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Introduction to the Bioproduct Transition Dynamics Model

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Webinar

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Overview

How does this webinar relate to the July 16 workshop?

- During the workshop, we'll be soliciting feedback on validity of our Bioproduct Transition Dynamics model and on ways to improve the model.
- This webinar provides background information on the BTD project and model to enable more in-depth discussions during the workshop.

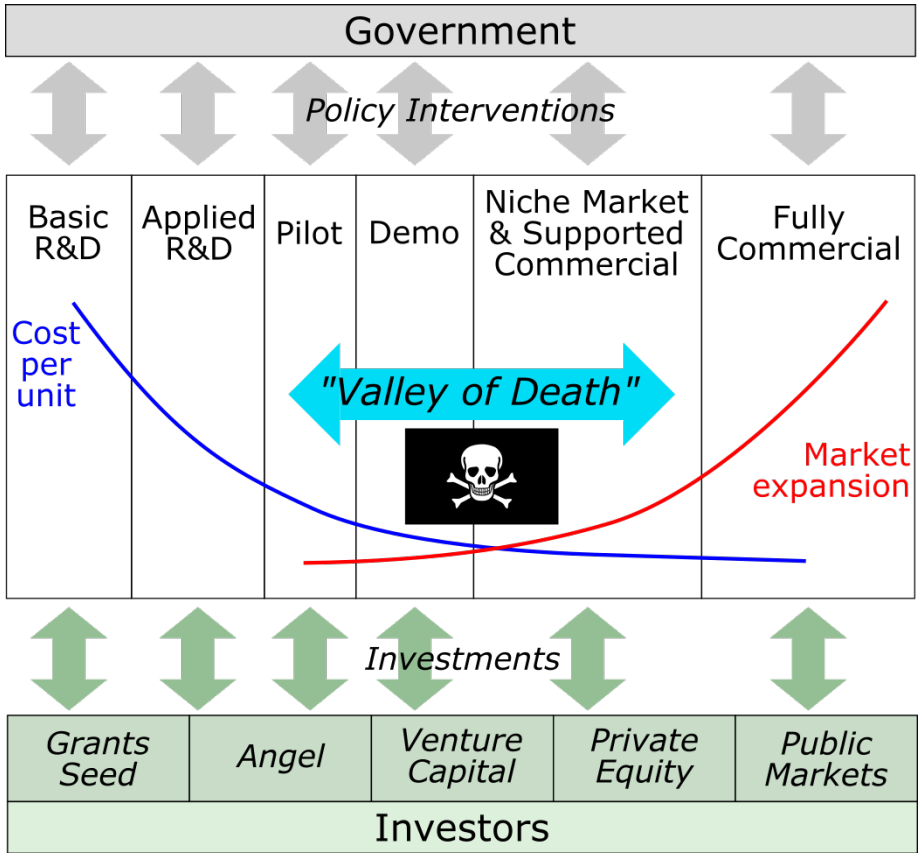
What are we hoping you'll gain from this webinar?

- Knowledge of the BTD project motivations, objectives and outcomes
- A high-level understanding of the BTD model assumptions, structure, logic and use cases

Bioproduct Transition Dynamics Project

BETO has been developing a broad understanding of different conversion processes that produce bioproducts and the associated end use attributes.

However, there is currently not much understanding around **how investment decisions are made** and the possible successful scenarios for **advancing the bioproducts and biofuels industries**.



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

Bioproduct Transition Dynamics Project

Outcomes

- Transparent, analytic **system dynamics** model
- Method for exploring transition dynamics during **early industry development** as a function of:
  - Investor decision-making
  - Bioproduct techno-economics
  - End use factors

Goal

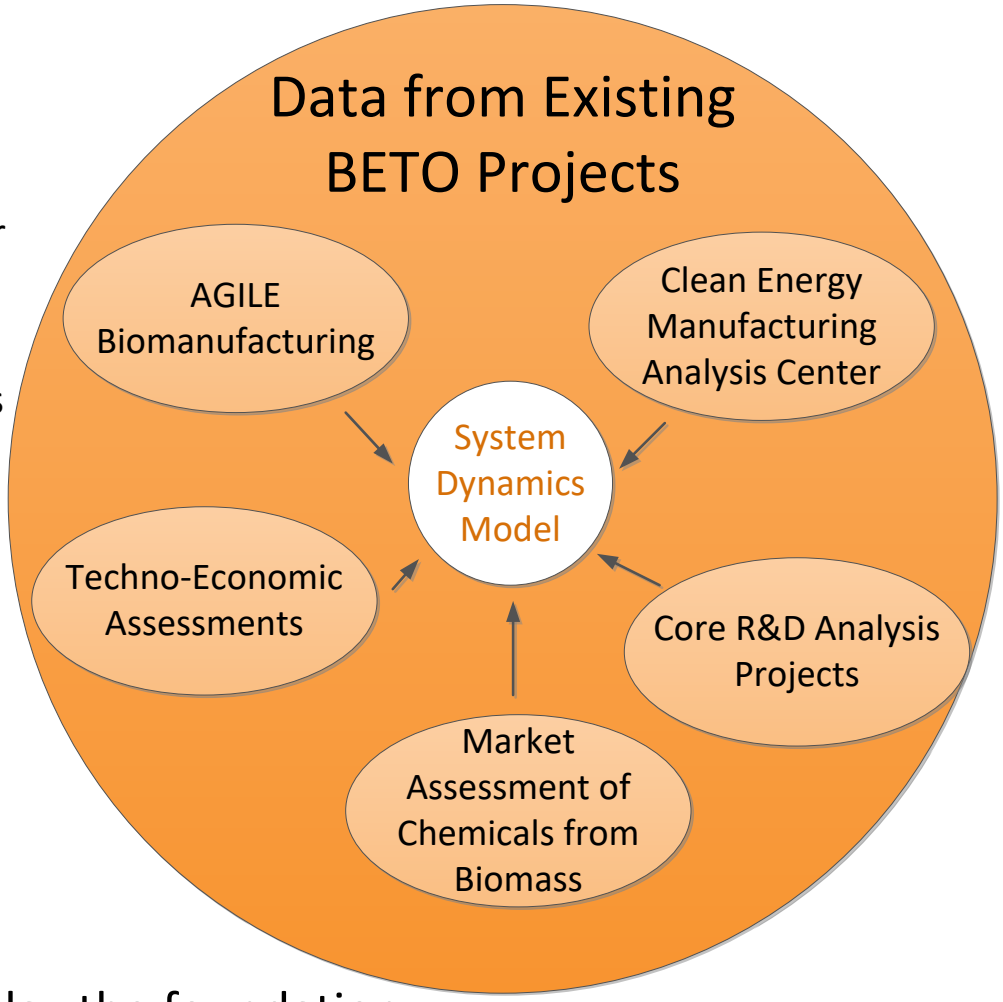
- Develop an analysis capability
- To achieve deeper understanding of the environment and drivers that impact the growth of the bioproducts industry
- In order to support BETO bioenergy strategy development

- How do developer-investor interactions and other factors impact low-TRL stages of bioproduct development?
- (How) Can the likelihood that a bioproduct development project succeeds be influenced, and by whom?

