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BELFER CENTER
for Science and International Affairs

ENERGY TECHNOLOGY
INNOVATION POLICY

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Principles and Innovative Methods for Public R&D Decision-Making

Modelling and Analyses in R&D Priority Setting and Innovation Workshop, International Energy Agency
Paris, France

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Outline

- Motivation
- Principles for effective public R&D decision making
- Our method
- Results
- Discussion and conclusion

Motivation

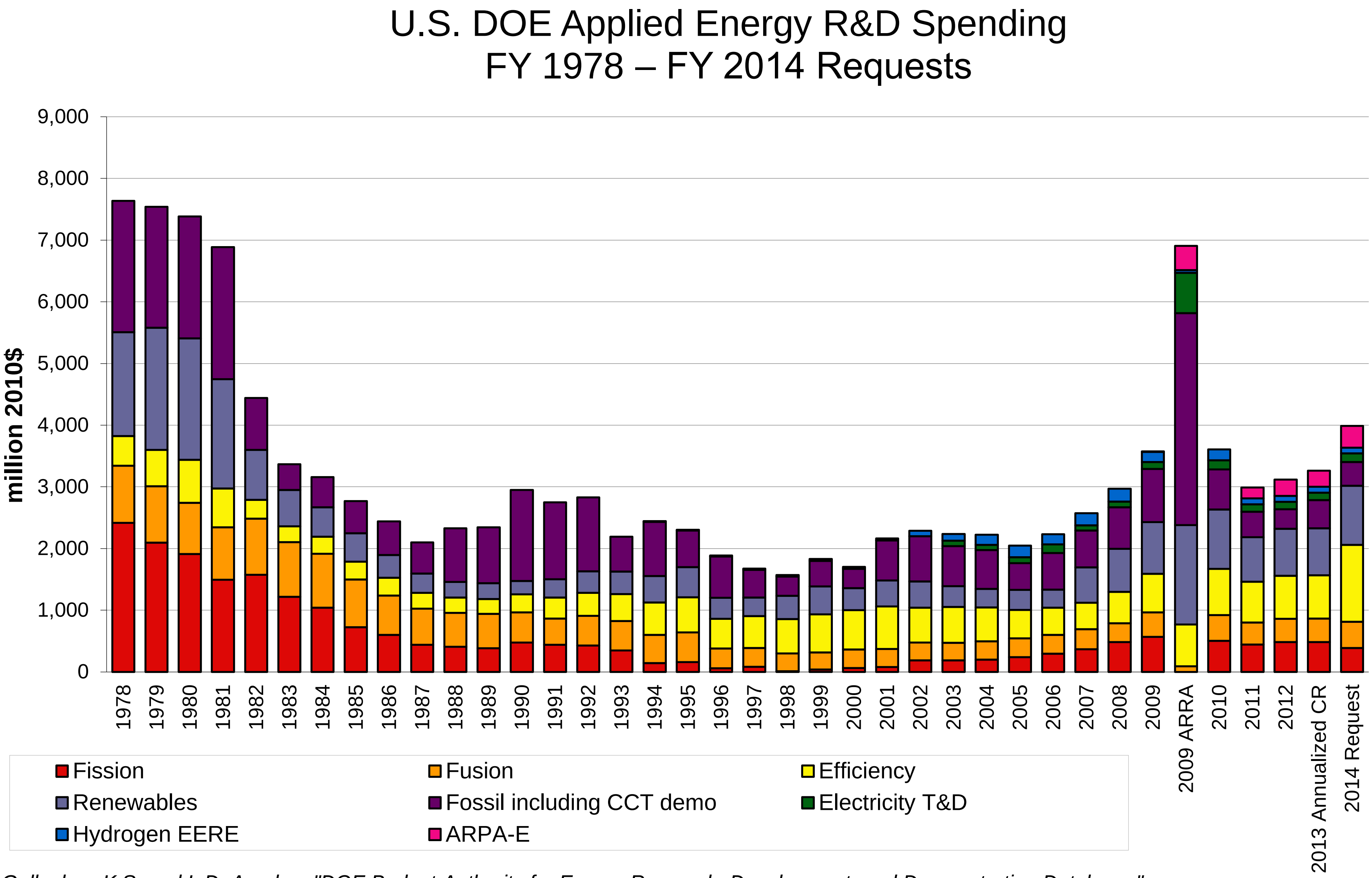
Public R&D strategies….

- affect growth and complement other policies
- are often poorly justified because methods in use are weak
- could better integrate available expertise
- are limited by organizational constraints
- can be improved

Public R&D Decision Making

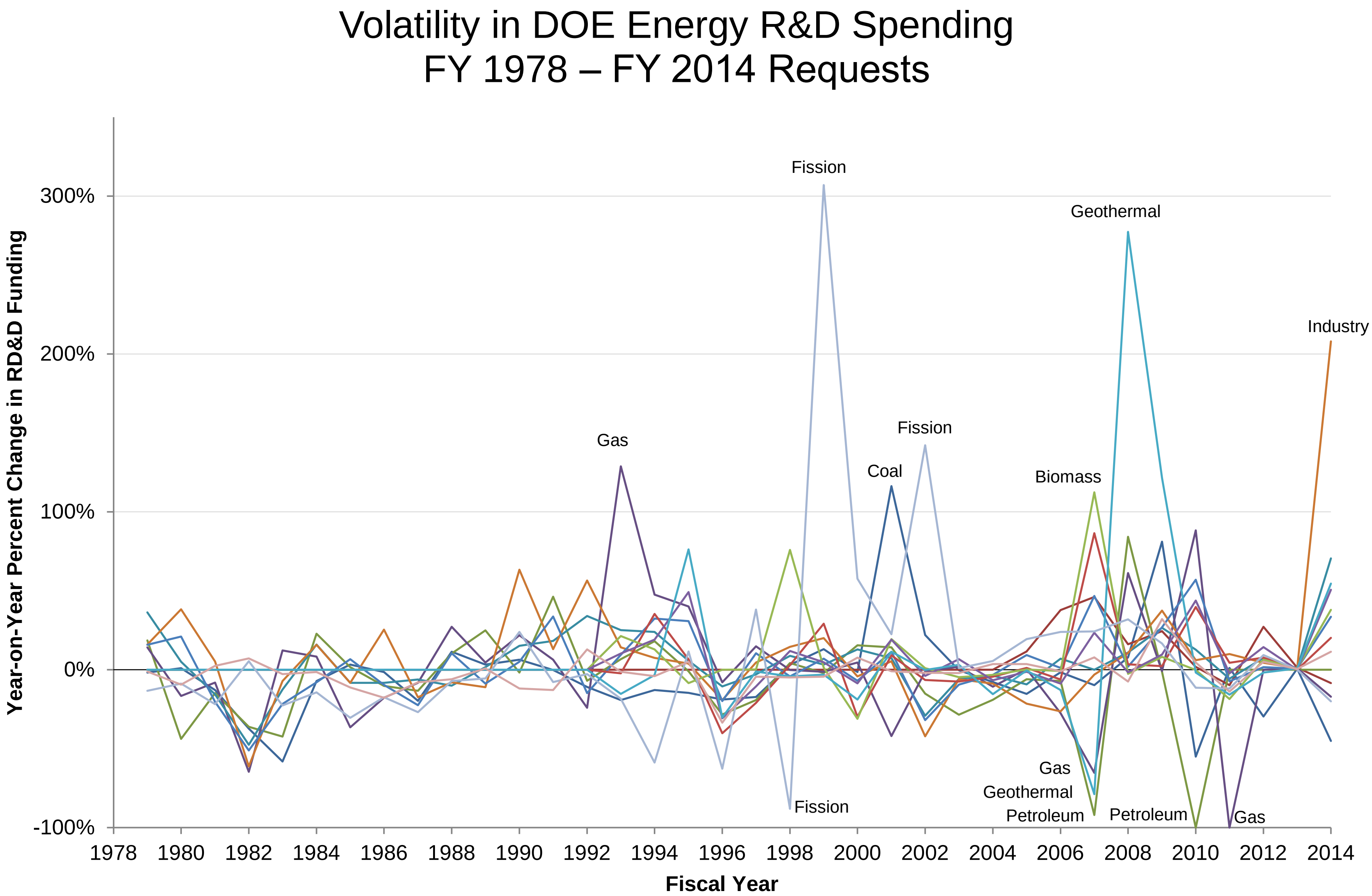
- There is a broadening portfolio of technologies, interacting in new and more complex ways
- Decision making is often shaped by individual technology-focused program offices
- Governments have called for more analytical approaches to R&D decision-making (e.g. US NRC, OMB)
- Our motivation for developing decision-making principles is driven by the technical and organizational complexity of the problem:
  - uncertainty in the returns to R&D
  - technology and market interactions
  - need for transparency and buy-in

Decision Making at DOE



Gallagher, K.S. and L.D. Anadon, "DOE Budget Authority for Energy Research, Development, and Demonstration Database," Energy Technology Innovation Policy, John F. Kennedy School of Government, Harvard University, April 16, 2013.

