# Cape Cod Triple-Value Simulation

Applying System Dynamics Modeling to the Nutrient Pollution Problem on Cape Cod

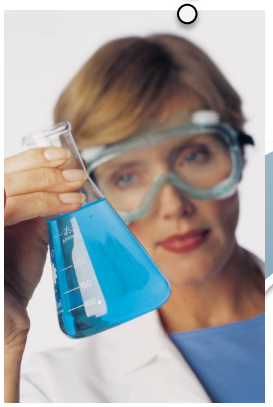
# Systems Thinking is a Sustainability Assessment Tool

# Systems Models Support Decision Making by Bridging Science, Policy, and Human Values

What do we know today, and what are the unknowns?

What are our goals and options?

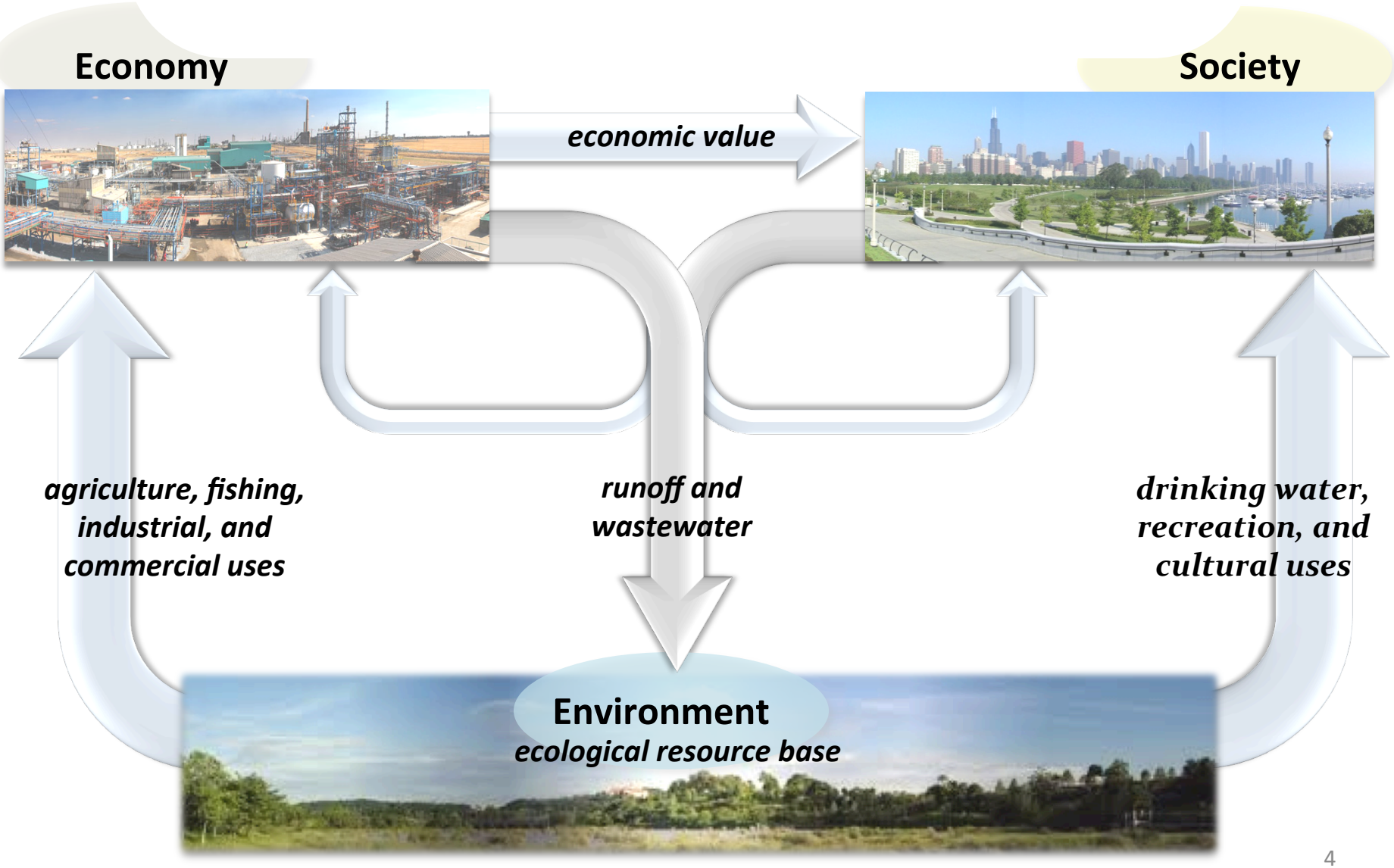
What do we care about most?



