Mad Max, Star Trek, Big Brother, or Ecotopia: The Role of PSE in Enabling Future Scenarios

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2040 Visions of Process Systems Engineering
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Alternate Worldviews: Technological Optimist

Technological Optimist

- Technology will find solutions to all problems facing humanity
  - No resource constraints
  - No environmental challenges
- Innovation and progress are encouraged by competition
  - The free market, as practiced today, is able to find appropriate solutions and is the guiding principle
- Current engineering paradigm of dominating and controlling nature is appropriate

Costanza, *Ecology and Society*, 2000

Alternate Worldviews: Technological Skeptic

Technological Skeptic

- Technological breakthroughs may never happen or may not happen soon enough to avoid many negative impacts
  - There are fundamental limits that cannot be overcome by human ingenuity
- Relies on human cooperation to devise goals and markets as one option for achieving the goals
- Current engineering paradigm needs to shift toward respecting nature by working within its limits

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Optimist or Skeptic?

- Which worldview should we adopt now for a better future?
- What role can PSE play in either worldview?

A **Star Trek** Future

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- Population keeps increasing
- We colonize outer space

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Visions of PSE

- PSE will enable automation, manufacturing in and of space colonies, geoengineering the climate, personalized medicine
- We may already be on this path

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This is a **sustainable** outcome

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Visions of PSE

- May need to rediscover PSE of the past!

This is an **unsustainable** outcome

An **Ecotopia** Future

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- Our activities stay within planetary boundaries
- Engineering respects and learns from nature

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Visions of PSE

- PSE expands to include ecosystems within its system boundary
- Engineering respects and learns from nature
- Manufacturing operates with "net positive impact"

This is a **sustainable** outcome

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- Environmental taxes are unnecessary
- Respecting nature's limits is constraining
- Economic growth is slower than it could have been

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Visions of PSE

- PSE will be needed to move toward the Star Trek future

This is a **sustainable** outcome

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Current World View & Policies	Real State of the World: Optimists right	Real State of the World: Skeptics right
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Current World View & Policies	**Technological Optimist**	Star Trek	Mad Max
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- The technological skeptic world view is a safer bet

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Current World View & Policies	Real State of the World: Optimists right	Real State of the World: Skeptics right
Technological Optimist	Star Trek	Mad Max
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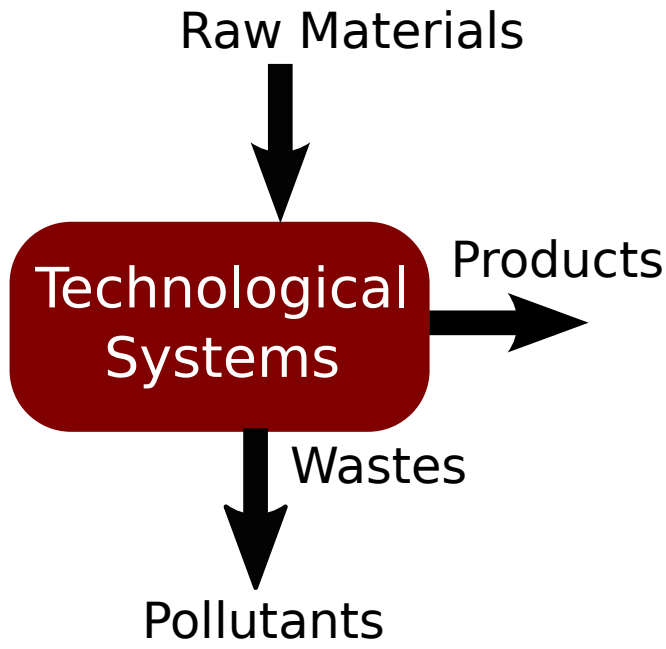
- The technological skeptic world view is a safer bet
- 2040 Visions of PSE for the technological skeptic
  - Shift engineering paradigm to respect and learn from nature
  - Expand engineering to include ecosystems within its system boundary
  - Operate manufacturing with "net positive impact"

Toward Techno-Ecological Synergy



- Eco-efficiency, life cycle design

Bakshi, Ziv, Lepech, *Env. Sci. Technol.*, 2015

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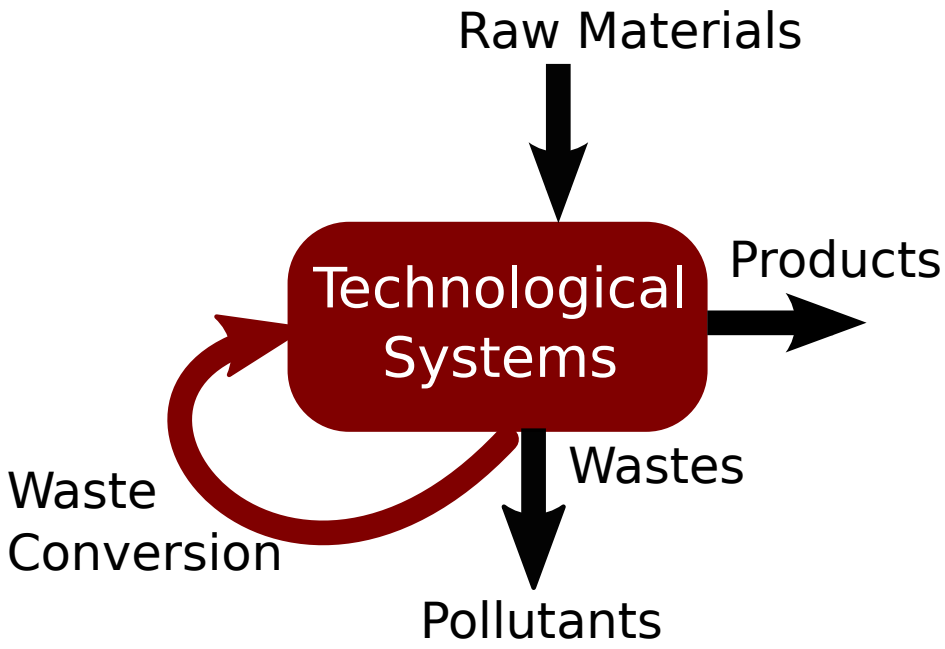

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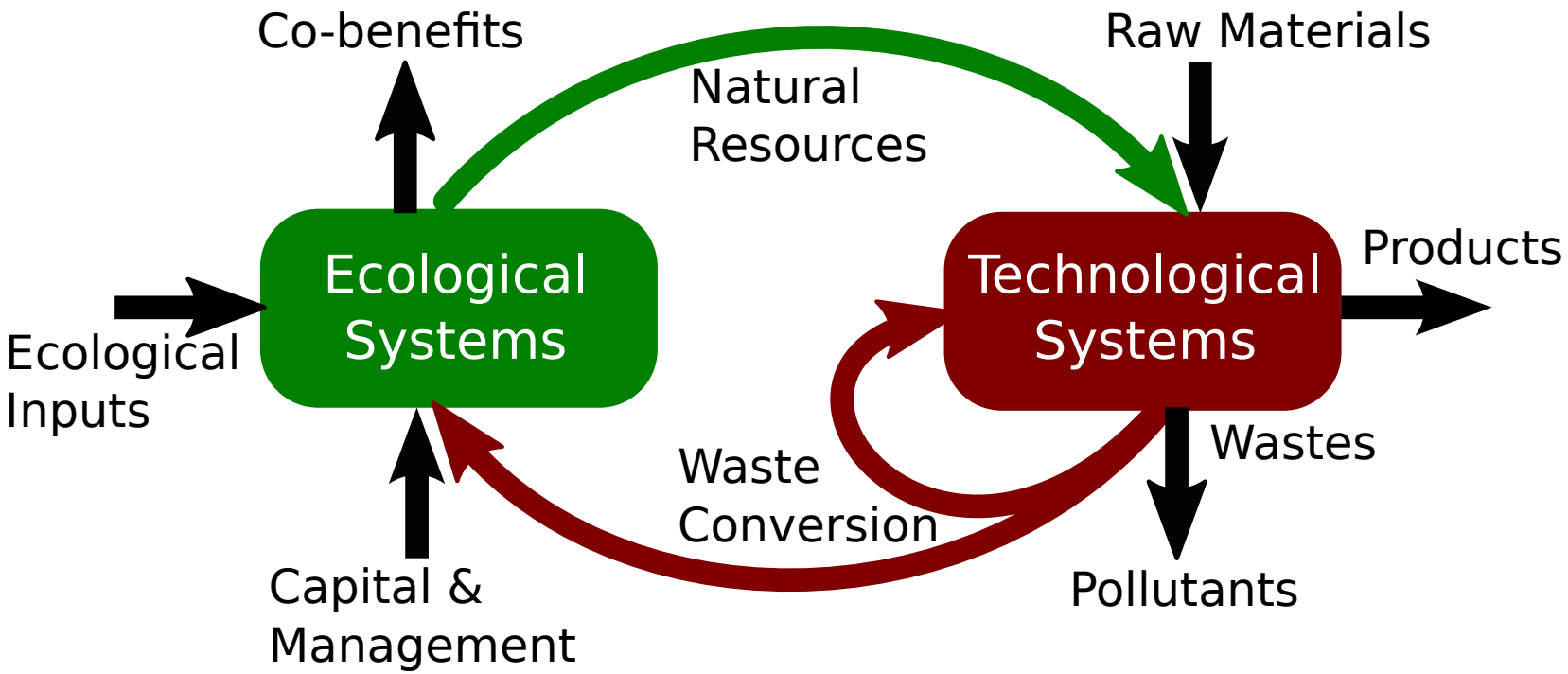

