Using System Dynamics Models to Make Better Decisions

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What is Sustainability?

"Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs."

World Commission on Environment and Development, 1987

How to become sustainable?

"Sustainable development is not a fixed state of harmony, but rather a **process of change** in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs. We do not pretend that the process is easy or straightforward. **Painful choices have to be made.**"

World Commission on Environment and Development, 1987

What is involved in these "painful choices?"

- Multiple parties making decisions together.

- Sustainability decisions frequently involve some issues that are determined by **physical world constraints** and some that are influenced by the **stakeholders' interests** alone.

- Sustainability decisions also often contain some **trade-off** and some **win-win** issues.

Models can integrate different kinds of issues.

- Many researchers[1] suggest that models help decision makers make sense of different kinds of issues (physical world & stakeholder interests; trade-off & win-win).

- Though, some researchers[2] find evidence that decision makers are not using models as often as the model-builders anticipated.

1 . Dowlatabadi, 1995; van Delden et al., 2011; van den Belt, 2004; van den Belt et al., 2013
2 . Edwards et al., 2010; McIntosh et al., 2011

What can be done to get more decision makers to use models?

- **Collaborative modeling**: To encourage model usage, these and other researchers[3] suggest including the decision makers in the model-building process.

3 . Bourget et al, 2013; Langsdale et. al., 2013; Cutcher-Gershenfeld et al., 2004; Rotmans, 2006; McIntosh et al., 2011; Czaika and Selin, 2016
4. Langsdale et al., 2013; Rotmans, 2006
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  - By participating in the modeling process, decision makers learn about the enviro-socio-technical system in which the decision is contextualized[4].

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  - There are many case studies which provide in-depth research in the application of collaborative modeling processes in real world decisions[5].

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- **Build models** in a way that increases their "usefulness and usability."[6]

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Challenge an Assumption

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  - What is the impact of using a model in a sustainability decision?

  - How does model use compare to other often-used decision tools?

How do we address these open questions?

- **Serious game experiments** allow the social interactions to be more natural[7] while still allowing important variables to be controlled.

- They come in many forms such as management flight simulators[8], war games for military training[9], and **role play simulations**[10].
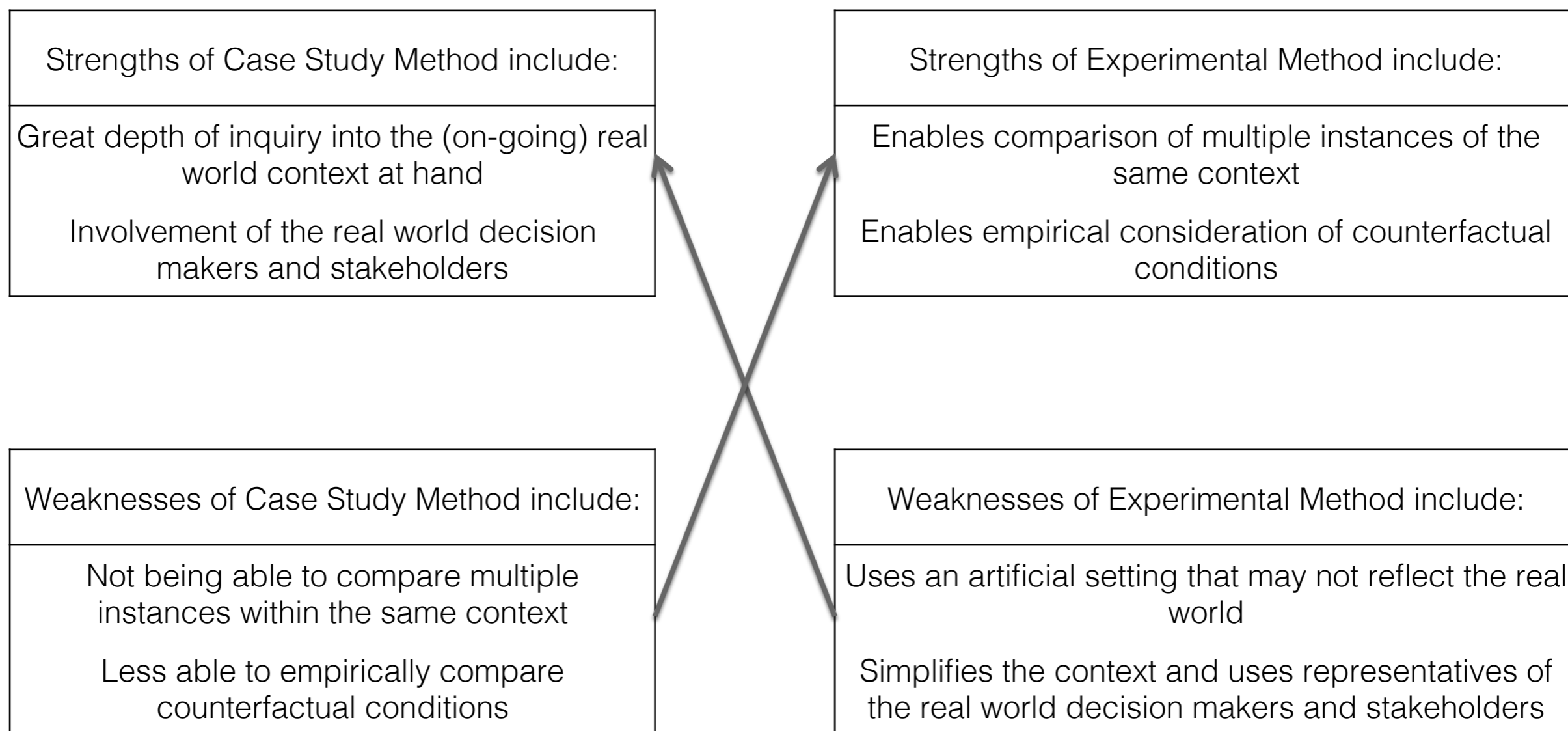
7. Corrigan et al., 2015.

