

National Research Council
Roundtable on Science and Technology for Sustainability
December 6, 2012

Considerations for Developing Sustainable and Resilient Energy Systems

Role of Natural Capital in Sustainability & Resilience

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Note: The content of this presentation
reflects the views of the author and
does not represent the policies or
position of the U.S. EPA.

Urgent Questions

- Can we trust our predictive capabilities in a tightly-coupled, complex, and turbulent world?
- How can the current “risk-based” paradigm be extended to address “inherent” resilience?
- When does pursuit of resilience support or conflict with sustainability goals?
- How can the public and private sectors adopt a more “adaptive” approach to decision making?
- Can we develop a new generation of analytic tools based on “systems thinking” that are suitable for the “new normal”?

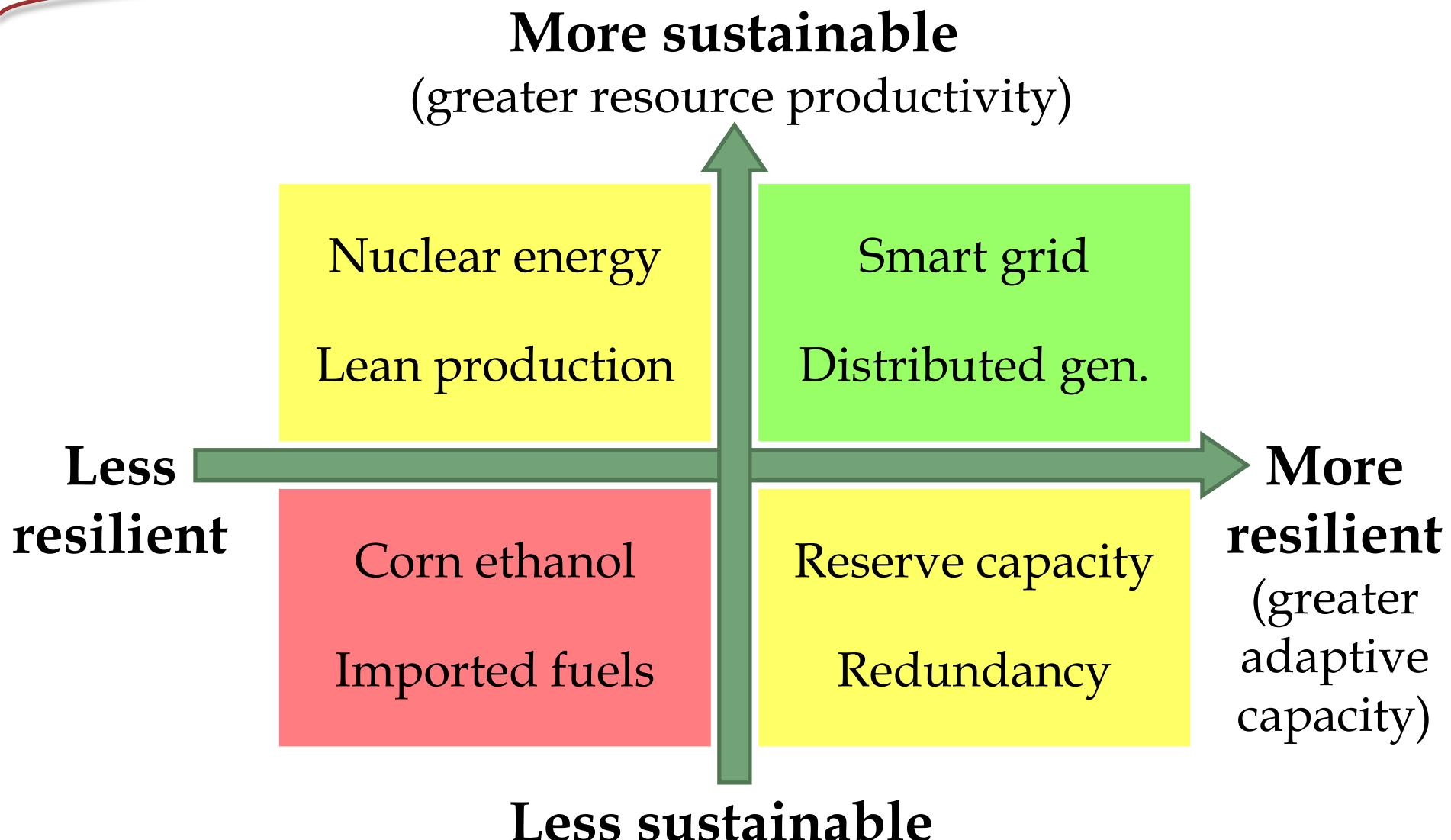
Sustainability and Resilience

- **Sustainability** is the capacity for long-term realization of human health and well being, economic prosperity, & environmental protection
 - However, **unforeseen** conditions can lead to unintended and/or undesired consequences
- **Resilience** is the capacity to survive, adapt, and flourish in the face of changing conditions and potential disruptions (assuring continuity)
 - Dispersion, diversity, foresight, agility, redundancy, flexibility, simplicity, buffering, adaptability, etc.
- In a complex and turbulent world, resilience is a **prerequisite** for realization of sustainability goals

