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# Assimilation of Scientific Information into Complex Problem Solving

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## What is this lecture?

- In Winter of 2006 I started a graduate course called, *Climate Change: The Intersection of Science, Economics, and Policy*. This morphed to *Climate Change: The Move to Action* and will be *Problem Solving in Climate Change*.
- This is something of a lessons learned presentation.



# Class Website

- Class Web Site
  - [Climate Change: The Move to Action](#)
    - [Winter 2008 Term](#)
- [2008 Climate Change Projects](#)
  - Energy, Water, Climate Change, and Economic Development of the Navajo Nation
    - [Narrative](#)      [Presentation](#)
  - Exxon and BP: An Analysis of Two Companies' Approach to Climate Change
    - [Narrative](#)      [Presentation](#)
  - Iron Fertilization in the Ocean: Environment and Business Opportunity
    - [Narrative](#)      [Presentation](#)
  - Biofuel and Hybrid Buses in Ann Arbor: A Consideration of the Cost of Climate Change
    - [Narrative](#)      [Presentation](#)
  - Carbon Management Initiative: The Integration of Carbon Management into the University of Michigan Curriculum
    - [Narrative](#)      [Presentation](#)



# Outline of Lecture: A thread through the class

- Inventory of the “communities” vested in the climate change “problem”
  - Some early lessons learned
- The Uncertainty Fallacy
- Relationships: Big view
- Scales: Time, Space, Wealth
- Policy Redux: Policy-Uncertainty Interface
  - Urgency of energy security
- Relationships: Building Perspective
  - Economics
  - Impacts
  - Law
  - Belief system
  - Business
- Some attention to business
- Summary



# Inventory of the “communities” vested in the climate change “problem”

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Based on scientific investigation

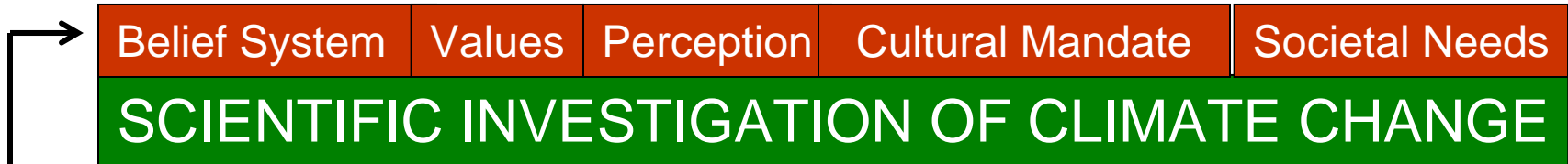
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**SCIENTIFIC INVESTIGATION OF CLIMATE CHANGE**



# How we interpret the results of that investigation

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# Which relies on how we get out information

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Belief System

Values

Perception

Cultural Mandate

Societal Needs

information flow: research, journals, press, opinion, ...