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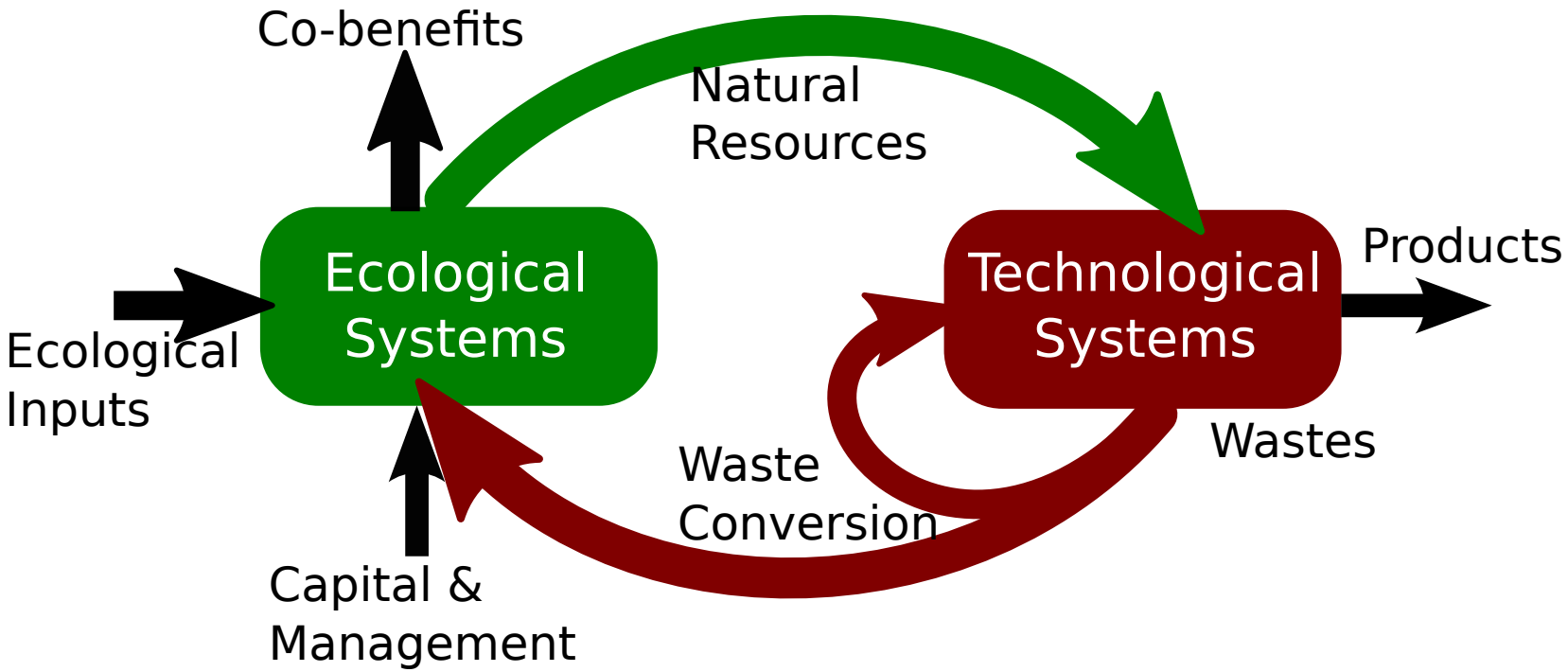

- Eco-efficiency, life cycle design
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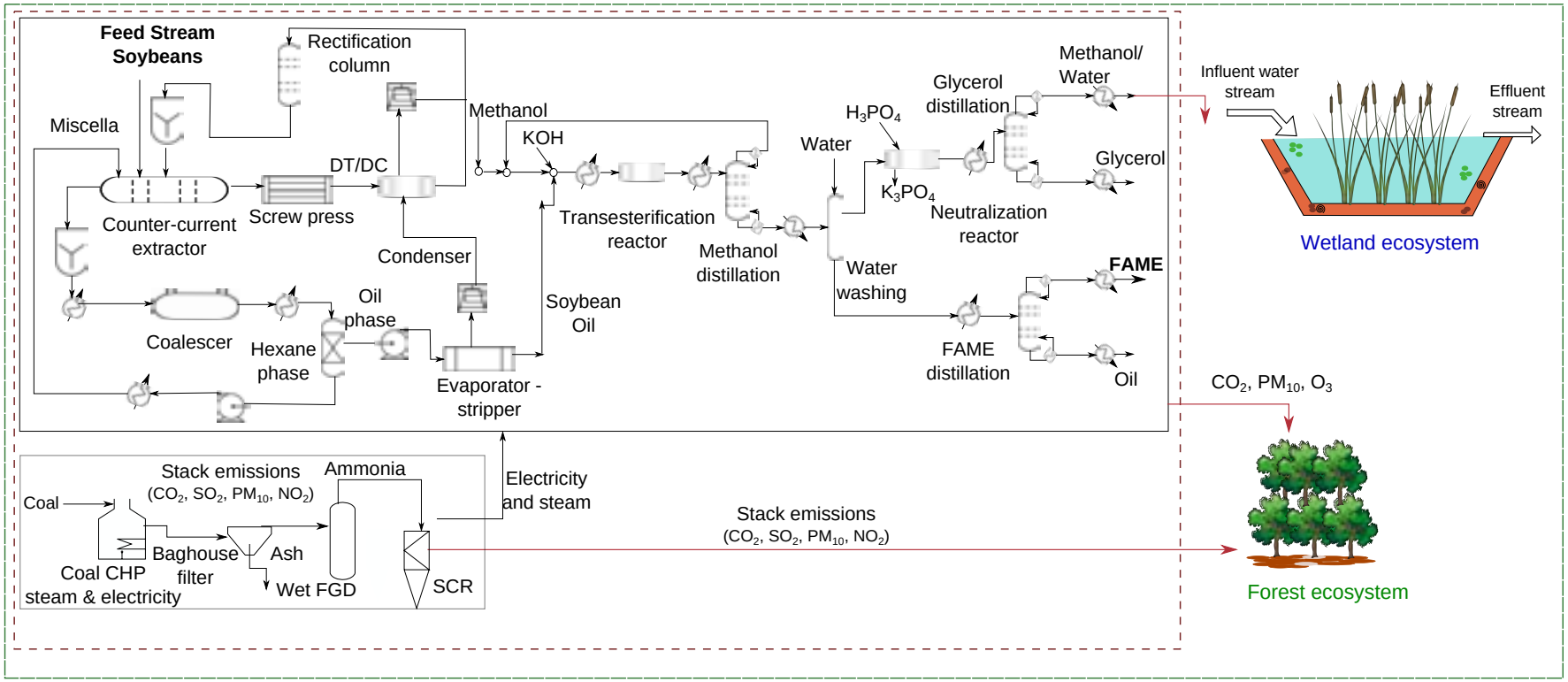
- Techno-ecological synergy
- Sustainable TES