8. Bakken et al., 1992; Sterman, 2014.

9. Wilson, 1968

10. Butler, 1991; Curhan et al., 2004)

Complementing methods of other research

Strengths of Case Study Method include:
Great depth of inquiry into the (on-going) real world context at hand Involvement of the real world decision makers and stakeholders

Strengths of Experimental Method include:
Enables comparison of multiple instances of the same context Enables empirical consideration of counterfactual conditions

Weaknesses of Case Study Method include:
Not being able to compare multiple instances within the same context Less able to empirically compare counterfactual conditions

Weaknesses of Experimental Method include:
Uses an artificial setting that may not reflect the real world Simplifies the context and uses representatives of the real world decision makers and stakeholders

What is the impact of using a model in a sustainability decision?

What is the impact of using a model in a sustainability decision?

Overarching Research Questions:

- Does model use impact **the outcomes of sustainability decisions** that involve multiple interests and a mixture of trade-offs and win-win issues, and **if so, how**?

Does model use impact decision outcomes?

Research Questions of the 3E Game:

1. Does model use—compared to other decision tools*—increase participants' ability to create a policy that does what they want it to do?

2. Does model use—compared to other decision tools*—increase participants' ability to reach the set of optimal policy outcomes?

*Defined on subsequent slide

Hypothesize based on best available research

Compared to use of other decision tools:

- H1: model use will increase the likelihood that decision makers create a policy that reaches their stated, initial priorities.

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Compared to use of other decision tools:

- H1: model use will increase the likelihood that decision makers create a policy that reaches their stated, initial priorities.

- H2: model use will increase the likelihood that decision makers create a policy whose outcome is on the Pareto Front of achieved outcomes.

Comparing Decision Tools—the Decision Maker's Assessment

- **Credibility**: how accurate and valid the decision maker assess the decision tool to be.

- **Salience**: how relevant to the decision at hand the decision maker assess the decision tool to be.

- **Legitimacy**: the decision maker's assessment of how well the decision tool includes multiple perspectives and treats them in an unbiased manner[10].

10. Cash et al., 2003; Eckley, 2001

Credibility, Salience, Legitimacy impact tools' influence[11]

Least

- **Credibility**: how accurate and valid the decision maker assess the decision tool to be.

- **Salience**: how relevant to the decision at hand the decision maker assess the decision tool to be.

