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Data-Informed Evaluation Framework for Integrated Energy Systems: Insights from Power, Process Heat, and Hydrogen Production Applications

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Changing the World's Energy Future

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Data-Informed Evaluation Framework for Integrated Energy Systems: Insights from Power, Process Heat, and Hydrogen Production Applications

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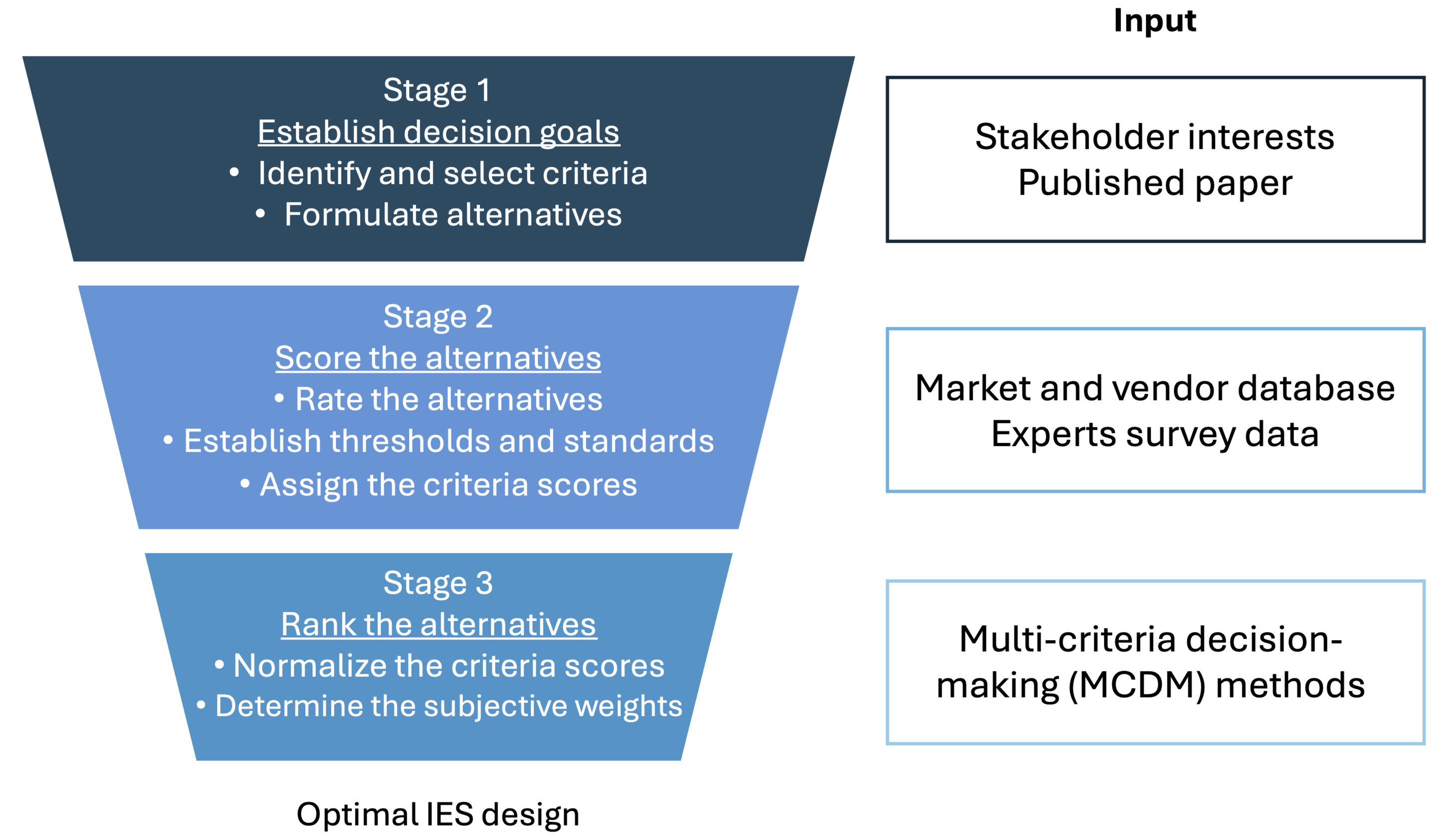
I. BACKGROUND

Multi-Criteria Decision Analysis (MCDA)