**SCIENTIFIC INVESTIGATION OF CLIMATE CHANGE**





# Which does influence scientific investigation

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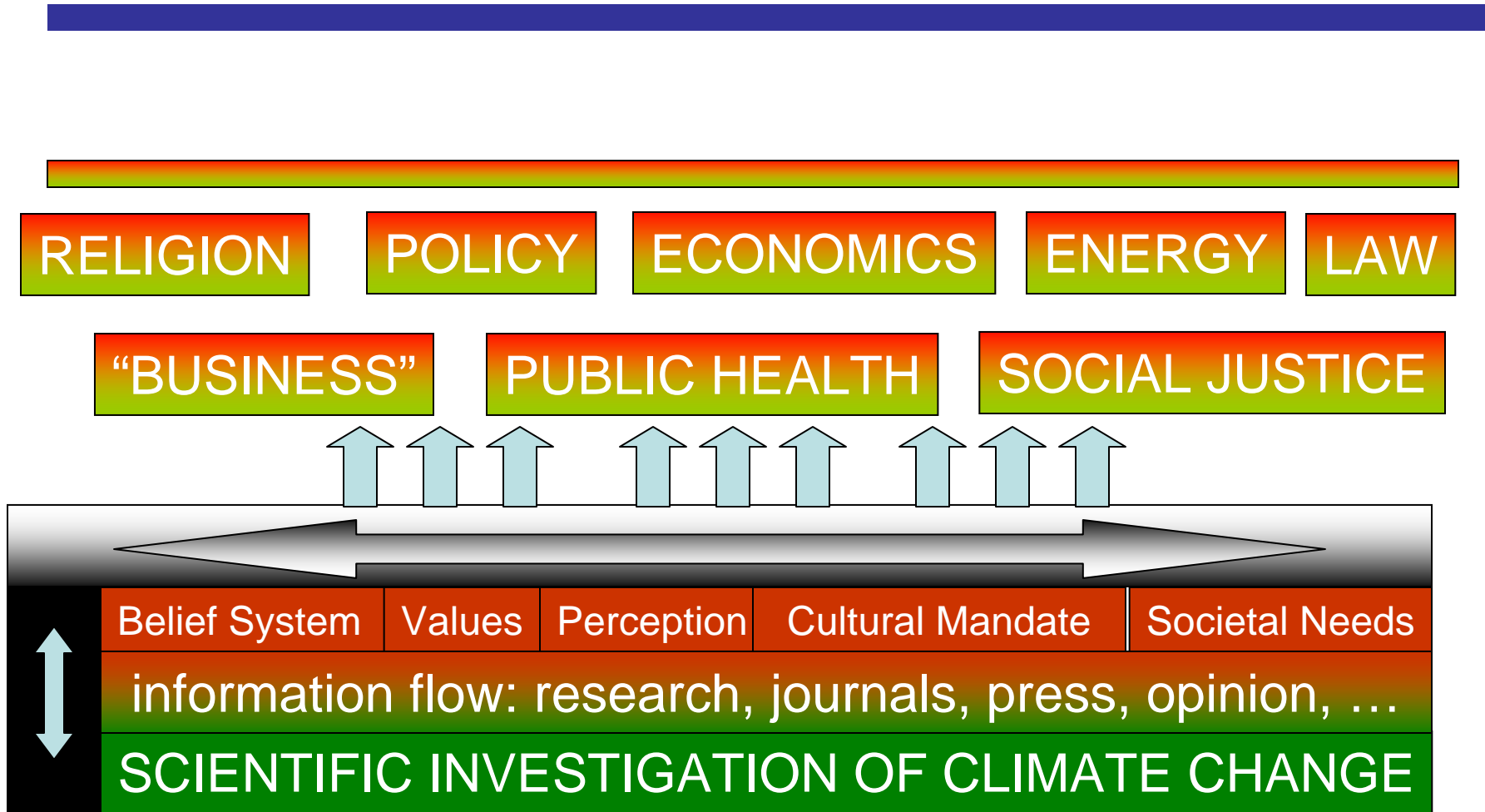