Most[12]

- **Legitimacy**: the decision maker's assessment of how well the decision tool includes multiple perspectives and treats them in an unbiased manner[10].

11 . Cash et al., 2003; Eckley, 2001; Posner et al., 2016

12 . Posner et al., 2016

Comparing Types of Decision Tools

Decision tools

1. Model use

2. Briefing about the logic of the model

3. Briefing about energy sustainability

4. Briefing unrelated to the policy setting

Comparing Types of Decision Tools

Decision tools

1. Model Use—**Model**

2. Briefing about the logic of the model—**Model Logic**

3. Briefing about energy sustainability—**General Energy**

4. Briefing unrelated to the policy setting—**Control**

Participants ratings matched experimental design goal

	Post Ratings		
Experimental condition	Credibility	Salience	Legitimacy
Model	3.9	4.3	3.6
Model Logic	3.8	3.8	3.2
General Energy	3.9	3.5	3.2
Control	3.8	2.9	2.9

Czaika and Selin, 2017

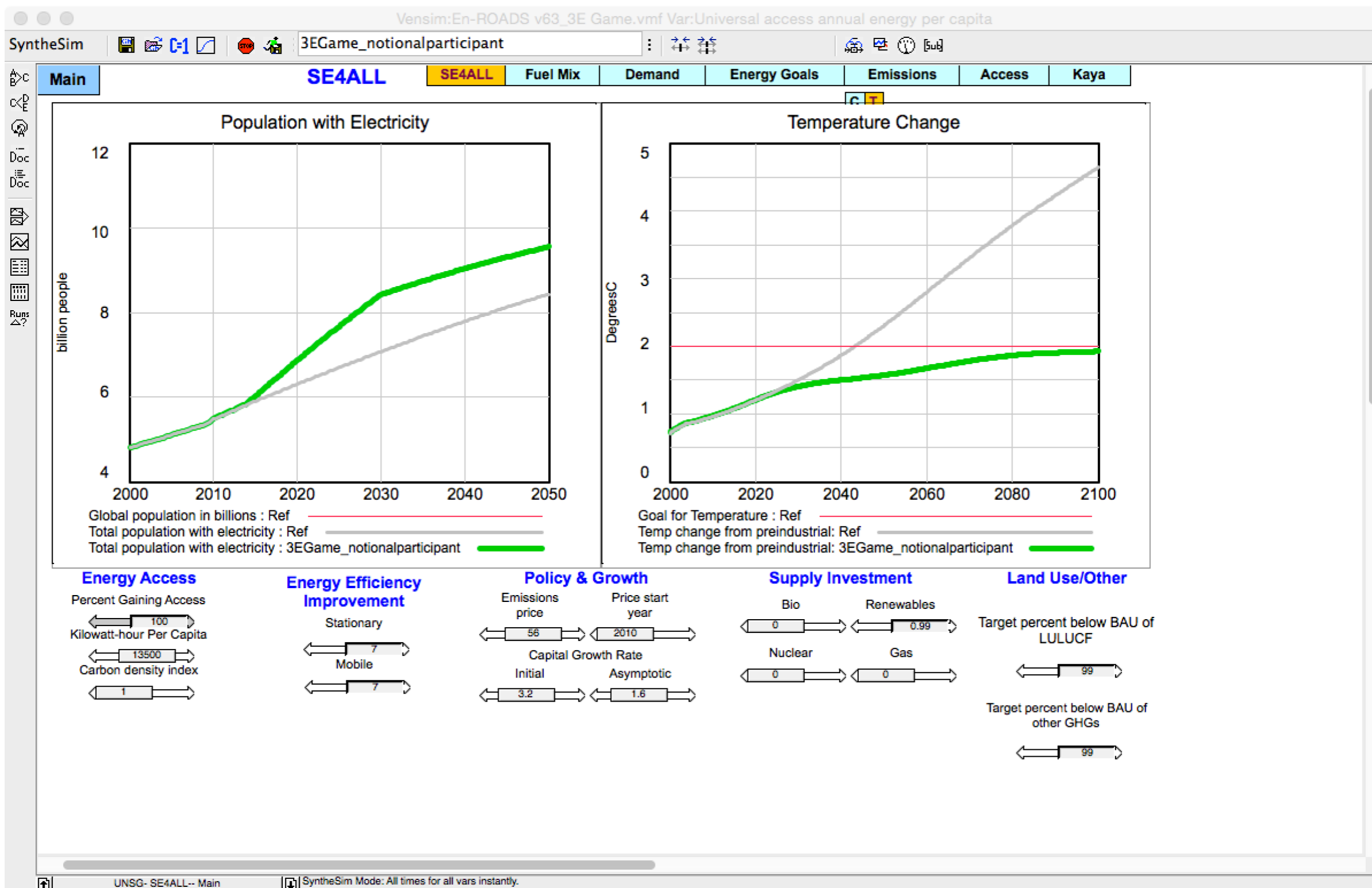# Decision Tools: Typical of what a busy decision maker might use