Decision Making at DOE



Anadon, Bunn, Narayanamurti (Eds.) *Transforming US Energy Innovation*.
Forthcoming 2014, Cambridge University Press

Public R&D Decision Making

- We propose four decision making principles:

    1. Technology improvement benefits prospectively quantified with a full account of uncertainty
    2. Social benefits evaluated in a common framework
    3. Flexible to changing assumptions
    4. Feasible transparency

- We then propose a method designed based on these principles in the context of national public R&D decision-making at the U.S. Department of Energy

Principles for Effective Public R&D Decision Making

Four Principles:

1. Technology improvement benefits prospectively quantified with a full account of uncertainty
2. Social benefits evaluated in a common framework
3. Flexible to changing assumptions
4. Feasible transparency

Principles for Effective Public R&D Decision Making

Principle 1: Technology improvement benefits prospectively quantified with a full account of uncertainty

The relationship between R&D and technology improvements should be estimated…

- conditional on R&D levels with all other factors held constant
- as dependent on technological improvements in other areas
- over sufficiently long time horizons
- with an explicit representation of uncertainty

Principles for Effective Public R&D Decision Making

Four Principles:

1. Technology improvement benefits prospectively quantified with a full account of uncertainty
2. Social benefits evaluated in a common framework
3. Flexible to changing assumptions
4. Feasible transparency

Principle 2: Social benefits evaluated in a common framework

The relationship between technology improvements and social benefits should be estimated…

- in common units to facilitate assessment of tradeoffs
- as dependent on other technology improvements, capturing market interactions
- to accommodate the assumptions under which the relationship between R&D and technology improvement was estimated

Principles for Effective Public R&D Decision Making

Four Principles:

1. Technology improvement benefits prospectively quantified with a full account of uncertainty
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Principles for Effective Public R&D Decision Making

Principle 3: Flexible to changing assumptions

To build institutional buy-in, a decision support tool for public R&D should …

- readily accommodate different sets of technical assumptions
- readily accommodate new policy scenarios
- be capable of sensitivity analysis

Principles for Effective Public R&D Decision Making

Four Principles:

1. Technology improvement benefits prospectively quantified with a full account of uncertainty
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Principle 4: Feasible transparency

The degree of transparency in an R&D decision-making process can affect the credibility and quality of analysis (positive or negative).

Transparency can build internal and external buy-in and establish legitimacy within aspects of the process

Procedurally, decisions should be feasibly transparent in its **assumptions** and **methods**.

Method

Based on these principles, we develop a method with three components:

1. Expert elicitation of technology cost conditional on public R&D levels and allocations

2. Benefit estimation in an economic model (MARKAL) with Monte Carlo simulation

3. Optimization of R&D portfolios based on greatest expected benefits

Method 1: Expert Elicitation

We quantify technology improvement benefits (conditional on public R&D investments) using expert elicitation, a formal method for quantifying uncertainty.

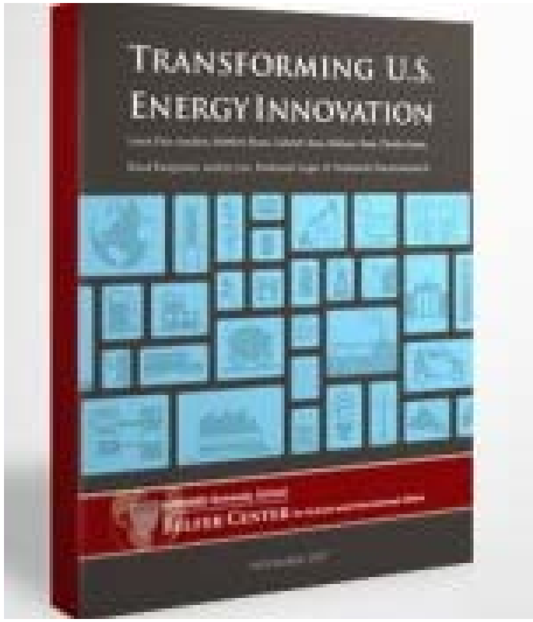
This approach has advantages relative to other approaches because expert elicitation …

- can incorporate all available data (published, unpublished, public, proprietary, personal experience)
- allows for technologies to improve in ways that depart from historical trends
- readily adapts to new R&D scenarios
- is naturally supplemented with qualitative information

Method 1: Expert Elicitation

We conduct our expert elicitation in 7 technology areas, covering 37 specific technologies. Over 100 experts participated over three years

Full qualitative results and intermediate quantitative results are published in *Transforming U.S. Energy Innovation* (Belfer Center Report, 2011; forthcoming as a book in Cambridge University Press, 2014)

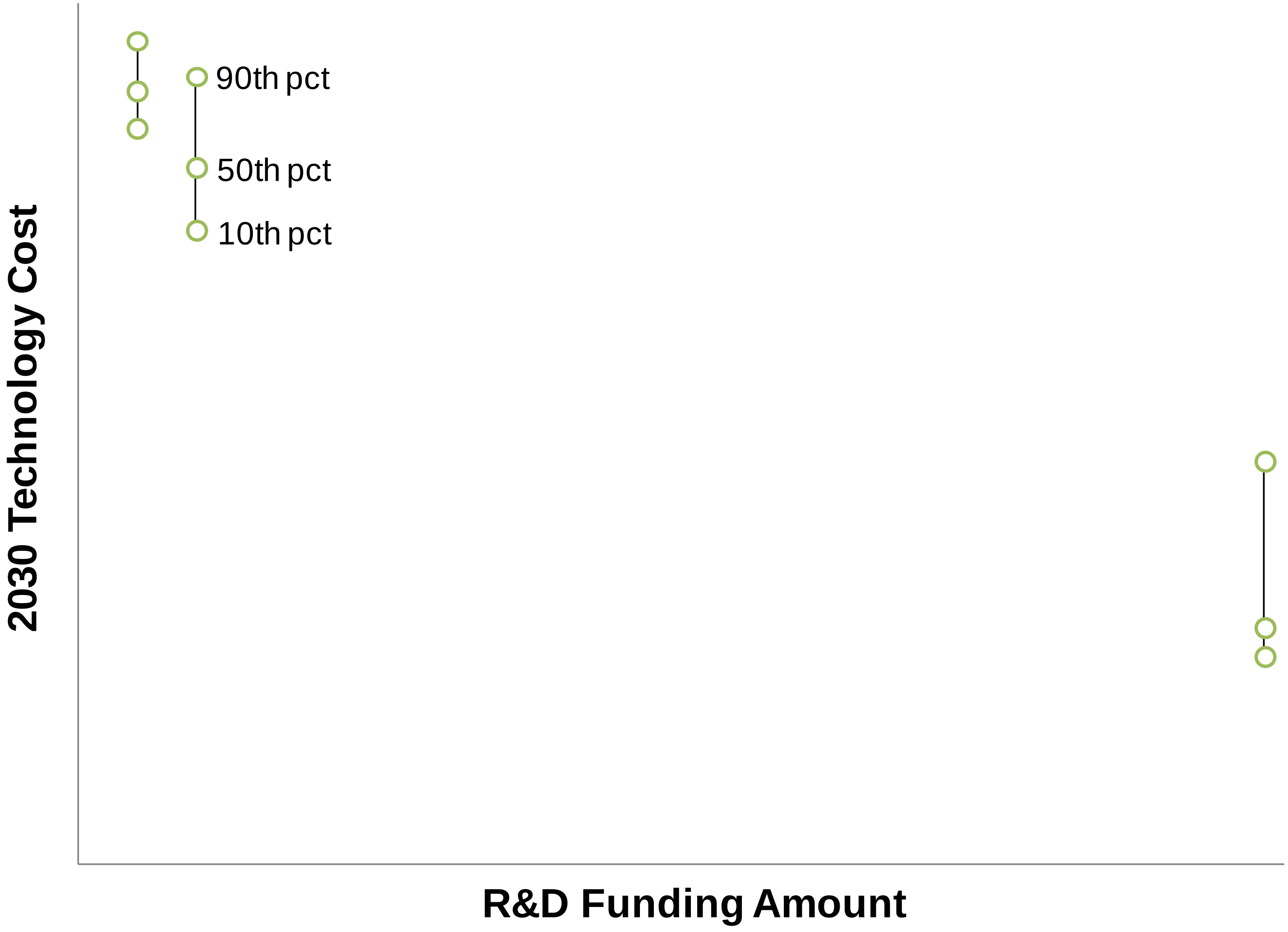


Authors: Laura Diaz Anadon (Project Director), Matthew Bun (Co-PI), Gabriel Chan, Melissa Chan, Charles Jones, Ruud Kempener, Audrey Lee, Nathaniel Logar, Venkatesh Narayanamurti (Co-PI)