# It all gets stirred together



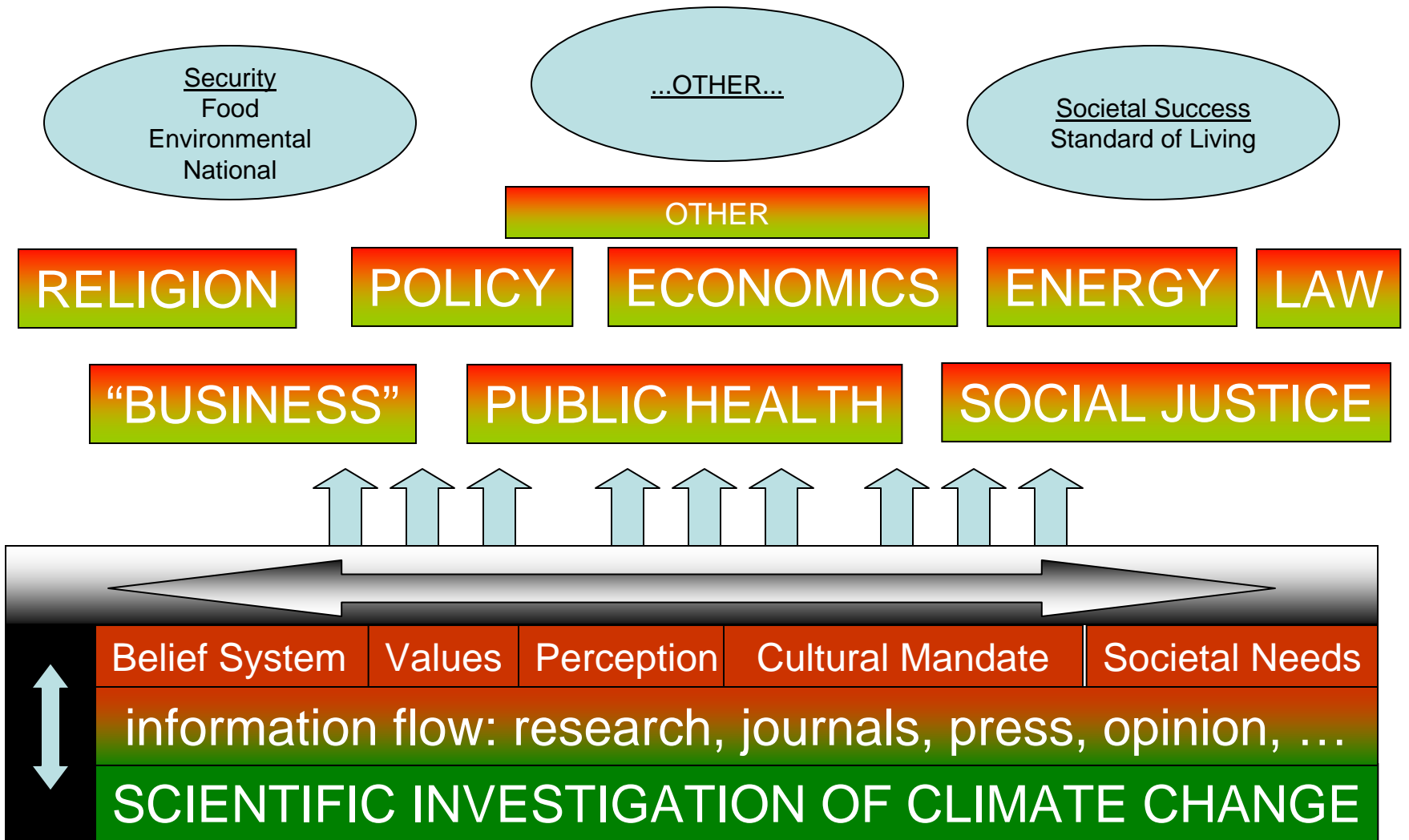


And different communities have intrinsic interests





# Possible broad consequences of climate change





## In the beginning

- Many start from the position that climate change is a problem the we all face, and that what is needed to address climate change is “policy,” and then fall into the discussion of the Kyoto protocol.



## Some things discovered early on

- Our focus on discipline-based expertise and two-subject interfaces, *e.g.* climate-policy, climate-energy, climate-business, *etc.*, inhibit our ability to develop solution paths.
  - The need for trans-disciplinary discourse and rationalization of the interfaces between “disciplines.” (communities instead of disciplines?)
- On the whole, there is a remarkable knowledge of climate and the climate system by those in non-science disciplines.
  - This has implications for education and outreach activities.
- The use of science-derived information by non-scientists is not well understood by science students (or scientists).
  - The uncertainty fallacy.



# The Uncertainty Fallacy

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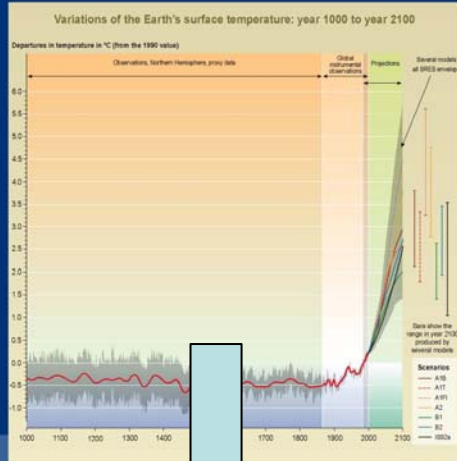
# The Uncertainty Fallacy?

