

Advanced Reactor Licensing: *Navigating the Dual Statutory Mandates of Adequate Protection & Efficiency*

Zahra Mohaghegh

Professor, Department of Nuclear, Plasma, and Radiological Engineering (NPRE)

Director, **Socio-Technical Risk Analysis (SoTeRiA)** Research Laboratory

Grainger College of Engineering

University of Illinois at Urbana-Champaign (UIUC)

zahra13@illinois.edu

<https://npres.illinois.edu/people/profile/zahra13>

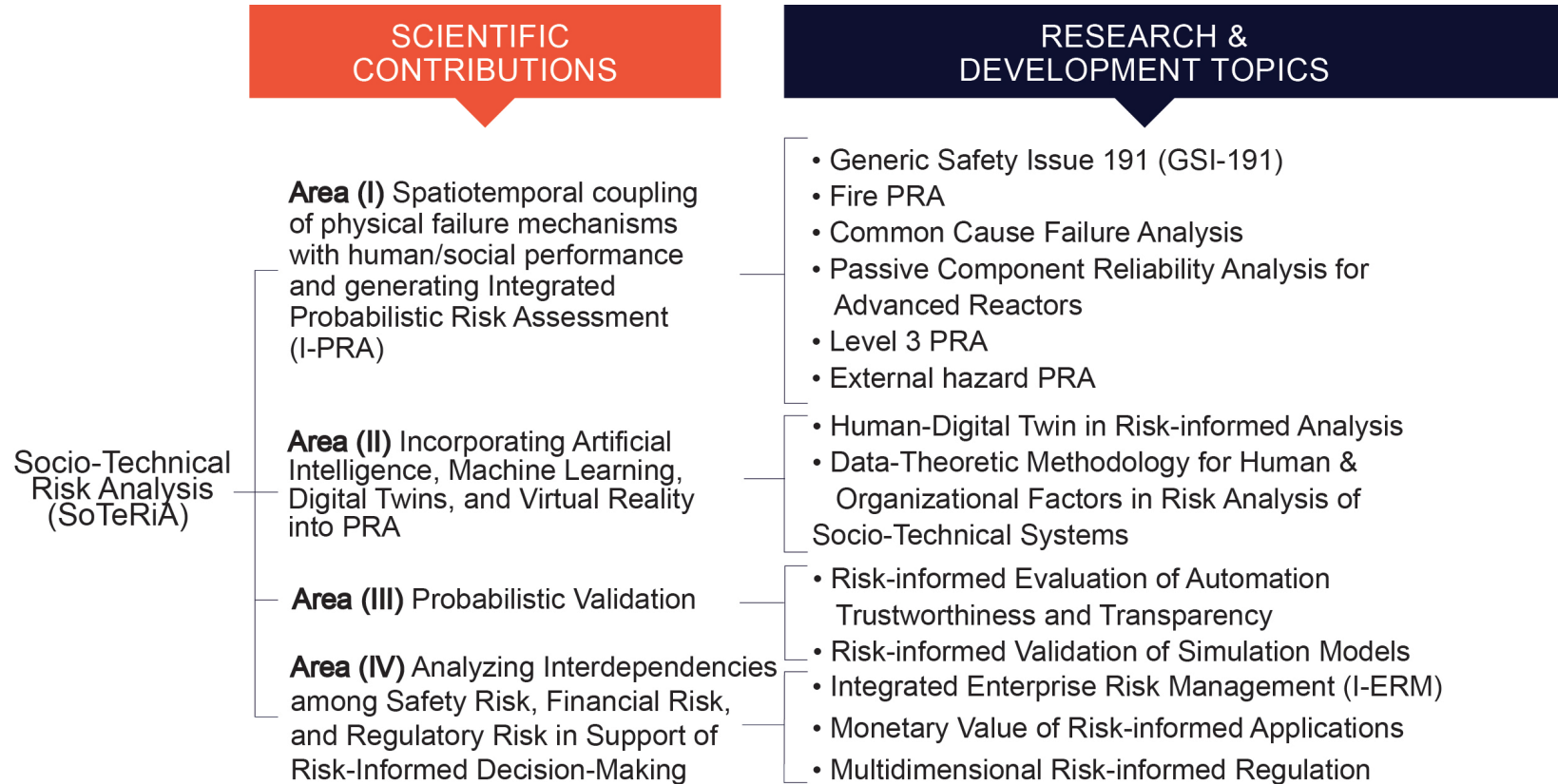
Socio-Technical Risk Analysis (SoTeRiA)

Research Laboratory



**The Grainger College
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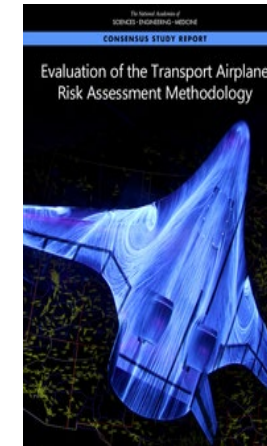
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National Academies of Sciences, Engineering, and Medicine. 2022. *Evaluation of the Transport Airplane Risk Assessment Methodology*. Washington, DC: The National Academies Press.
<https://doi.org/10.17226/26519>.



Half NPM Mock-Up in Corvallis

Formerly proposed NuScale Power SMR plant
<https://www.cfppllc.com>



<https://safety4sea.com/uscg-certificate-of-compliance-for-lng-carriers/>

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Co-authors: George Joslin¹, Arden Rowell^{1,2}, Ha Bui¹, Justin Valentino¹, Seyed Reihani¹, Zahra Mohaghegh¹

- **¹Socio-Technical Risk Analysis (SoTeRiA) Laboratory**, Department of Nuclear, Plasma, and Radiological Engineering (NPRE), Grainger College of Engineering, University of Illinois at Urbana-Champaign (UIUC), Urbana, IL, USA.
- **²College of Law**, UIUC, Urbana, IL, USA.

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- A. What does **efficient regulation** mean in the context of nuclear energy?
- B. What **risk and safety assessment methods** are technically and legally essential?
- C. How can the **dual statutory mandates** of regulatory efficiency and reasonable assurance of adequate protection be satisfied simultaneously?

A. What is meant by **efficient regulation** in the context of nuclear energy?

- **Fact (1):** The **ADVANCE Act** (2024) requires that the NRC adopt an **efficient** approach to regulation that does not unnecessarily limit:
 - ✓ Civilian use and deployment, and
 - ✓ **Societal benefits** from nuclear energy technologies.
- **Fact (2):** The Supreme Court case **Loper Bright Enterprises v. Raimondo** (2024) overturned the principle of Chevron deference.
 - ✓ Courts will now make their own **independent judgment** about the meaning of “efficient,” relying on judicial reasoning and precedent, instead of deferring to the NRC’s interpretation.
- **Fact (3):** According to the constitutional framework established by **Trump v. Slaughter** (2026), the NRC no longer possesses the structural independence that Congress assumed when it created the agency in 1974.

- ❖ **Technological Efficiency:** Performance of nuclear systems themselves.
- ❖ **Organizational Efficiency:** NRC internal processes, including timeliness and procedural smoothness.
- ❖ **Judicial/Regulatory Efficiency:** Whether regulatory decisions are benefit-justified, typically evaluated via a comprehensive cost-benefit analysis.
 - Past courts have read statutory mandates for efficiency as requiring **cost-benefit analysis** (See, for example, *Business Roundtable v. Securities and Exchange Commission [SEC]*);
 - Presidential policy also reinforces this reading (See, for example, Executive Order 12866).