Available at: http://belfercenter.ksg.harvard.edu/publication/21528

Method 1: Expert Elicitation

Experts considered a range of U.S. public R&D scenarios, and projected probability distributions of future (2030) cost and performance metrics:



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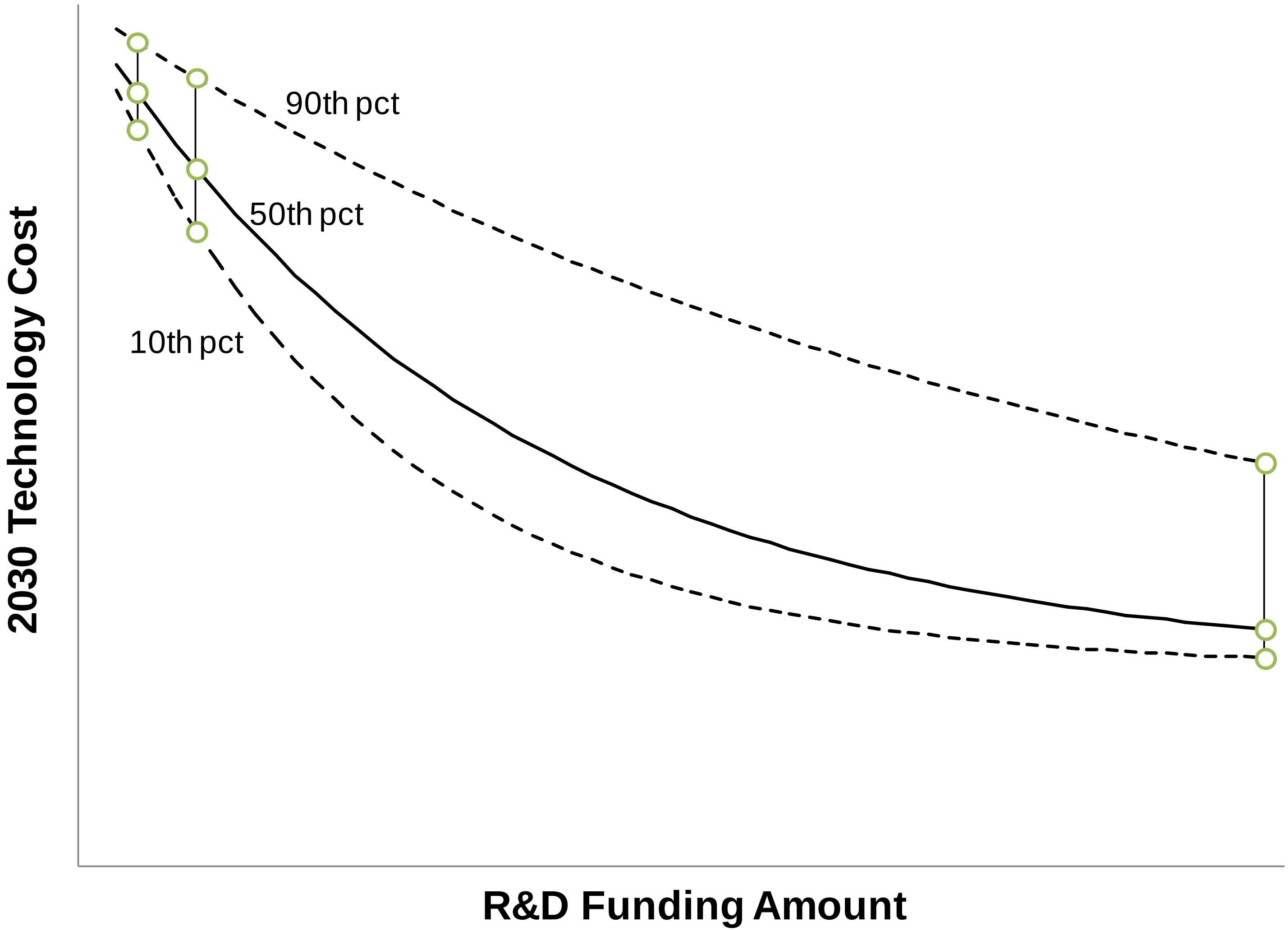

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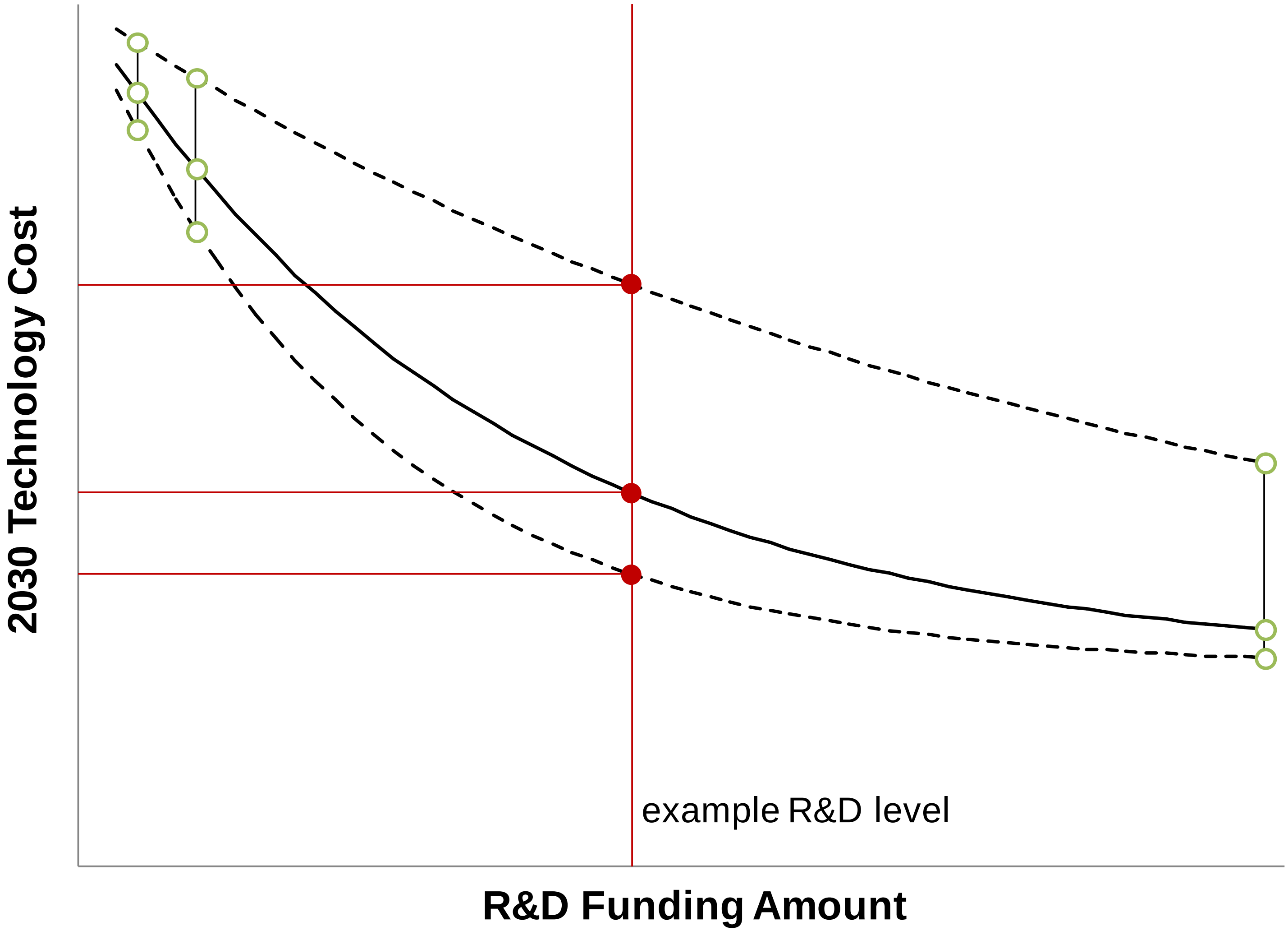