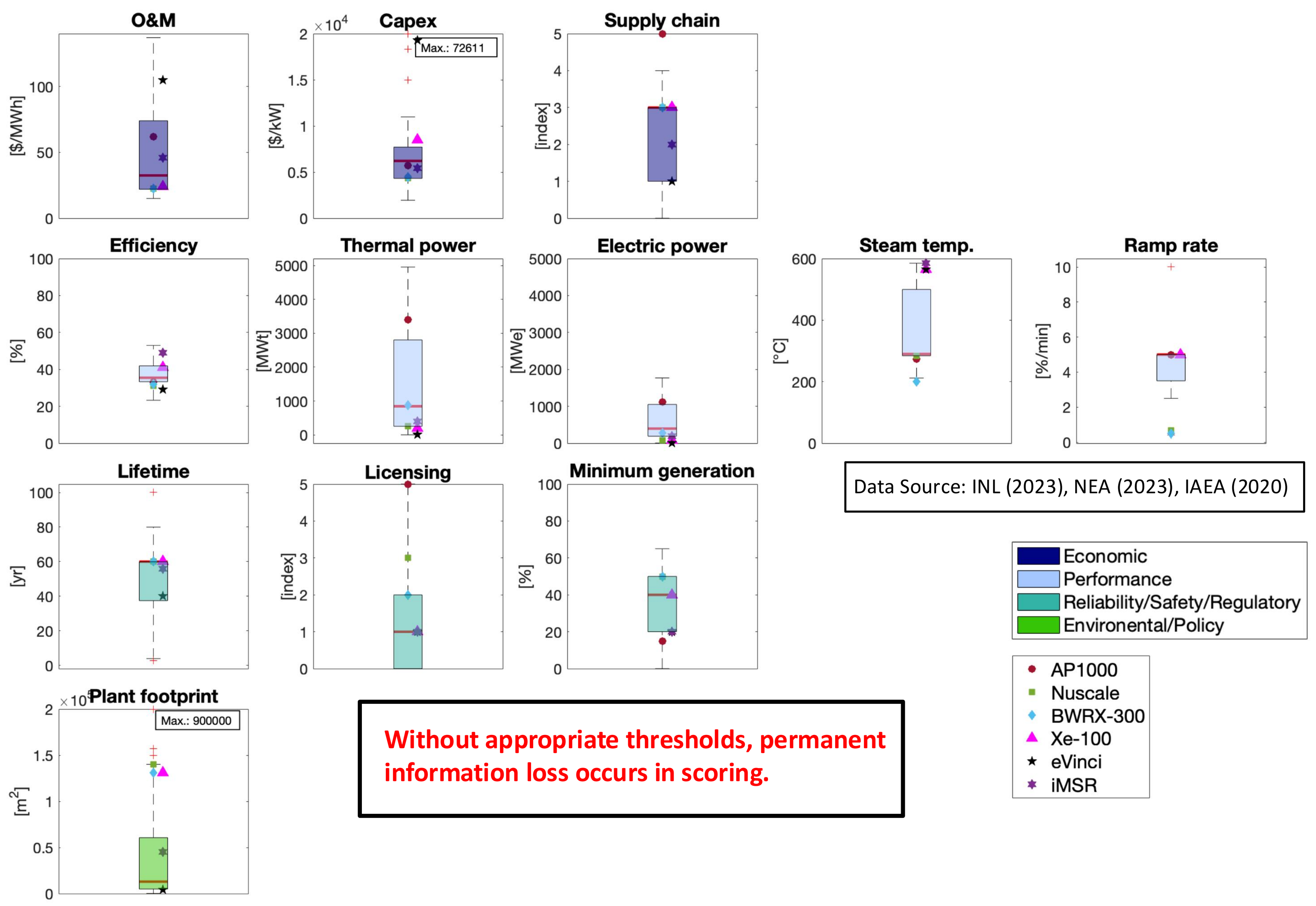
Overview of the conventional MCDM process for selecting the optimal integrated energy system (IES) design

IMPACTS

- **We propose a framework for achieving consistent assessments across various stakeholder groups.**
- **Our approach effectively synthesizes the relative standing of each criterion.**