- Scientific investigation produces two things
  - Knowledge
  - Uncertainty about that knowledge

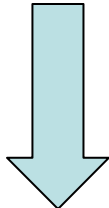




# Science: Knowledge and Uncertainty

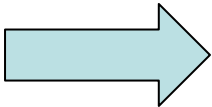


**Knowledge from Predictions**



**Motivates policy**

**Uncertainty of the Knowledge that is Predicted**

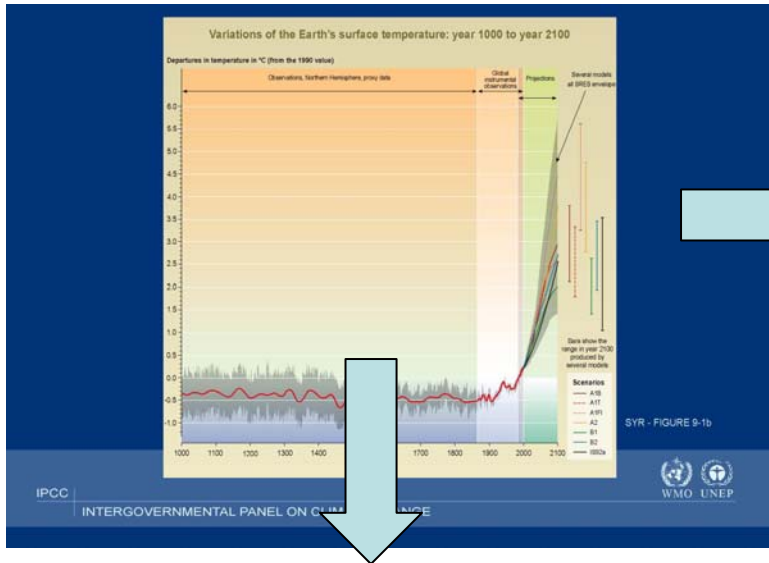


**Policy**

- 1) Uncertainty always exists
- 2) New uncertainties will be revealed
- 3) Uncertainty can always be used to keep policy from converging



# Science: Knowledge and Uncertainty



**Knowledge from Predictions**

**Motivates policy**

**Uncertainty of the Knowledge that is Predicted**

**Policy**

- 1) Uncertainty always exists
- 2) New uncertainties will be revealed
- 3) Uncertainty can always be used to keep policy from converging

What we are doing now is, largely, viewed as successful. We are reluctant to give up that which is successful. We are afraid that we will suffer loss.



# The Uncertainty Fallacy

- The uncertainty fallacy is that scientific investigation provides a systematic reduction of uncertainty of knowledge and that a systematic reduction of uncertainty is what is needed to motivate the development of policy or, more generally, “decision making.”
  - In addition, scientific uncertainty needs to be considered in relationship to other forms of uncertainty and needs to map to risk and benefit.