Bakshi, Ziv, Lepech, *Env. Sci. Technol.*, 2015

Process Design with Ecosystems as Unit Operations

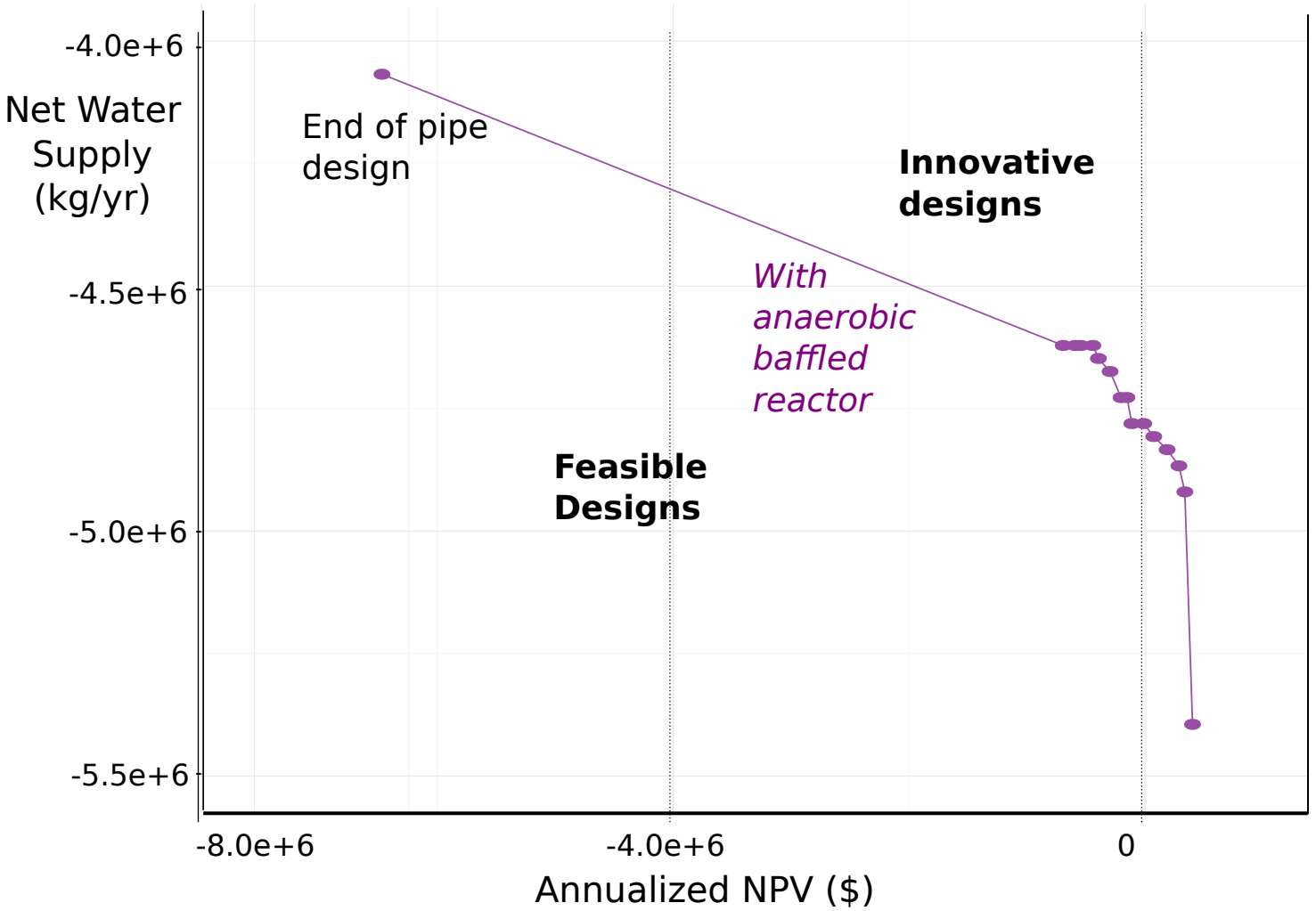


Do local ecosystems have enough capacity to supply goods and services to biodiesel manufacturing?

Biodiesel Manufacturing Site

Gopalakrishnan, Bakshi, Ziv, *AIChE J.*, 2016

TES Design of Biodiesel Process with Wetlands



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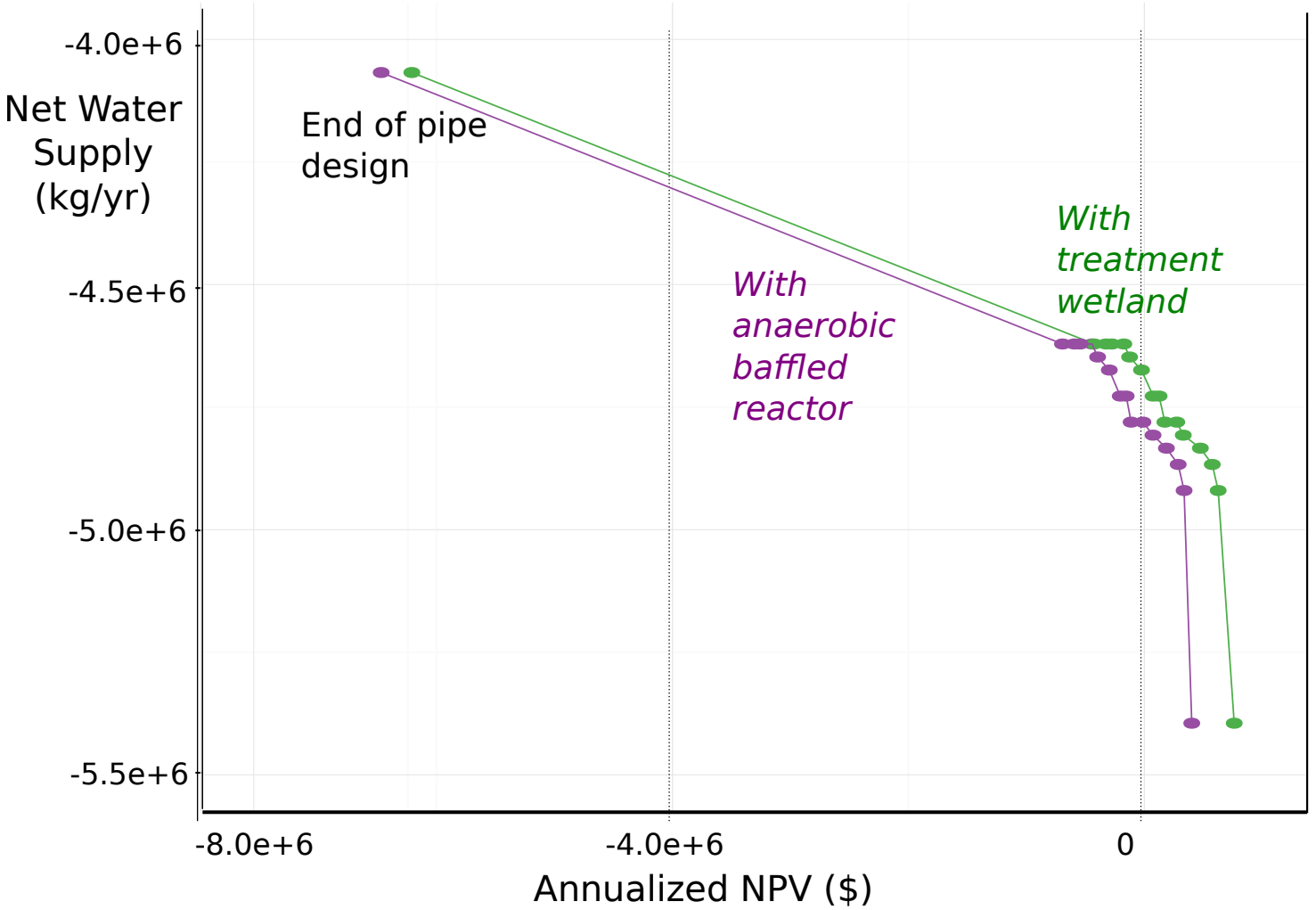