Bioproduct Transition Dynamics Project

This project builds upon existing work that has been funded by BETO:

- Industrial assessment of chemicals from biomass
  - Laid out the existing end use capacity for chemicals from biomass and potential for expansion.
- Techno-economic assessments
  - The Clean Energy Manufacturing Analysis Center (CEMAC) bioproducts task
  - Current BETO-funded work considers coproduction of biofuels and chemicals from biomass.
- Research & Development (R&D) projects
  - Current BETO-funded analysis work considers coproduction of biofuels and chemicals from biomass.
  - On-going efforts in the AGILE biomanufacturing project



These projects are information-rich and lay the foundation for exploring possible future scenarios and the connections between bioproducts and biofuels.

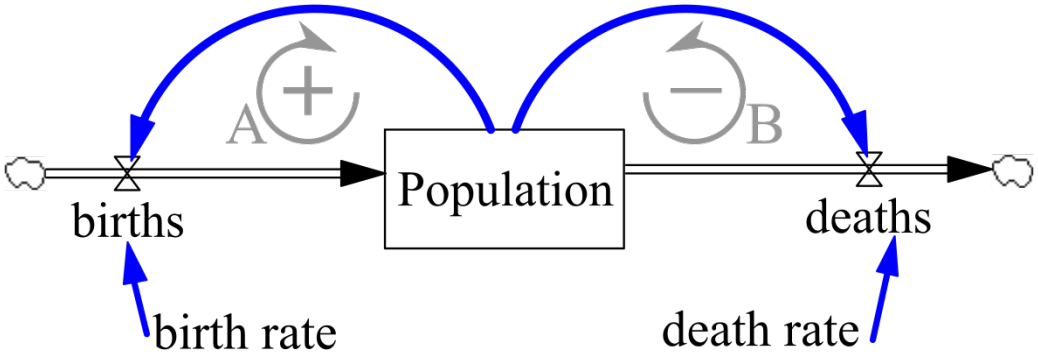
Why System Dynamics Modeling?

While systems are…	…our thinking processes often…
Constantly changing	…are static, equilibrium oriented
Tightly coupled/interdependent	…draw very narrow boundaries around issues and problems
Rich in feedback	…treat drivers of performance as external and independent
Nonlinear	…assume linear responses
History dependent	…neglect to consider path dependence, accumulations, and delays
Adaptive and evolving	…fail to pay sufficient attention to the sources of unintended consequences

Adapted from Sterman, *Am J Public Health*, 96:3 (2006)

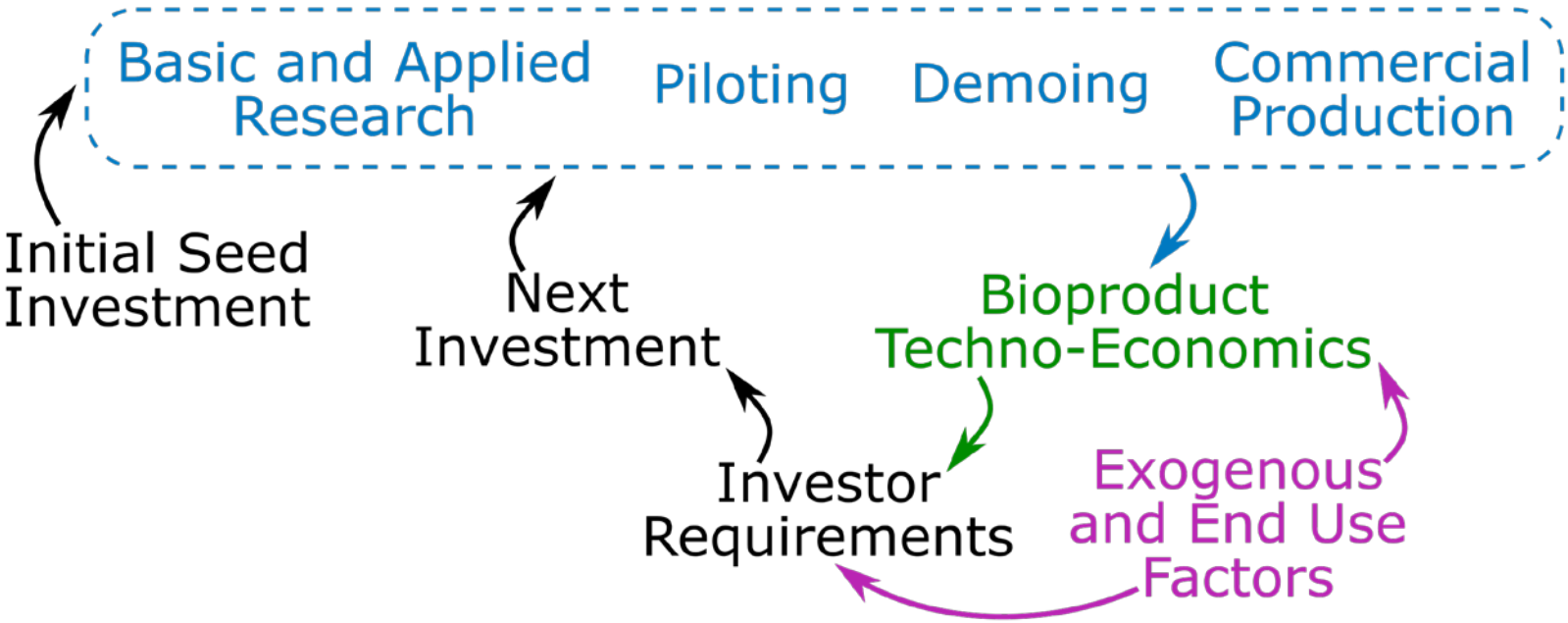
System Dynamics Example

System dynamics models are often developed as *stock-and-flow diagrams*, in which stocks and flows may represent physical or non-physical quantities.



