Supporting bioproducts industry growth with a system dynamics decision-support tool

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Bioproducts are a key component of the U.S. bioeconomy, but commercializing bioproducts and capturing market share has historically proven difficult.

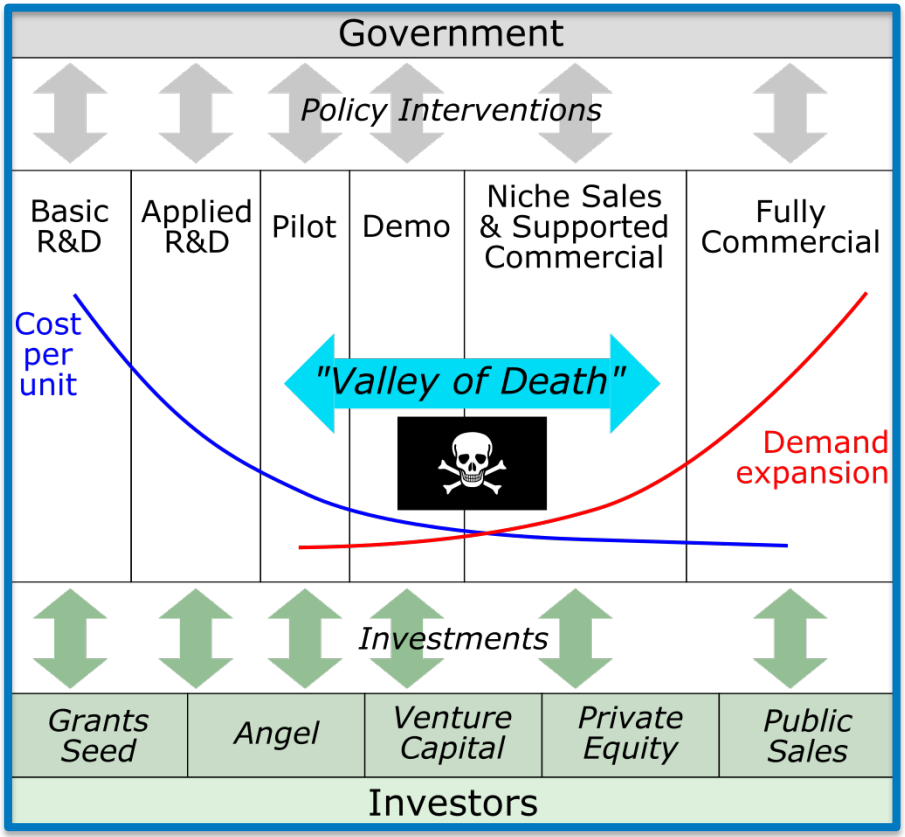
28%

Fraction of fossil fuels consumed by U.S. manufacturers as chemical feedstocks

Sector	Percent Bio-based Products in U.S. Economy as of 2013
Chemicals	4
Enzymes	3.93
Plastic packaging and bottles	0.28

U.S. Energy Information Administration, *Use of energy explained*, Last updated July 28, 2020
J. Golden, Handfield, R., Daystar, J., McConnell, T.E., *Industrial Biotechnology* 11(4), August 2015.