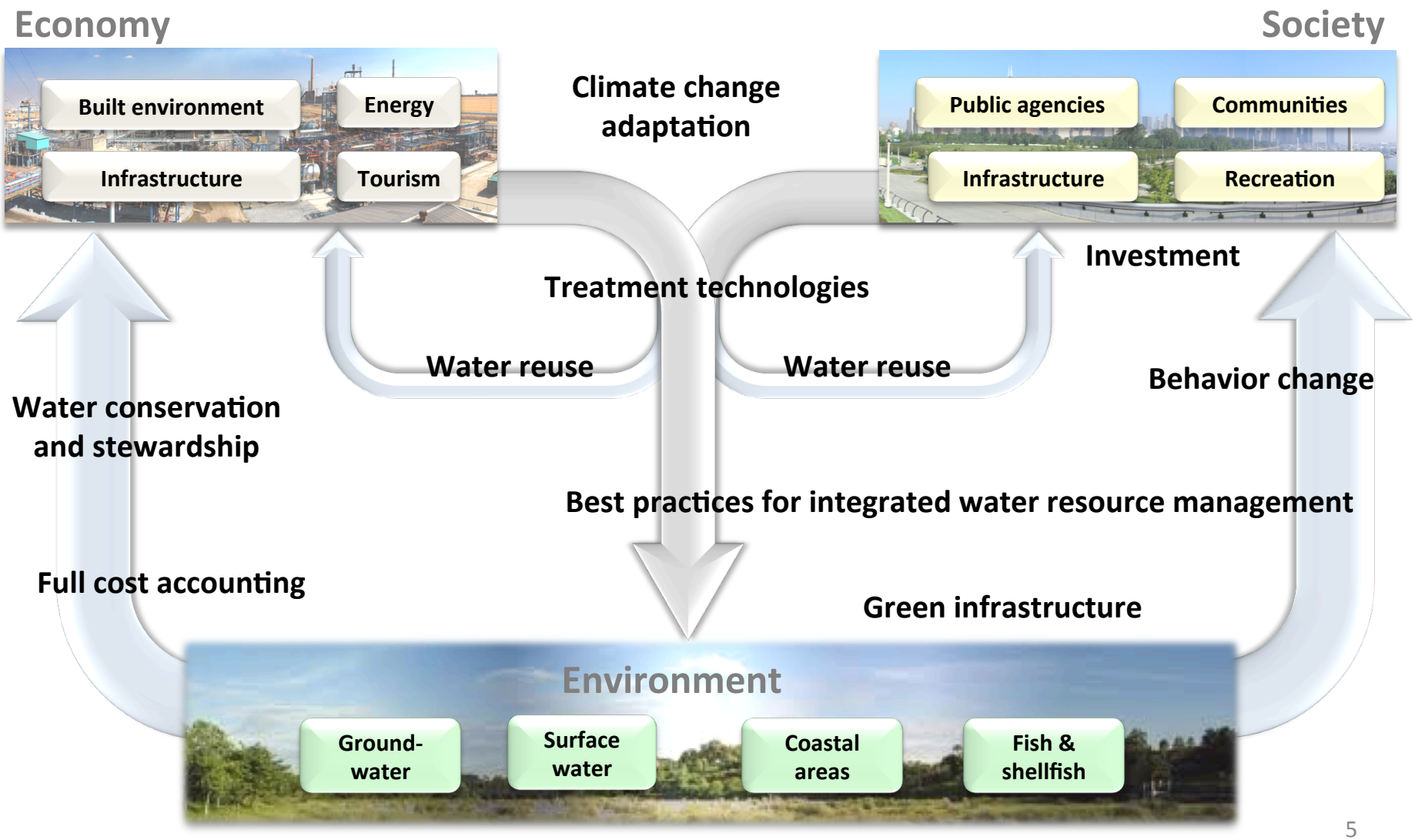
Systems Model

How should we proceed given the uncertainties and ambiguities?