- **Flows** (*births*, *deaths*) are the rates of change of stocks
- **Stocks** (*Population*) are the integrals over time of flows
- **Feedback loops** (*A*, *B*) exist among stocks, flows and model parameters
- Feedback loops are either *reinforcing* or *balancing*
  - Loop A is *reinforcing*
  - Loop B is *balancing*

Bioproduct Transition Dynamics Model Structure



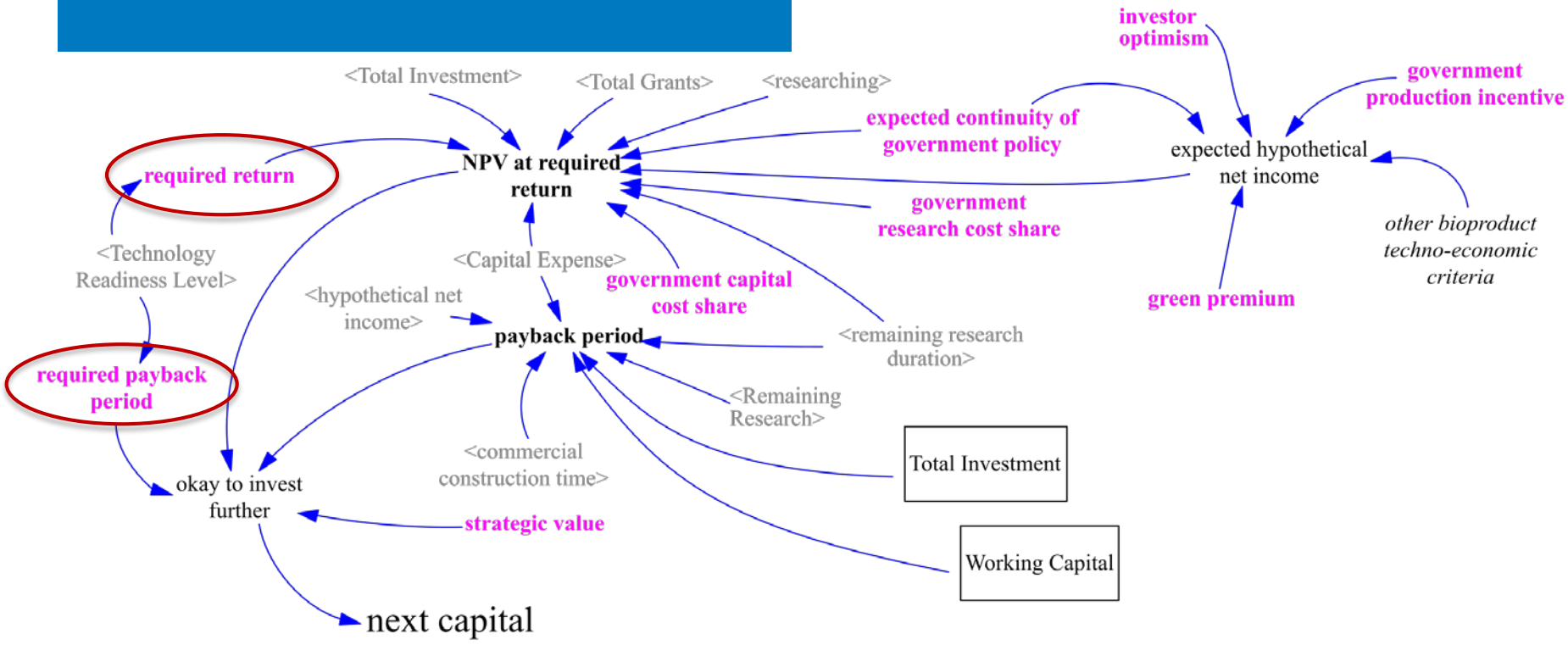
Actors include…

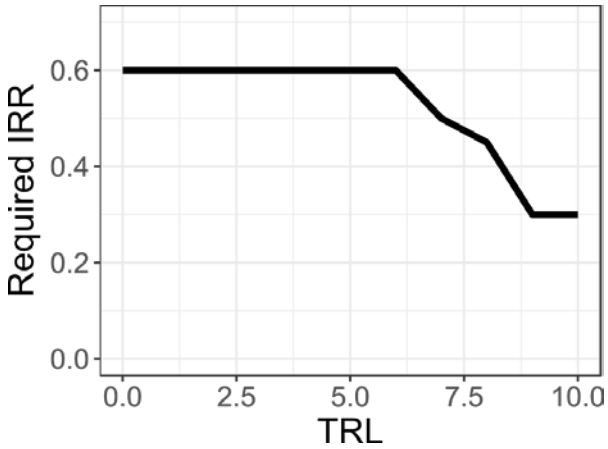
- Bioproduct developers (industry, academia)
- Investors (seed, venture)
- Purchasers (firms)
- Government agencies

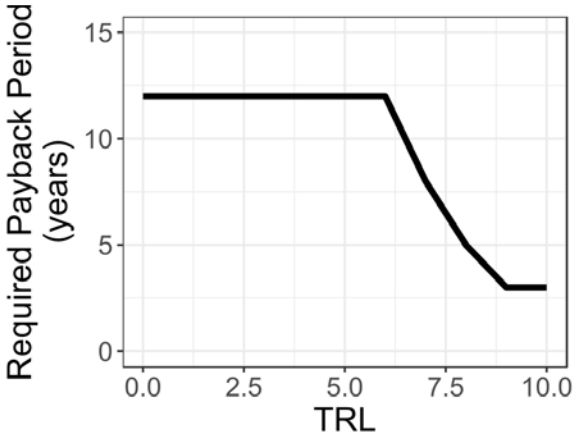
Model structure was derived from…

- Interviews with bioproduct industry experts
- Research on investor decision-making and innovation processes
- Shared learning models
- End use structure research