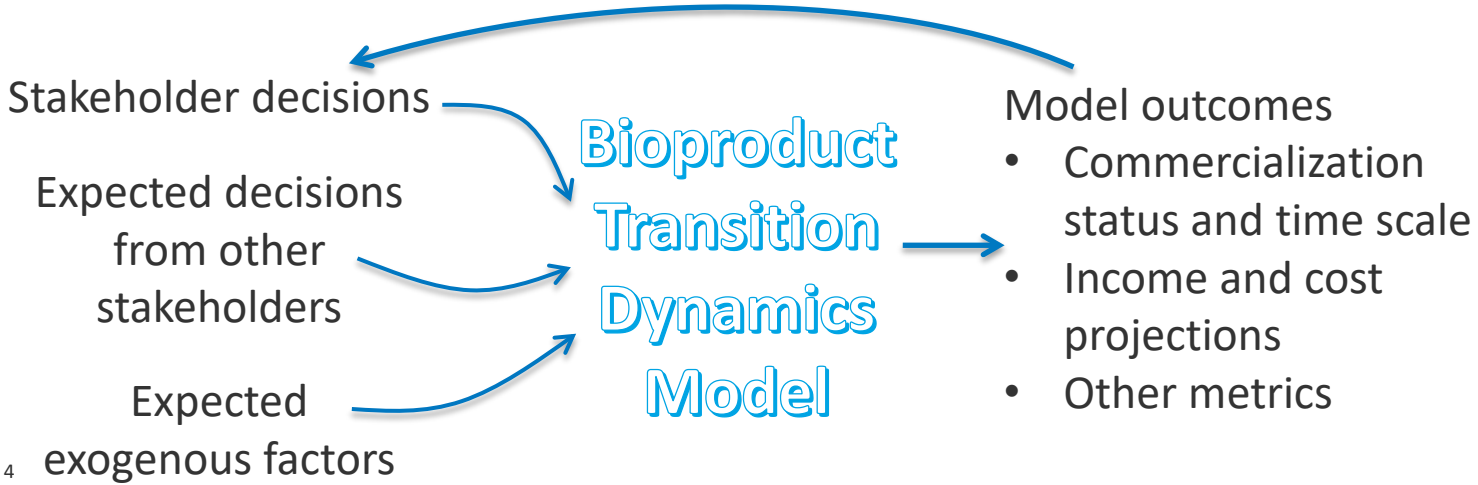
We need to know more about the factors that lead to bioproduct success or failure.



How can we consider factors throughout the development process and make decisions that will increase the likelihood of successful commercialization?

Adapted from Bürer and Wüstenhagen, *Energy Policy*, 37 (2009)

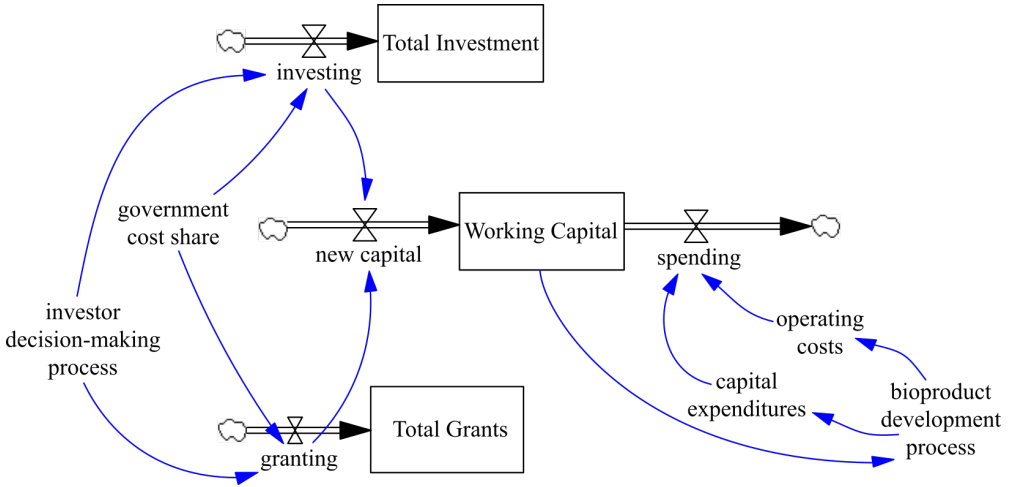
Our goal is to inform industry stakeholder decisions and help bring more bioproducts to market.



The BTD is a system dynamics model – What is system dynamics anyway?