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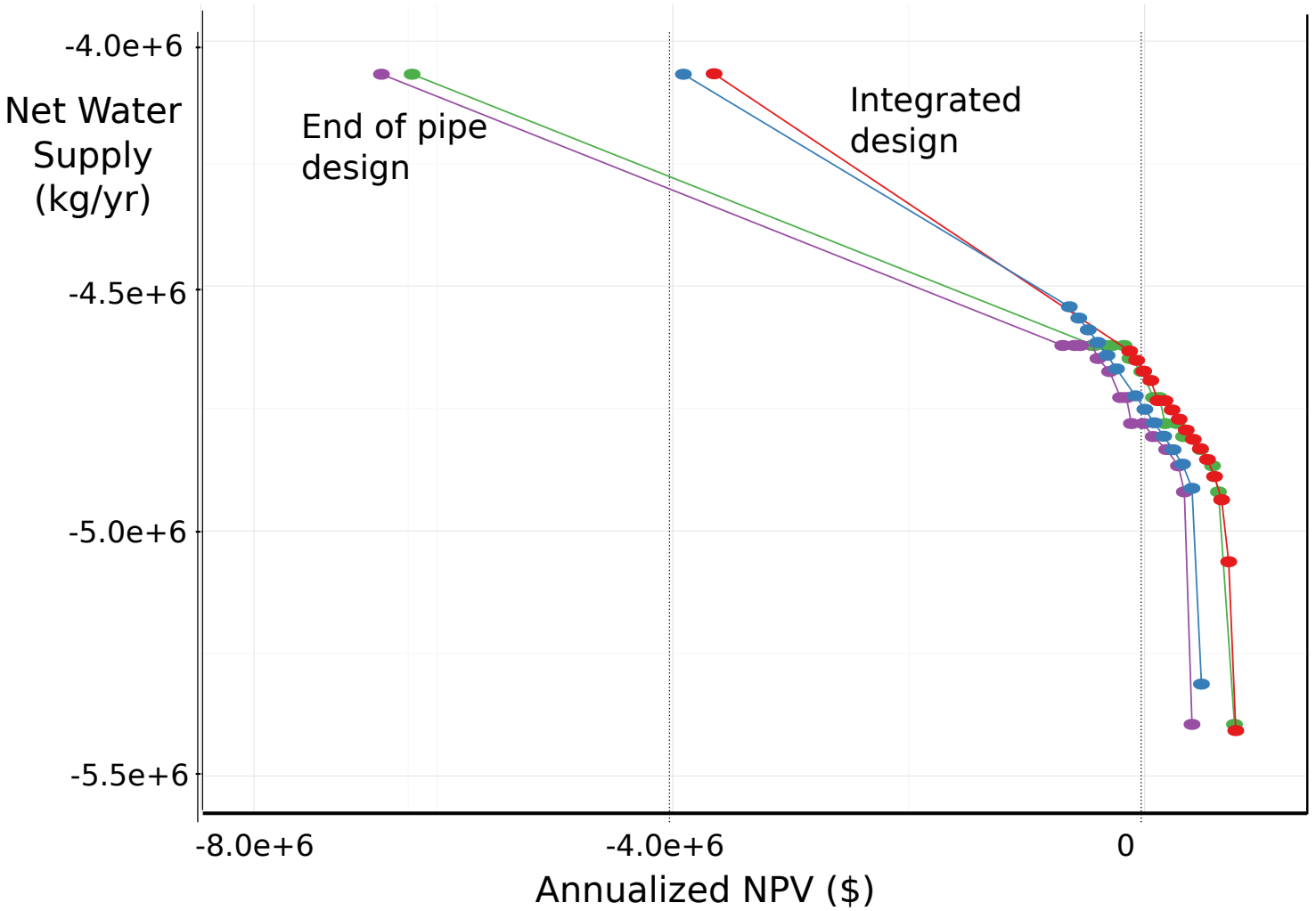
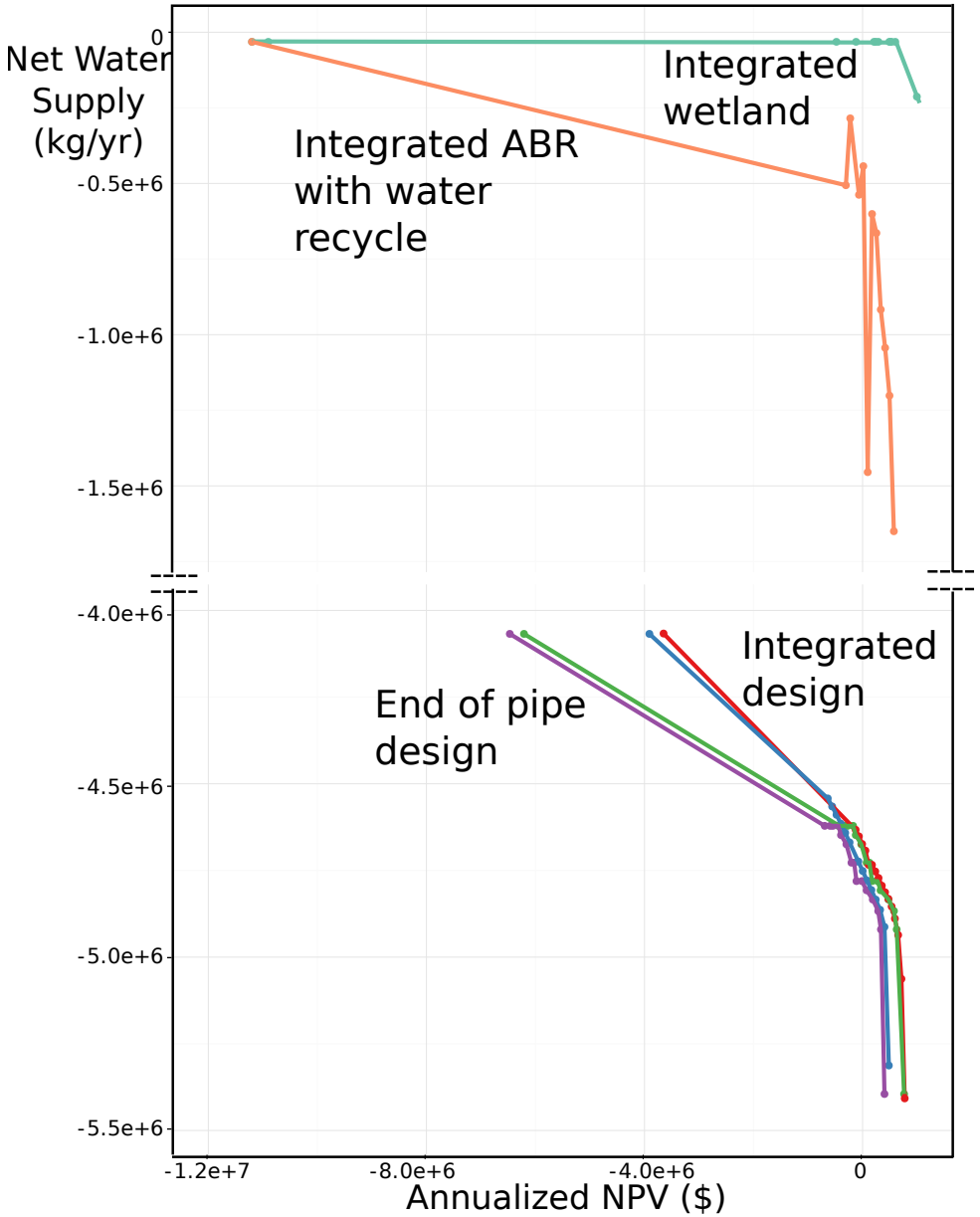
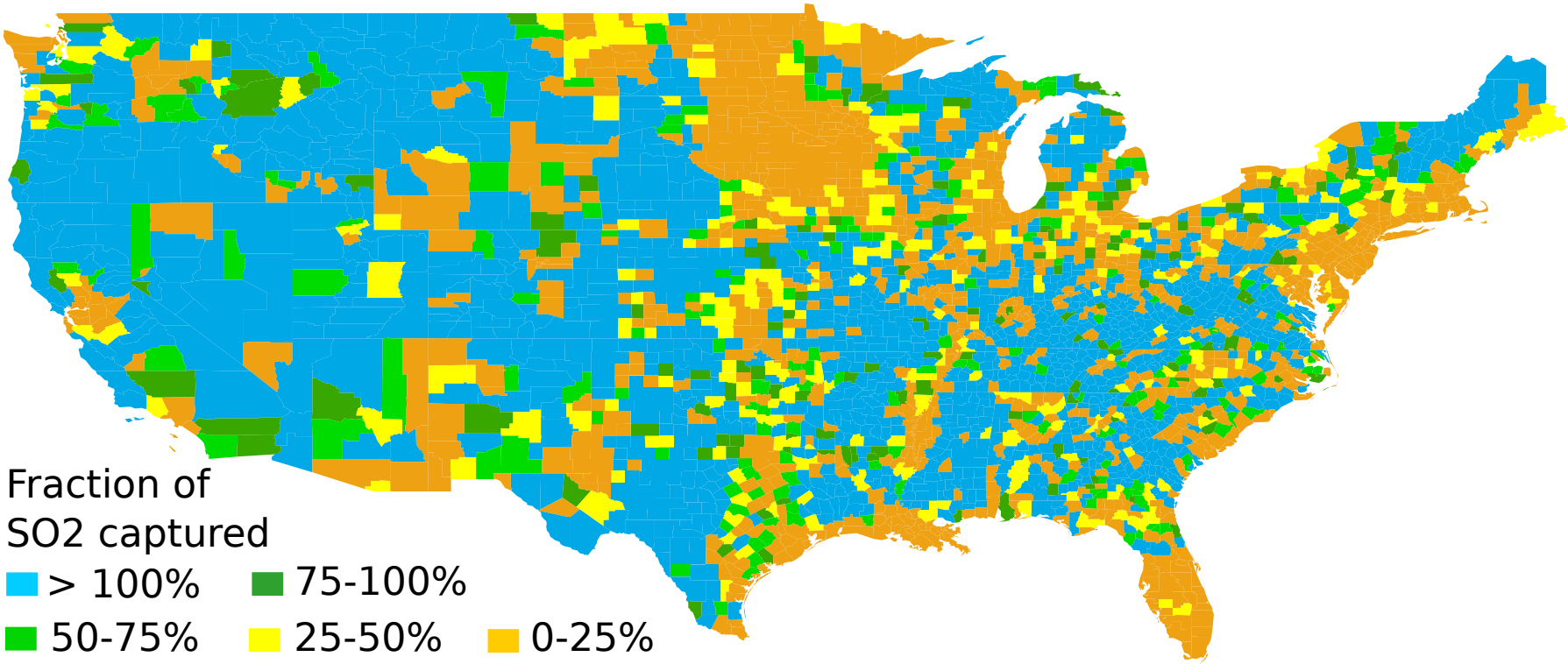