II. METHODS

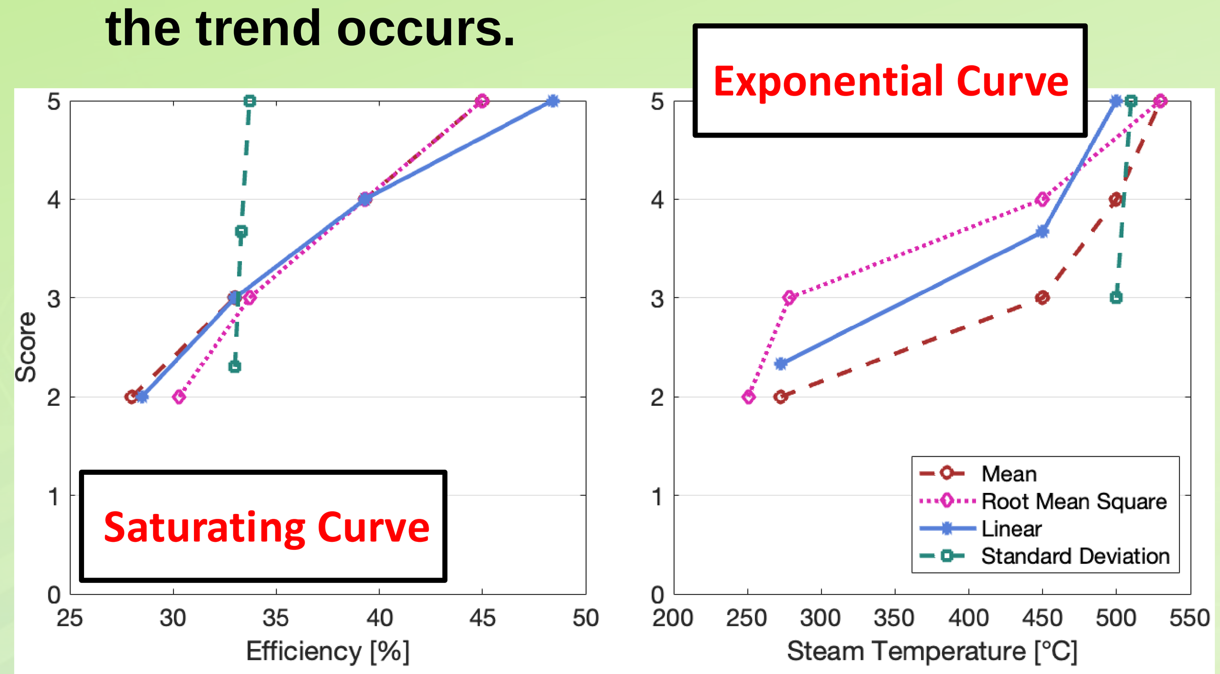
a. Data-Informed Thresholds Determination



Boxplots showing the distribution of values for each criterion across reactors, with the data for six individual reactor highlighted: Traditionally, threshold values for scoring on a numerical scale have been set based on decision-makers' subjective judgements.