System Dynamics Model

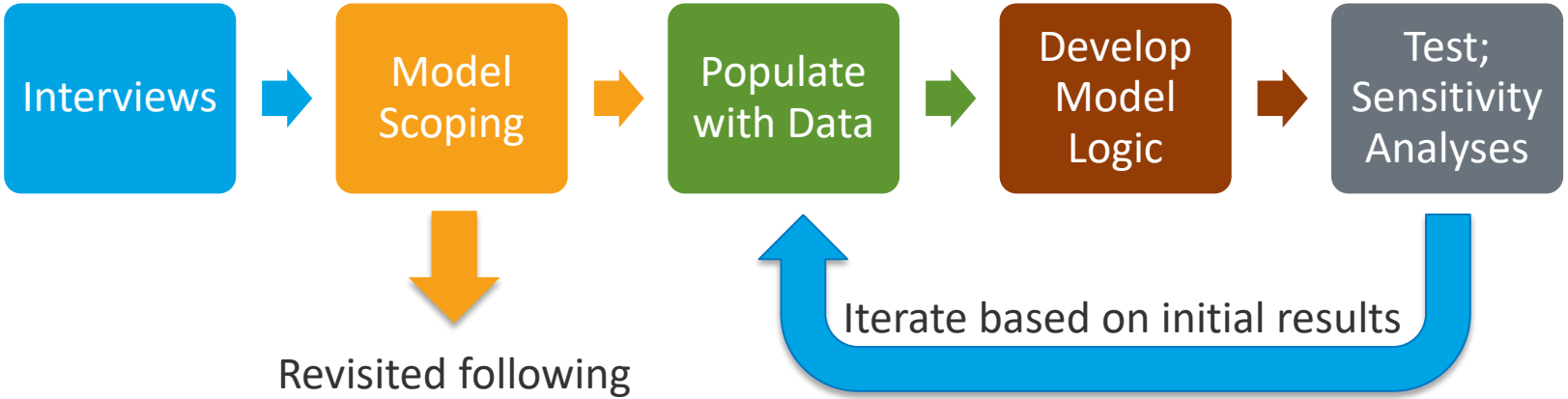
A system of coupled, nonlinear, first-order differential or integral equations



Software: Vensim DSS

Key Features of System Dynamics Modeling	Visual language can aid communication
	Can represent physical and non-physical flows, time delays, endogenous feedbacks, non-linearities, stochasticity
	Emphasis on simulation and scenario analysis

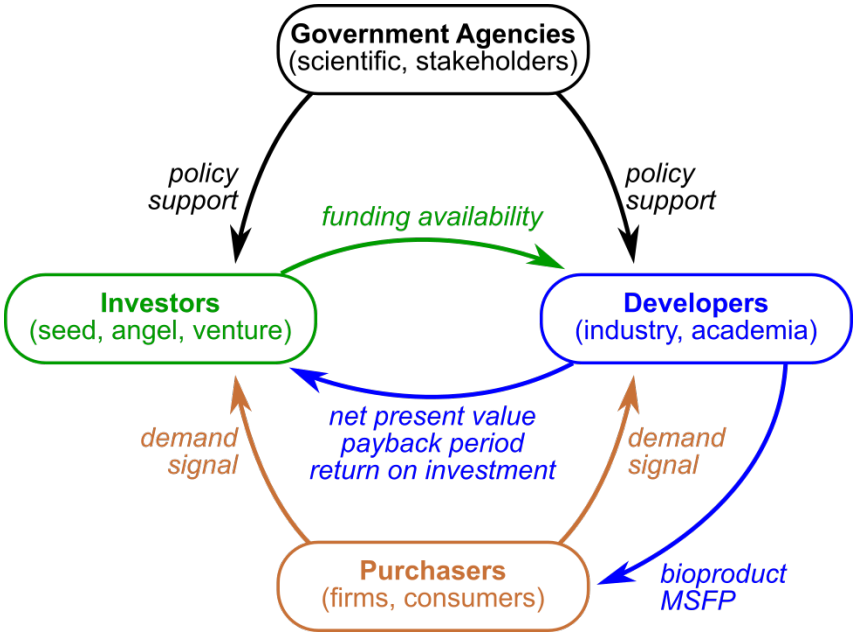
We used interviews and information from analogous industries to supplement scarce data.



Final steps:

- Model review by system dynamics expert
- General sensitivity analysis

System dynamics helps captures stakeholder interactions and decision-making processes.