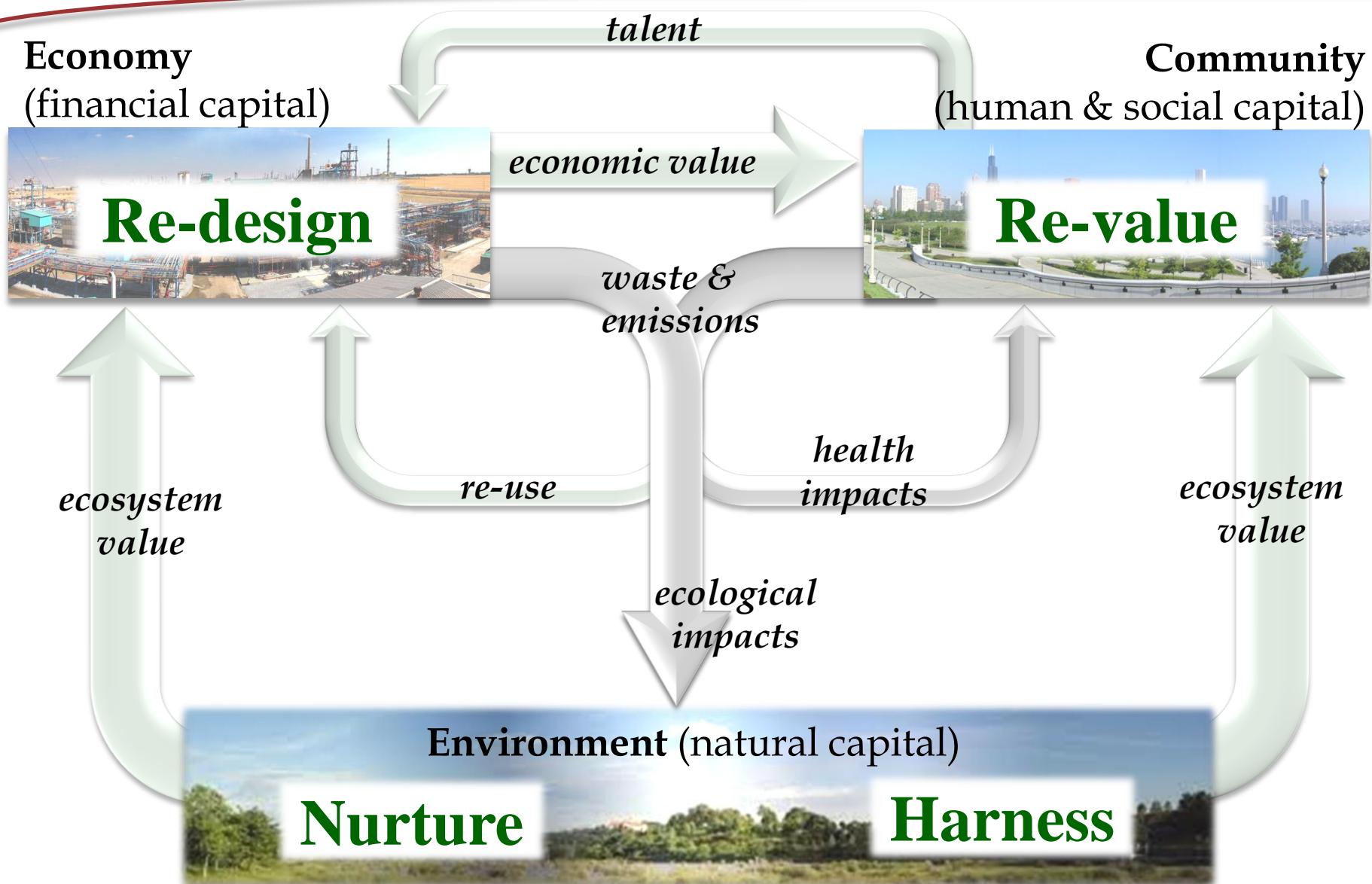
Principles of System Resilience

1. Resilience, i.e., adaptive capacity, is an intrinsic characteristic of all self-organizing systems.
2. Resilience is manifested in a system's response to gradual changes or sudden disruptions.
3. The resilience of a system is influenced by its components or subsystems and its environment.
4. The resilience of a system is influenced by cycles of change at different temporal and spatial scales.
5. Indicators of relative resilience can be defined for a specific category of systems.
6. The resilience of a system can be enhanced even without foresight about potential disruptions.
7. Resilience is necessary, but not sufficient, for long-term sustainability of a system.

