

Background

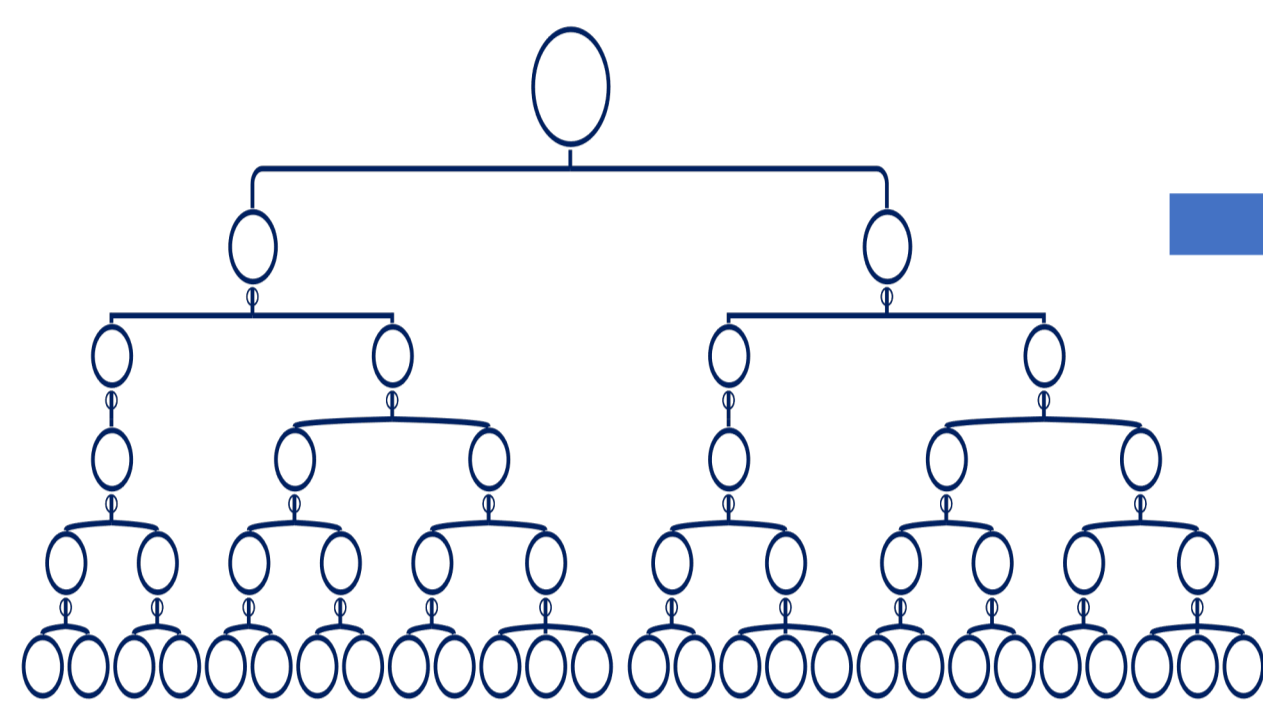
1. Although beneficial for decarbonization [1], the competitiveness of geothermal district heating is often challenged by its high upfront investment costs [2]. At the same time, the heating's contribution to wider economic impacts is rarely studied in the literature.
2. The complex interaction among district heating design parameters and uncertainty of geothermal resource parameters require broad decision analysis to evaluate the competitiveness and economic impacts of geothermal district heating.

Research questions

1. Considering many possible options to supply heat demand in the State of Geneva in Switzerland, which **decision paths (i.e. combinations of decisions)** to integrate geothermal resources in district heating will result in:
 - lower **levelized costs of heat**,
 - higher **ratio of economic impacts to total spending**,
 - higher share of **economic impact that remains in the Swiss economy?**
2. How do those impacts vary across all decision paths and which **decision parameters have the largest influence**
3. How can geothermal district heating be implemented to **optimize the levelized costs and economic impacts?**