Efficiency in Rule Making & Licensing

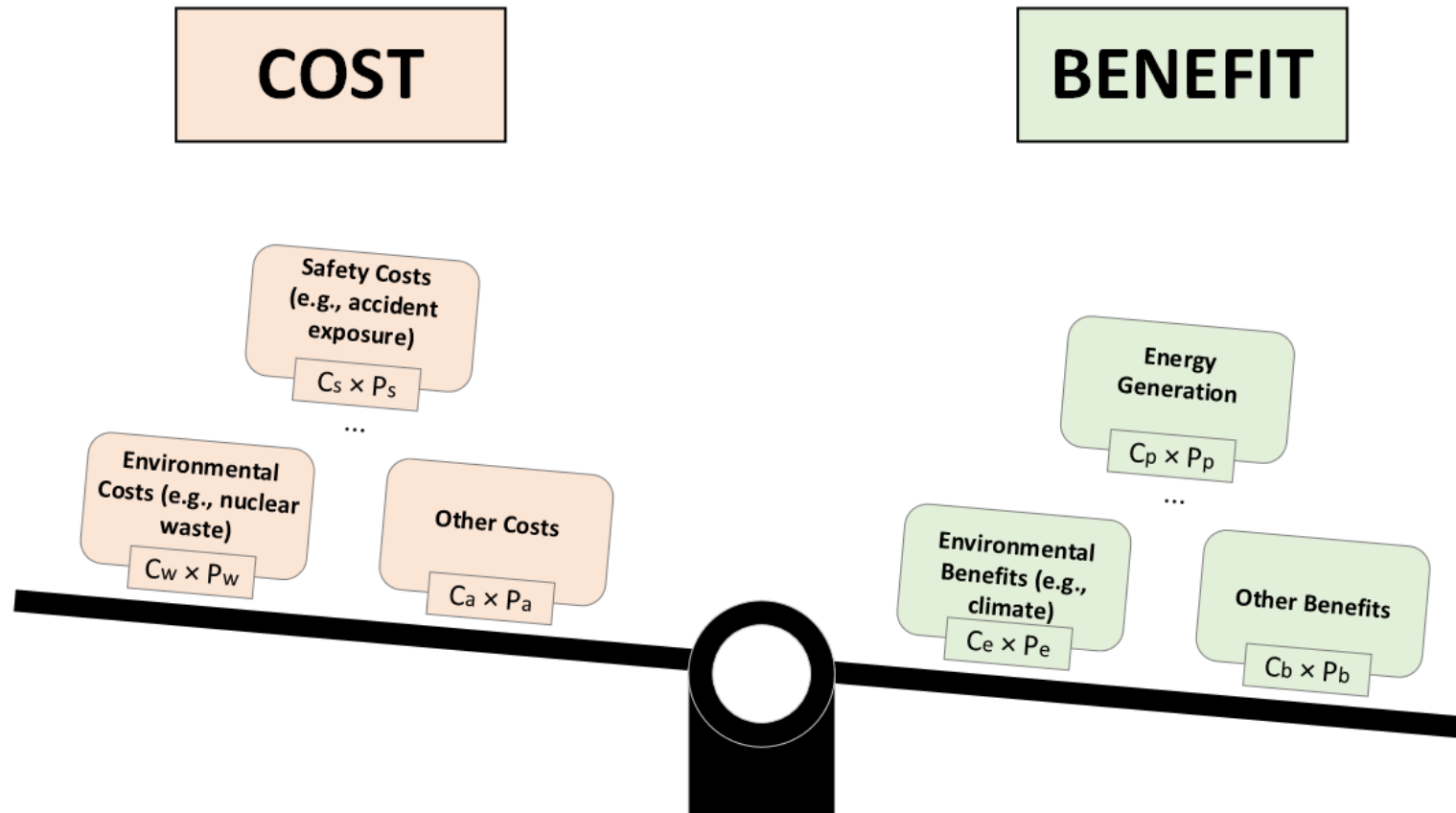
❖ **Efficiency in Rule Making:**

- The NRC has made progress in using cost-benefit analysis in rulemaking (e.g., Part 53, Part 57), but it should ensure that its analyses are supported by evidence and reflect a comprehensive assessment of both costs and benefits.
 - ✓ Otherwise, the agency's reasoning may be overturned as arbitrary and capricious and/or as exceeding its statutory authority.

❖ **Efficiency in Initial Licensing:**

- A comprehensive framework for evaluating whether the initial licensing decision is benefit-justified remains to be developed.
 - Part 53 permits site-specific comparisons of societal risks and benefits, but its siting provisions do not themselves specify a comprehensive set of cost-benefit elements or a detailed evaluation method.