Investor Decision Making



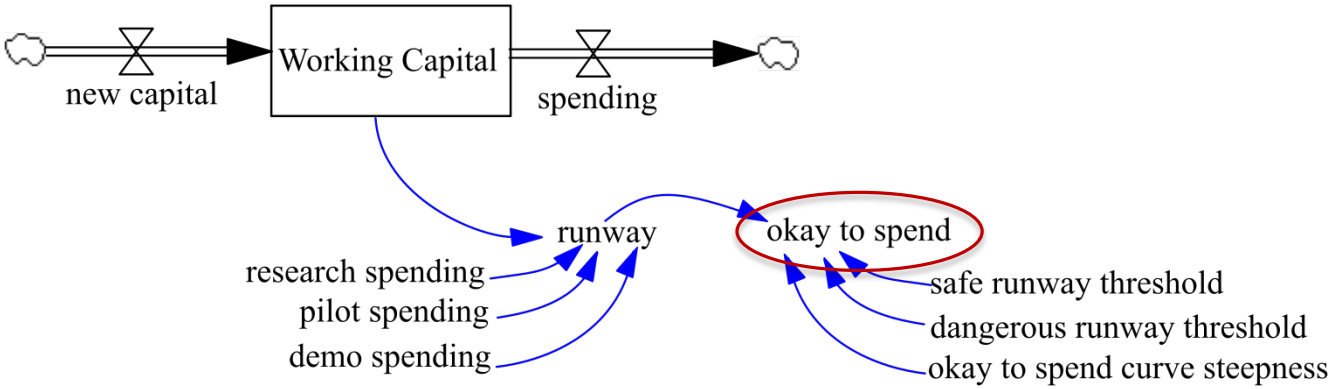


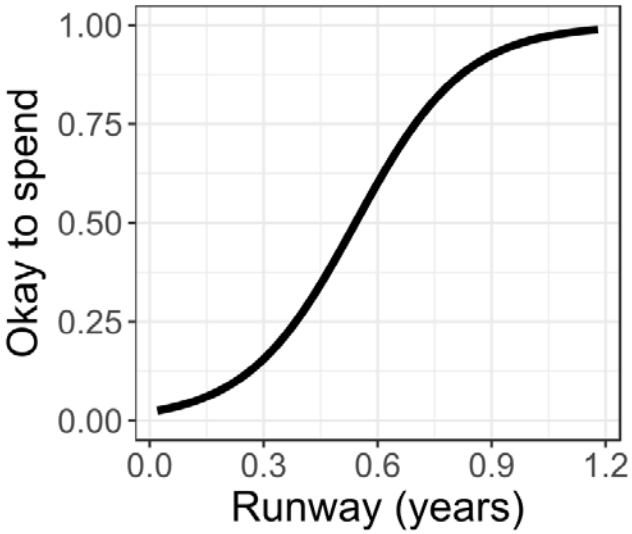


Input data quantifies how investor requirements vary by development stage. (Damodaran, 2009)

Developer Decision Making

Bioproduct developers spend money on researching, piloting and demoing as funds become available.