Methods

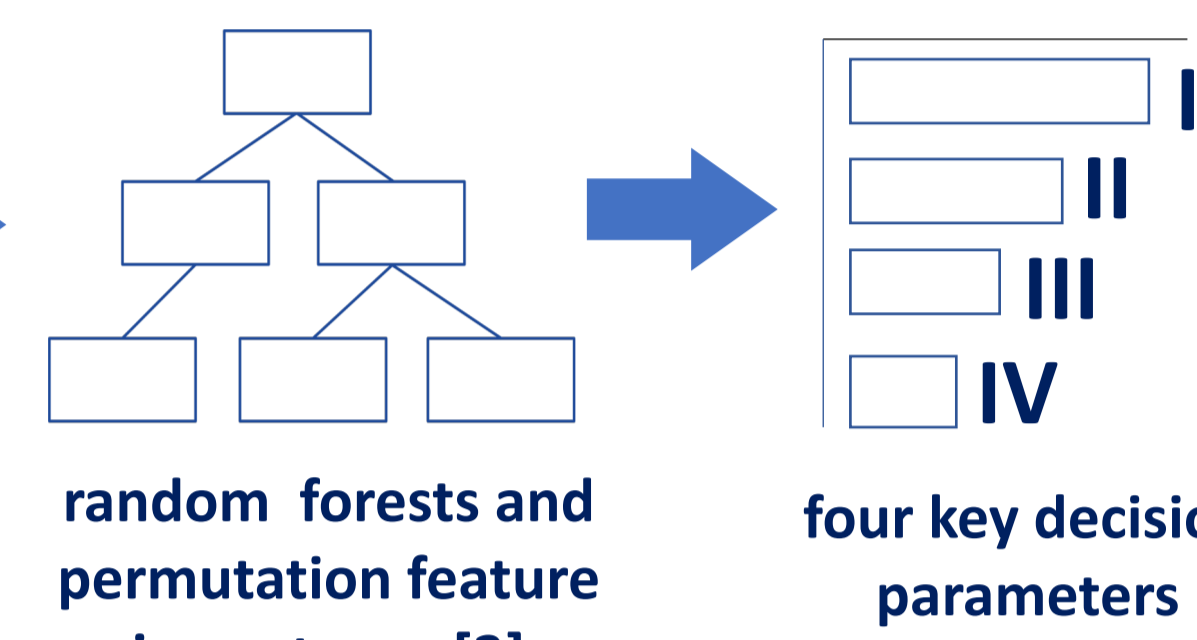
Decision tree combining 10 decision parameters to build decision paths