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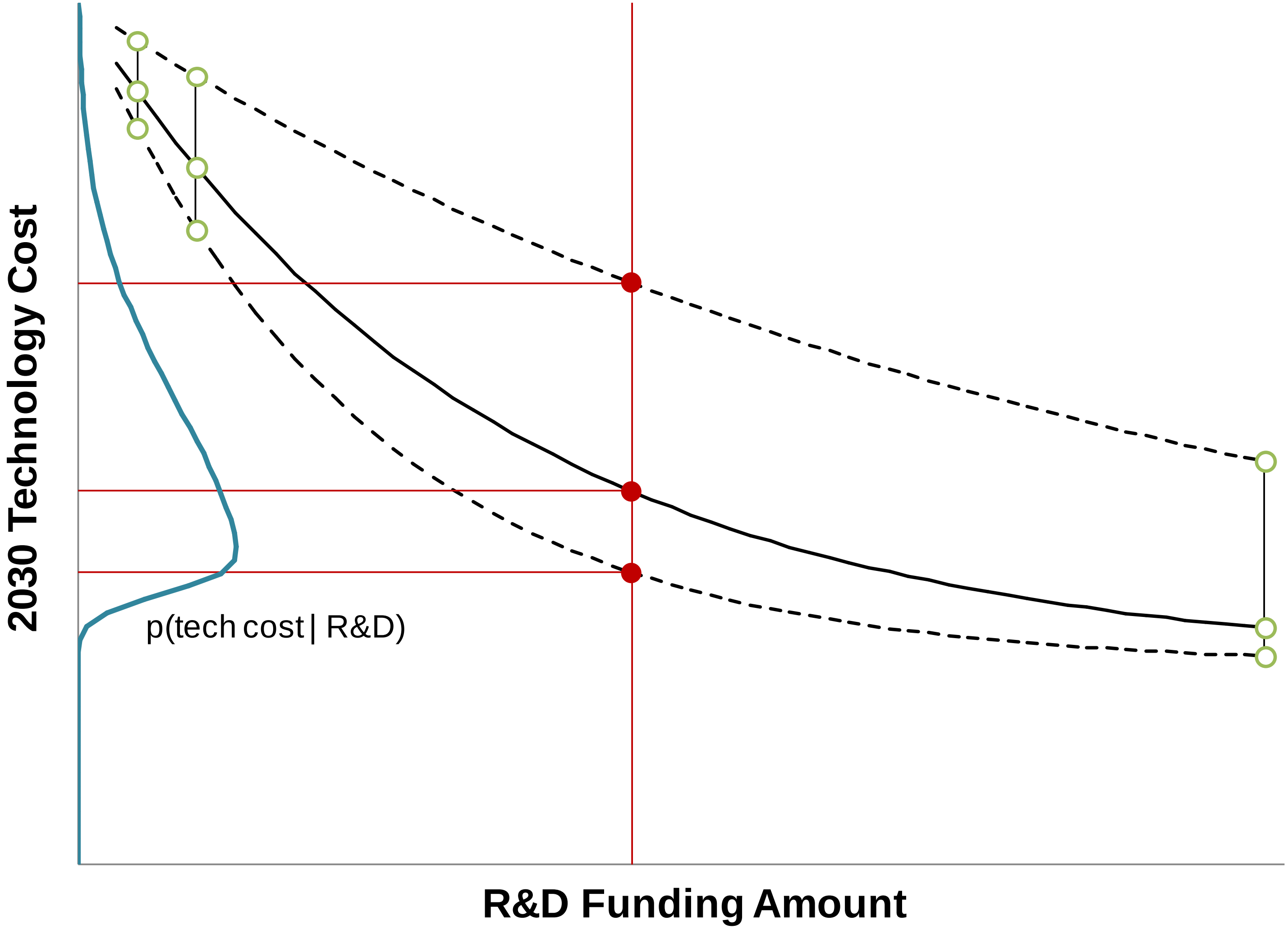


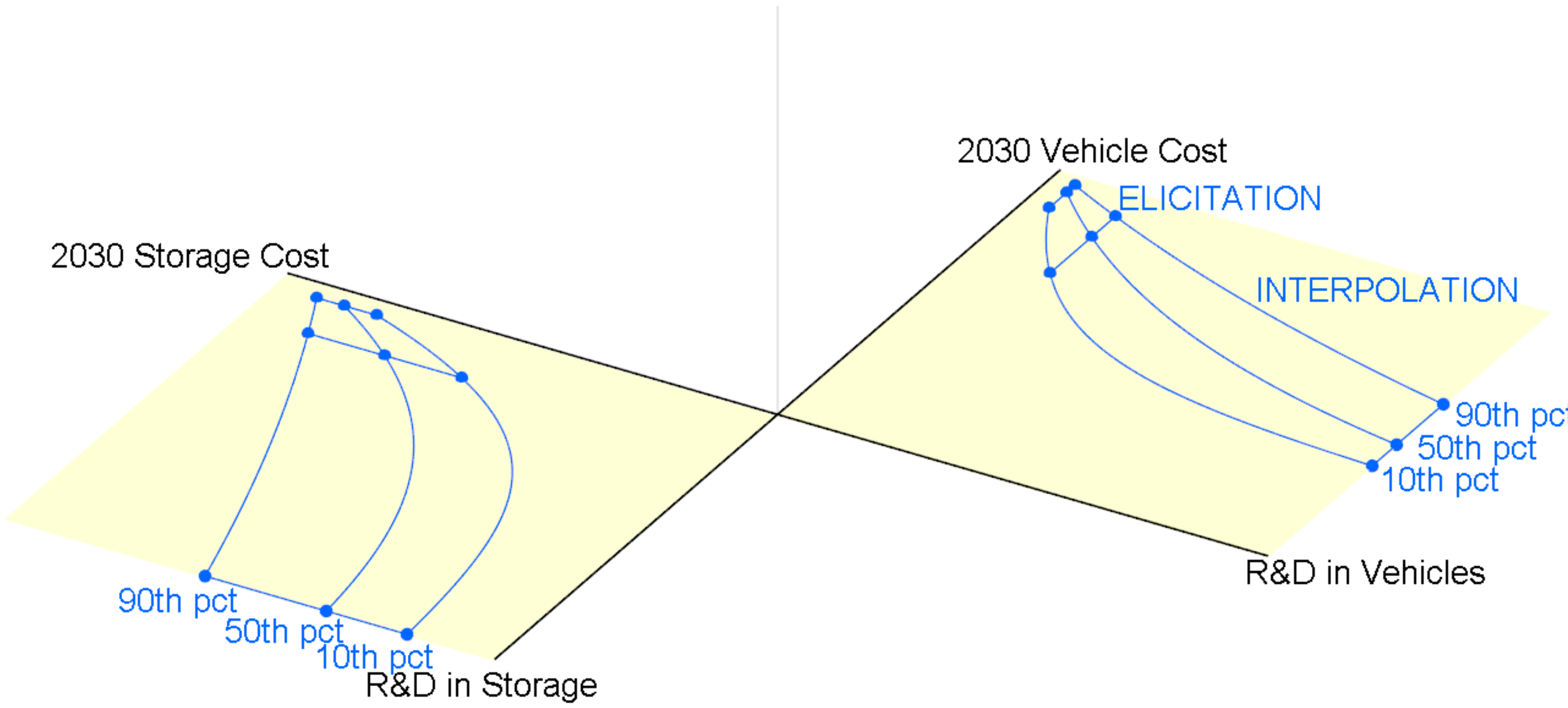
Method

We conduct expert elicitations in 7 technology areas, but 6 are comparable for this analysis:
(1) utility-scale energy storage, (2) bioenergy,
(3) advanced vehicles, (4) fossil energy, (5) nuclear energy, (6) solar photovoltaic technologies

For the reminder of the method discussion, we ***describe*** our method showing an example in 2 technology areas