Decision tools (randomly assigned)

1. Model: Use a model

2. Model Logic: Watch a movie* about the logic of the model

3. General Energy: Watch 3 movies about energy sustainability

4. Control: Watch a movie unrelated to the policy setting

* Movies are briefings that are the same each time.

En-ROADS Model

En-ROADS is made by ClimateInteractive.org and Prof. John Sterman

What the 105 Participants Did in the 3E Game

Participants role-play the Minister of Sustainability making global sustainability policy.

- Participants use a randomly assigned decision tool

- Participants create a policy with 15 inputs and are measured on 3 outputs:

  - Change in global average temperature in 2100 (in degrees Celsius)

  - Percent of global population with access to electricity in 2050

  - Gross World Product in 2100 (in trillions of USD)

# Model Users not matching outcome to priority more readily than others

H1: model use will increase the likelihood that decision makers create a policy that reaches their stated, initial priorities

$$\begin{bmatrix} \text{temperature change} \\ \text{electricity access} \\ \text{global economy} \end{bmatrix} = b_0 + b_1(\text{environment preference}) + b_2(\text{equity preference}) + e$$

Experimental Condition	Term	Pillai	Approx F statistic	P-value
Model	Env Pref	0.126	1.01	0.408
	SE Pref	0.0406	0.296	0.827
Model Logic	Env Pref	0.307	3.25	0.0410**
	SE Pref	0.0829	0.662	0.584
General Energy	Env Pref	0.352	3.44	0.0378**
	SE Pref	0.130	0.946	0.438
Control	Env Pref	0.139	0.810	0.508
	SE Pref	0.384	3.12	0.0577*

Czaika and Selin, 2017

Model Users Discovered win-win nature of SE

By discovering win-win nature of SE, Model Users outperformed their SE priorities.

73% of Model Users discovered win-win nature of SE.