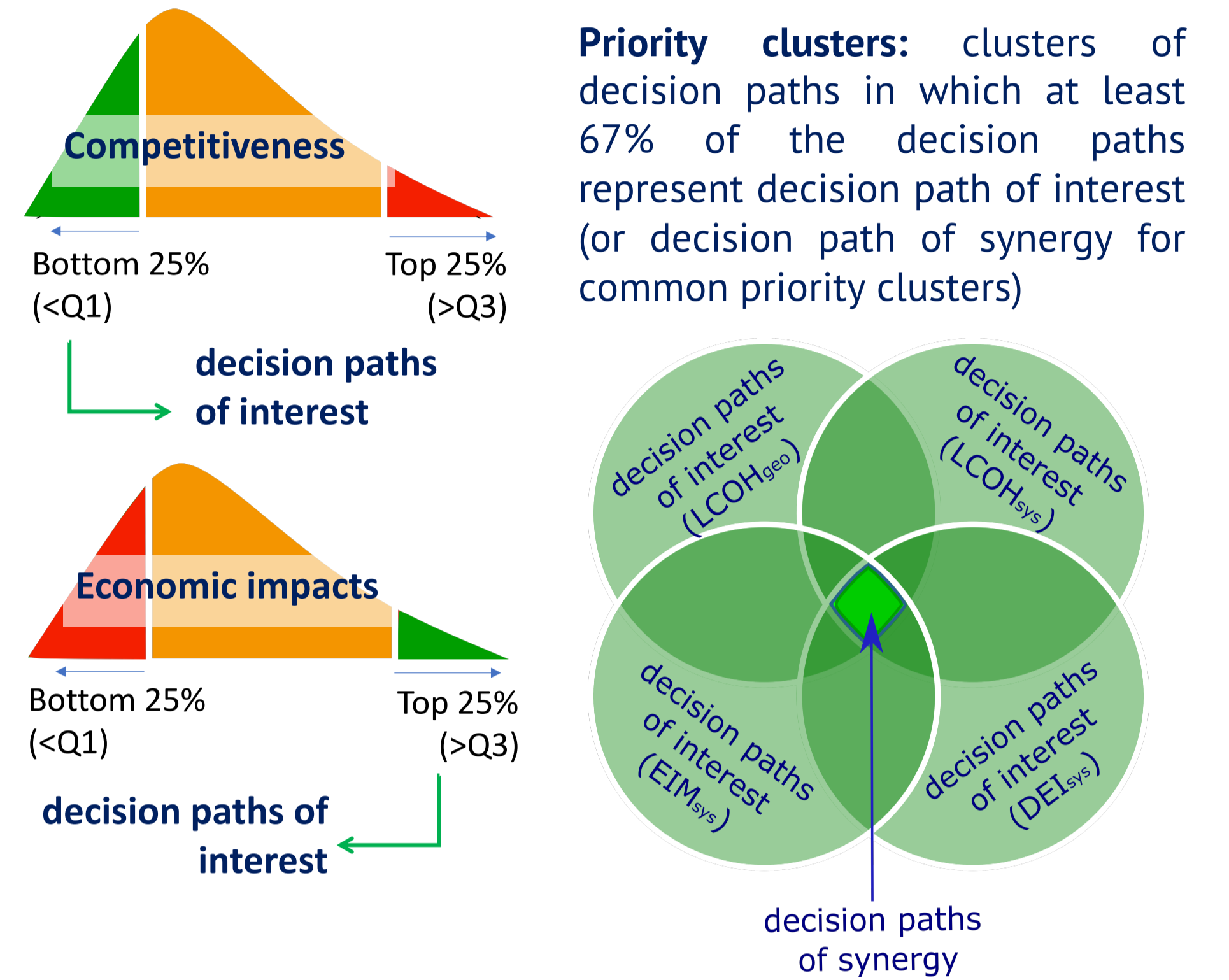
Quantification of four economic indicators



Identification of key decision parameters and common decision parameters



Identifying indicator-specific priority clusters and common priority clusters



Decision parameters

1. total target heat demand
2. number of districts
3. geothermal coverage
4. configuration of auxiliary heat source
5. type of auxiliary heat source
6. district heating generation
7. linear heat density
8. well depth
9. maximum flowrate per well-doublet
10. With or without 3D seismic

Competitiveness indicators

$LCOH_{geo}$ (CHF/MWh): Levelized costs of geothermal district heating
 $LCOH_{sys}$ (CHF/MWh): Levelized costs of the whole district heating system

Economic impacts indicators (I/O analysis [4] with EXIOBASE [5])

EIM_{sys} : Ratio of wider economic impact to total spending or economic impact multiplier
 $DEI_{sys}(\%)$: Share of domestic economic impact

Results

- The large variation of the indicators reflects the significance of evaluating multiple combinations of decisions as part of planning the implementation of geothermal district heating. (**Figure 1 top**)
- Key decision parameters differ across economic indicators. **Geothermal coverage is the common key decision parameter**, having strongest influence on the competitiveness indicators. In contrast, the **choice of auxiliary heat source** influences the economic impact indicators the strongest. (**Figure 1 bottom**)
- Priority clusters for $LCOH_{geo}$ are found when geothermal energy covers 40% of heat demand of a district with a linear density of 8 MWh/(m-year) using geothermal resources from 1500 m depth. Under the same geothermal coverage, if geothermal resources are from 2500 m depth, the priority clusters will be limited to scenarios where the network is distributed to 2 districts or more. If the district has a linear density of 6 MWh/(m-year), the priority clusters will be even more limited to 3 districts or more. (**Figure 2**). Note: similar analysis for $LCOH_{sys}$, EIM_{sys} and DEI_{sys} were carried out but not presented here.
- Only two common priority clusters are identified, indicating the narrow available options to find synergy between competitiveness and economic impacts. Synergy is 60% or more likely to be achieved when a geothermal coverage equals 40% and complemented by centralized waste incineration and deployed in a district with a linear heat density of 6 MWh/(m-year) or more using second generation district heating. (**Figure 3**)