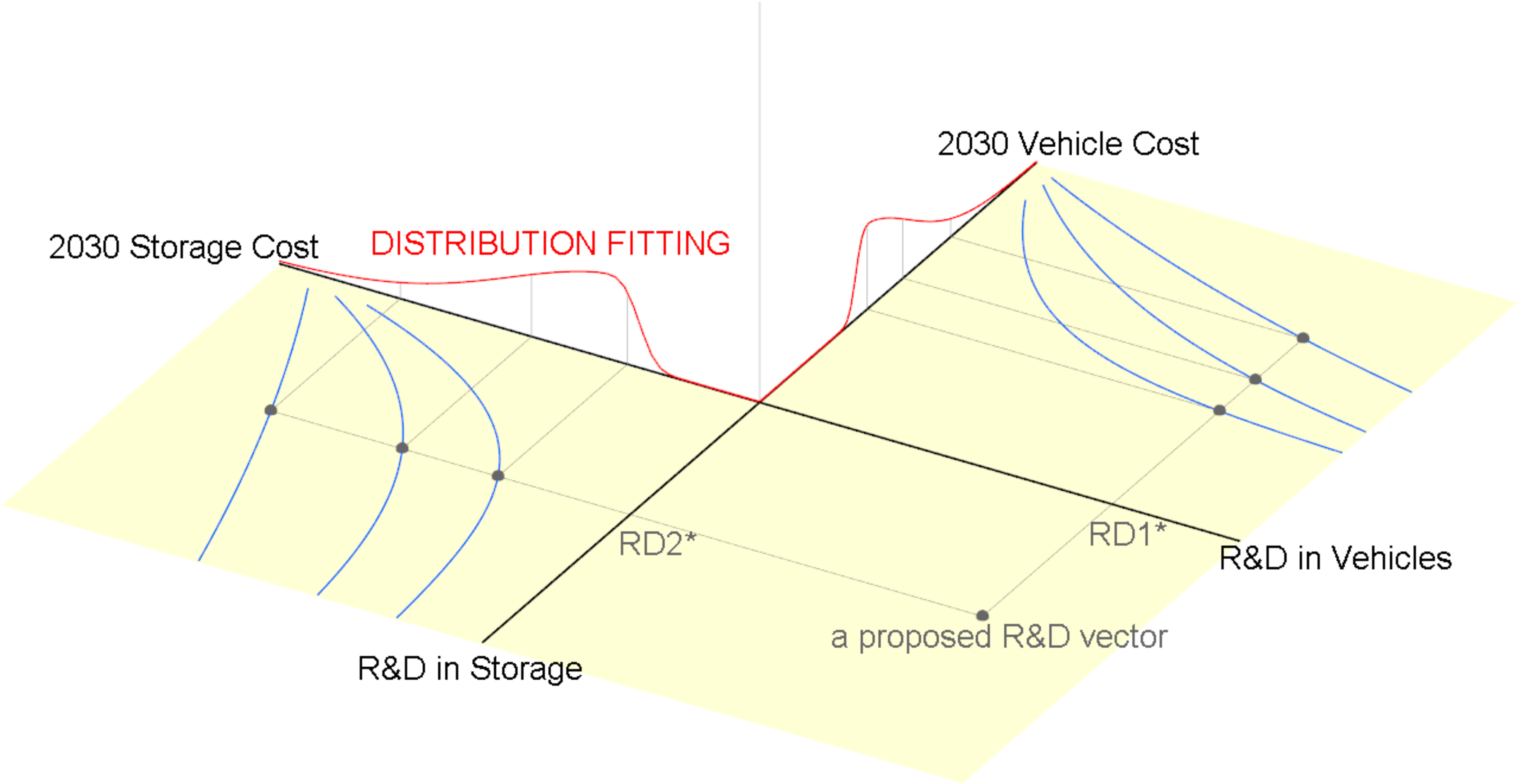
Method

1a. We use expert elicitation to parameterize impacts of R&D on technological improvements