Czaika and Selin, 2017
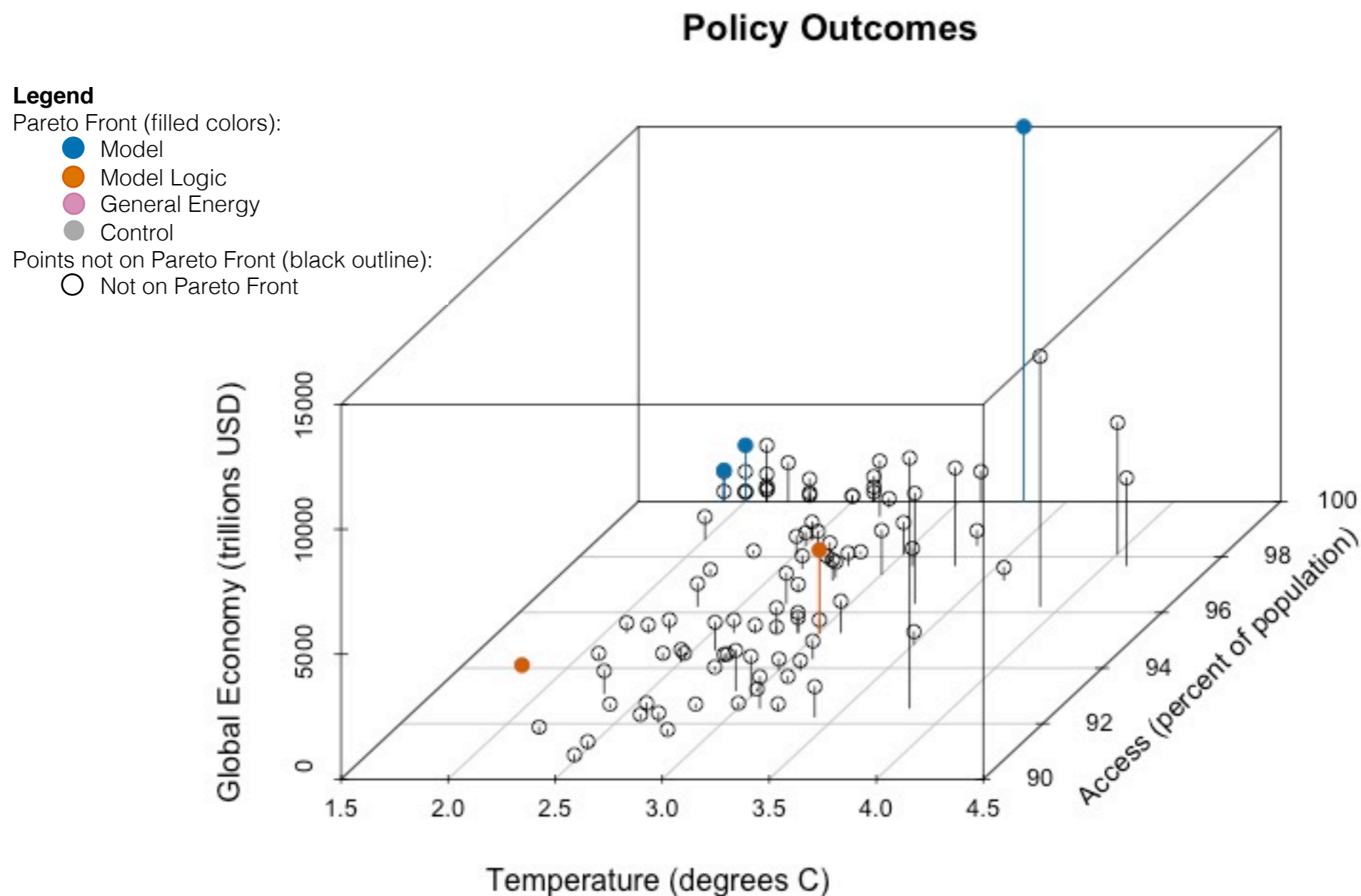
Diamond is the mean.