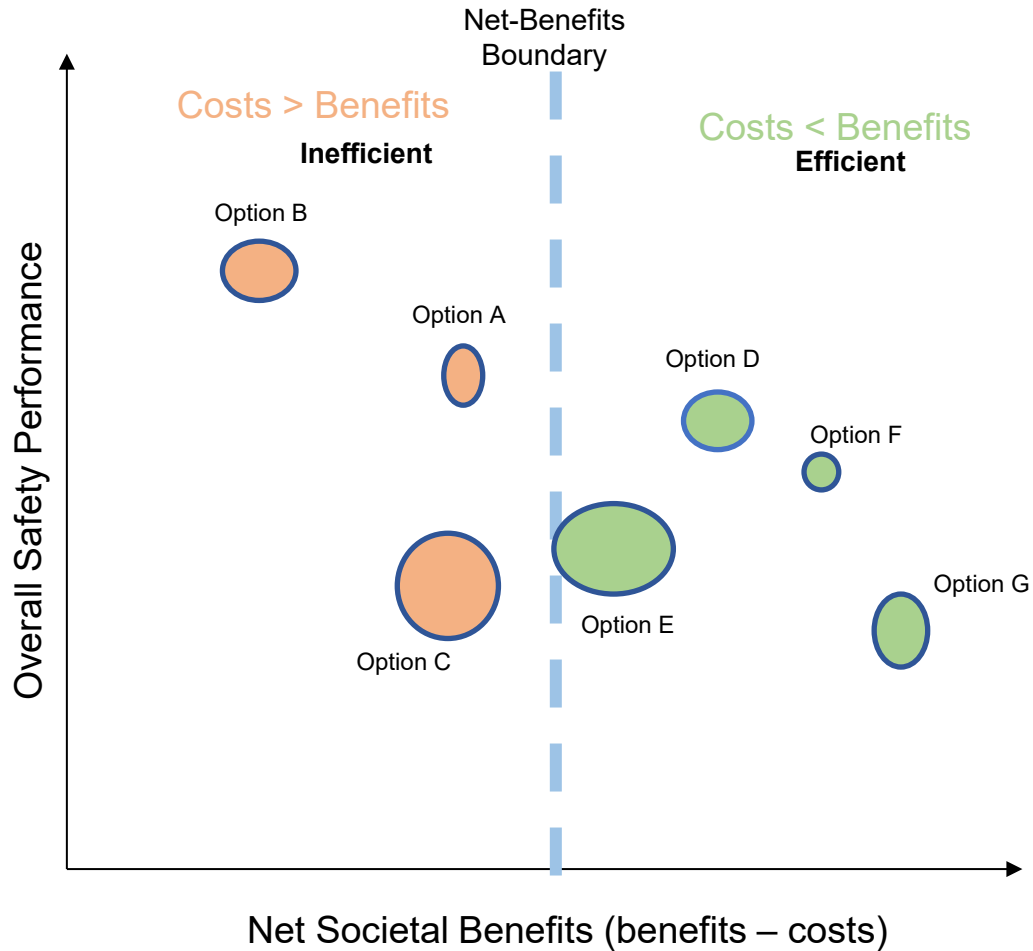
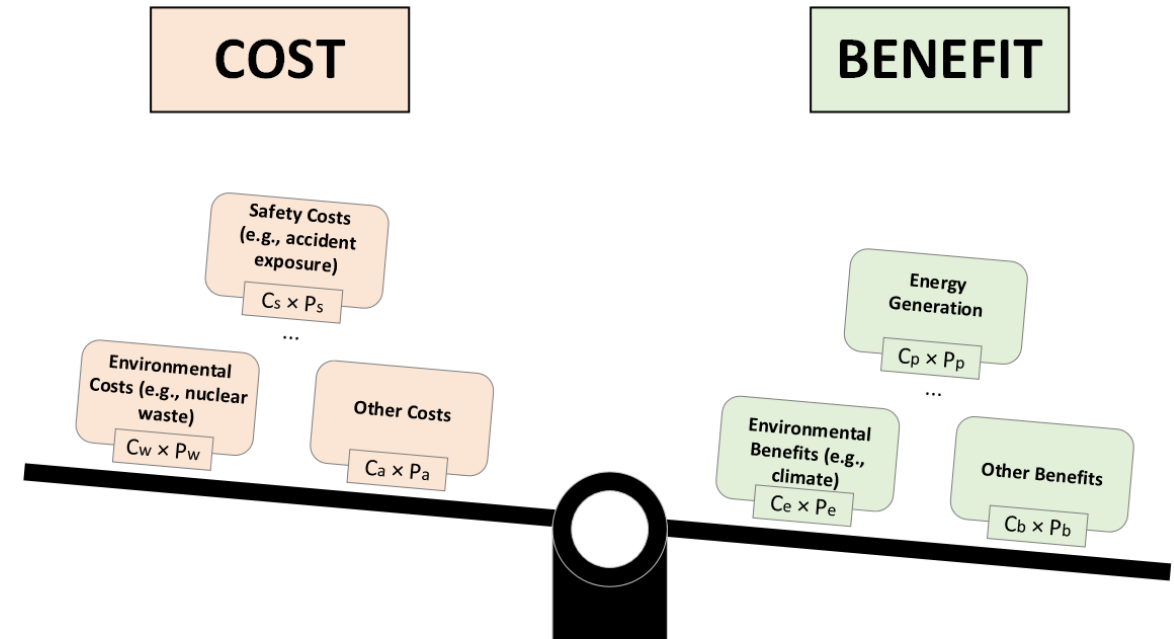
Proposed Cost-Benefit Analysis to Address Efficiency in Licensing (1)



Note: C_i and P_i correspond to the consequence and probability, respectively, of cost/benefit item i

Note: The list of costs and benefits shown in this figure includes some examples and is not meant to be comprehensive

Proposed Cost-Benefit Analysis to Address Efficiency in Licensing (2)



Note: C_i and P_i correspond to the consequence and probability, respectively, of cost/benefit item i

Efficiency in Rule Making & Licensing (cont.)

❖ Efficiency in Rule Making

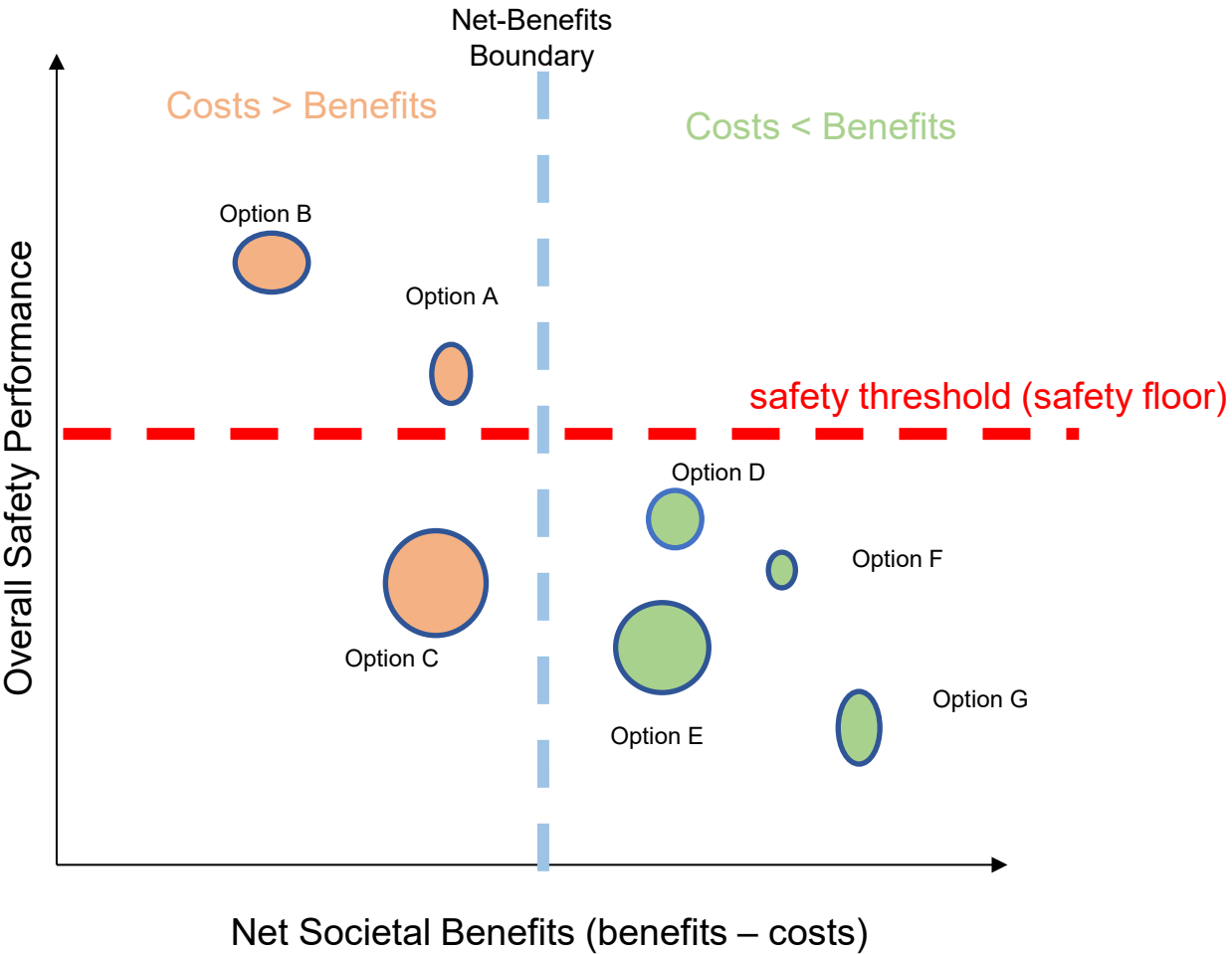
- The NRC has made progress in using cost-benefit analysis in rulemaking (e.g., Part 57), but it should ensure that its analyses are supported by evidence and reflect a comprehensive assessment of both costs and benefits.