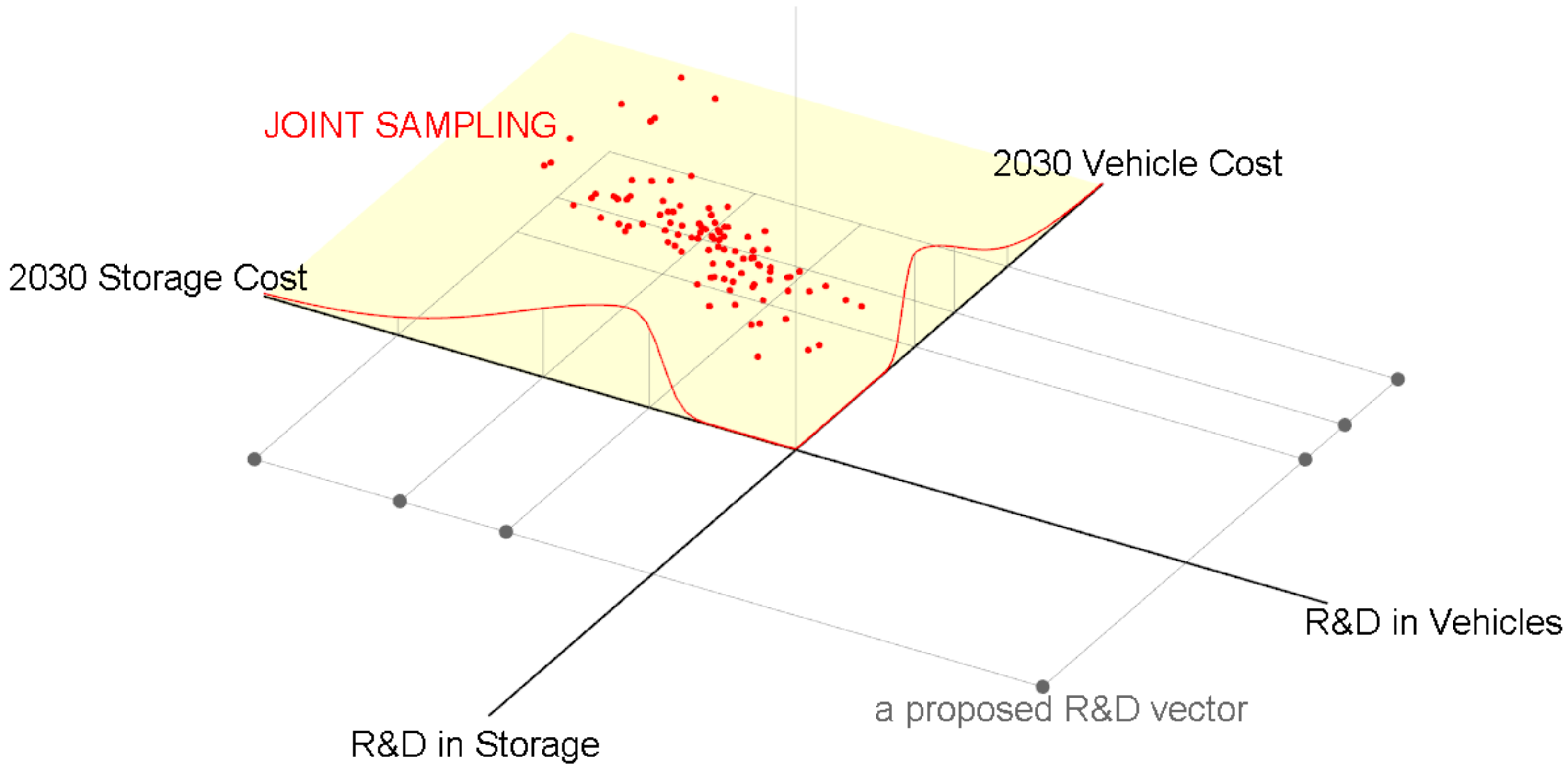


Method

1b. We fit probability distribution to interpolated expert elicitation outputs

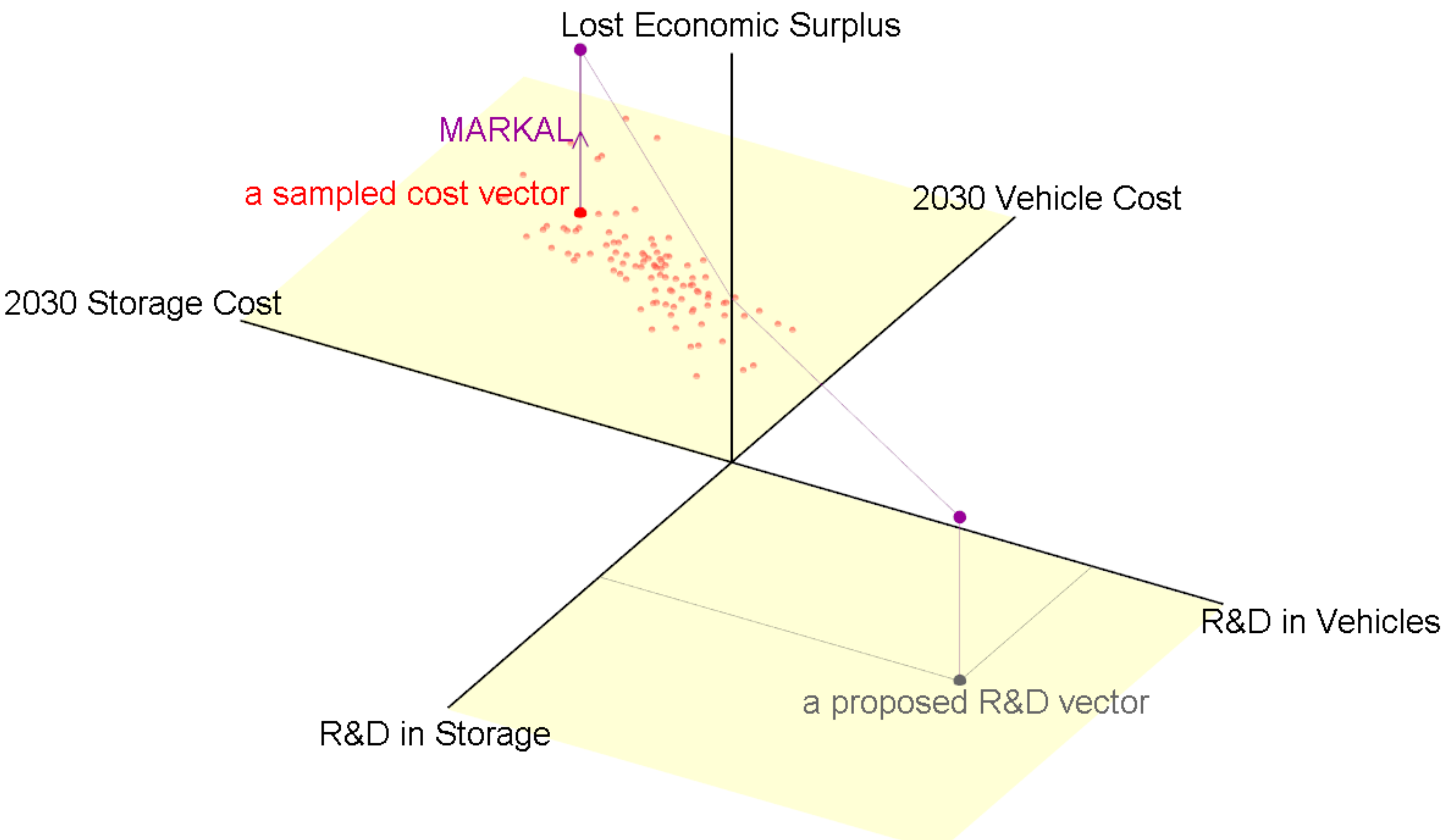


1c. We jointly sample technology improvement benefits conditional on R&D levels

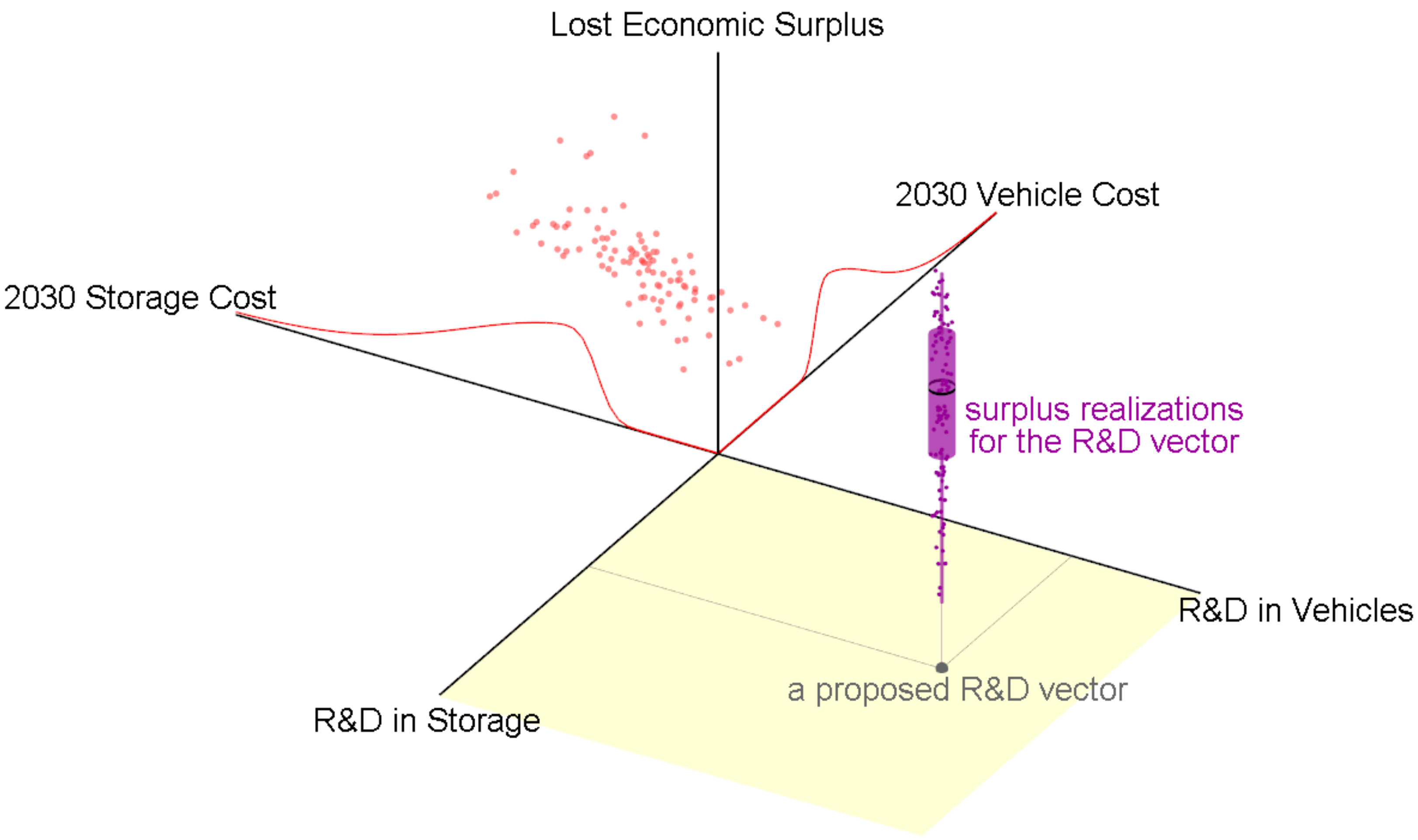


Method

2a. We integrate individual sampled technology costs in MARKAL, an economic assessment model

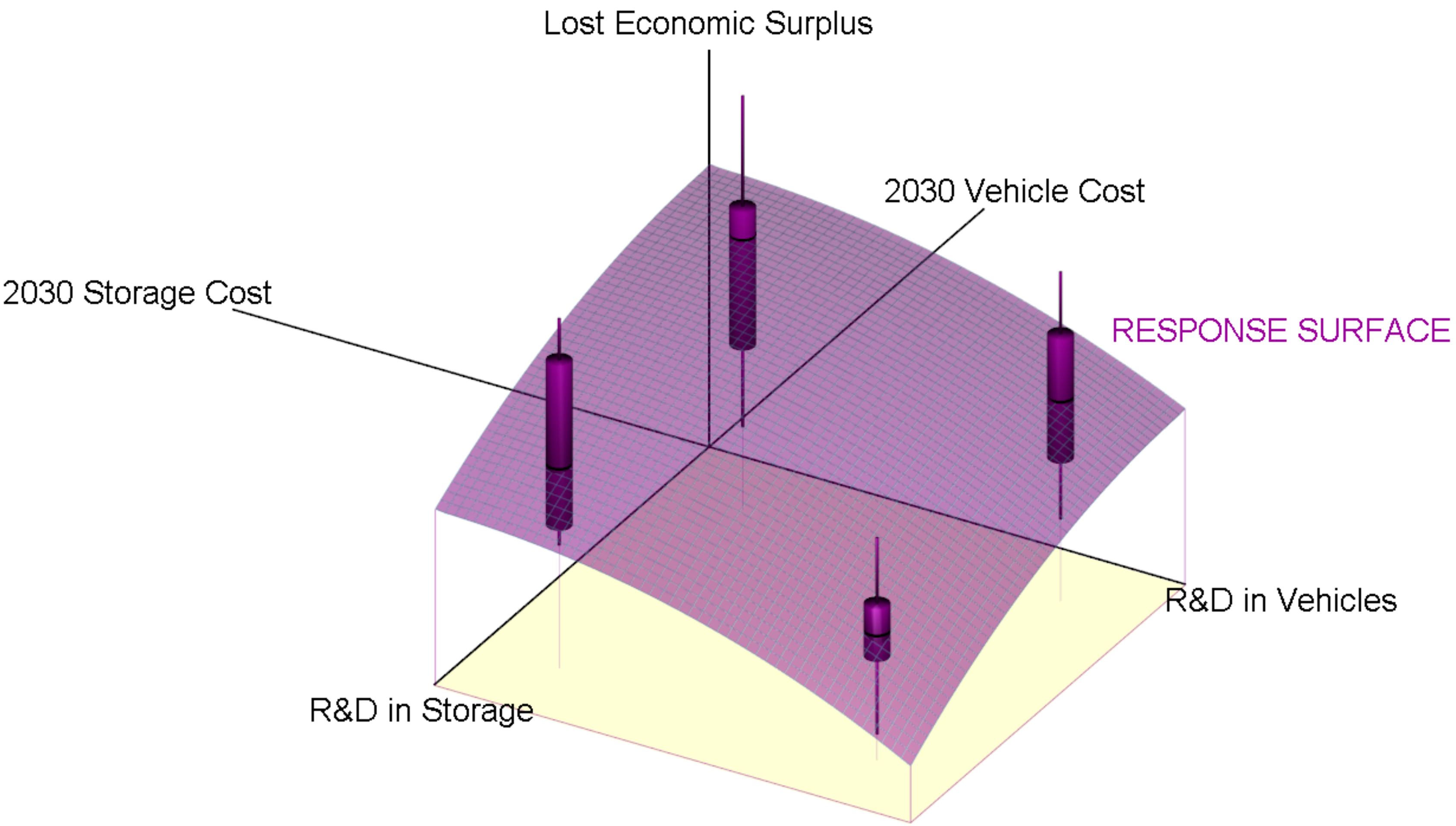


2b. With repeated samples, this becomes a Monte Carlo distribution of social benefits conditional on R&D levels