- The BTD synthesizes what we know about the bioproduct development and scale-up process
- Stakeholder decisions are informed by other stakeholders and by exogenous or scenario factors

Scenario definitions impact decision outcomes and encompass three main types of factors.

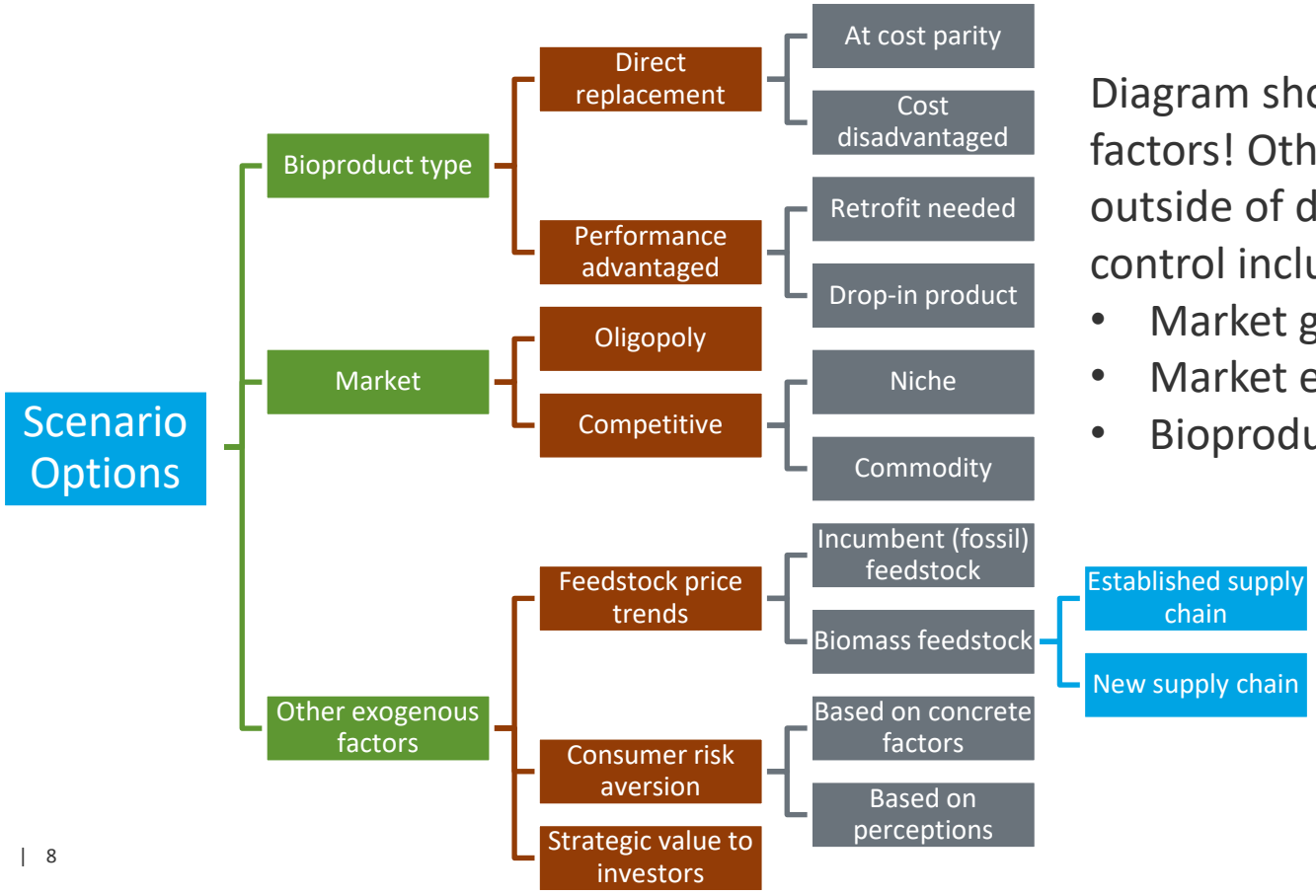


Diagram shows only selected factors! Other critical factors outside of direct stakeholder control include:

- Market growth rate
- Market entry response
- Bioproduct price over time

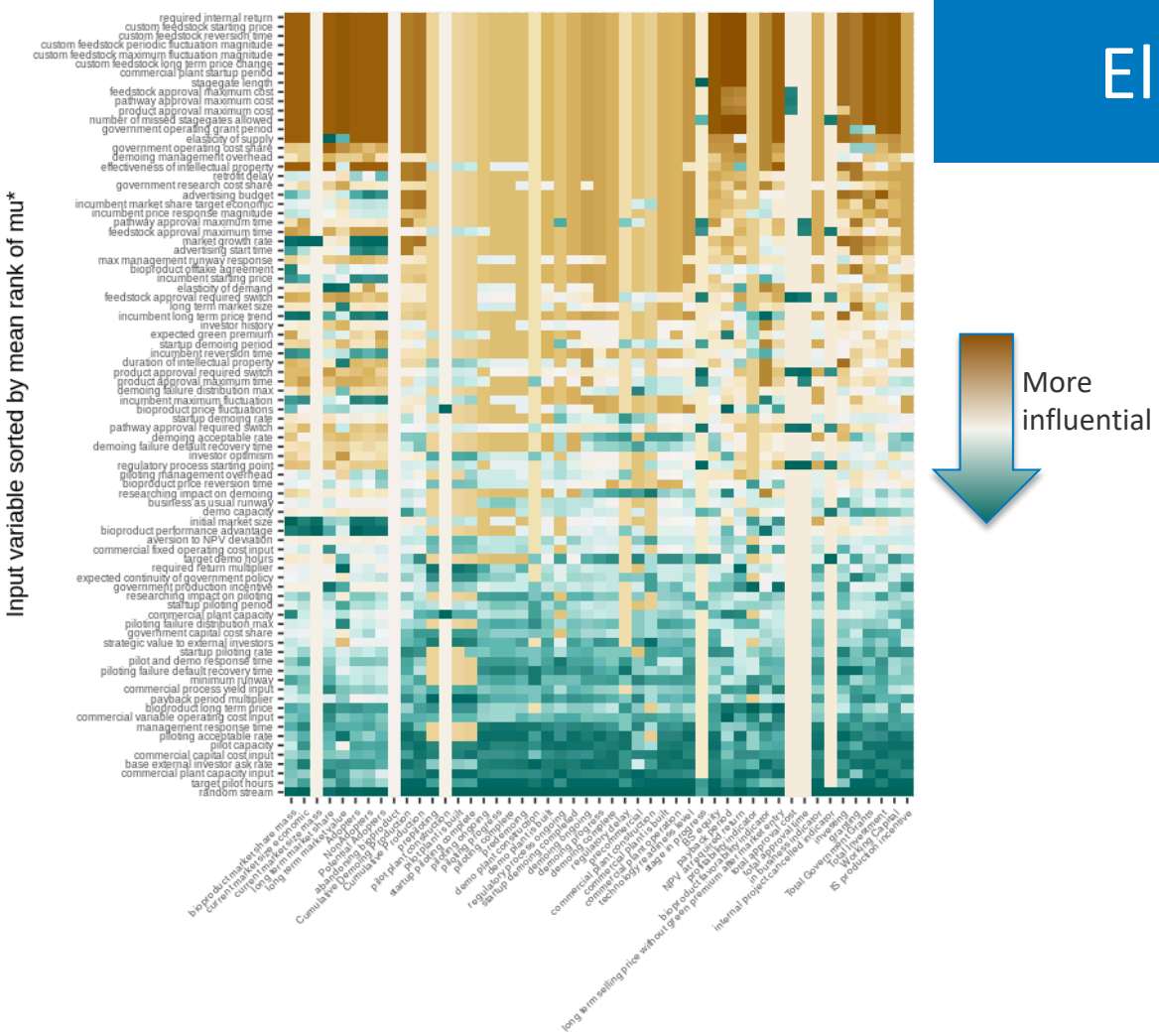
We performed a general sensitivity analysis to build trust in BTD model logic and outcomes.