❖ Efficiency in Initial Licensing

- A comprehensive framework for evaluating whether the initial licensing decision is benefit-justified remains to be developed.

❖ Backfit Decisions (10 CFR 50.109)

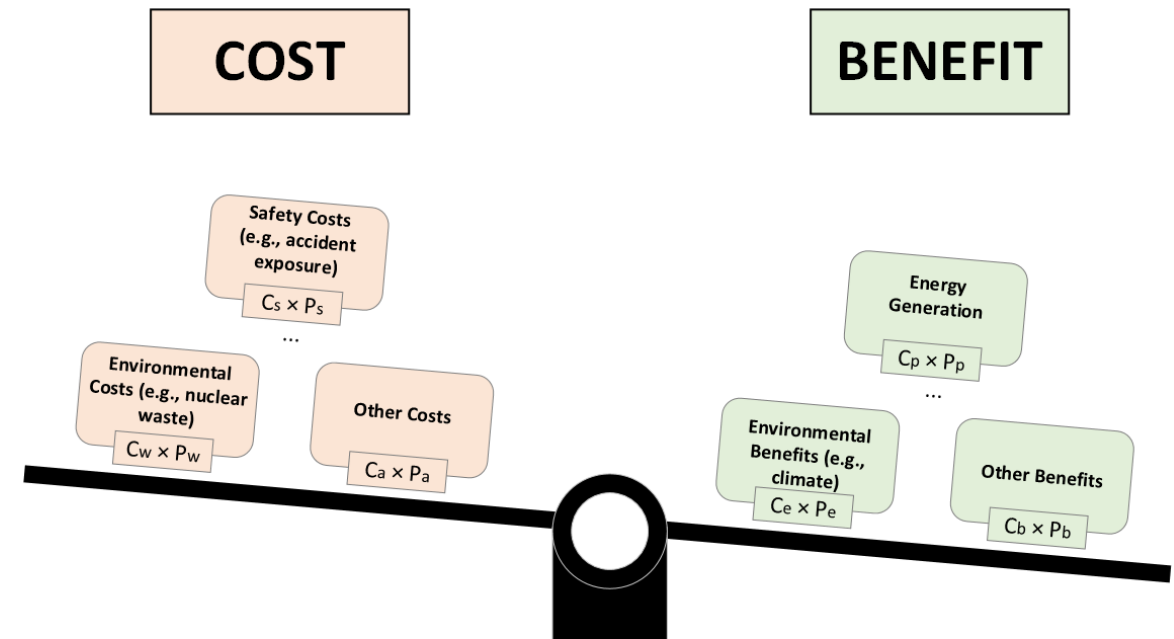
- Incremental regulatory analysis is used to determine whether additional safety improvements justify their costs.



The backfit evaluation compares the incremental safety benefit and implementation costs of moving from A (existing plant) to B (proposed backfit).

- A. What does efficient regulation mean in the context of nuclear energy?
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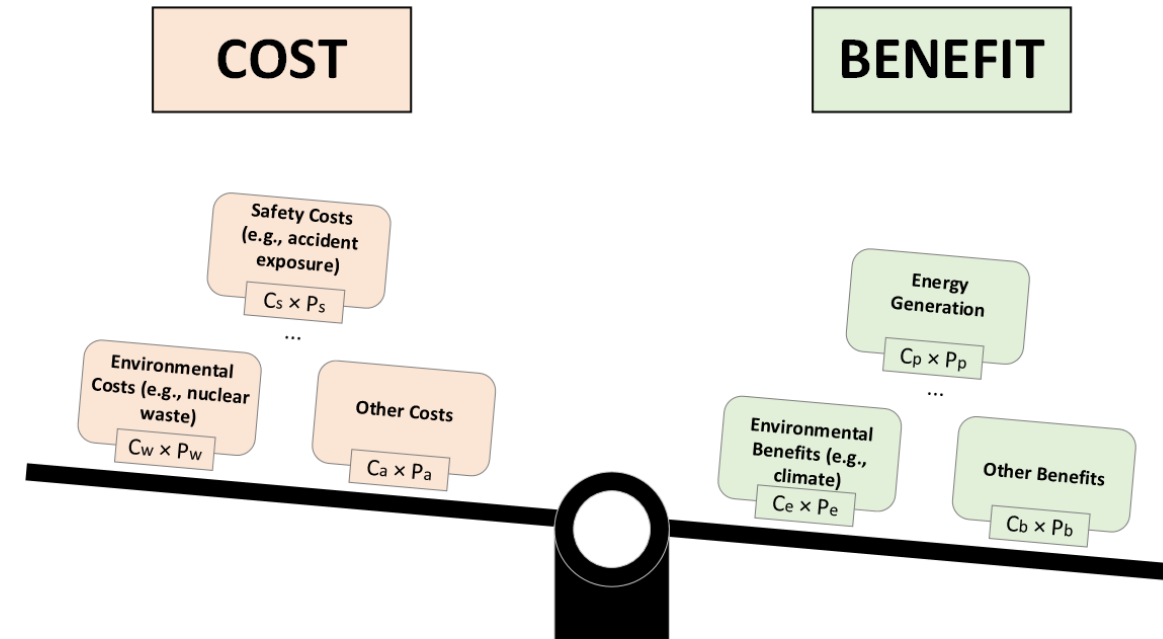
B. What risk and safety assessment methods are essential?



Note: C_i and P_i correspond to the consequence and probability, respectively, of cost/benefit item i

B. What risk and safety assessment methods are essential?

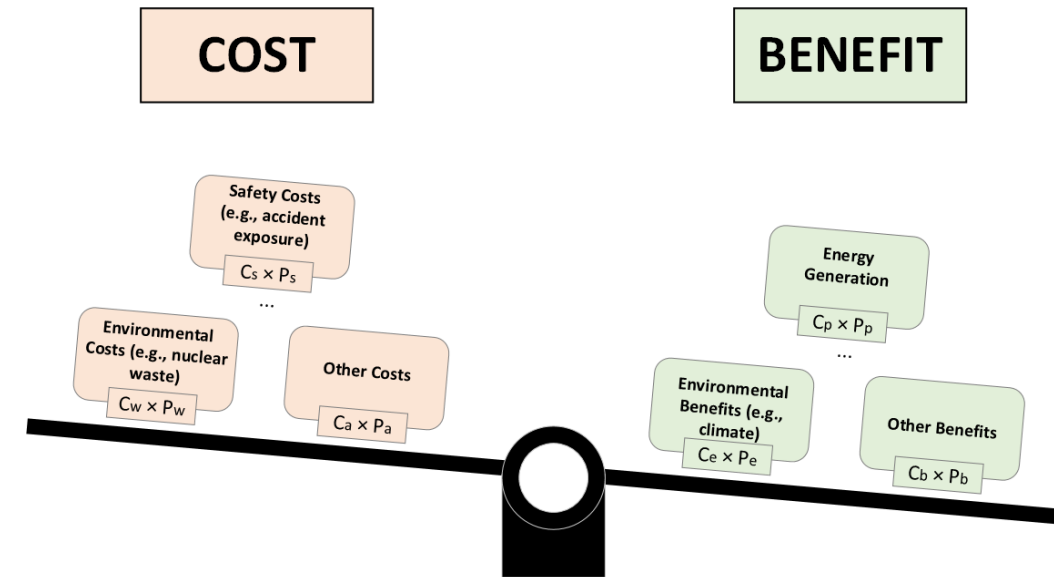
- Multi-dimensional risk assessment (e.g., security risk, safety risk, nuclear waste risk, generation risk)