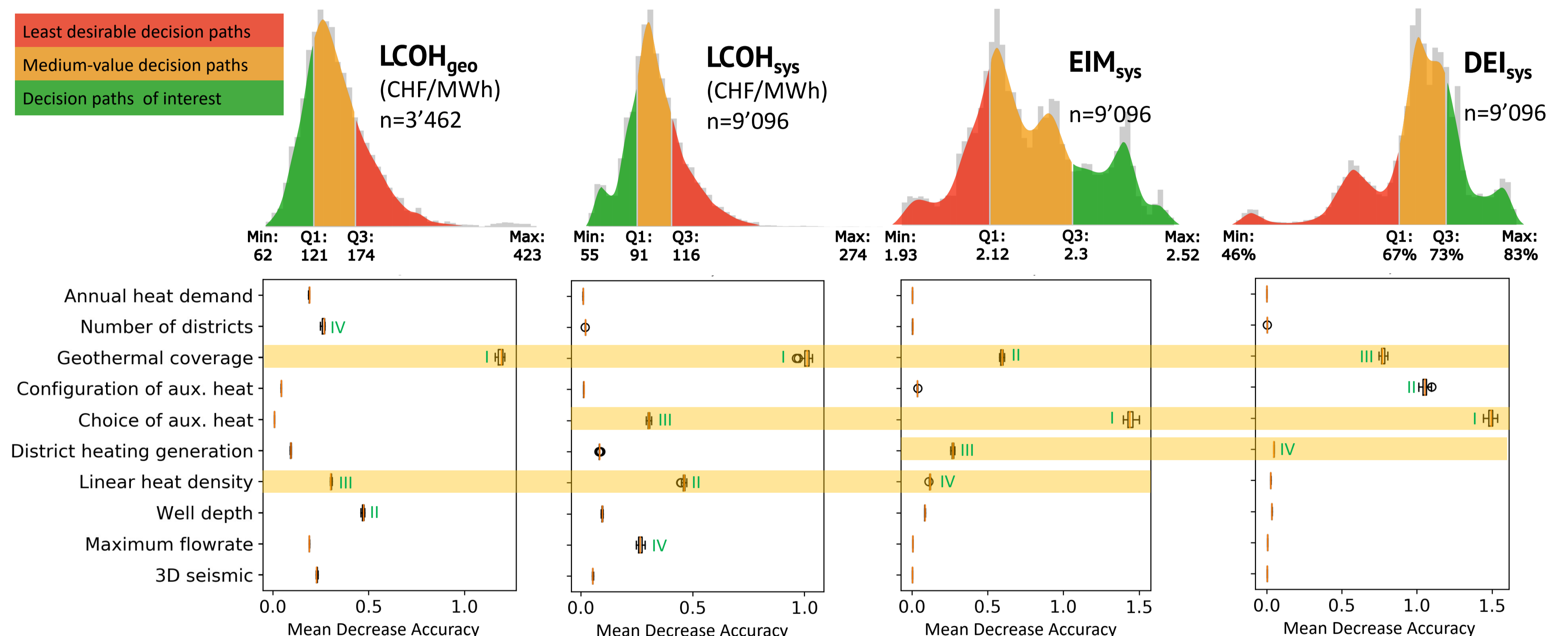


Figure 1. **Top:** Ranges, distributions and classifications of the four economic indicators. **Bottom:** Ranking of decision parameters' importance measured using random forests and permutation feature importance. 'I' indicates the most important parameters and 'IV' indicates the fourth most important ones. Shaded yellow are key decision parameters shared among two economic indicators or more.