(1) What are the most important factors in the model?
(2) Do the factors affect the expected outcomes?
(3) Does the model "break" in ways that it shouldn't?

We'd be suspicious of
- Overly influential factors
- Failed model runs

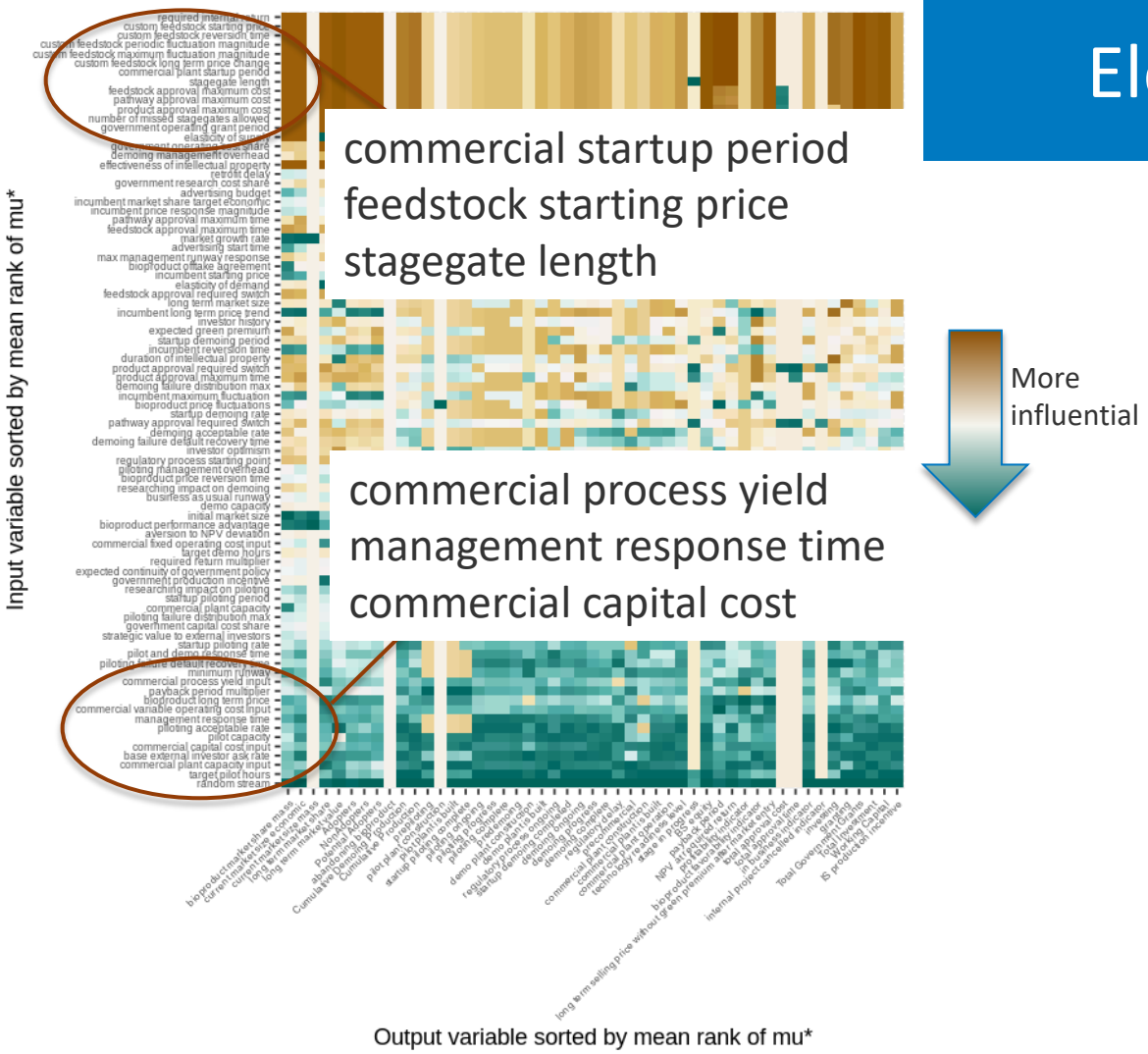
One-at-a-time Elementary Effects Screening

Elementary Effects



- A variable may be influential for some output metrics, but not for others.
- Some variables are influential for most model outcomes, but not all.