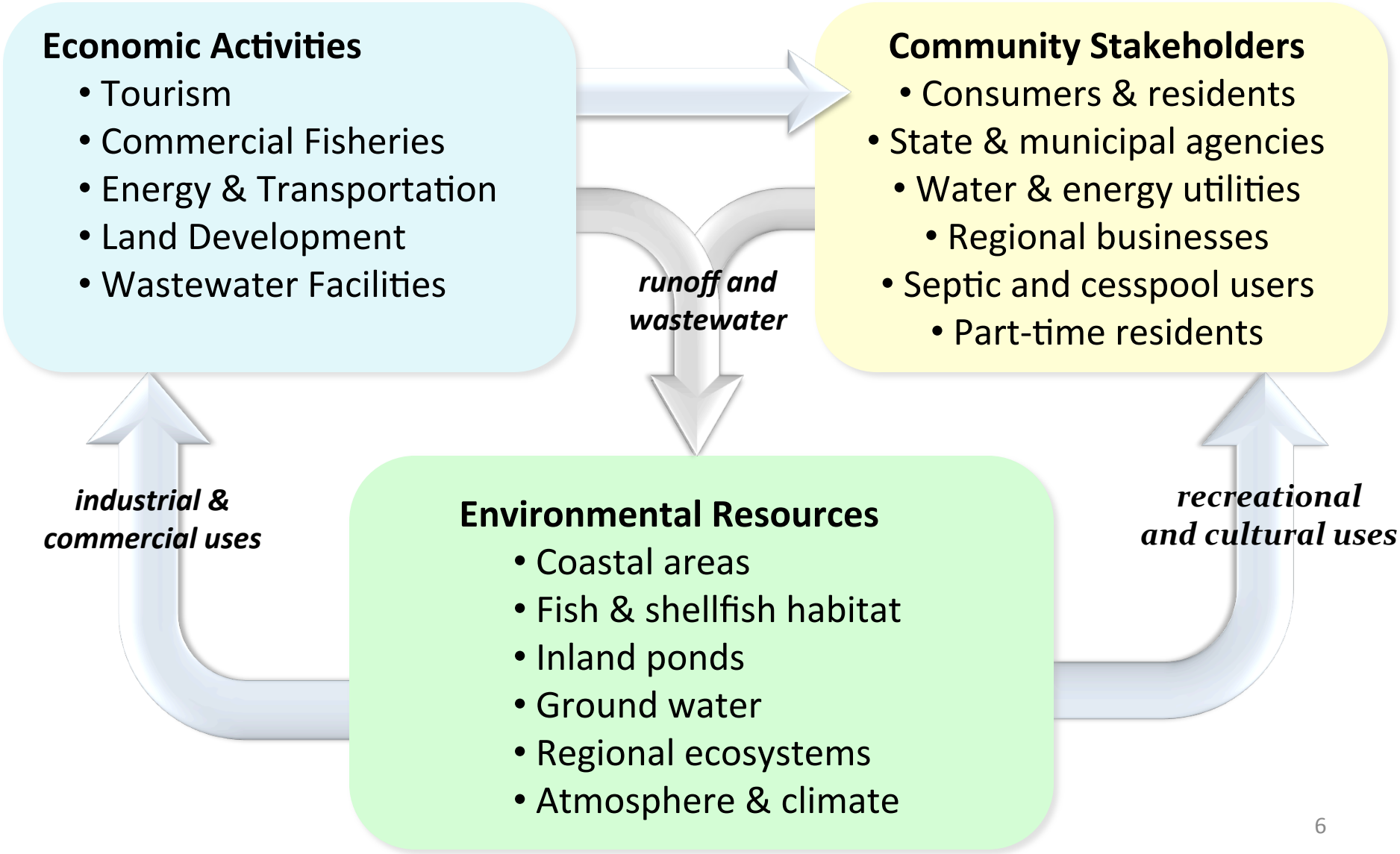
# “Triple Value” Framework



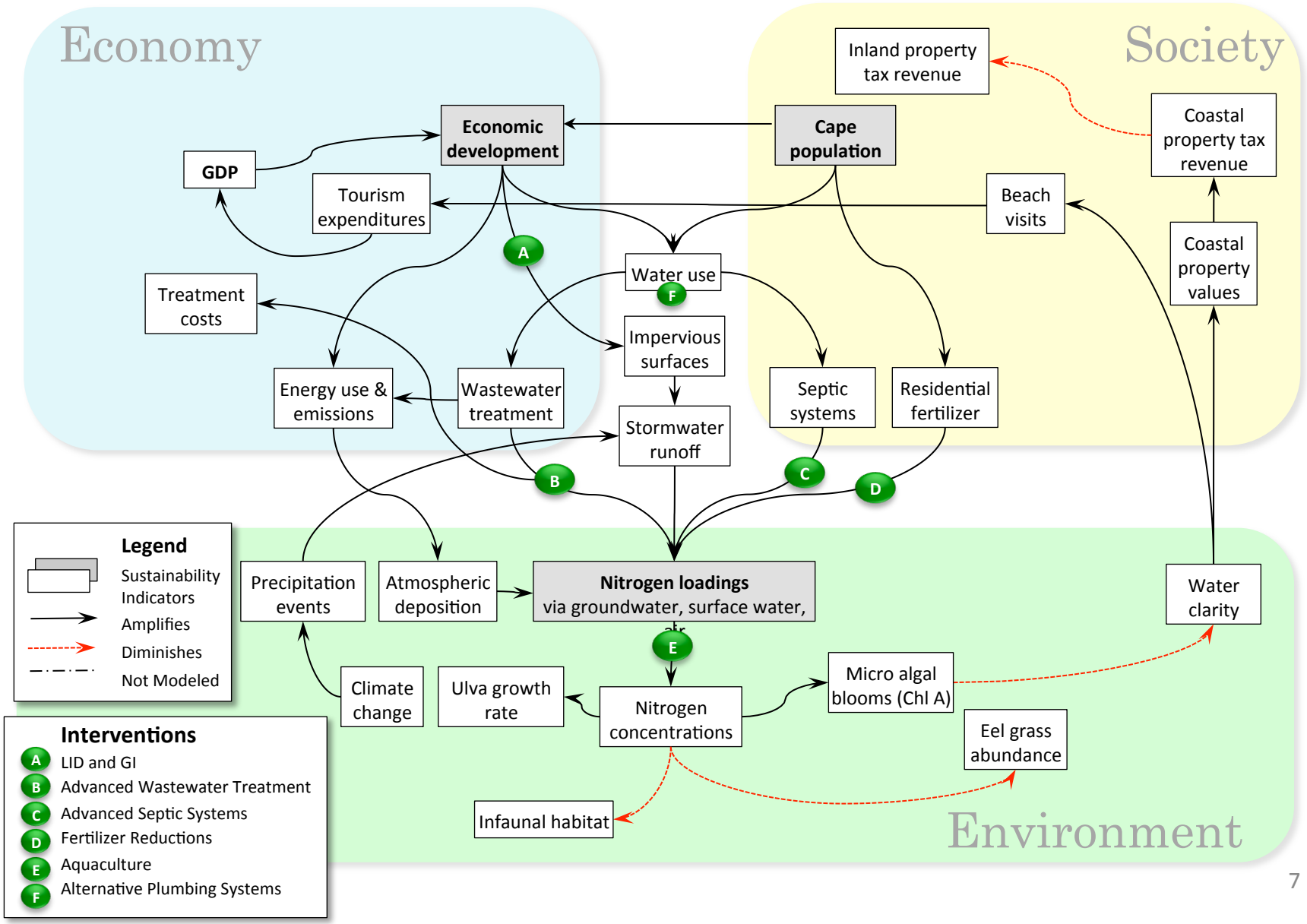
# Potential Interventions to Improve Sustainability of Water Resources