Note: C_i and P_i correspond to the consequence and probability, respectively, of cost/benefit item i

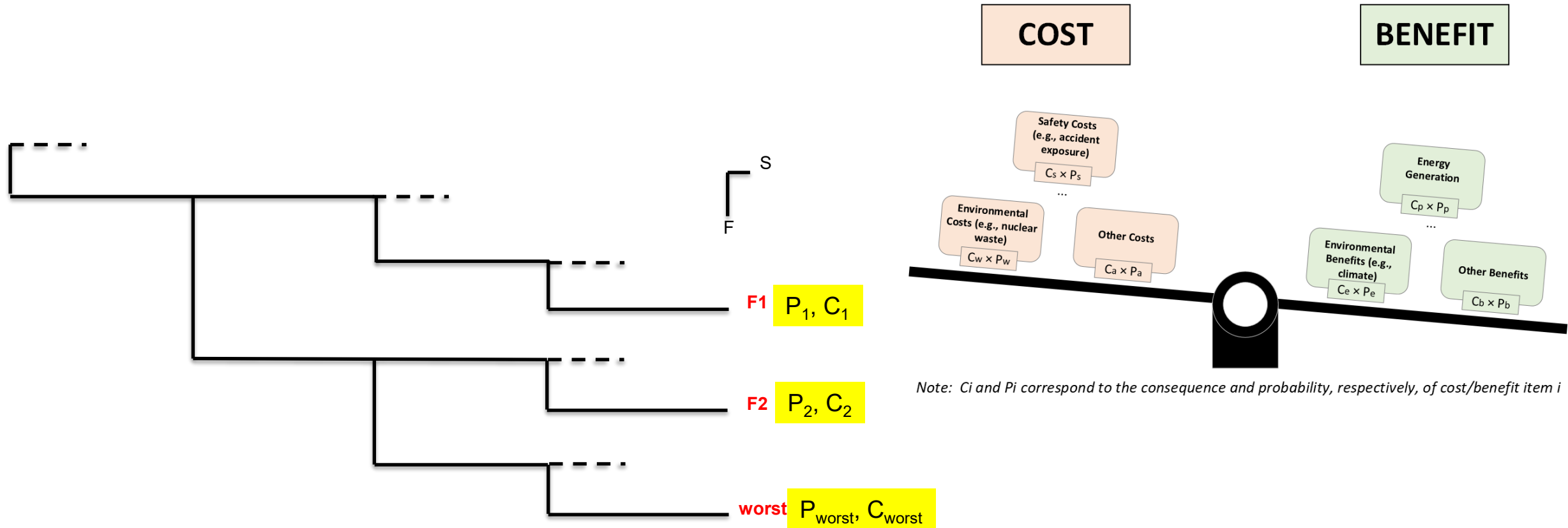
B. What risk and safety assessment methods are essential?

- **Qualification of methods** (e.g., safety assessment methods such as Maximum Hypothetical Accident [MHA], Probabilistic Risk Assessment [PRA])



Note: C_i and P_i correspond to the consequence and probability, respectively, of cost/benefit item i

Techno-Legal Limitations of the MHA Approach (1)



$$\text{Expected Radiological Exposure Cost in the Cost-Benefit Framework} = P_1 \times C_1 + P_2 \times C_2 + P_{\text{worst}} \times C_{\text{worst}}$$

❖ If the assumed accident is not truly the maximum accident

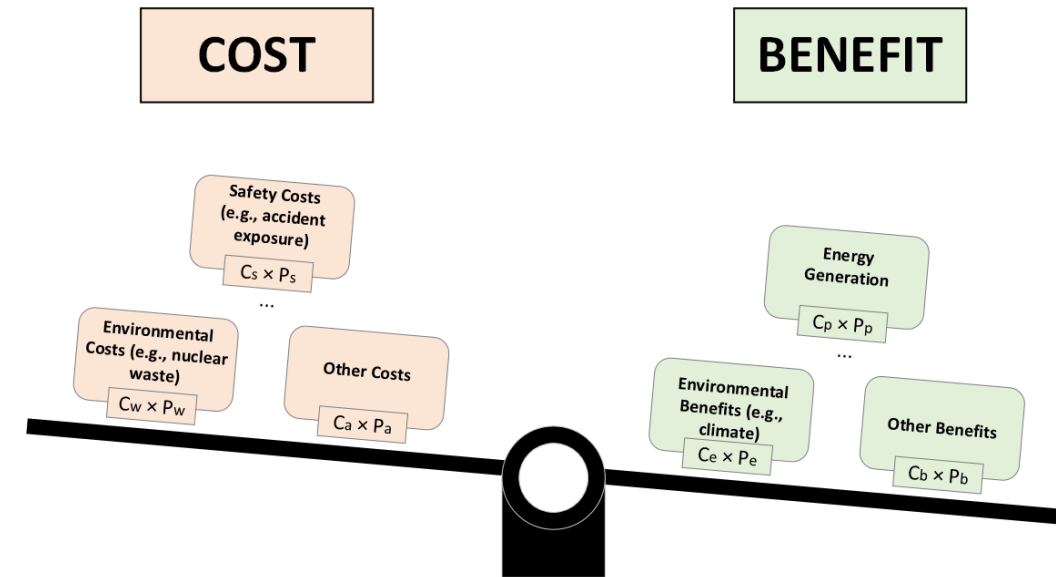
- Leaves higher-consequence scenarios unaddressed, weakening the safety justification. (safety concern)
- Creates vulnerability to an arbitrary-and-capricious challenge under the Administrative Procedure Act (APA).

❖ If the assumed accident is truly the maximum accident

- Overestimates expected safety costs when its consequences substitute for probability-weighted estimates.
- Biases the efficiency assessment against otherwise benefit-justified designs.

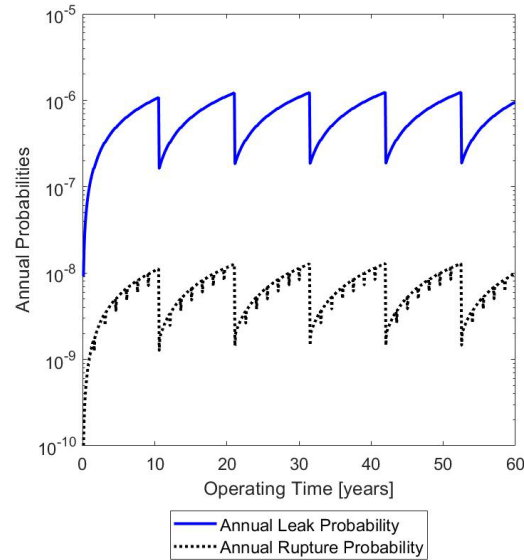
B. What risk and safety assessment methods are essential?

