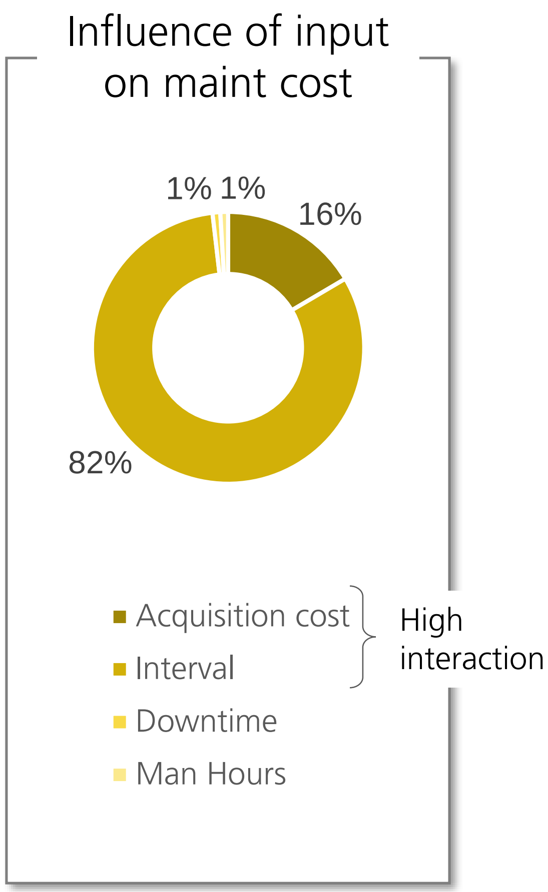
Influence of input on maint cost



Results

Interpretation of the GSA



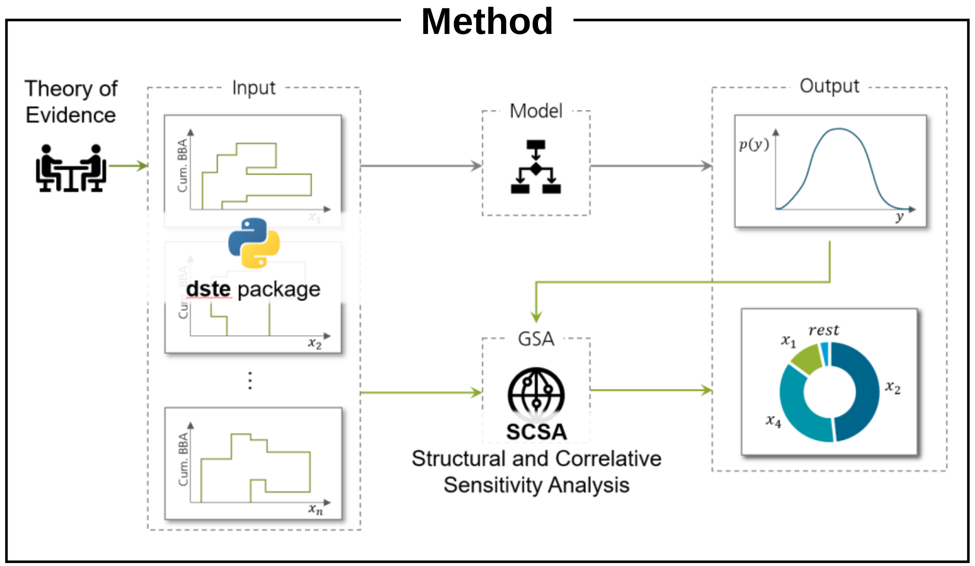


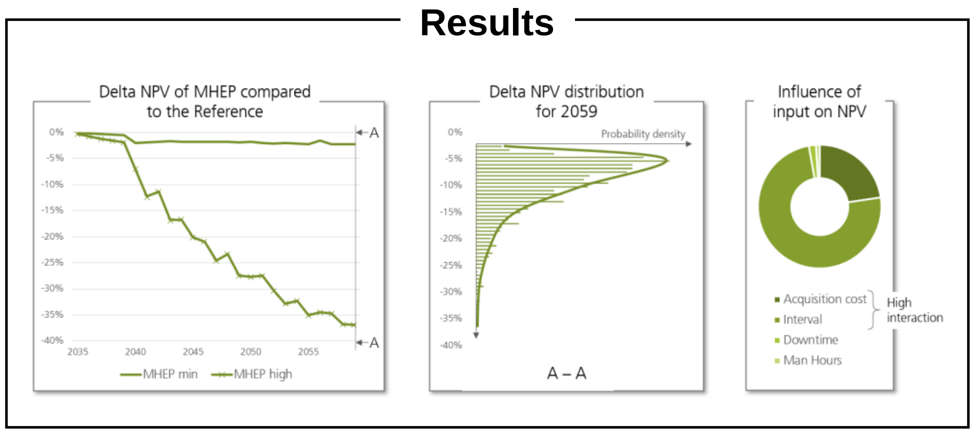
- The result dispersion is largely due to the **uncertainty in the input** for the **maint. Interval**

→ A **reduction of the uncertainty** in the maint. interval thus **leads to the strongest reduction** of the result dispersion

RECAP AND OUTLOOK

Recap and Outlook





- Theory of Evidence is a valid method to translate expert beliefs into samplings
- First combination of GSA and evidence theory was successful
- The maintenance interval of the H_2 tank has the highest impact on the overall results

- Feasibility study based only on a few expert beliefs
  → further experts could make the result more meaningful
- Future work: Include more uncertainties for improved understanding and design feedback

Thanks For Your Attention!

In case of any further questions:

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