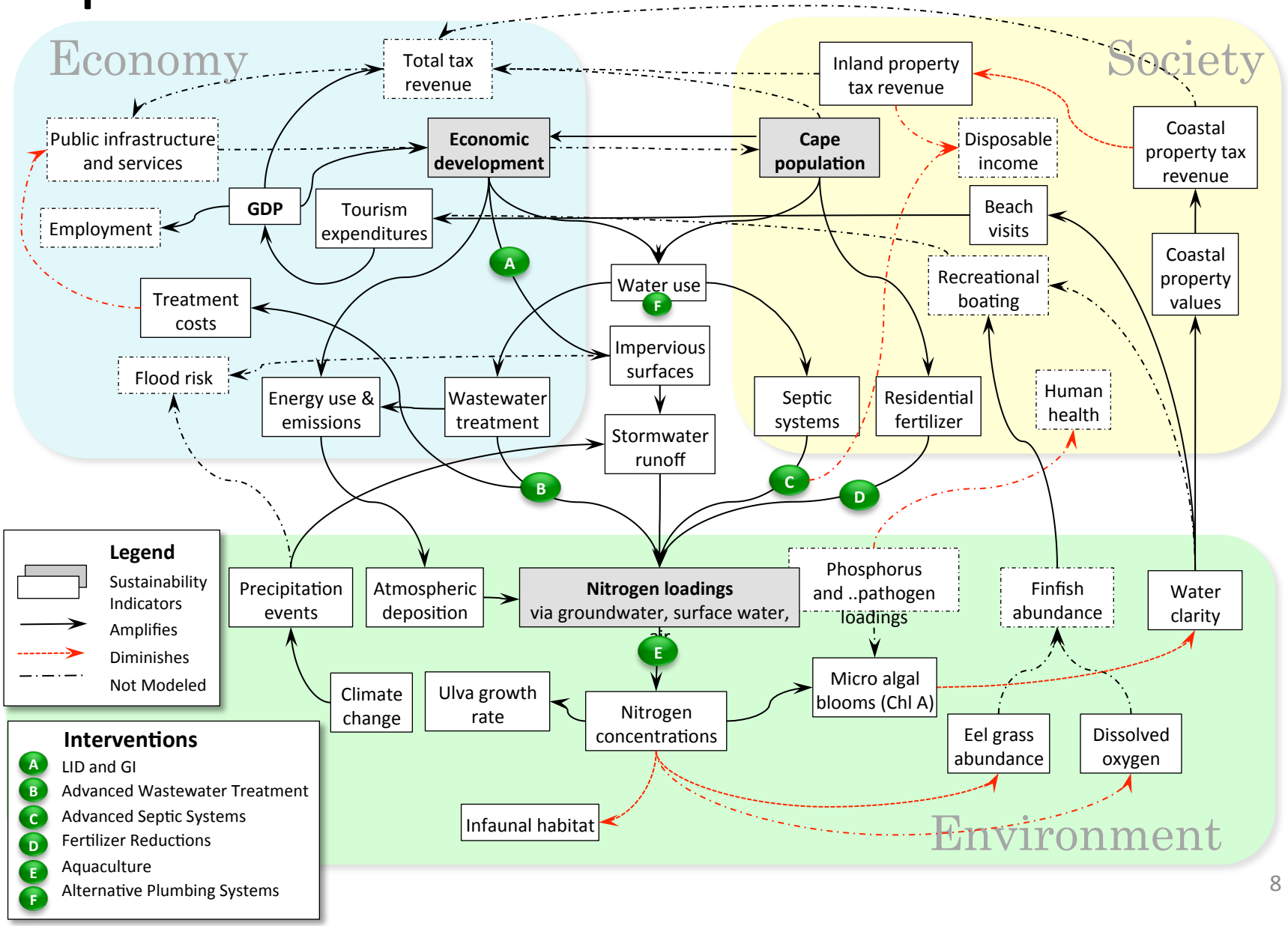
# Modeling the Cape Cod System with a Triple Value Simulation (3VS) Model



# Cape Cod 3VS Schematic: Initial Model



# Cape Cod 3VS Schematic: Planned Model



# Cape Cod 3VS Model: Data Sources

- The 3VS model relies on multiple data sources. Examples include:

| Variable | Source |
|---|---|
| Nitrogen Loadings | Watershed MVP model, Massachusetts Estuaries Project (MEP) Watershed Reports |
| Nitrogen Concentration and Environmental Quality Indicators by Embayment | MEP Watershed Reports |
| Real Estate Value | 2010 Census |
| Regional GDP by Industry Category, including Output, Earnings, and Employment | Bureau of Economic Analysis, Regional Input-Output Modeling System (RIMS), Stats Cape Cod |
| Treatment Costs | Watershed MVP model |