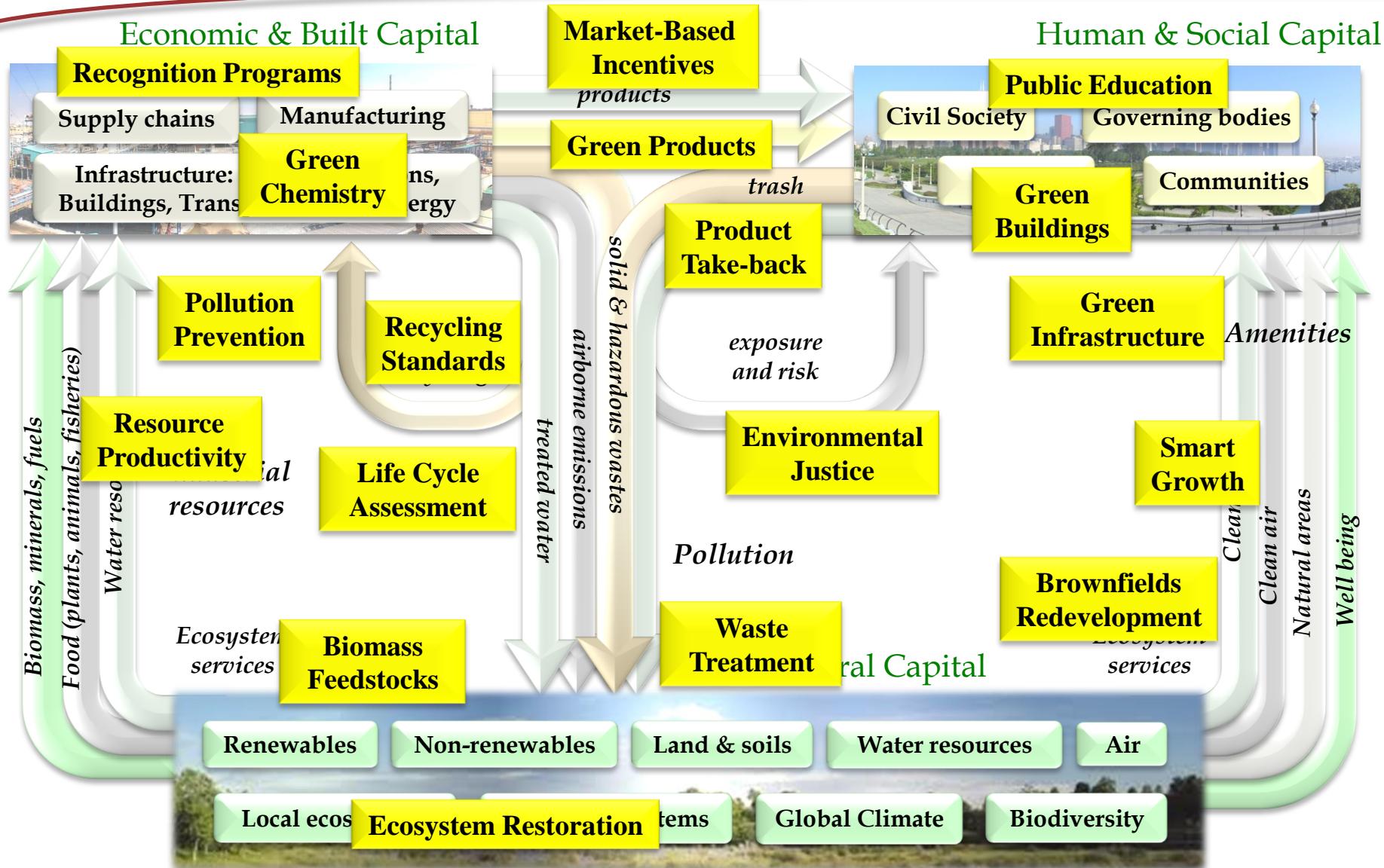
Resilience vs. Sustainability: Examples of Synergies and Trade-offs