Elementary Effects



- A variable may be influential for some output metrics, but not for others.
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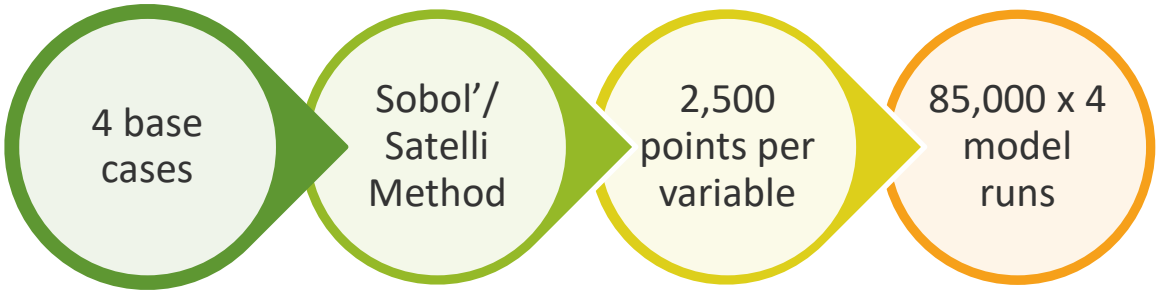
Then we designed an analysis to answer a specific question from our client.

How do the factors that lead to the Valley of Death change when the bioproduct being developed is a drop-in replacement versus performance-advantaged?