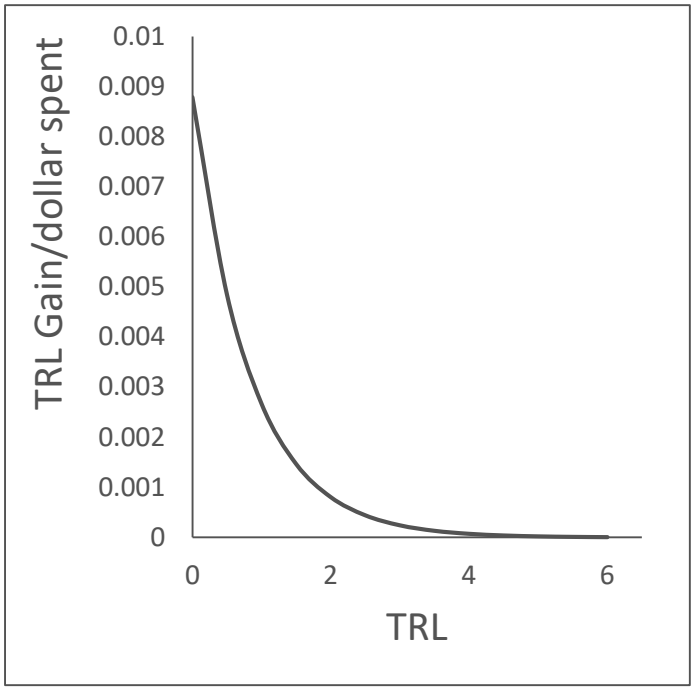


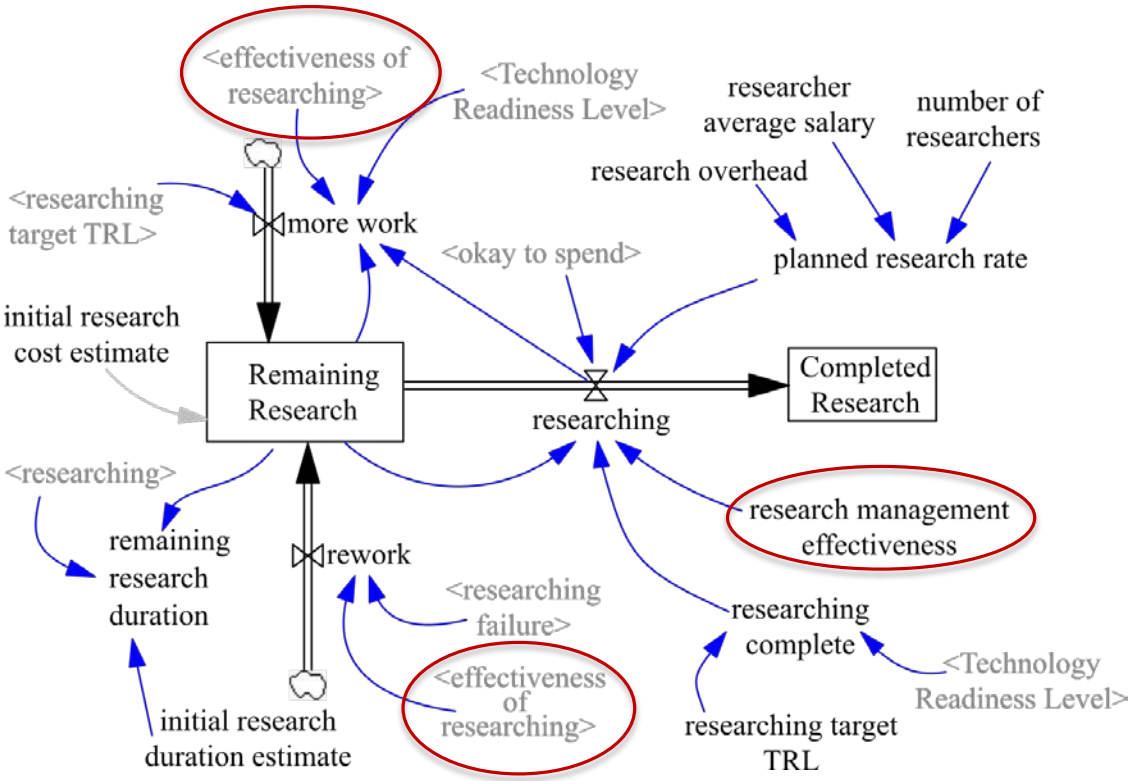


When funds are close to depleted, the spending rate is reduced, slowing development work, until more funds are received or the project fails.

Research Process

Effectiveness of researching controls the rate at which TRL is gained during research.

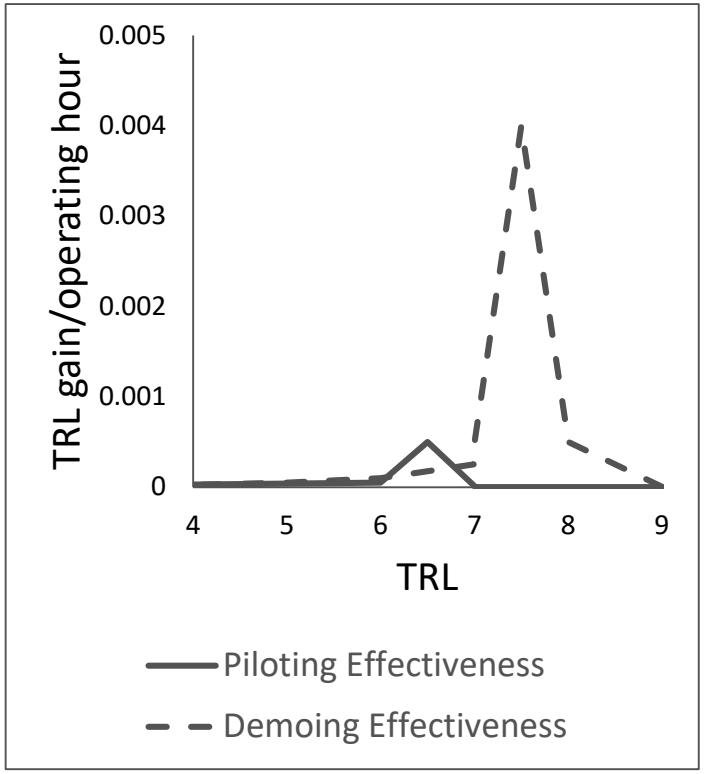


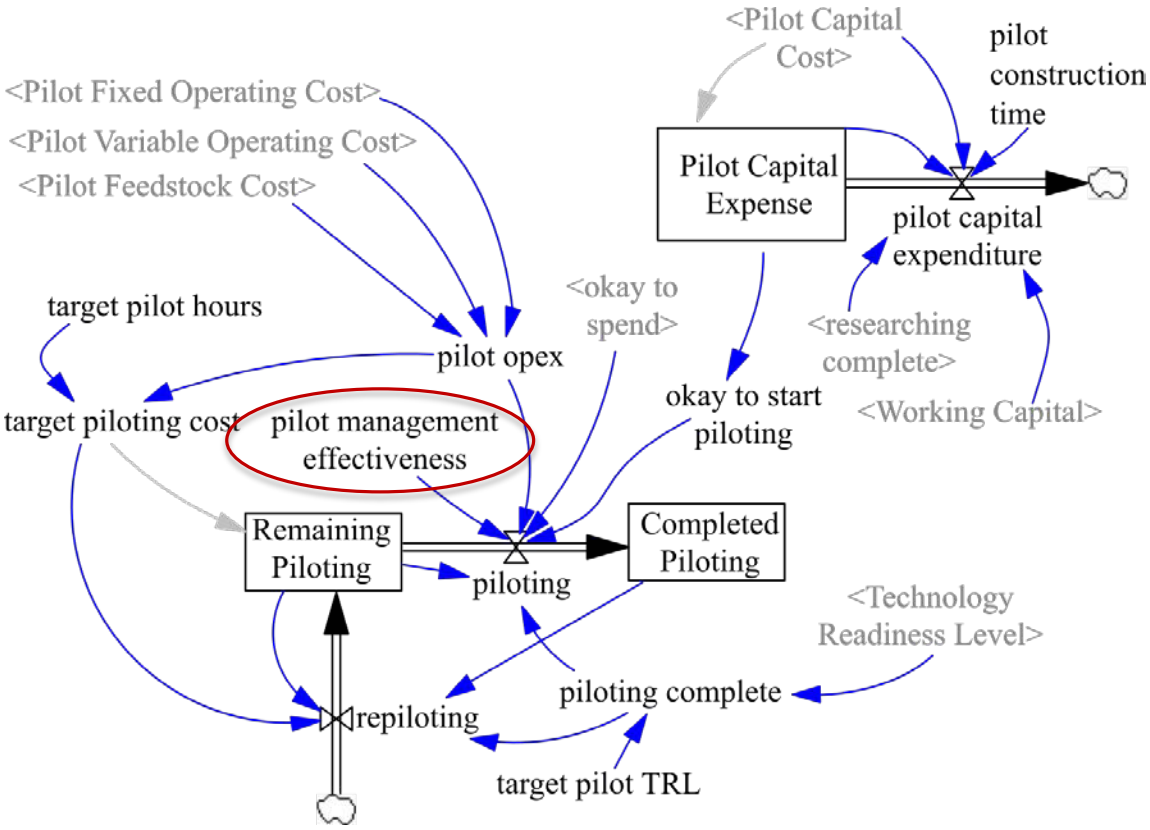


Research management effectiveness controls how much of each dollar spent is available for conversion into TRL gains.