# Example Questions for the 3VS Model to Address

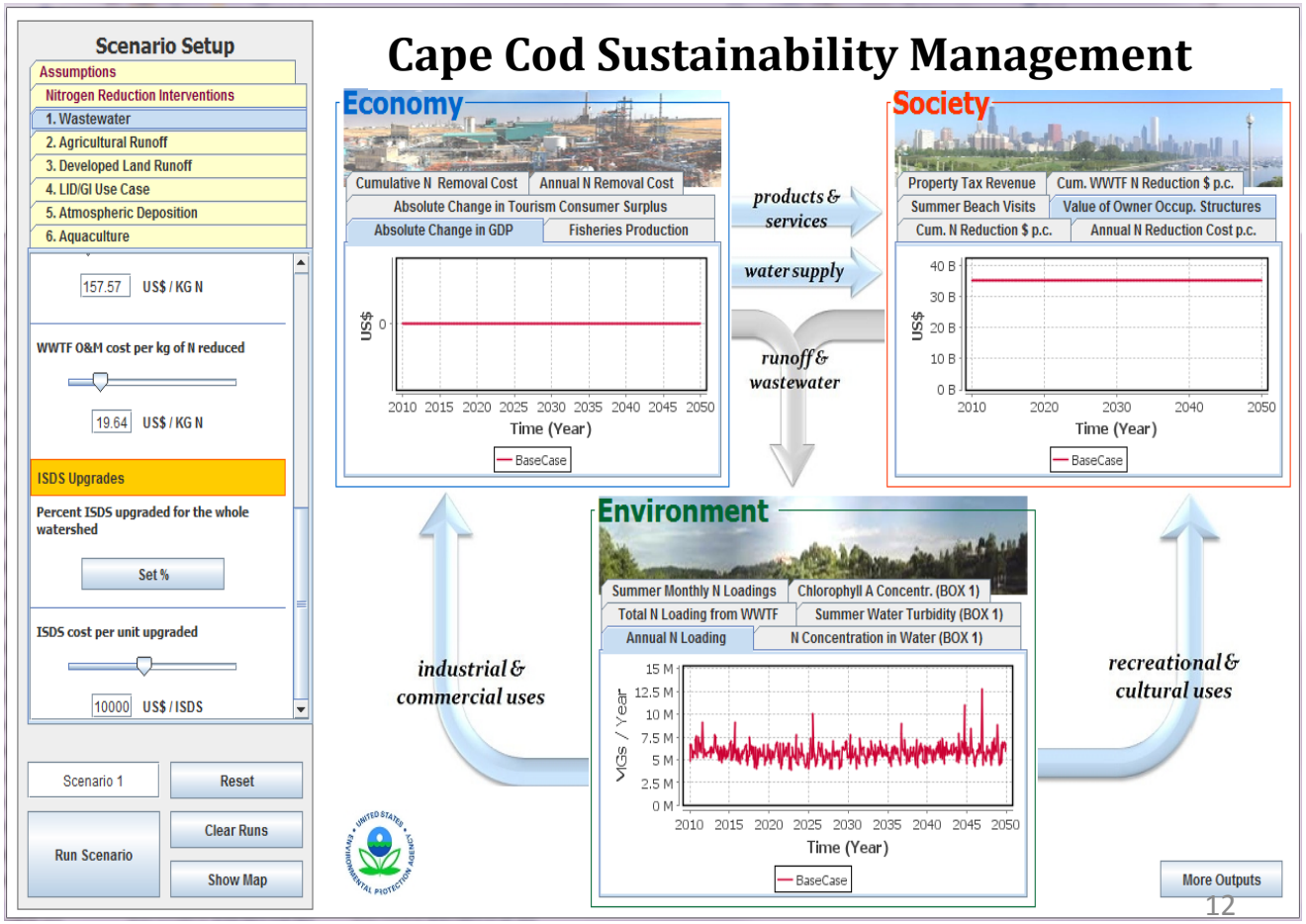
- In the absence of additional interventions, how would future projected growth in N loadings impact housing values, employment, income, and seasonal economic activity?
- What is the cost per capita of different combinations of interventions that can meet TMDLs for embayments around the Cape?
- How might climate change affect the viability and effectiveness of different approaches to nutrient management?
- What is the return on investment (or impact on employment) for a given set of approaches to nutrient management?