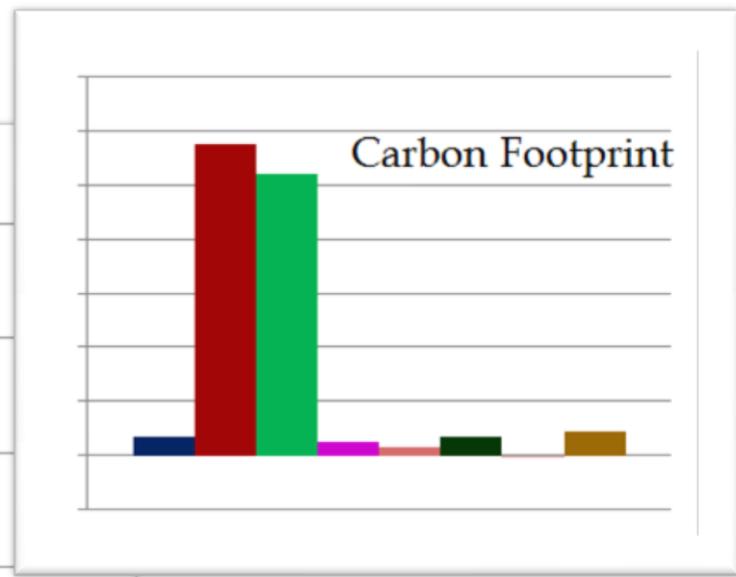
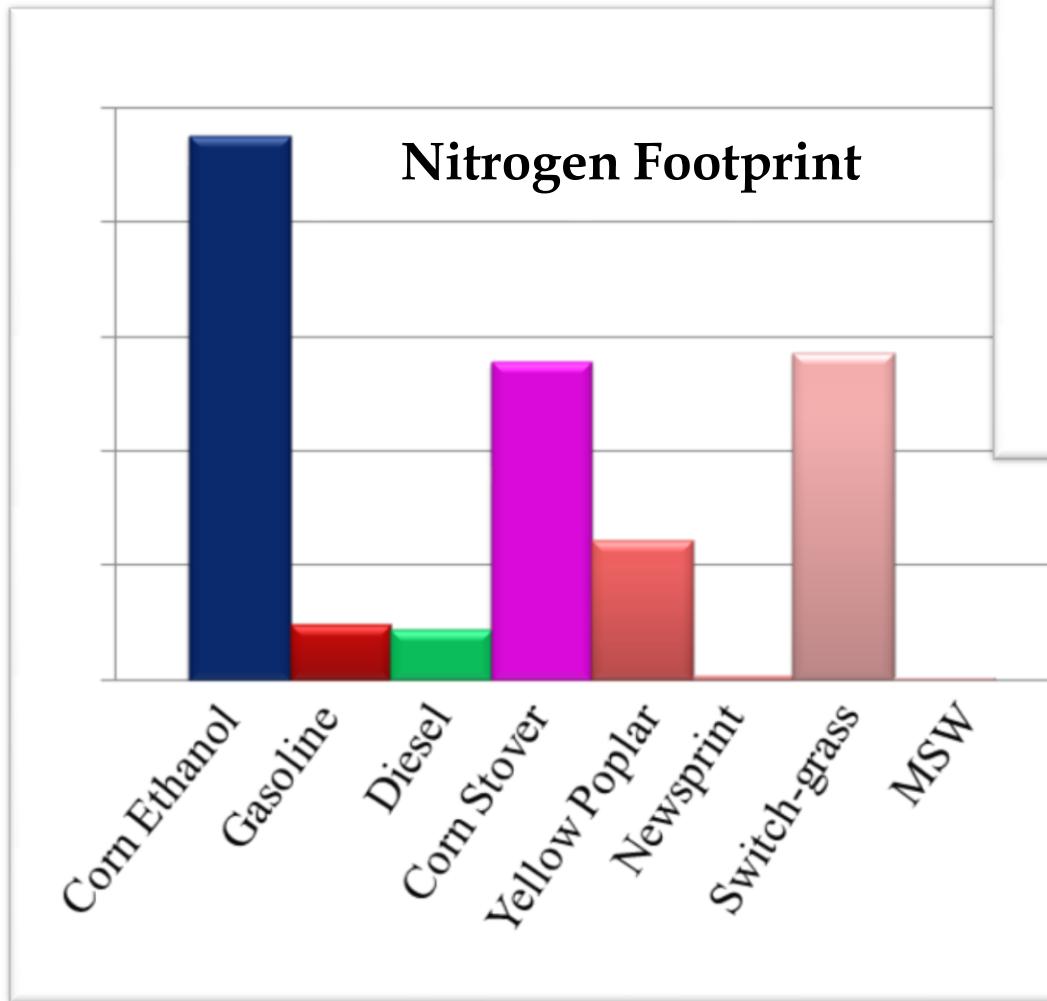
Systems View: Triple Value Model