- **Qualification of methods**
 - The PRA of advanced reactors faces challenges due to limited experiential data, highlighting the need to advance PRA methodologies through:
 - Modeling and simulation of underlying phenomena, the use of AI techniques, and advanced uncertainty analysis.



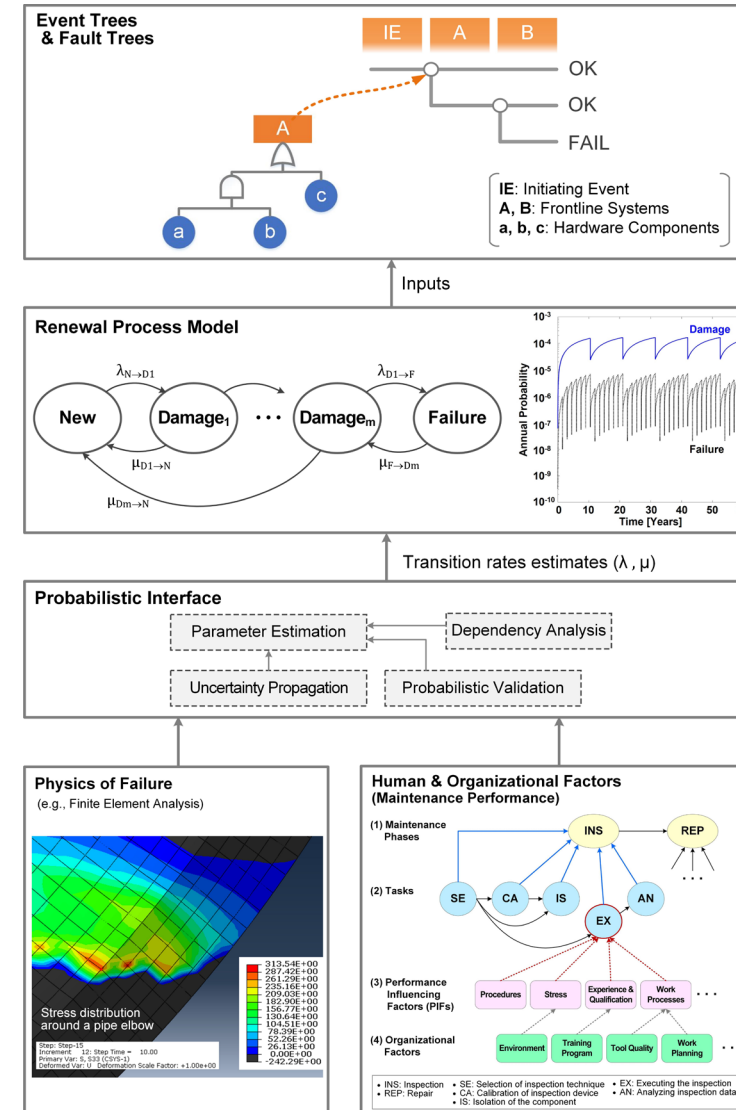
Note: C_i and P_i correspond to the consequence and probability, respectively, of cost/benefit item i

Coupling Physics of Failure and Maintenance Performance for Piping Reliability Analysis