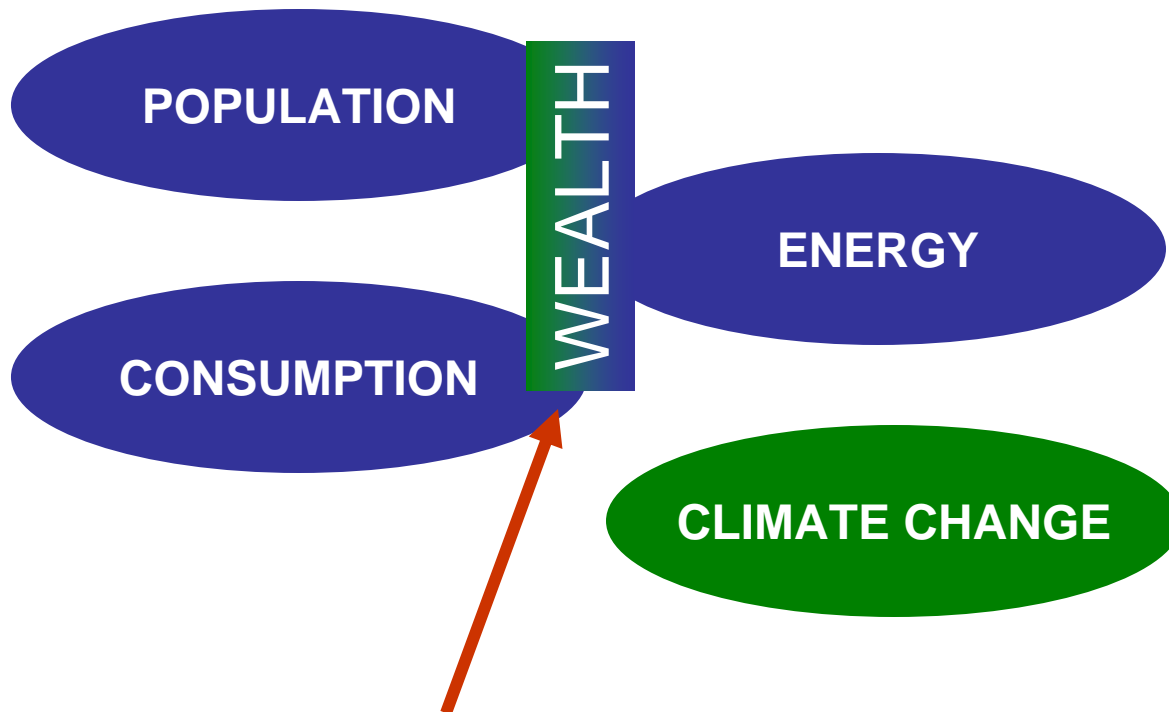
# Relationships: Big View

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# Climate Change Relationships

- Consumption // Population // Energy

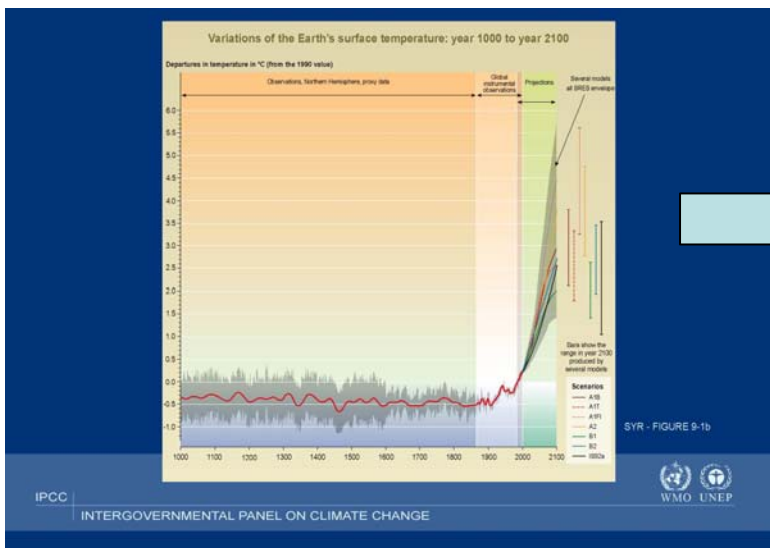


**Acquisition and preservation of wealth is of central importance to people. Hence, “wealth” is a source of urgency, and it often works on the “short term.”**

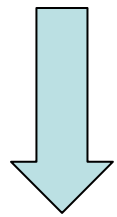
As do energy security and population pressure



# What scientific investigation tells us



**Knowledge from Predictions**  
**Surface temperature will rise**  
**Sea level will rise**  
**Weather will change**



**Reveals**  
**Risk**  
**Benefit**

**Motivates**  
**Policy**

**CLIMATE CHANGE IS PERCEIVED  
 PRIMARILY AS A “LONG-TERM” PROBLEM**



# Climate Change Long-Term Problem?

- This is from the perspective that if we were to take actions to reduce carbon dioxide, then it would be a long time before we see benefit, and
  - the general idea that climate change is a slow warming that will be a long time coming, and
  - there will be technological solutions to the problem.
- 
- Hence, climate change is viewed by most as long term.