28
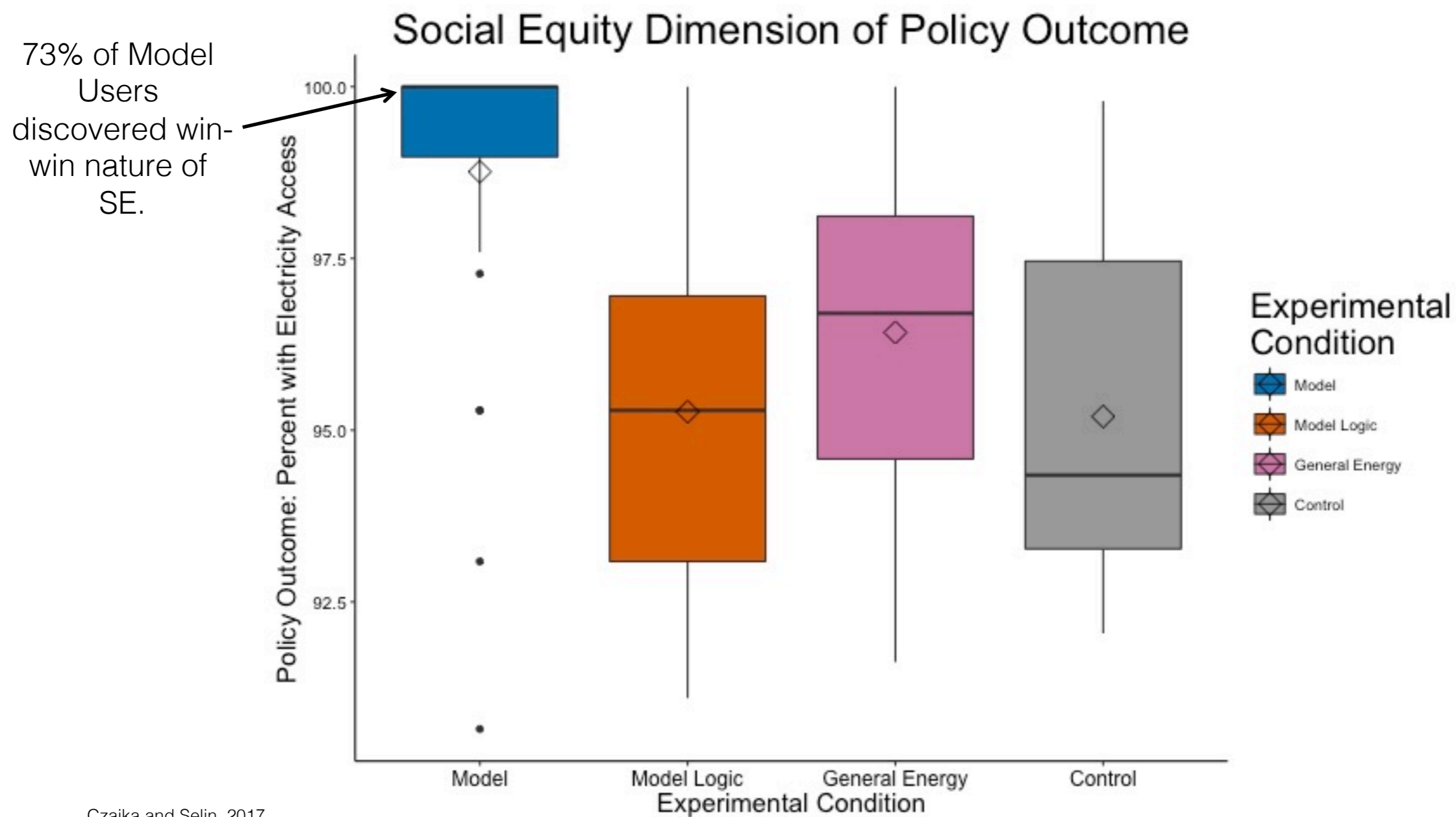
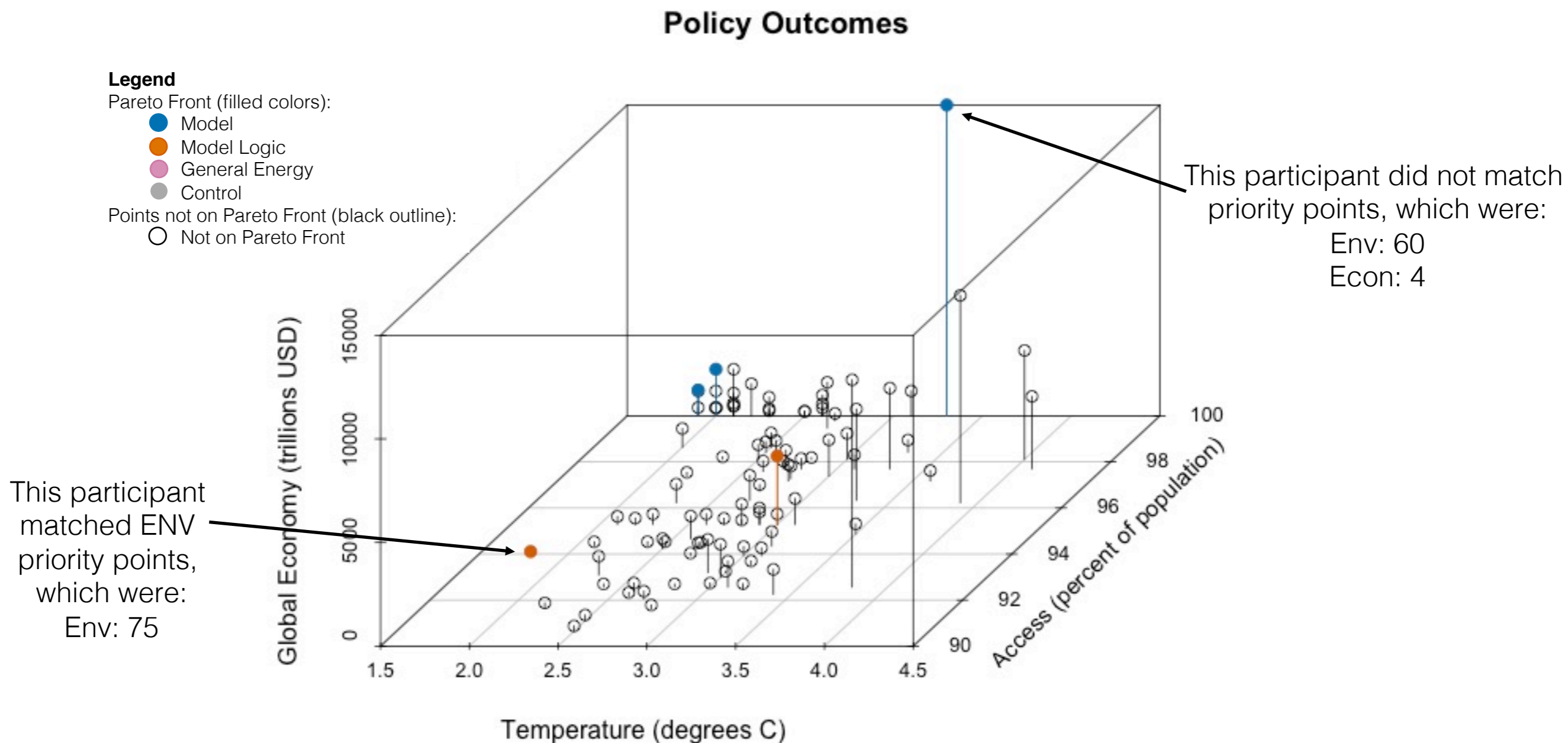# Pareto Front categorizes the trade space of achieved outcomes