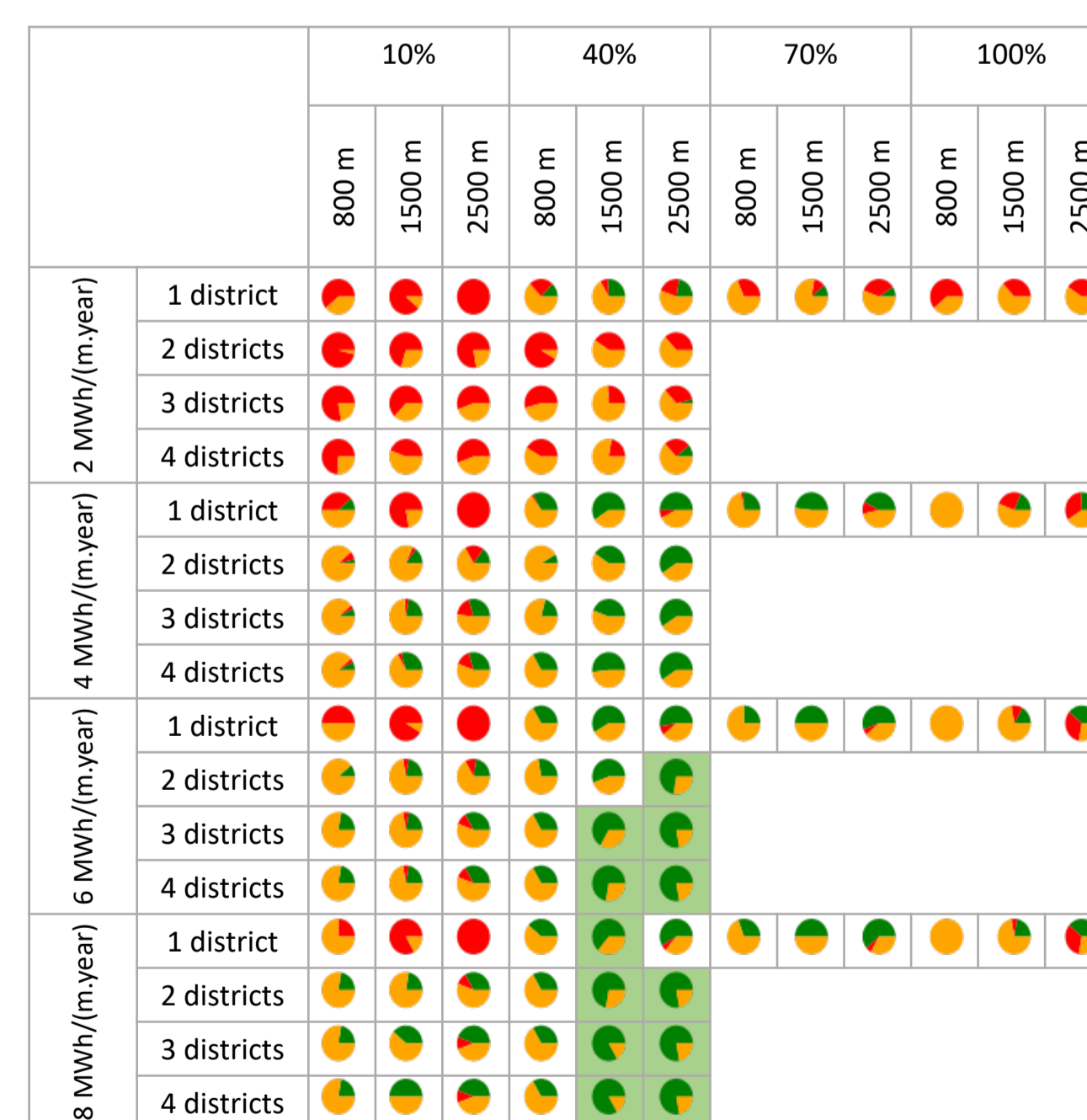


Figure 2. Share of $LCOH_{geo}$ classification of decision paths clustered under the key decision parameters for $LCOH_{geo}$ (geothermal coverage, linear heat density, well depth, number of districts). Shaded green are **priority clusters**, in which 67% of the decision paths represent **decision paths of interest**.