## The Relation between Climate Change and Energy Production is Dominant

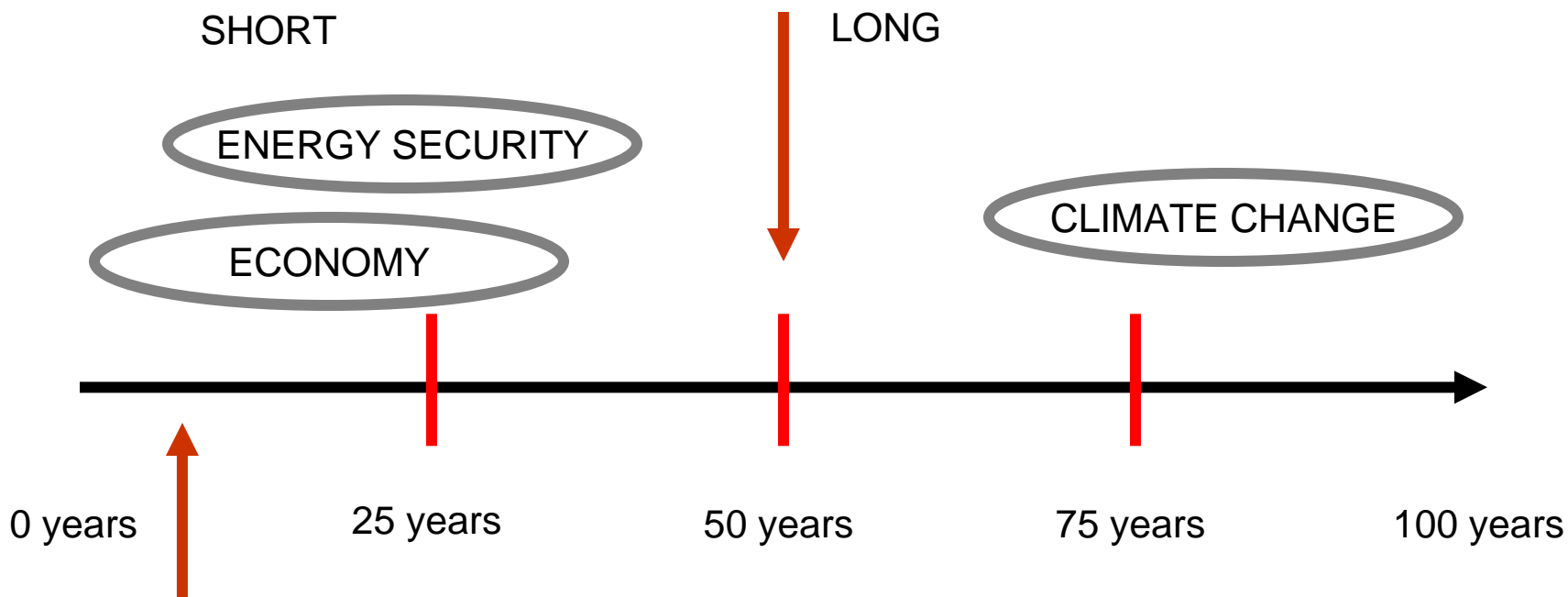
- Burning of fossil fuels and the release of carbon dioxide waste into the atmosphere is the primary cause of human-caused climate change
  - Other greenhouse gases
  - Land-use changes
- The other greenhouse gases and land-use change are relevant to short-term responses.





# What is short-term and long-term?

**Pose that time scales for addressing climate change as a society are best defined by human dimensions. Length of infrastructure investment, accumulation of wealth over a lifetime, ...**