# User Interaction with Cape Cod 3VS

- Users can define scenarios in the model, selecting different combinations of policy alternatives.
- The model will simulate the scenario and project results 30 years into the future.
- Users can compare model outputs across multiple scenarios, including the "No Action" scenario.
  - No new treatment beyond existing systems
  - Maintenance and replacement costs for existing systems
  - Projected growth in population and land development
- Two Options for interacting with the model:
  - Dashboard Interface
  - CCC Watershed MVP Model

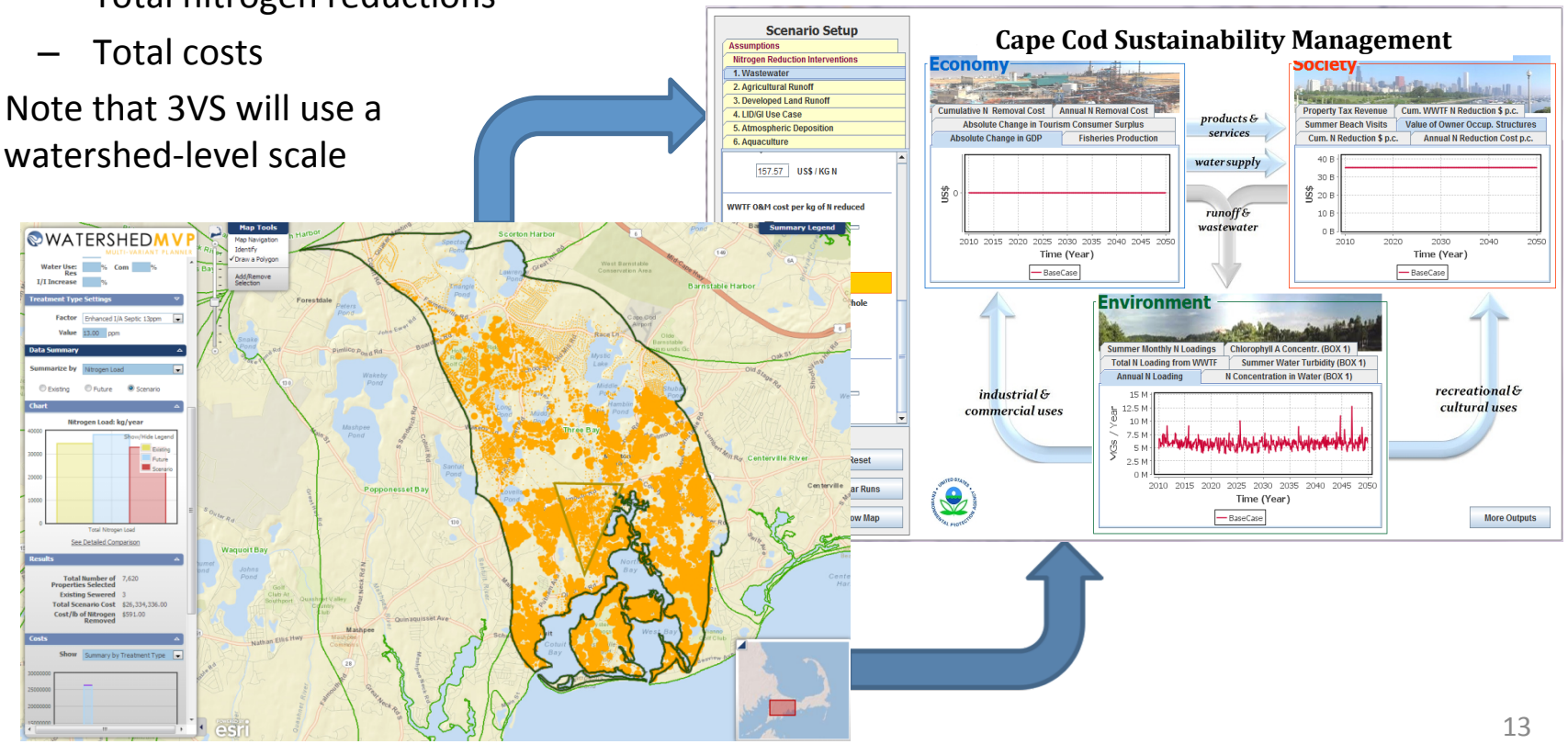
# User Interaction with 3VS:
## Option 1. Interactive "Dashboard" Interface

- Users set scenarios for pre-defined areas (towns or watersheds) or select pre-made scenarios.
- Scenario parameters include policy interventions, unit costs, and assumptions (e.g., precipitation).
- Interface has sliders and graph inputs for defining scenarios.
- Dashboard presents results for several indicators.