Piloting and Demoing Process

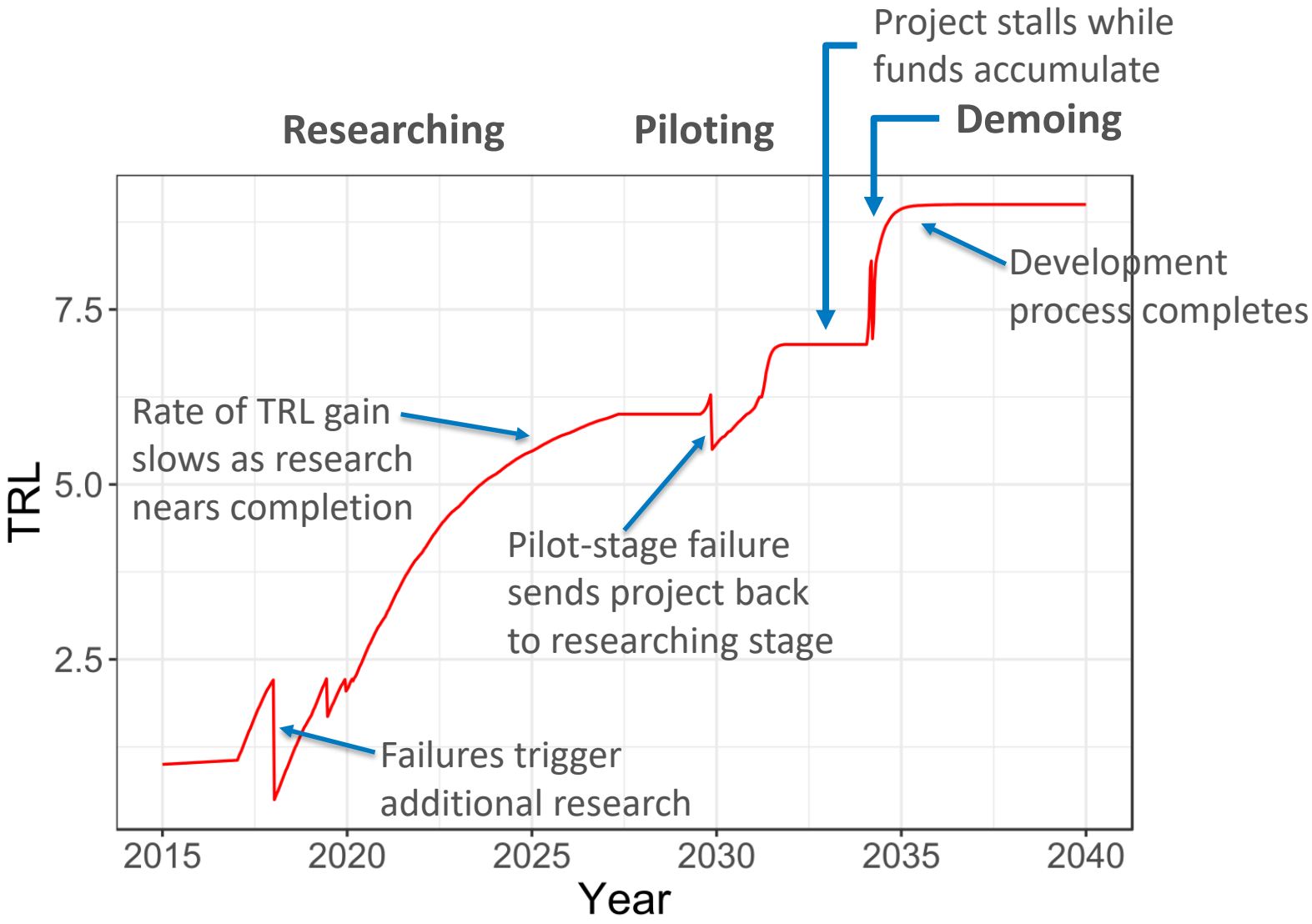
Piloting effectiveness and *demoing effectiveness* (not shown in diagram) control the rate at which TRL is gained during piloting and demoing.





Pilot and *demo management effectiveness* are both analogous to the *research management effectiveness* parameter.

Sample TRL Path and Events



Shared Learning

- Commercial-scale bioproduct production creates shared learning that benefits the biofuels industry
- Learning is accounted for on a unit operation level
- Only unit operations in common between the bioproduct and biofuel processes benefit.

Unit Operations	Biofuel Process	Bioproduct Process	Learning Rate
LC biomass processing	1	1	0.2
Enzymatic hydrolysis	1	1	0.2
Biological upgrading	0	1	0.2
Catalytic upgrading	1	0	0.2
Extraction, purification and finishing	1	0	0.2

- 1: Indicates a unit operation shared between the biofuel and bioproduct processes
- 0: Indicates a unit operation that does not appear in one or both processes

Sensitivity Analysis and Model Verification

- 14.9 million simulations
- Assess sensitivity to investor, developer decision-making parameters and bioproduct (succinic acid) techno-economics

- **Selling price potential**
  - Selling price
  - Size of green premium
- **Government policy**
  - Research cost share
  - Capital cost share
  - Production incentive
- **Developer effectiveness**
  - Research stage