Principal Stocks and Flows and Beneficial Policy Interventions



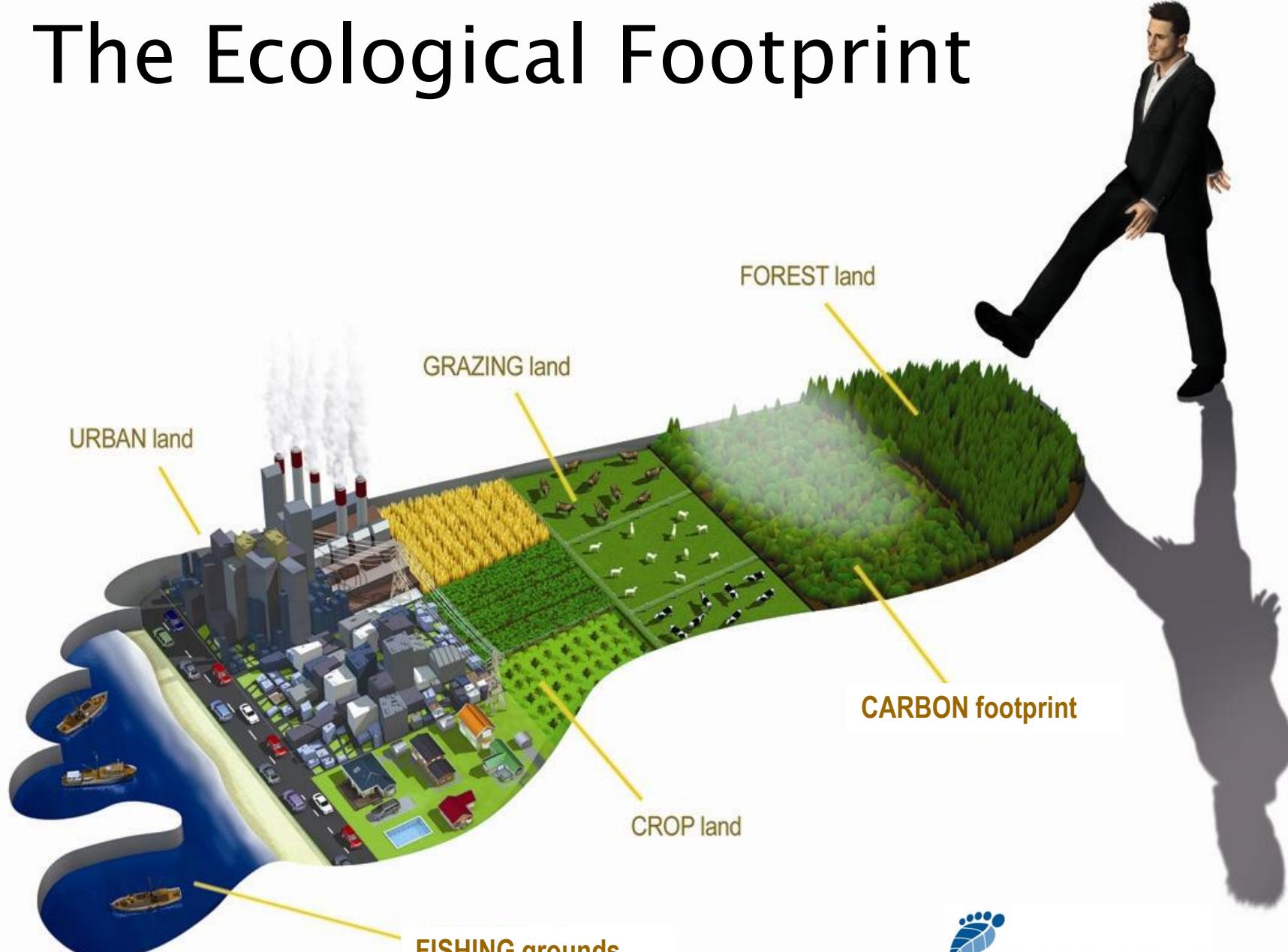
Example: The Carbon-Nitrogen Nexus



Life-cycle
footprints of
emissions for
selected biofuels
(kg/km)