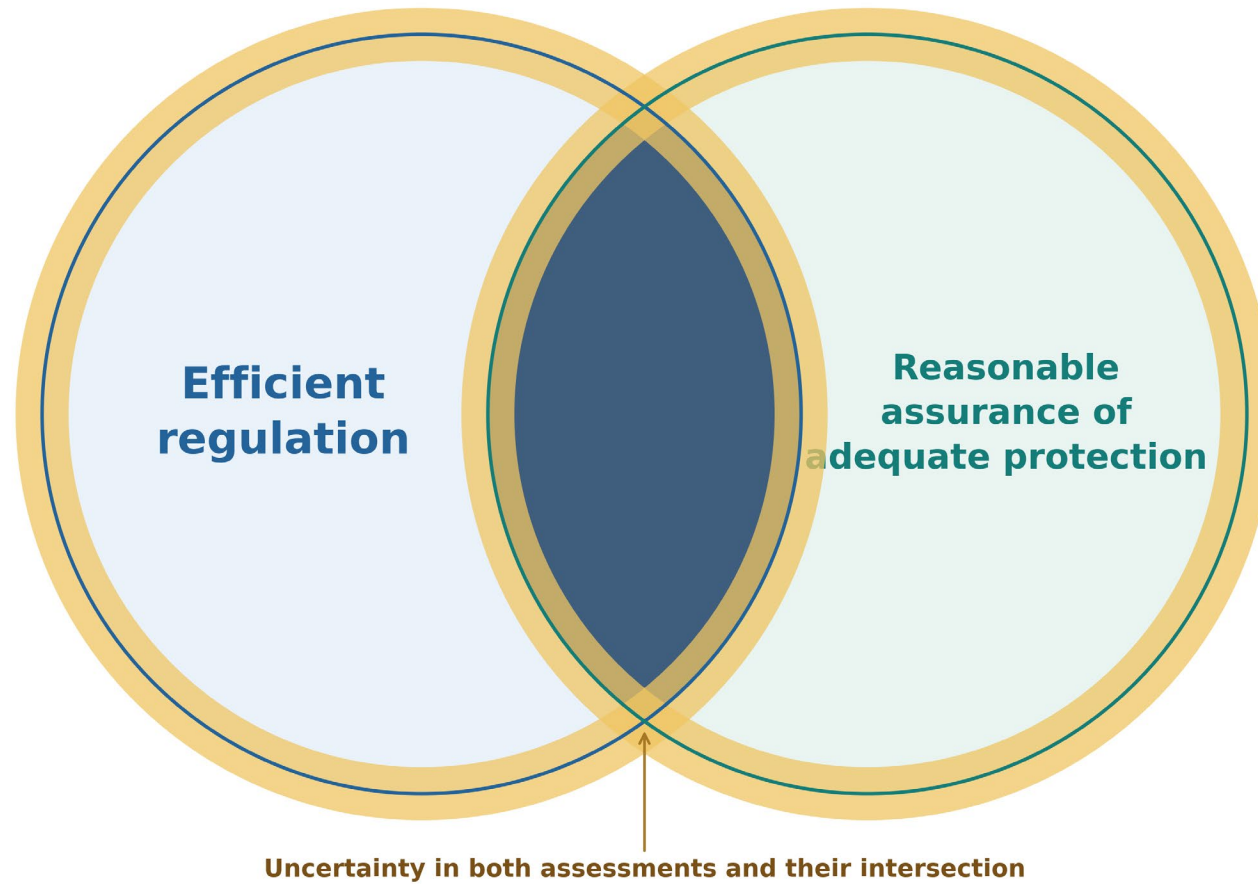


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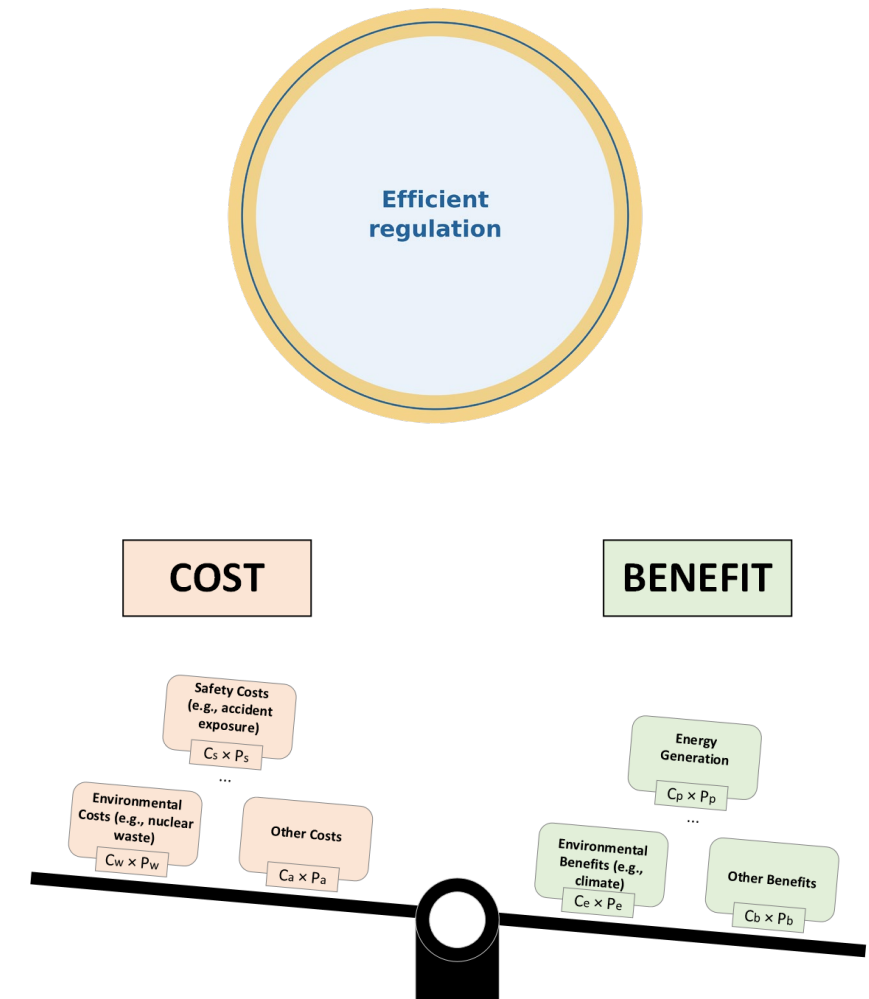
Step-I Evaluate the technical basis for demonstrating safety

- ❖ **Current NRC practice draws on:** A combination of deterministic safety analyses, PRA insights, defense-in-depth, safety margins, and applicable safety criteria and risk acceptance guidelines, informed by engineering judgment and consideration of uncertainty.
- ❖ This assessment can be conducted under the existing licensing pathways (e.g., Part 53).
- ❖ **Cautionary Notes:**
 - **Probabilistic risk characterization.** Proposed Part 57 permits MHA/MCA demonstrations of its dose-based entry criterion without requiring PRA for that demonstration.
 - **Cumulative risk:** Address dependencies and shared hazards across units, modules, and regional facilities. Proposed Part 57's screening approach is framed largely in single-reactor terms.



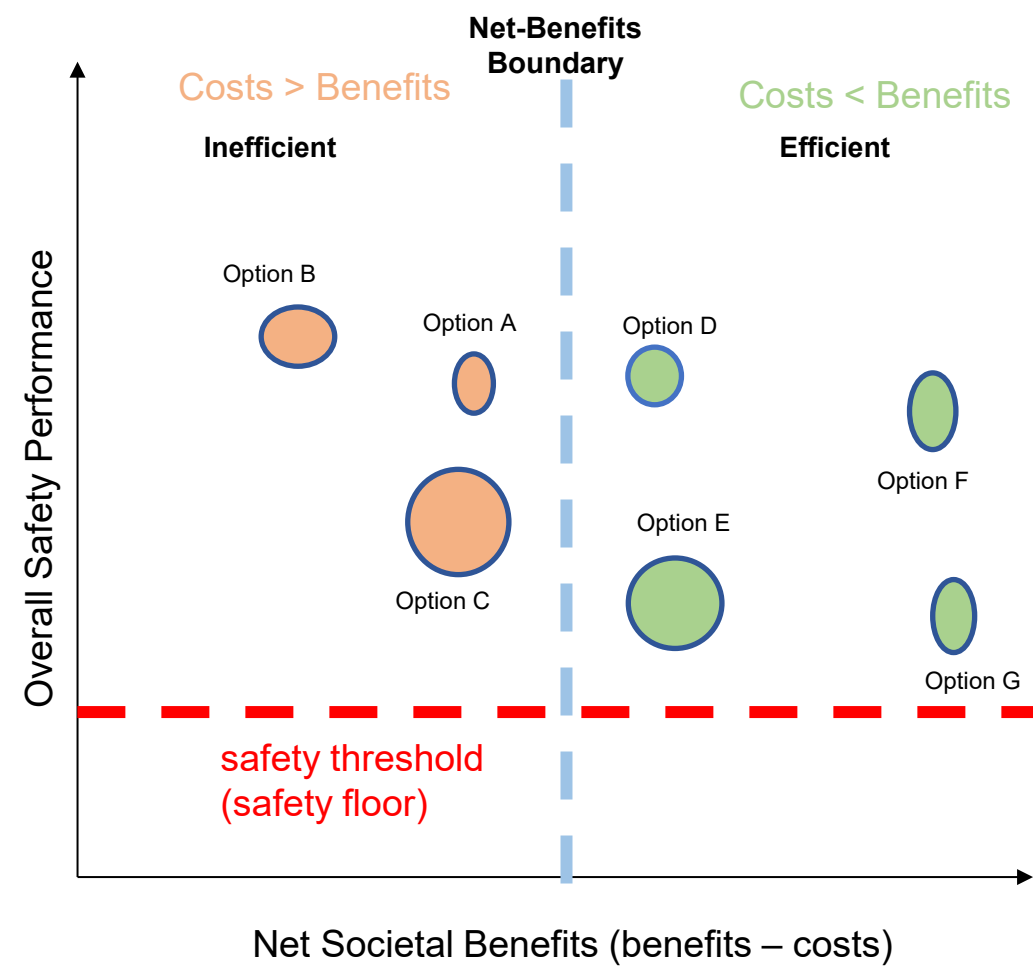
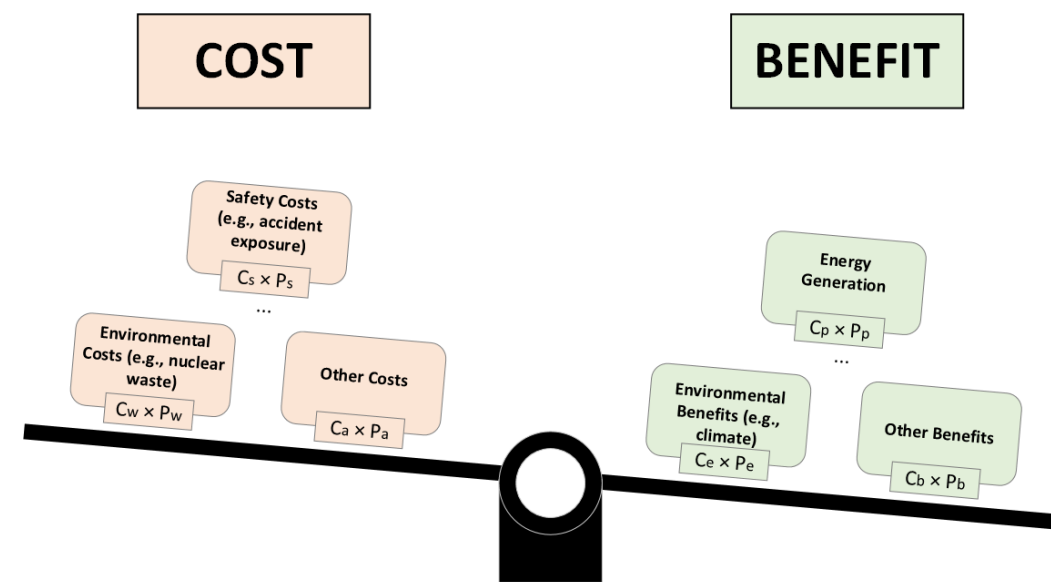
Step-II Conduct cost-benefit analysis to evaluate regulatory efficiency (*safety as an input*)