# User Interaction with 3VS:
## Option 2. Watershed MVP

- Users can choose specific treatment technologies in Watershed MVP and apply them to an area defined by a polygon
- Outputs from Watershed MVP can then be used as inputs into 3VS
  - Treatment technologies
  - Total nitrogen reductions
  - Total costs
- Note that 3VS will use a watershed-level scale



# Cape Cod 3VS Model, Phase 1:
## No Action Scenario


- Population growth and economic development drive increased wastewater N loadings.
- N loadings increase N concentrations in embayments, leading to degraded marine environmental quality.
- Poor environmental quality reduces the attractiveness of beach visits and boating trips , as well as coastal property value.
- Reduced tourism leads to loss of jobs. Lost tax revenue from tourism and property taxes increases the tax burden on local residents.

# Cape Cod 3VS Model, Phase 2:
## Evaluation of Policy Interventions

- Policy interventions simulated in the model will include:
  - Advanced septic systems
  - Centralized wastewater treatment
  - Alternative water systems*
  - Low-impact development
- For each intervention, the model will simulate:
  - Direct effects (nitrogen reduction and cost)
  - Indirect effects (environmental, social, and economic impacts)
  - Life-cycle impacts (costs and benefits of materials and processes used)

*Examples include waste-reduction toilets and next-generation on-site treatment systems

# Example Scenario Summary:
## No Action (Three Bays Watershed)

| Sector | Indicator | Direction of Impact | Interpretation |
|---|---|---|---|
| Environment | Total N Loadings from wastewater | ↑ | Increased by growing population |
| | N Concentration in Water | ↑ | Increased by higher N loadings from wastewater |
| | Micro Algal Blooms | ↑ | Increased by higher N concentration in water |
| | Eel Grass Abundance | ↔ | Already not present in Three Bays system |
| | Water Clarity | ↓ | Reduced by higher micro algal blooms |
| Society | Coastal Property Values | ↓ | Reduced by lower water clarity in embayments |
| | Beach Visits | ↓ | Reduced by lower water clarity in embayments |
| | Disposable Income | ↓ | Reduced by lower GDP and by shifting tax burden to local residents and inland property owners |
| Economy | Tourism Expenditures | ↓ | Reduced by lower beach visits |
| | GDP | ↓ | Reduced by lower tourism expenditures |
| | Tax Revenue | ↔ | Reduced by lower tourism expenditures; increased by shifting tax burden to local residents and inland property owners |
| ↑: Increase ↓: Decrease ↔: Ambiguous Impact | | | |

Note: Table presents likely results of an example scenario, not actual modeled results.

# Example Scenario Summary:
## Advanced Septic Systems (Three Bays Watershed)

| Sector | Indicator | Direction of Impact | Interpretation |
|---|---|---|---|
| Environment | Total N Loadings from wastewater | ↓ | Reduced by advanced septic systems |
| | N Concentration in Water | ↓ | Reduced by lower N loadings from wastewater |
| | Micro Algal Blooms | ↓ | Reduced by lower N concentration in water |
| | Eel Grass Abundance | ↑ | Increased by lower N concentration in water |
| | Water Clarity | ↑ | Increased by lower micro algal blooms |
| Society | Coastal Property Values | ↑ | Increased by higher water clarity in embayments |
| | Beach Visits | ↑ | Increased by higher water clarity in embayments |
| | Disposable Income | ↔ | Increased by higher GDP; reduced by costs of advanced septic systems. |
| Economy | Tourism Expenditures | ↑ | Increase d by higher beach visits |
| | GDP | ↑ | Increased by higher tourism expenditures |
| | Tax Revenue | ↑ | Increased by higher GDP and higher coastal property values |
| ↑: Increase ↓: Decrease ↔: Ambiguous Impact | | | |

Note: Table presents likely results of an example scenario, not actual modeled results.

# Notes and Limitations

- Appropriate scale (local/municipal/county) of the model depends on types of questions asked by users and availability of data.
  - Some questions require a local focus, while others are county level.
  - Some data sources have a finer degree of resolution than others.
- High degree of uncertainty for some key relationships in the model (e.g., impact of poor environmental quality on tourism).
  - Even if the precise scale of impacts is not known, the model can illustrate a range of downstream effects reflecting different impacts within a likely range.

# Your Input Is Needed!

- What are your questions and concerns about water quality management and sustainable development in Cape Cod?
- What policy interventions or economic, social, and environmental indicators would you like to see included in the model?
- Do you know of additional data sources that could provide information on additional policies or indicators?