TES Design with Water Recycle



- Integrated design of biodiesel process with wetlands and feedback of water results in new "win-win" designs
- Including vegetation along with wetlands results in further improvement

TES Across the United States: Air Quality Regulation



- Fraction of SO_2 emissions taken up by current vegetation

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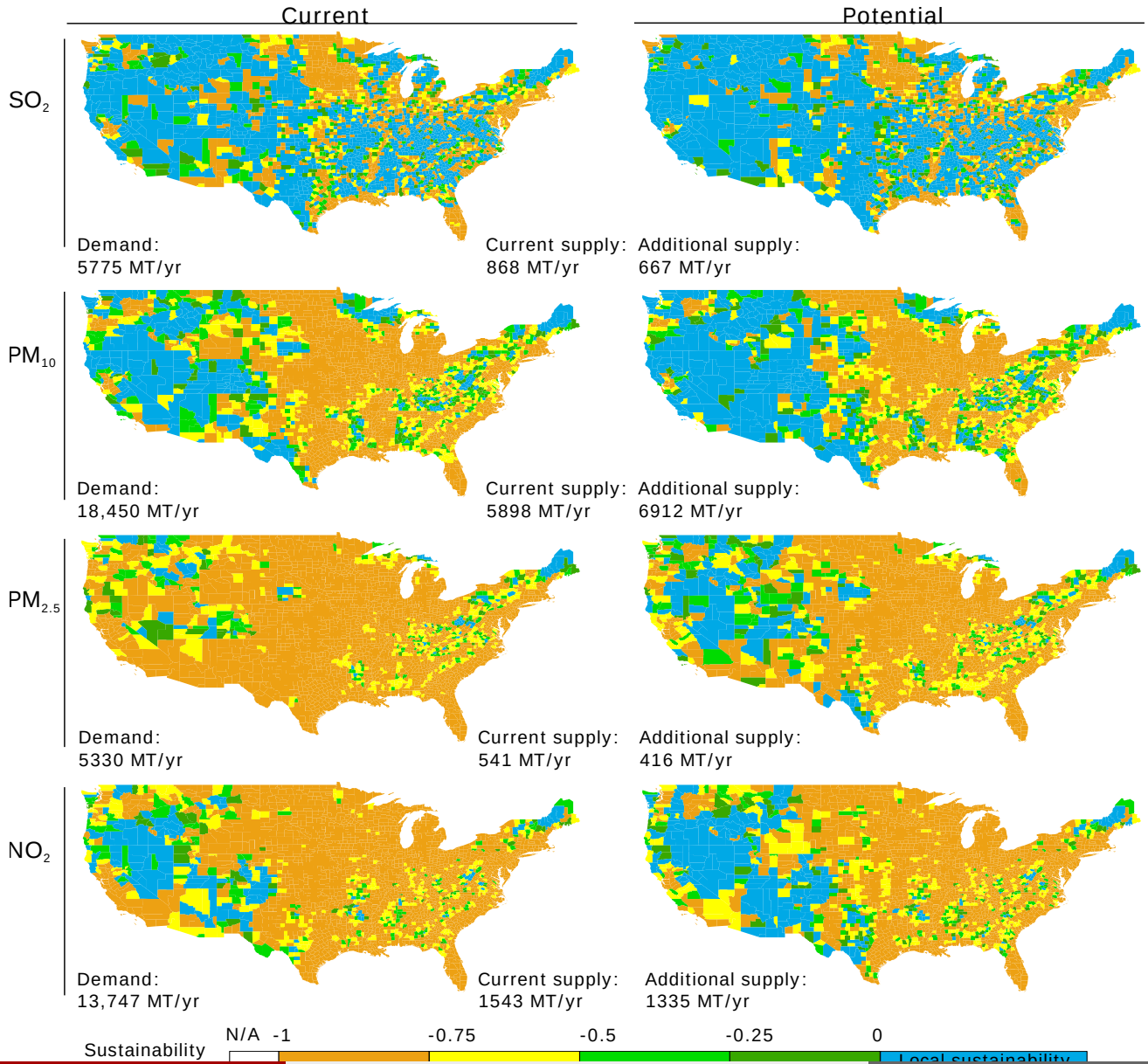