- ❖ The NRC should allocate dedicated resources, leveraging existing regulatory analysis and best practices from other agencies, such as the EPA, to develop a robust cost-benefit analysis framework to support efficient licensing.
- ❖ Cost-benefit analysis is performed **only for the alternative(s) that satisfy safety evaluation in Step I.**
- ❖ PRA probabilities and consequences are used to estimate expected accident consequences, including expected safety costs expressed in monetary terms.



Note: C_i and P_i correspond to the consequence and probability, respectively, of cost/benefit item i

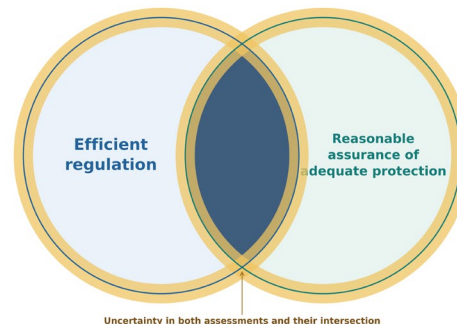
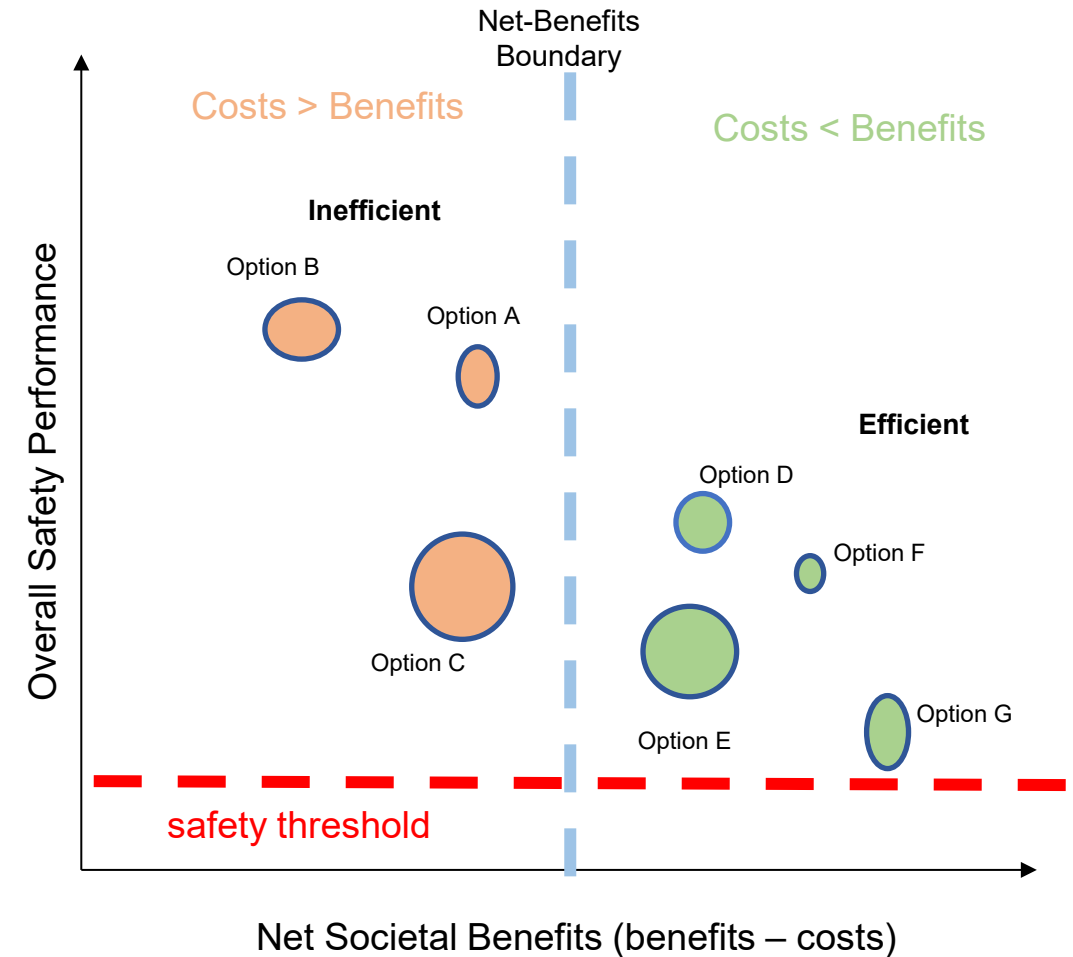
Step-II Cost-benefit Analysis to Evaluate Efficiency (cont.)



Note: C_i and P_i correspond to the consequence and probability, respectively, of cost/benefit item i

Step-III Regulatory Licensing Decision

- ❖ The final licensing decision **must lie within the intersection** of reasonable assurance of adequate protection and regulatory efficiency mandates.
- ❖ **Open question:** What selection rule would courts accept?
 - Any alternative within the intersection?
 - The safest benefit-justified alternative (ALARA-informed decision making)?
 - The alternative with the greatest net societal benefit among those satisfying safety requirements?



Recommendation 1: Strengthen cost-benefit analysis for efficient licensing and regulation

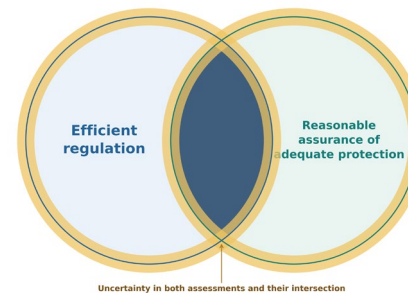
- ❖ The NRC should allocate dedicated resources to develop a robust cost-benefit analysis framework to support efficient licensing and regulation.

Recommendation 2: Strengthen probabilistic risk assessment methods and cumulative risk assessment across units and facilities.

- ❖ Given the challenges associated with worst-case-based methods and the fact that not all designs are benefit-justified under such an approach, there is a need to invest in advancing probabilistic risk assessment methods for new reactors.

Recommendation 3: Integrate reasonable assurance of adequate protection and efficiency

- ❖ Develop a technically and legally justified decision framework that integrates reasonable assurance of adequate protection and regulatory efficiency.



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 - Agency response: Comment categorized as “UL;” Agency wrote over eight pages in response, agreeing in part, including in [Final Rule: Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors \(RIN 3150-AK31; NRC-2019-0062\) NRC Response to Public Comments, Volume I](#) (pp. 14-17) and [NRC Response to Public Comments, Volume II](#) (pp. 101-102; 106-107).
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