Method

3. By considering many R&D levels, we can fit a polynomial surface that can be used in optimization



Evaluating our Method

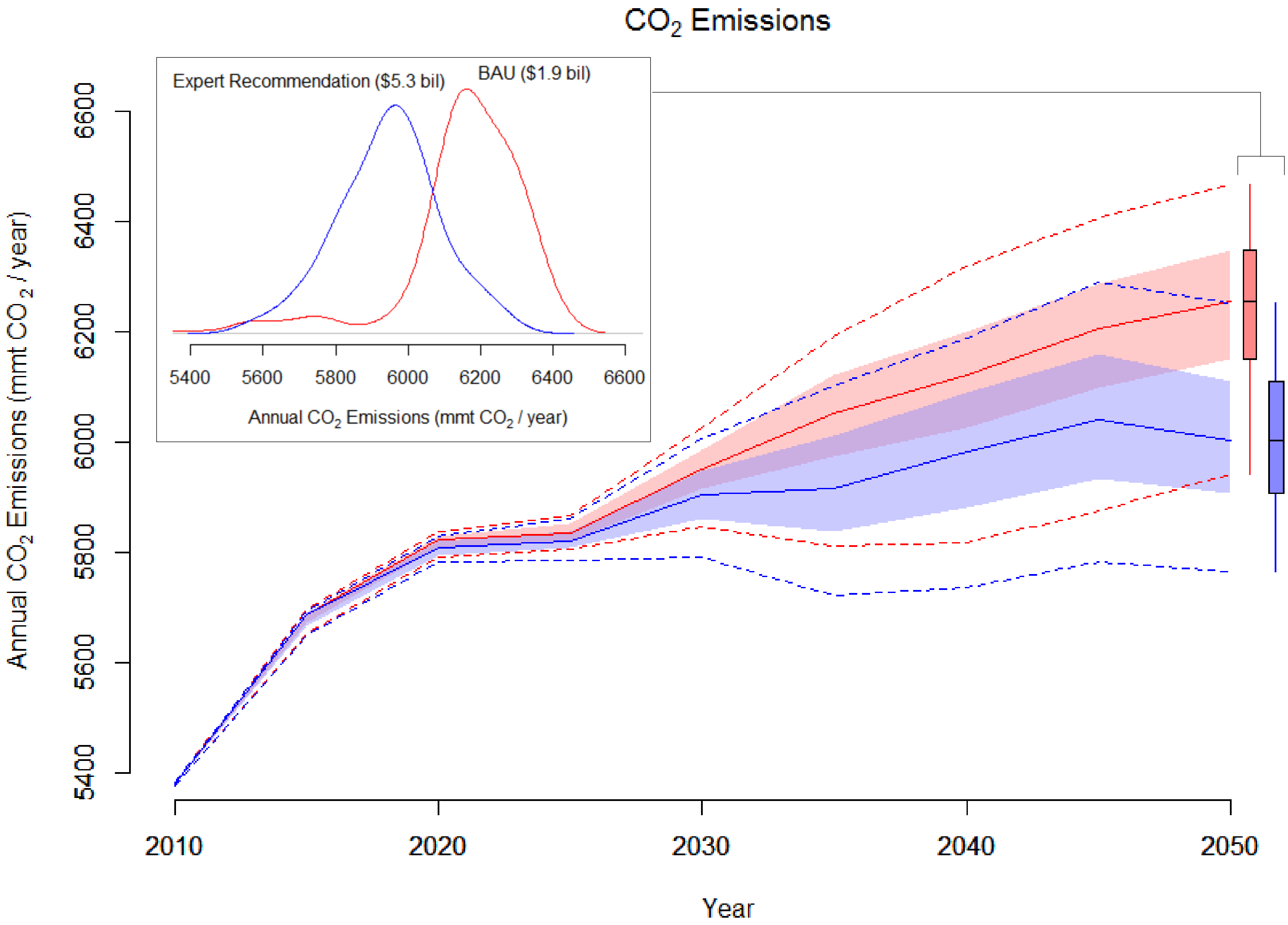
1. Joint uncertainty quantified conditional on R&D in a common framework over a 20-40 year time horizon

2. Aggregate social benefits estimated in a single economic model yielding consistent evaluation metrics across R&D areas

3. Flexibility to changing assumptions through importance sampling. Flexibility to policy changes through scenario analysis.

4. Transparency feasible: external experts names and affiliations published, all results anonymized and published on the internet