Variance-Based Sensitivity Analysis



- 34 variables after down-selection

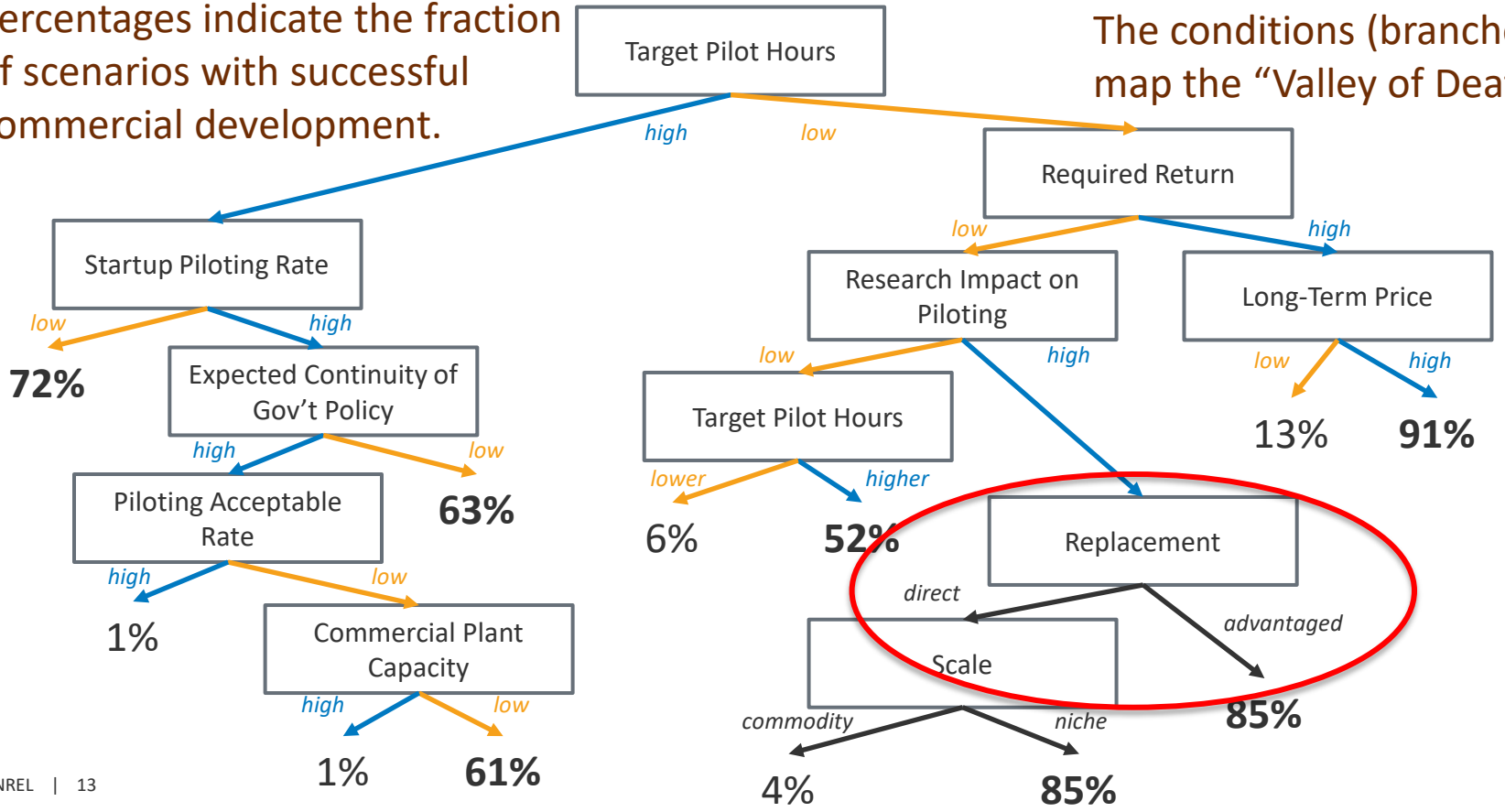
In the results, we'll be looking for

- Which factors are most influential for each base case
- How those factors change for different bioproduct types

Decision-Tree Insight Analysis

Percentages indicate the fraction of scenarios with successful commercial development.

The conditions (branches) map the "Valley of Death".

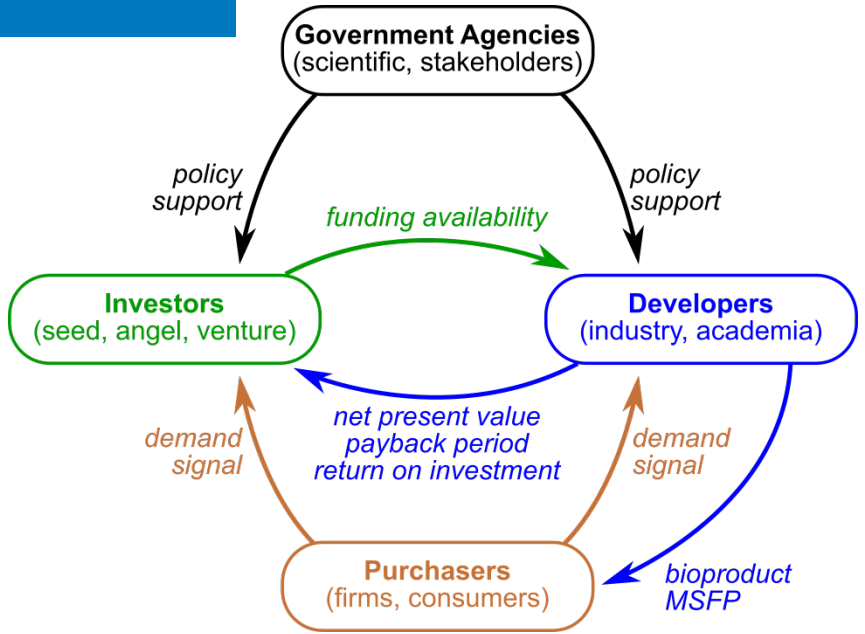


Recap and Conclusion

The BTD decision-support tool can help inform decisions made by bioproduct industry stakeholders such that more bioproducts can be brought to market in the U.S.

Look for our upcoming publications:

1. Journal article providing additional information about our insight analysis
2. NREL technical report combining a user guide with complete model documentation



Thank You

Additional information or questions?
Contact Rebecca Hanes at rebecca.hanes@nrel.gov

www.nrel.gov

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