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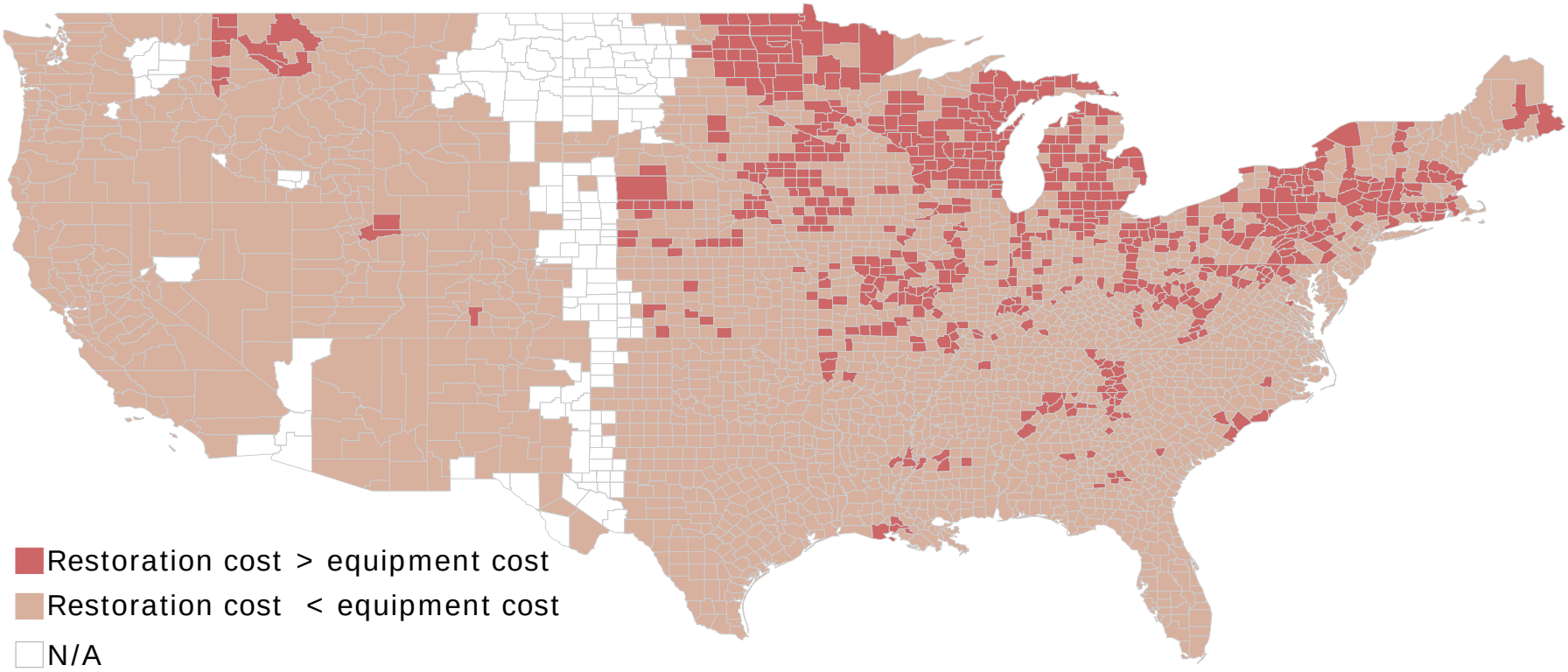

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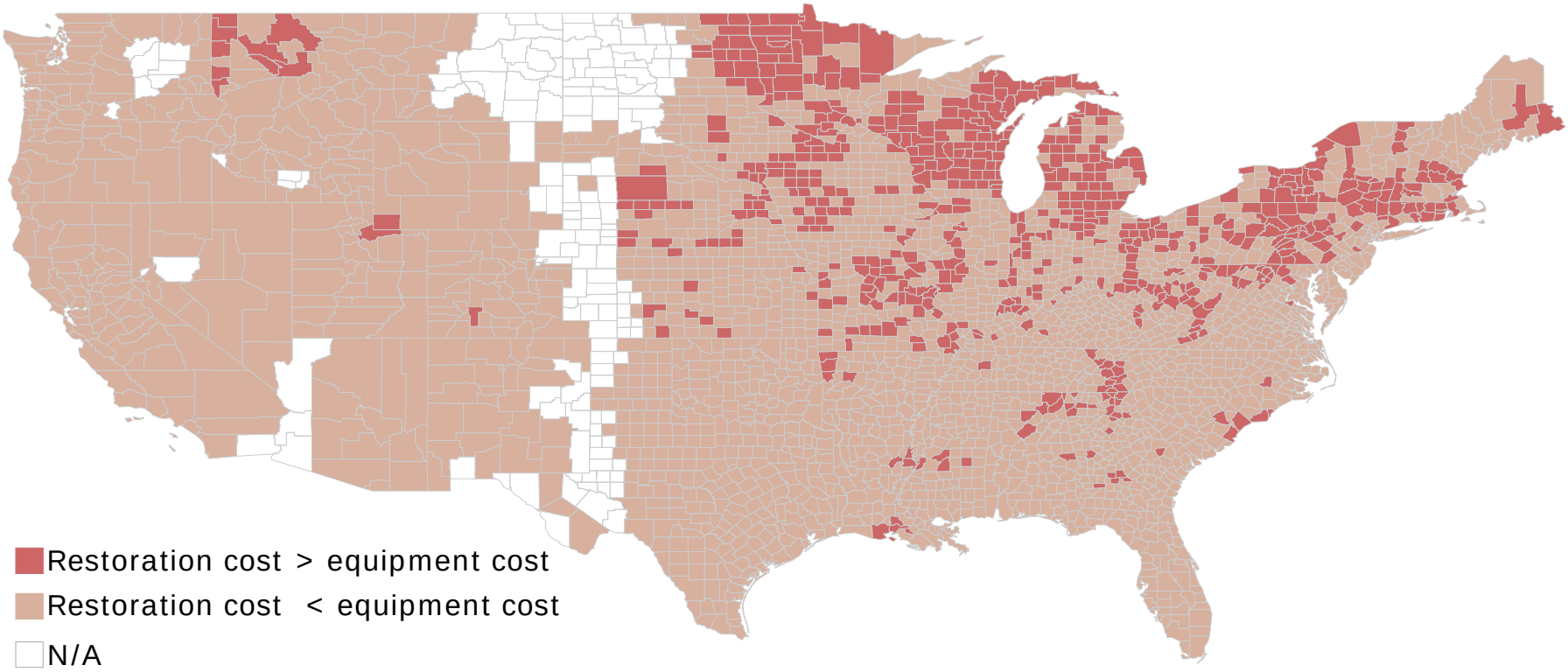
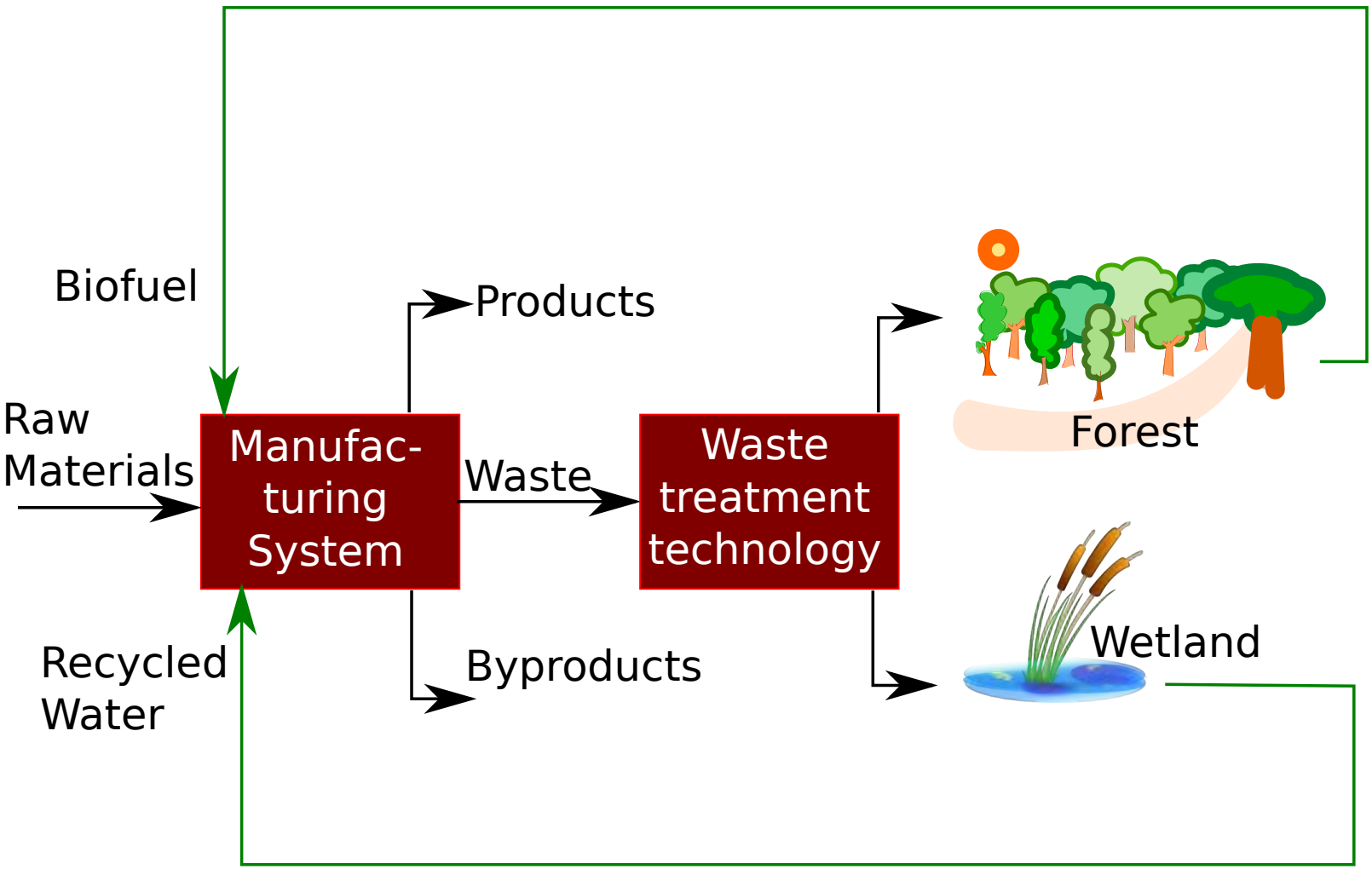