Investor behavior

- Optimism
- Bioproduct strategic value
- Expected government policy continuity

Management effectiveness

- Research stage
- Pilot stage
- Demo stage

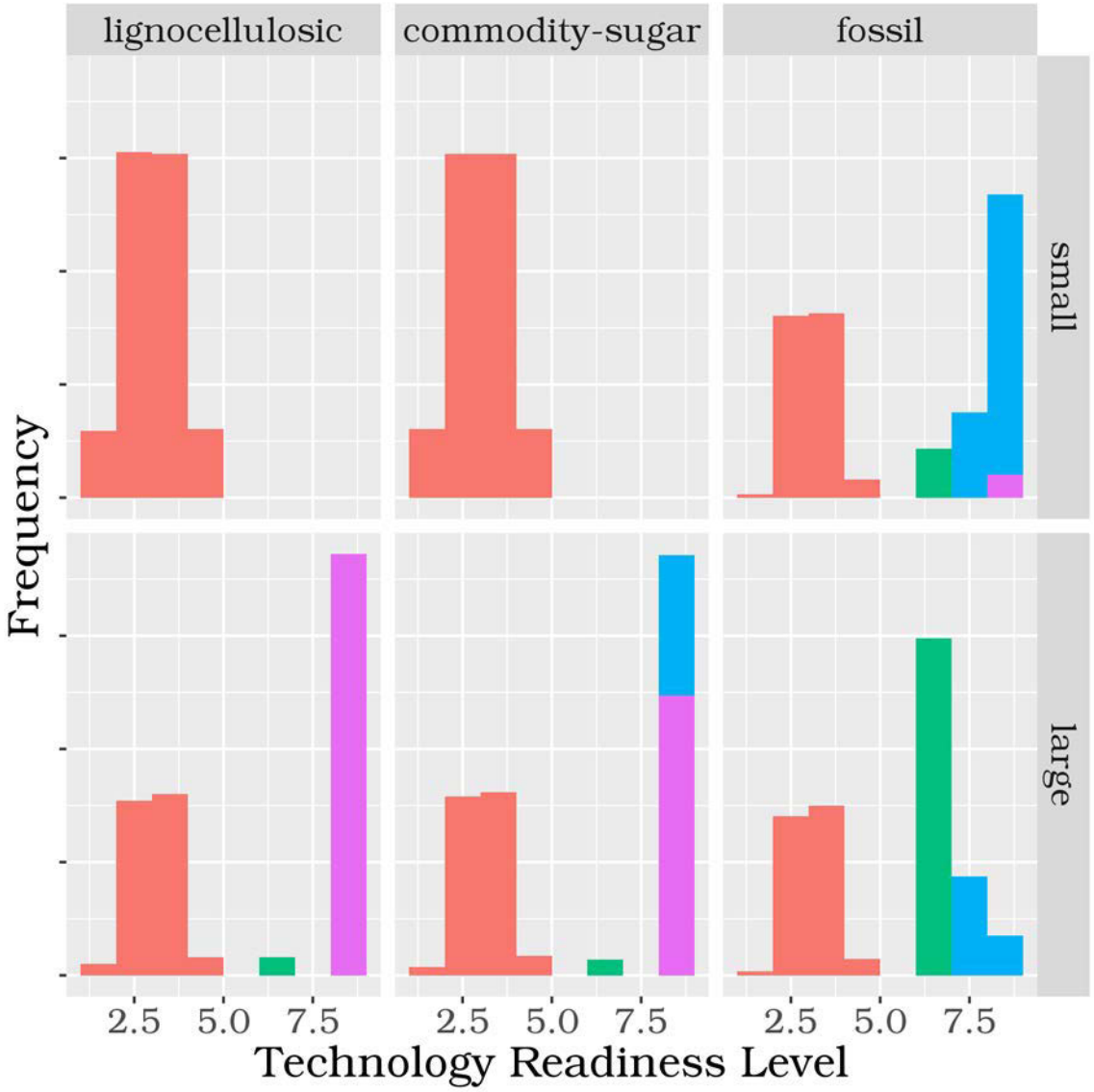
Succinic Acid Techno-Economics

The three pathways differ significantly in their cost structure.

Nth Plant Parameters		Lignocellulosic		Commodity Sugar		Maleic Anhydride (fossil)		
		Large	Small	Large	Small	Large	Medium	Small
Capacity	Ton product/year	286,300	28,630	283,465	28,627	83,00	41,500	20,750
Capital cost	USD	$1,253M	$462M	$906M	$401M	$131M	$92.8M	$70.9M
Feedstock cost	USD/ton	$100		$263		$1,500		
Fixed operating cost	USD/year	$27.0M	$12.8M	$21.0M	$11.4M	$10.8M	$8.57M	$7.29M
Variable operating cost	USD/ton product	$494	$815	$504	$1,219	$29		
Process yield	Ton product/ton feed	0.409		0.770		1.179		
Lifetime	Years	30						

Feedstock	Capital Cost	Operating Cost	Feedstock Cost
Lignocellulosic	High	High	Low
Commodity Sugar	Moderate	High	Moderate
Maleic Anhydride (fossil)	Low	Low	High

Results: Highest TRL Reached



- Color indicates TRL at end of model run for each simulation
- Failure to progress to higher TRLs results from inability to raise new investor funds.