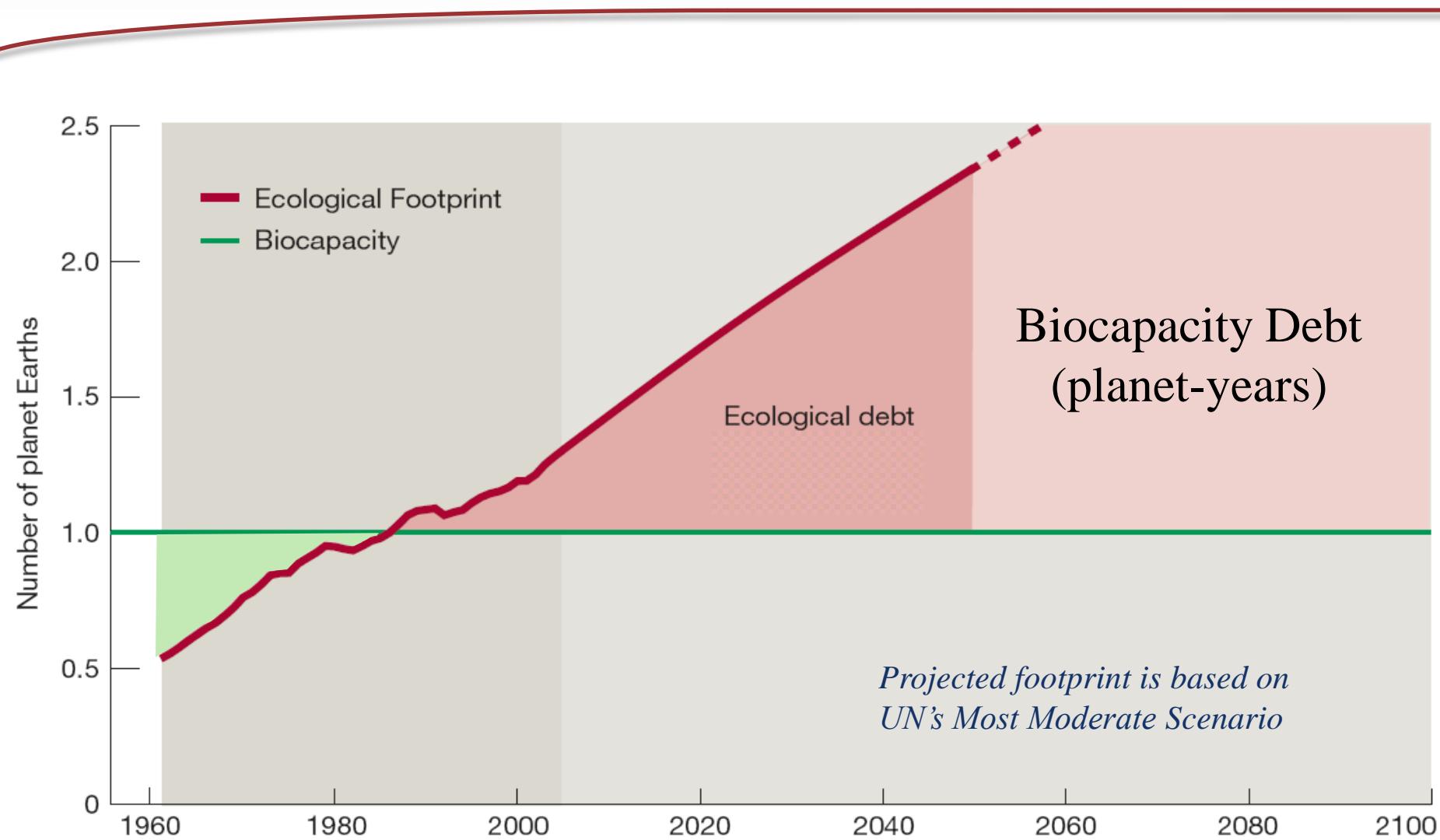
Source: B. Bakshi, OSU

The Ecological Footprint



Global Footprint Network
Advancing the Science of Sustainability

Projected Natural Capital Deficit



*Projected footprint is based on
UN's Most Moderate Scenario*

Example: EPA's Integrated Model for Nutrient Mitigation in New England

Narragansett Bay Sustainability Management

Scenario Setup

Assumptions

Interventions--

- 1. Wastewater
- 2. Animal
- 3. Fertilizer
- 4. Low Impact Development
- 5. Atmospheric Deposition

Wastewater Treatment Unit Capital Cost
0.525 US\$ / KG

Nitrogen Removal Unit Cost
20.77 US\$ / KG N

Average Precipitation

Effect of Algal Bloom on Eelgrass Decrease

Scenario 2

Industry

Tourism Value Added Nitrogen Removal Cost

Agriculture Production Fisheries Production

Absolute Change in GDP

US\$

Time (Year)