- The Pareto Front is the set of points such that to do better in any one dimension, other dimensions would have to do worse.

- Pareto Front calculated using genetic algorithm based on Chong and Zak, 2013.

Model Users reached Pareto Front of achieved outcomes more readily

H2: model use will increase the likelihood that decision makers create a policy whose outcome is on the Pareto Front of achieved outcomes.

Policy Outcomes

Legend
Pareto Front (filled colors):
- Model
- Model Logic
- General Energy
- Control

Points not on Pareto Front (black outline):
- Not on Pareto Front

Pareto Front of achieved outcomes is not same as reaching priorities

Policy Outcomes

Legend
Pareto Front (filled colors):
- Model
- Model Logic
- General Energy
- Control

Points not on Pareto Front (black outline):
- Not on Pareto Front

This participant did not match priority points, which were:
Env: 60
Econ: 4

This participant matched ENV priority points, which were:
Env: 75

Global Economy (trillions USD)

Access (percent of population)

Temperature (degrees C)

Czaika and Selin, 2017

Model Use does impact decision outcomes

1. Did model use increase participants' ability to create a policy matching their priorities?

   - No, because they outperformed their social equity measure by discovering the win-win

   - Participants who were briefed on the model logic or general energy information did match their stated priorities

Model Use does impact decision outcomes

1. Did model use increase participants' ability to create a policy matching their priorities?

    • No, because they outperformed their social equity measure by discovering the win-win

    • Participants who were briefed on the model logic or general energy information did match their stated priorities

2. Did model use increase participants' ability to create an optimal policy?

    • Yes, model users reached the Pareto Front of achieved outcomes more readily than other other participants; followed by those briefed about the model logic.

Applying these Findings in Real World Sustainability Decisions

What if it is not possible for decision makers to co-create a model?