Results: Comparing Individual R&D Portfolios



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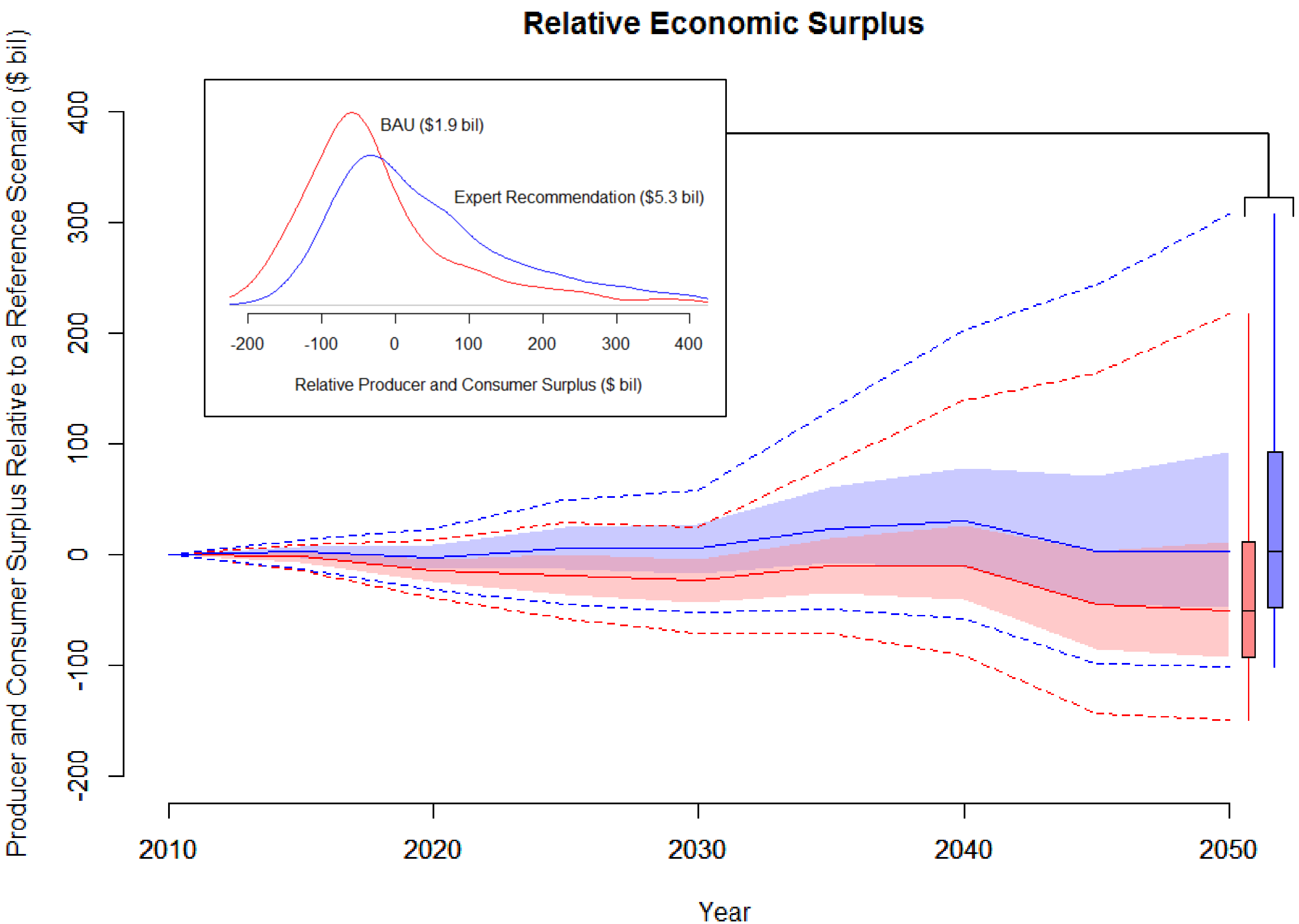
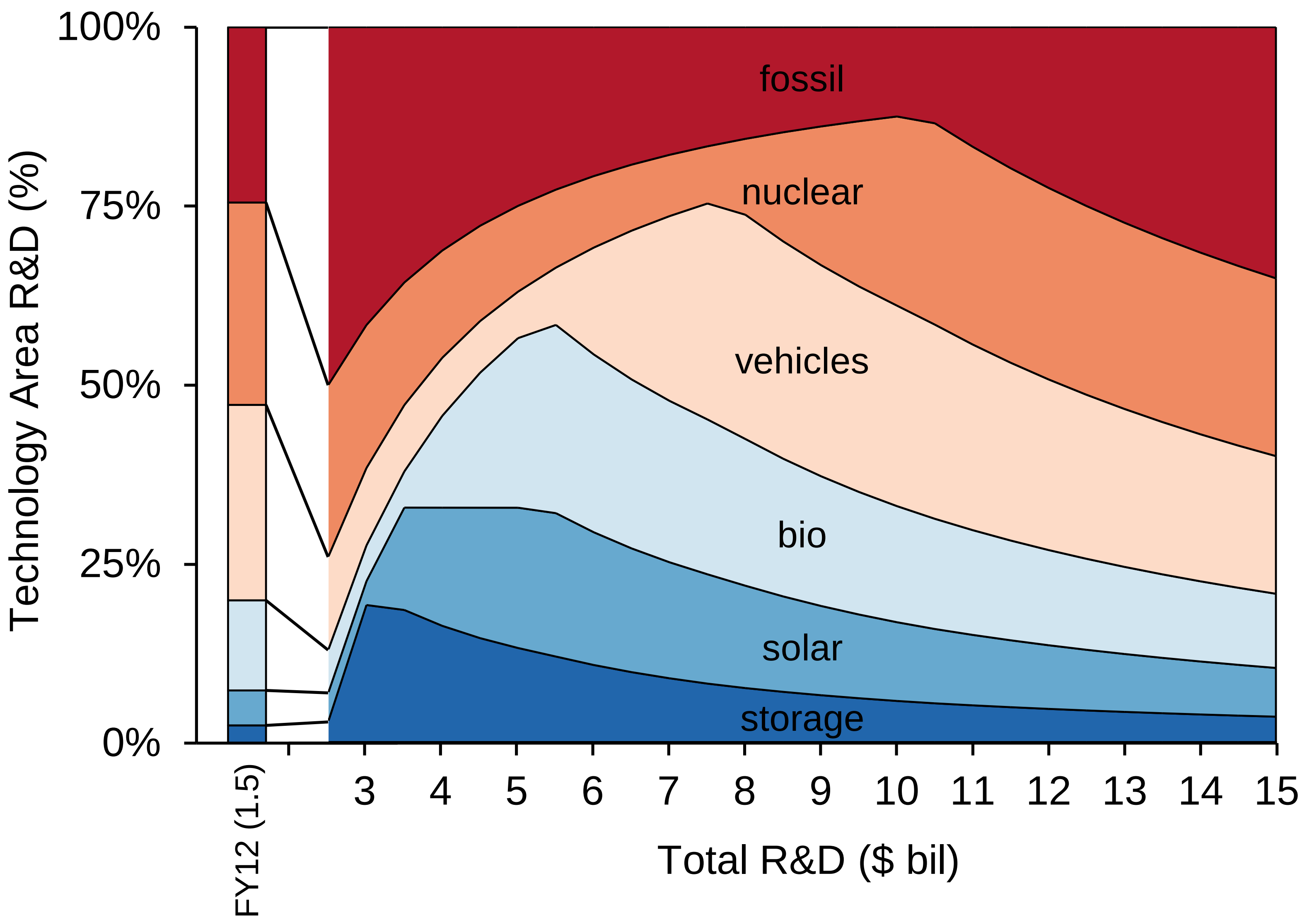


Results: Optimizing R&D Portfolios



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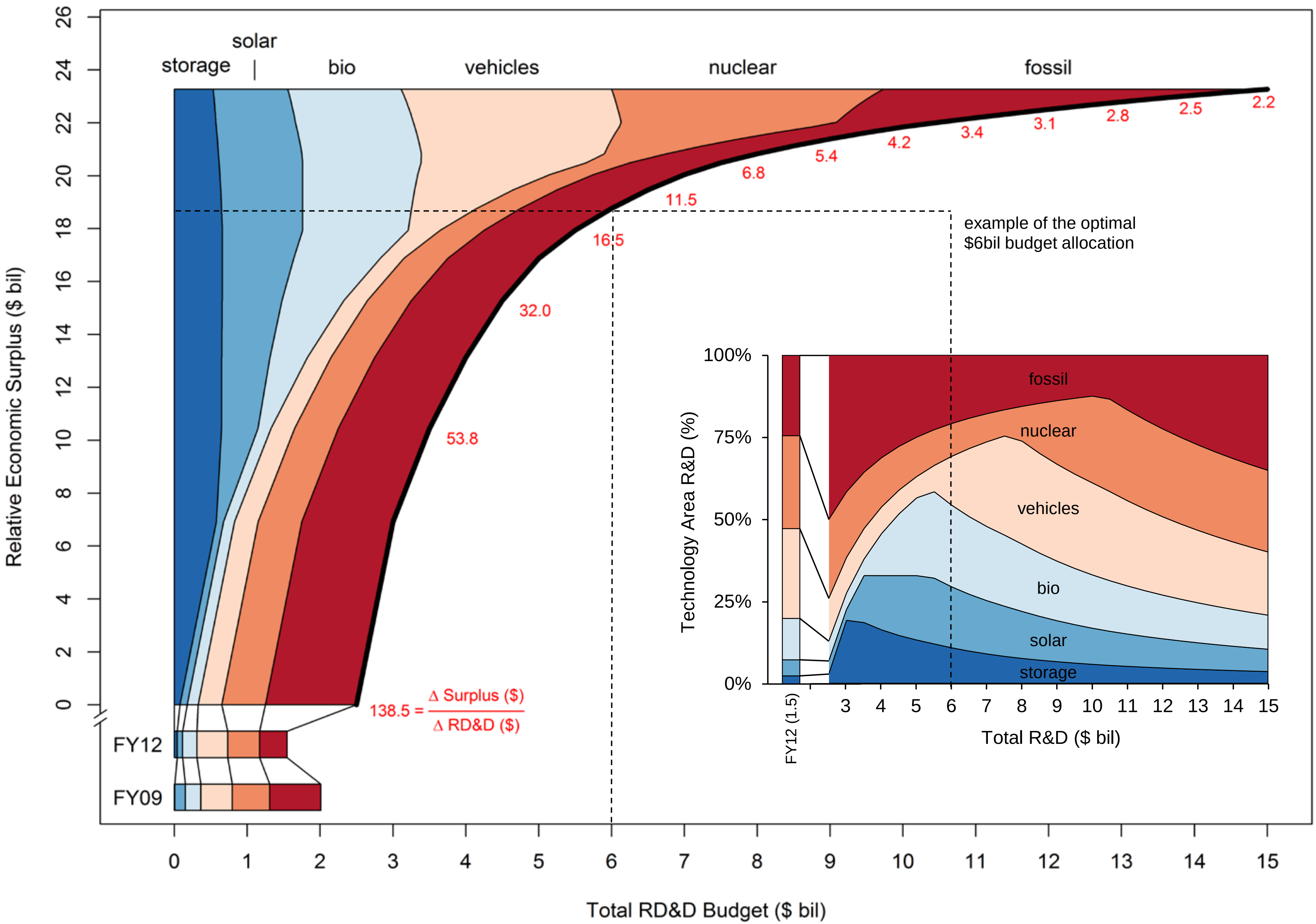

Results: Optimizing R&D Portfolios

1. The rate of decreasing marginal returns implies that there are R&D budget allocations above $15 billion for which net economic surplus exceeds R&D cost

2. Prioritization of investments based on marginal returns: (1) energy storage, (2) solar PV, (3) bioenergy, (4) vehicles, (5) nuclear, (6) fossil

3. The current R&D allocation differs substantially from the allocation that optimizes net economic surplus

Discussion

- The institutional separation of analysis from decisions and the role of deliberative decision making
- Interest from energy R&D decision makers
- Applicability to other sectors
- Areas for improvement
  - Public-private R&D interactions
  - International spillovers
  - Repeated decision with learning
  - Other notions of optimality (risk-aversion)
  - Integrating multiple criteria

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Thanks

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