3.75 B
3.5 B
3.25 B
3 B

2020 2030 2040 2050

BaseCase Nitrogen removal

Society

Employment Beach Closings Total Population

Absolute Change in Per Capita Disposable Income

People

2.3 M
2.2 M
2.1 M
2 M

2020 2030 2040 2050

BaseCase Nitrogen removal

Environment

Development Land N Concentration in Water

Total N Loading Total Water Demand Relative Fish Stock

MGs/Year

10.5 M
10 M
9.5 M
9 M
8.5 M
8 M
7.5 M

2015 2020 2025 2030 2035 2040 2045 2050

BaseCase Nitrogen removal

products & services

water supply

runoff & wastewater

industrial & commercial uses

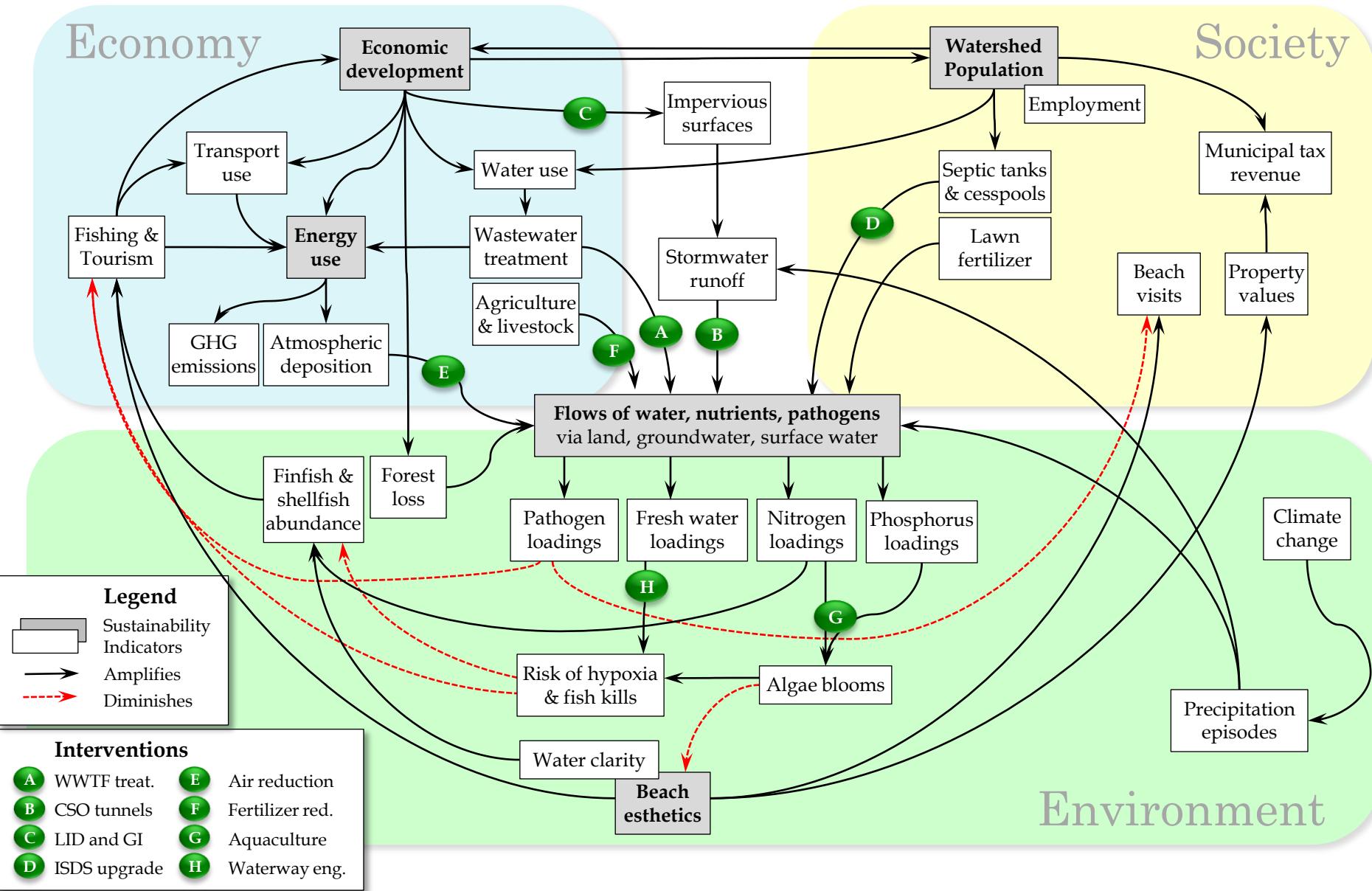
recreational & cultural uses

More Outputs

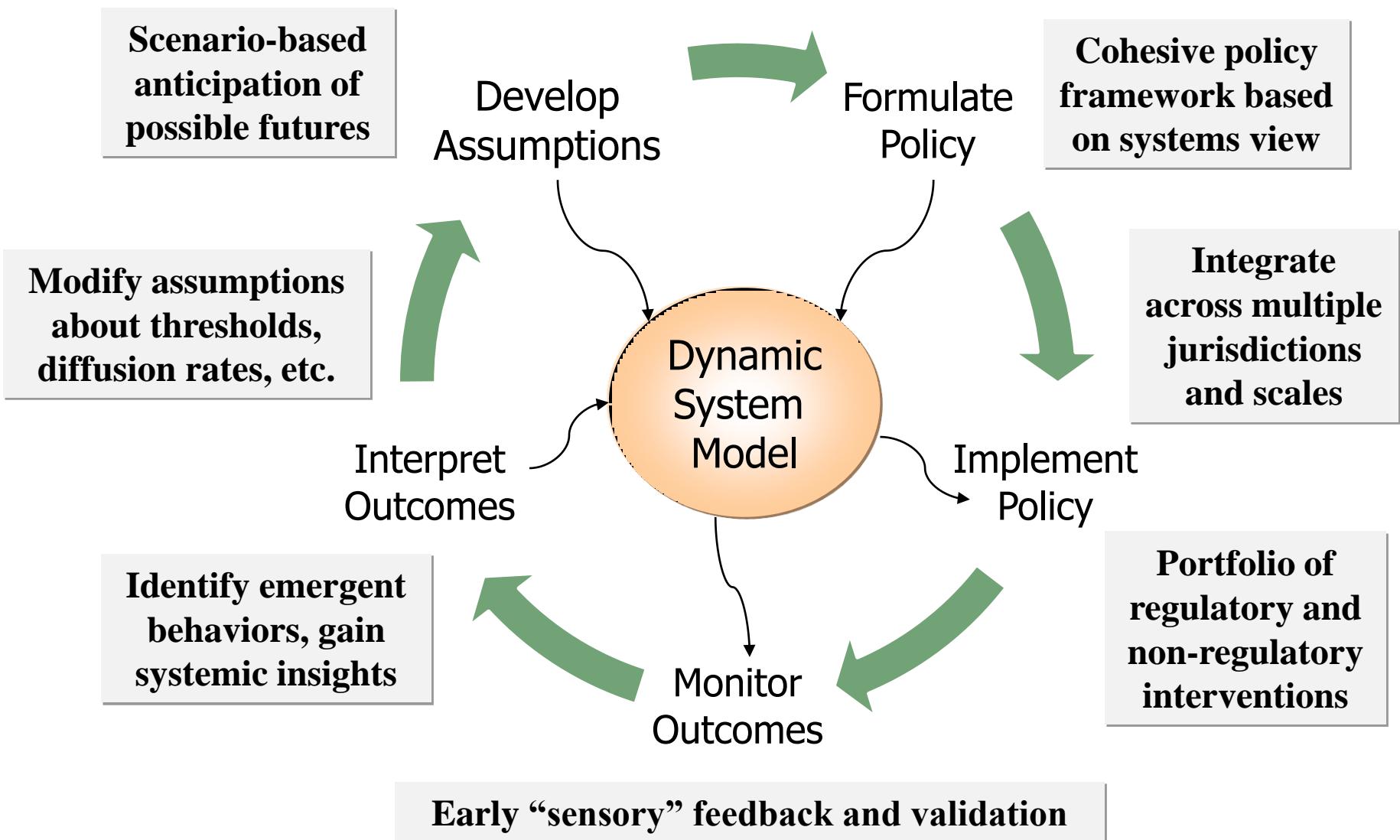
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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System Dynamics Model: Narragansett-3VS



Adaptive Approach to Public Policy



Waves of Innovation

Challenge	Response
Unintended environmental, health, or safety impacts over the product life cycle	Design for Environment (1990's)
Threat of resource scarcity and diminished opportunity for future generations	Design for Sustainability (2000's)
Complexity and turbulent change in global economic, social, & ecological systems	Design for Resilience

“...the widespread use of inherently resilient technologies for supplying energy, in conjunction with highly efficient energy use, can profoundly improve national security.”

Amory B. Lovins
and L. Hunter Lovins
Brittle Power, 1982



Thank You!



Resilience.OSU.edu