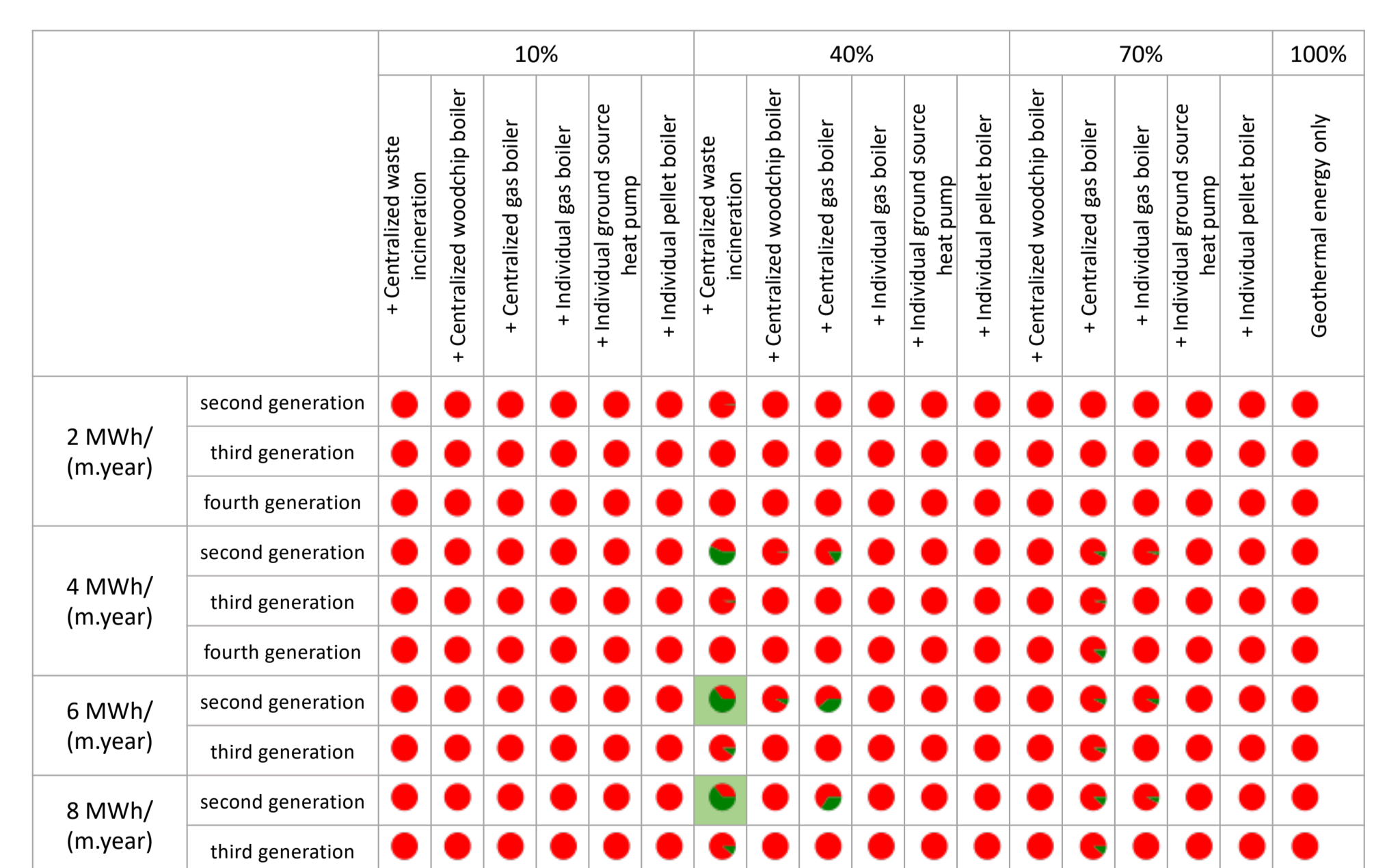


Figure 3. Share of classification of scenarios clustered under common key decision parameters (geothermal coverage, choice of auxiliary heat source, linear heat density, and district heating generation). Shaded green are **common priority clusters**, in which 60% of the decision paths represent **decision paths of synergy**.

Conclusions

Our study shows the importance of integrating a combination of decision parameters to identify the possibilities of finding synergy between competitiveness and the economic impacts of geothermal district heating. Although there are numerous decision parameters, four parameters determine the most the likelihood of synergy between competitiveness and economic impacts: geothermal coverage of 40%, centralized waste incineration as the choice of auxiliary heat source, linear heat density of 6 MWh/(m-year) or more and district heating of second generation.

References

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