- Vegetation can capture significant fraction of air emissions
- Ecosystem restoration is less expensive than technology for majority of counties
- Can identify sectors that are "low hanging fruit" for policy makers

Dynamics and Control of TES



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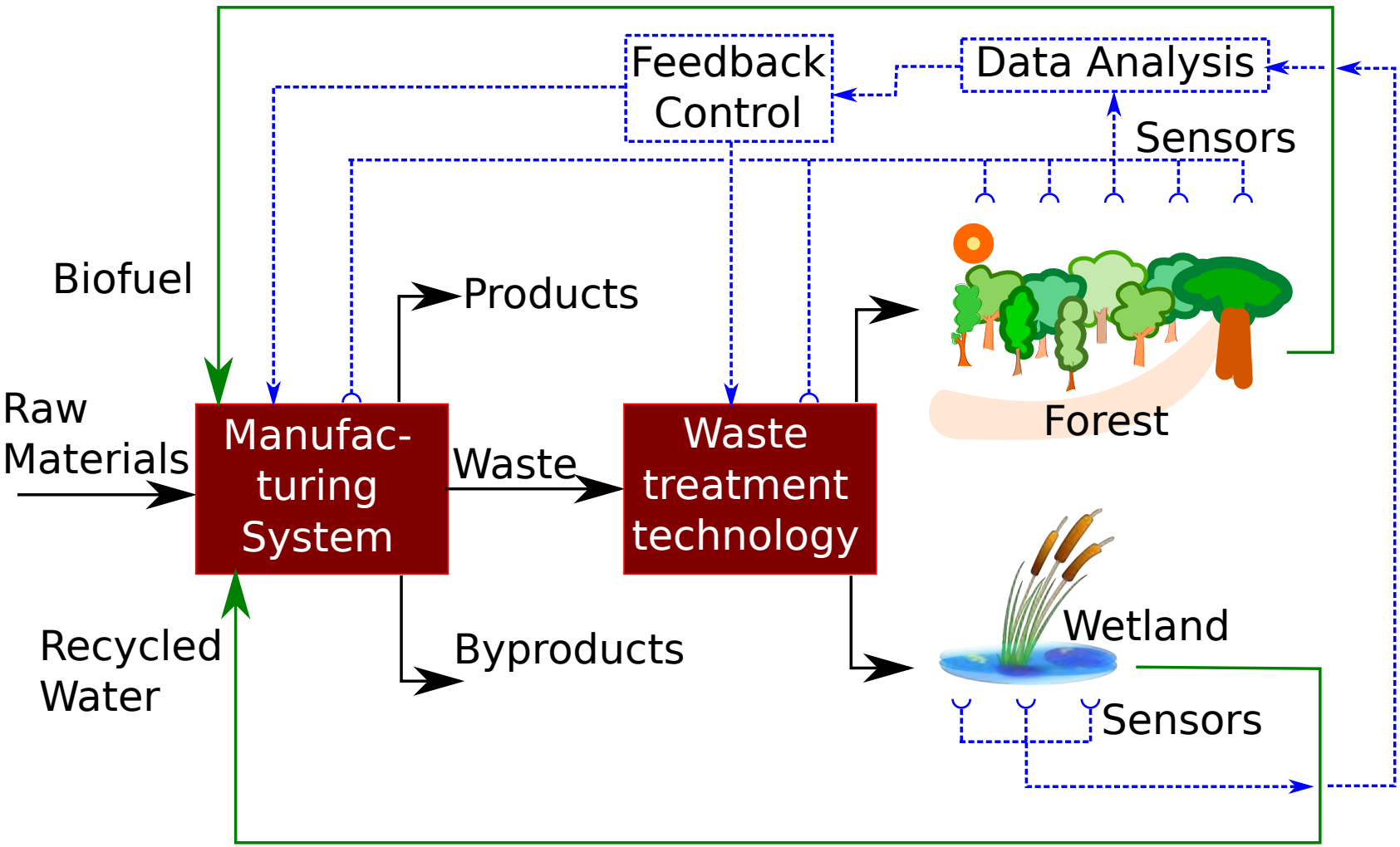
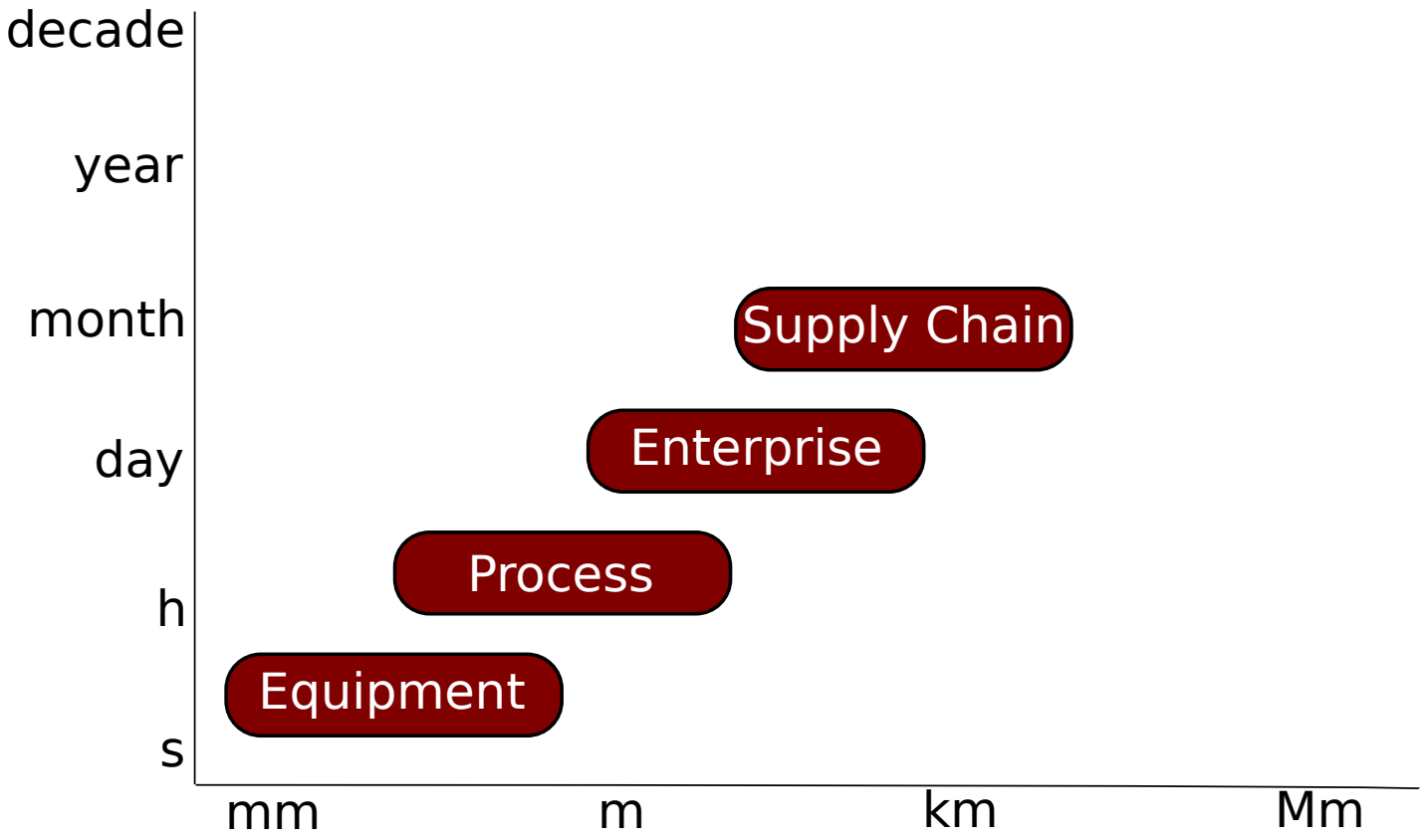