It isn't always possible to have the parties co-create a model.
When co-creating a model isn't possible, then encourage the decision makers to use a relevant expert-given model.

https://www.climateinteractive.org/tools/en-roads/

MITsdm
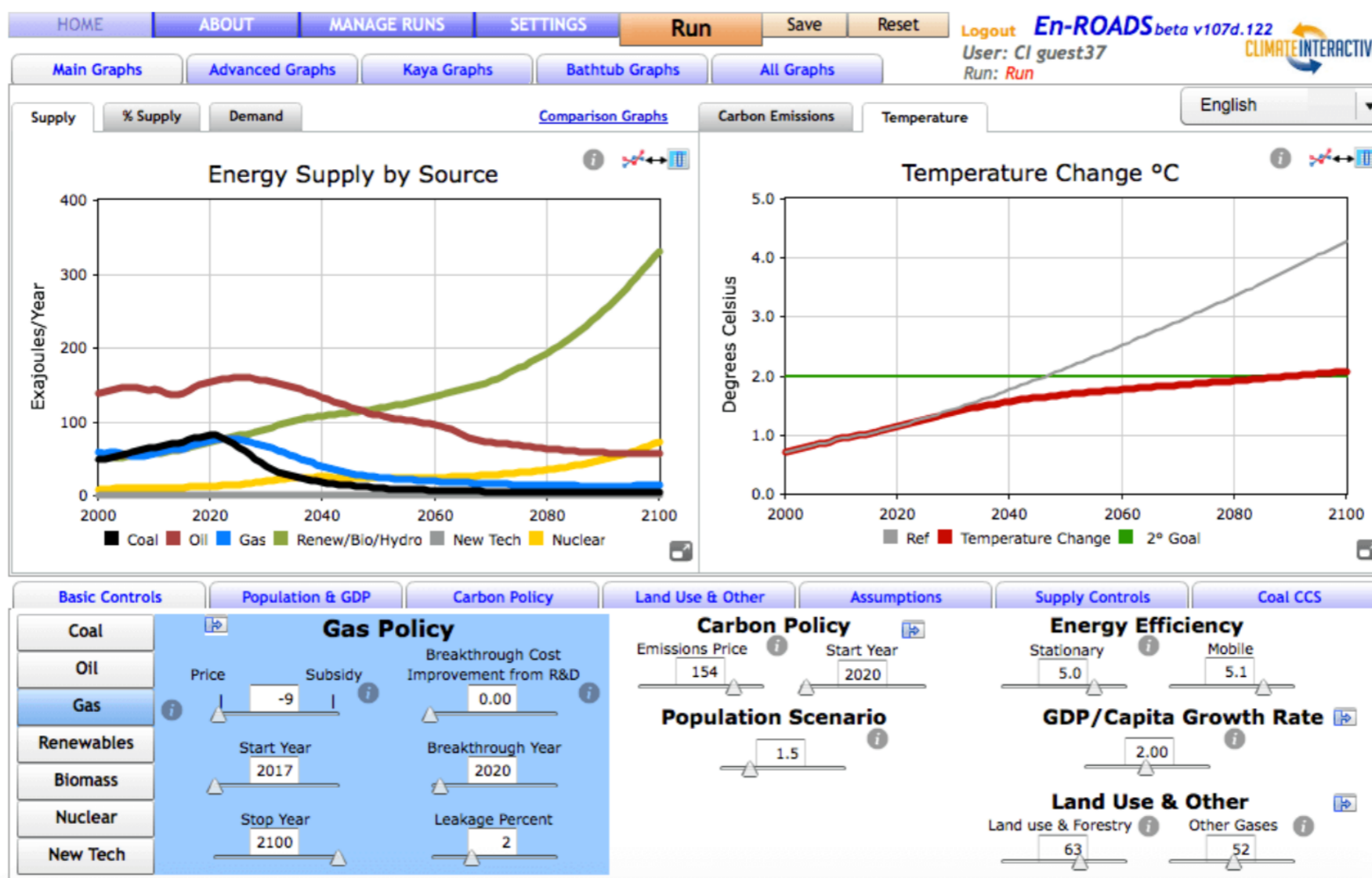
Advantages of Using a Model

Using a model:

- Increases the likelihood of reaching Pareto Front of achieved outcomes.

- Increases the likelihood of identifying win-win

What if it is not possible for decision makers to use a model?

It isn't always possible for decision makers to use a model.

When it is not possible for decision makers to use a model, then brief the decision maker on the the insights and logic of a credible, salient, legitimate model.

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- The SDM program
- Everyone who took a turn as the minister of sustainabilty in the 3E Game—the participants!

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Questions?

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