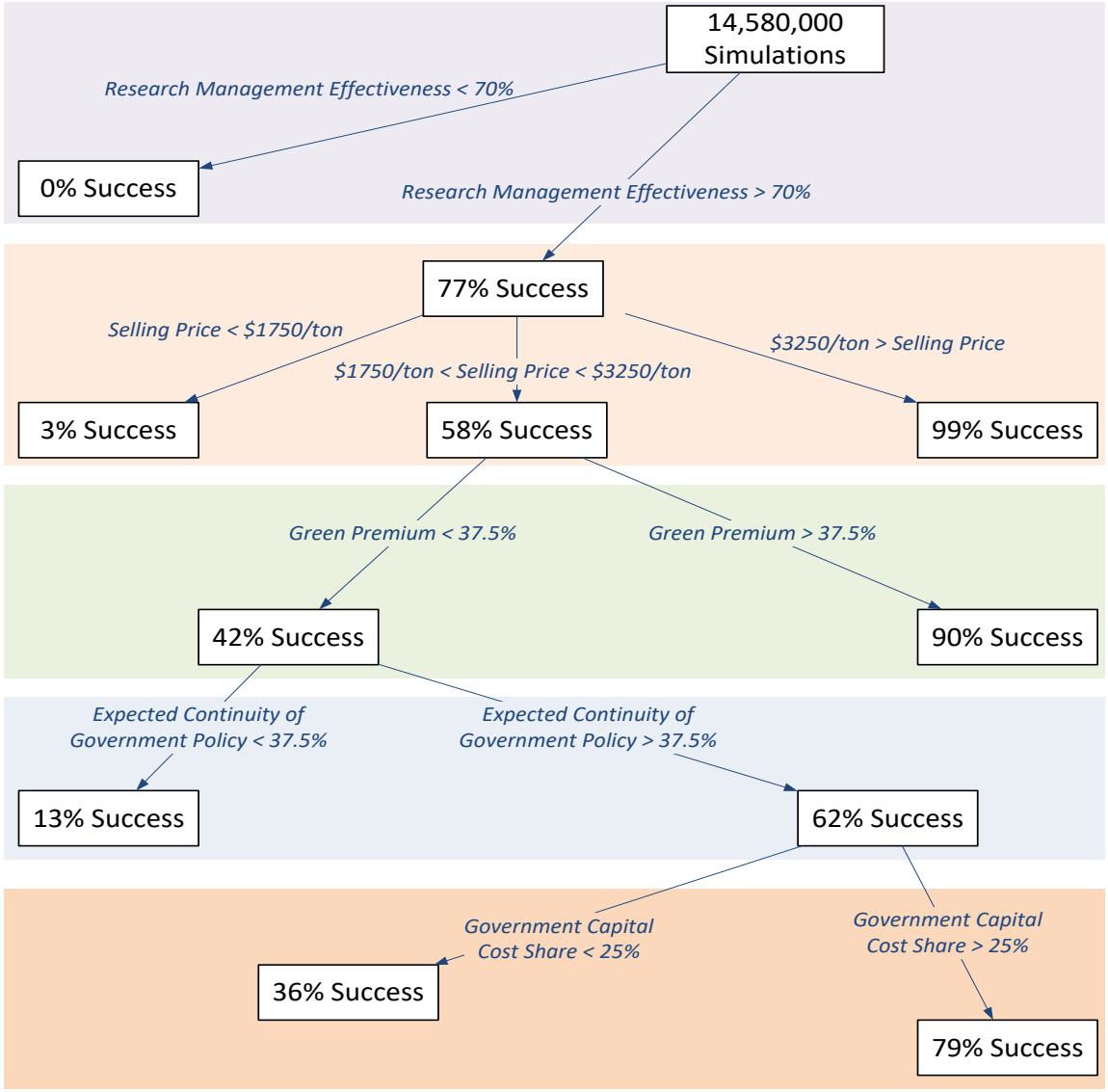
Results: Success Likelihoods

- The *interaction* of grants and policy continuity is more impactful than either alone
- Bioproduct selling price and expected green premium are good predictors of success

☹ Predominantly Unsuccessful

☺ Predominantly Successful

Results: Ranking Factors by Impact

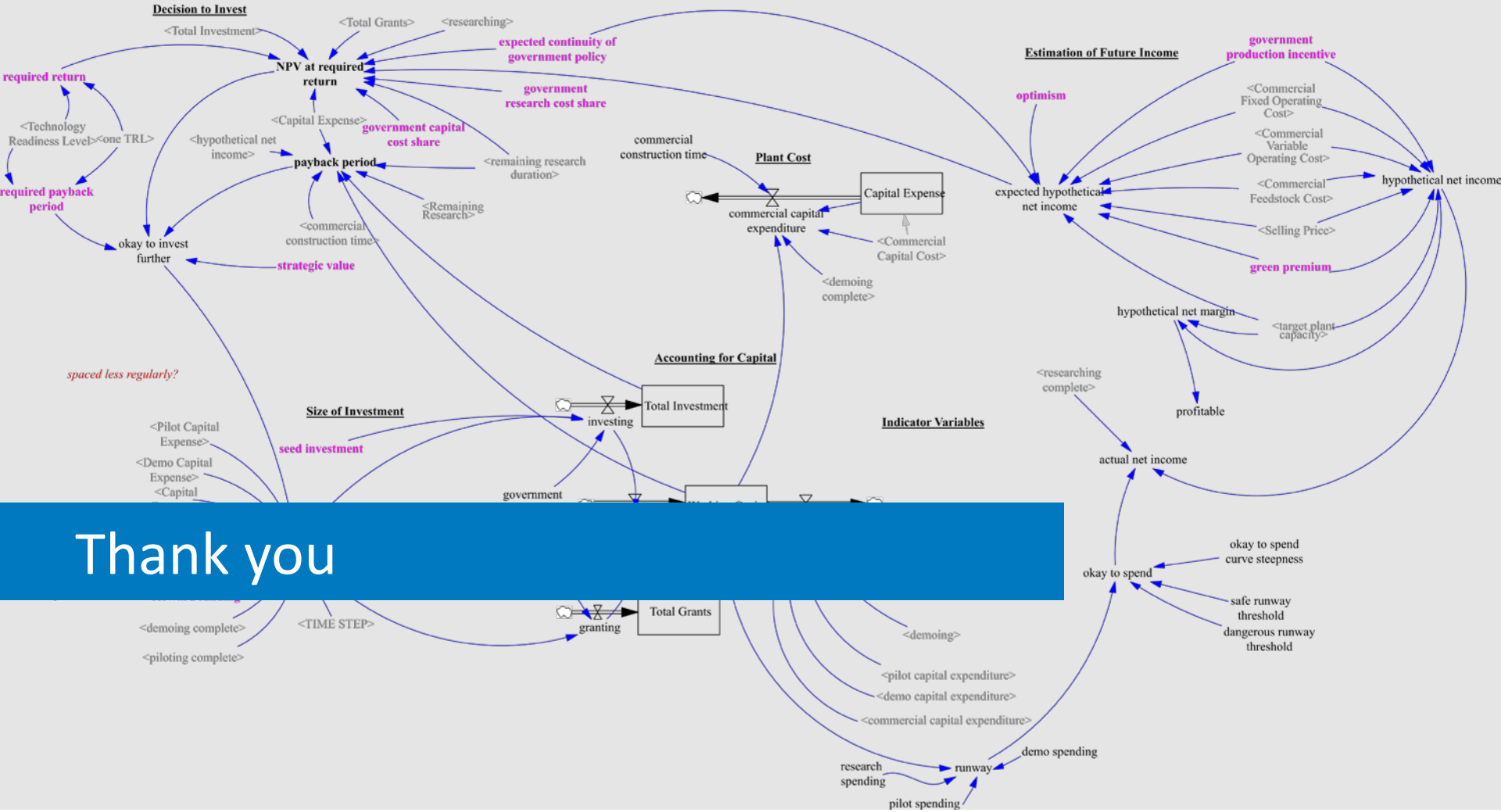


- Factors explored during the sensitivity analysis are ranked by their impact on the success likelihood
- Research management effectiveness was found to be the most impactful factor of those explored

Wrap-up and Next Steps

The Bioproduct Transition Dynamics model captures the bioproduct technology development process from basic research through commercial production, including interactions between developers and investors.

- BTD workshop will be held July 16, 2018
- An NREL technical report will be released in FY18, with the potential for additional publications
- BTD development, including implementing suggestions from the workshop, and model validation will continue in FY19.



Thank you

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