TES at Multiple Scales



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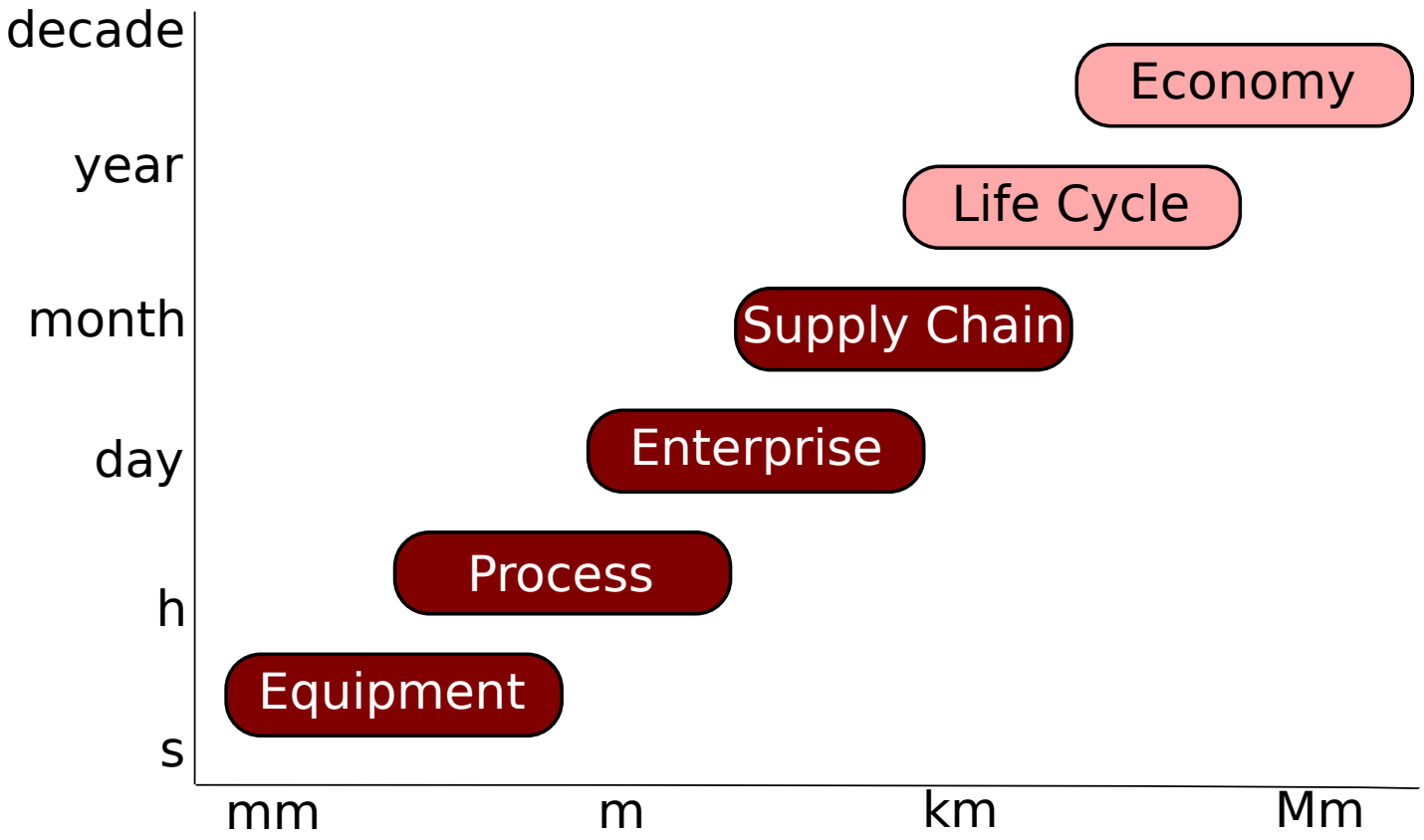

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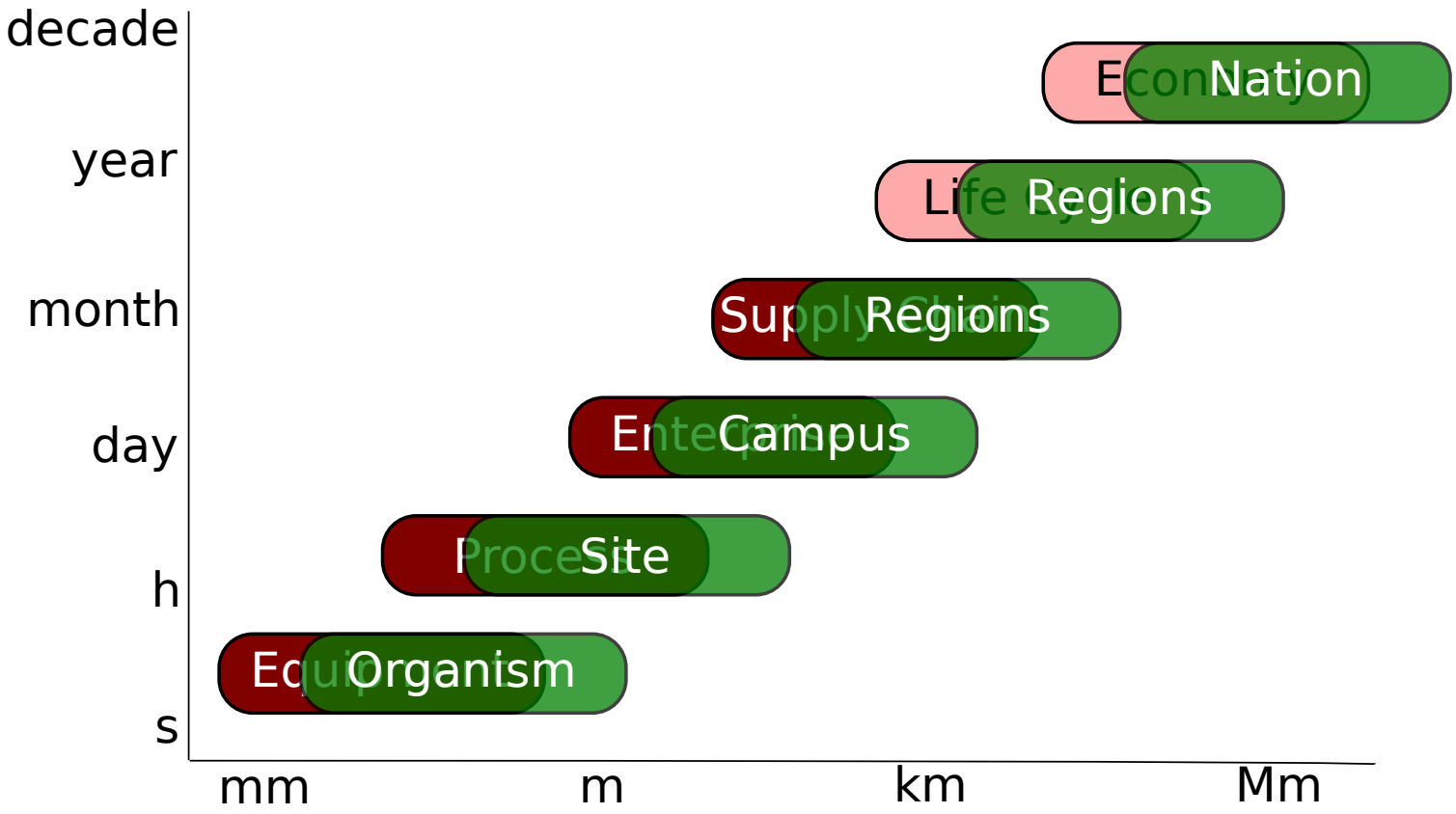

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Human Attitude and Behavior

- Consider socio-ecological-technological system

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2040 Vision of PSE

PSE enables engineering that functions in synergy with nature

Salute to my Guru

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Guru is verily the representative of
Brahma, Vishnu, Shiva.
He creates, sustains knowledge, and
destroys the weeds of ignorance.
I salute such a Guru.

https://www.pinterest.com/pin/497858933788145694/