b. Change-Point Analysis

- **Statistical methods identify points where a change in the trend occurs.**



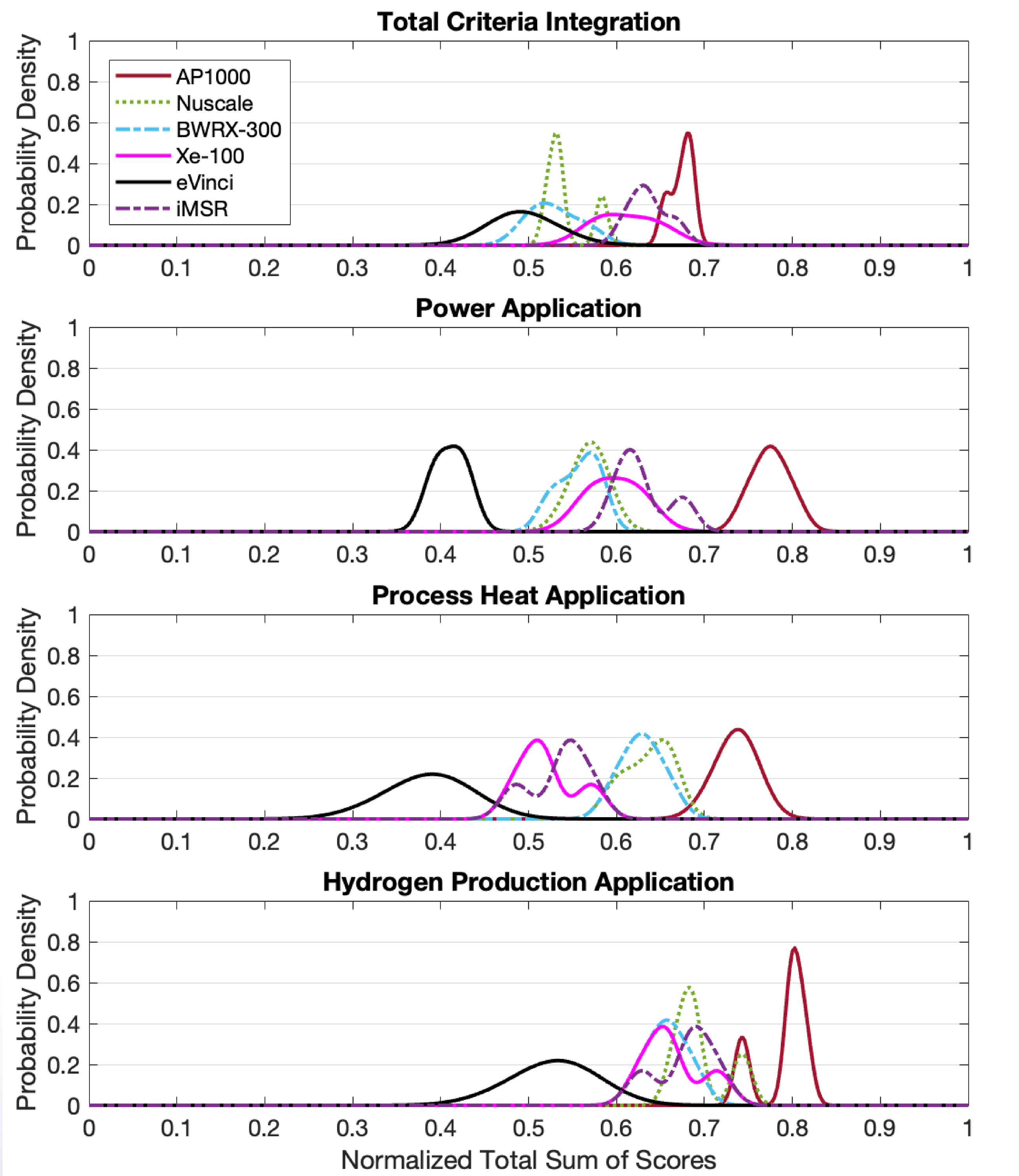
Comparison of different methods for determining thresholds: thermal-to-electric conversion efficiency (left) and steam temperature (right)

Derived thresholds based on selected 11 criteria: Thresholds are established based on the points where the mean of each criterion changes most significantly.

Criteria domain	Criterion	Criterion description/ Quantitative measure	Indicator(s)/Assessment	Thresholds 5	4	3	2	1
Economic	O&M cost	Variable O&M cost	[$/kWh] Direction: smaller-the-better	< 22	22	42	74	103 ≤
	Capital investment	Overnight capital cost (OCC)	[$/kW] or [$/kWh] Direction: smaller-the-better	< 4820	4820	8340	15000	26554 ≤
	Supply chain	Public announcements by suppliers and partners	OECD-NEA Small Modular Reactor Index Direction: larger-the-better	≥ 4	3	2	1	1 >
Performance	System efficiency	Thermal-to-electric conversion ratio	[%] Direction: larger-the-better	≥ 45	39.3	33	28	28 >
	Meeting requirements	Steam temperature	[°C]* Direction: larger-the-better	≥ 530	500	450	272.7	272.7 >
	Ramp time	Ramp rate	[%/min]* Direction: larger-the-better	≥ 10	5	3	2.5	2.5 >
	Scalability	Power capacity	[MWe]* [MWt]* Direction: larger-the-better	≥ 3926 ≥ 1356	2800 1000	1250 468	480 185	480 > 185 >
Reliability/Safety	Lifetime	Technology lifetime	[yr] Direction: larger-the-better	≥ 70	50	30	10	10 >
	System stability	Minimum generation level	[%] Direction: smaller-the-better	< 15	15	40	50	60 ≤
	Regulatory uncertainty	Licensing interactions with regulators	OECD-NEA Small Modular Reactor Index Direction: larger-the-better	≥ 5	3	2	1	1 >
Environmental	Land impact	Plant footprint	[10^3×m^2] Direction: smaller-the-better	< 24	24	65	100	200 ≤

III. RESULTS

Visualized Uncertainties in Decision Making



Score distributions for six reactor alternatives across various applications (with equal weights assigned to each criterion): The x-axis represents the competitiveness level of the reactors, while the y-axis indicates the probability of those levels being observed.

SUMMARY

- **We explicitly include uncertainties when establishing thresholds and scoring each criterion on a numerical scale (e.g., 1-5).**
- **We focus on the distribution of estimates for each criterion (e.g., costs and performance).**
- **We conducted case studies on six reactor designs for the three applications.**

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