**There are short-term issues important to climate change.**



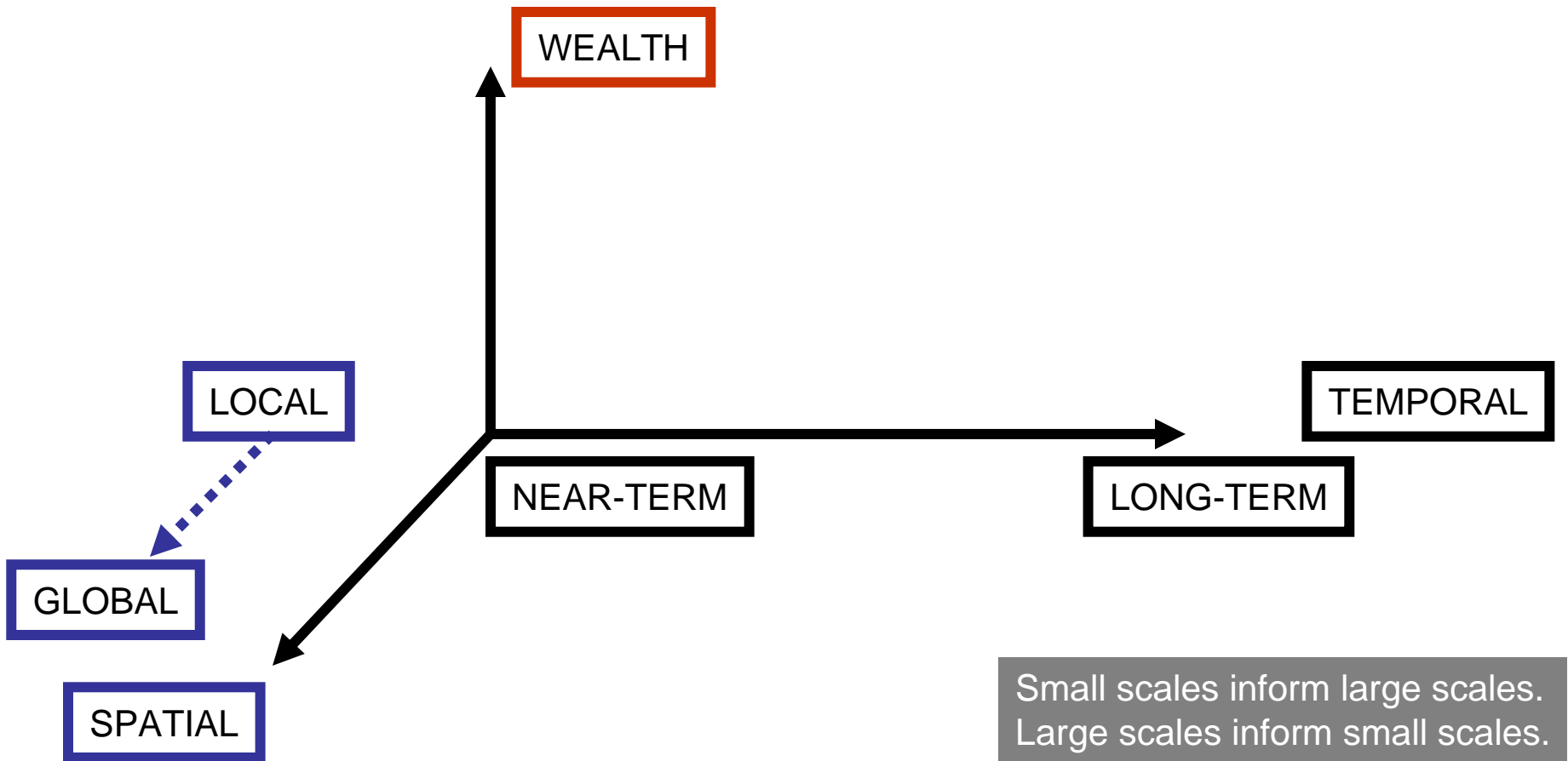
## Scales: Time, Space, and Wealth

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- Above we introduced the idea of near term and long term.
- We also need to introduce the idea of spatial scales, local, regional, national, and global.



# We arrive at levels of granularity





# Policy Redux: Policy-Uncertainty Interface

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## A Conclusion about Policy

- Because of the extensive reach of both climate change and energy security, “policy” is an essential element in addressing the challenges of climate change, but it is not “the solution” to the climate change problem.
- Policy exists on short and long time scales and local to global scales. It is strongly related to issues of wealth.



## Motivators for Policy

- More is needed than scientific knowledge to motivate the development of policy.
  - A policy accelerator or catalyst is needed to promote convergence on policy.
    - Apparent benefit
    - Excess risk
  - What are important sources of benefit and risk?



## What are the motivators of policy?

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- Or more generally, what are the motivations that are most effective for the development and convergence of policy?
  - If there is time, I stop and make a list.



# Energy – Climate Change

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- Many alternative energy sources don't reduce carbon dioxide in atmosphere.
- Coal is our easy energy security
  - Without sequestration (carbon removal), coal makes the problem worse.





## NEED CLIMATE POLICY (CARBON POLICY)

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- Quest for energy security-national security, demand for cheap energy, economic security will reduce priority we give to reduction of carbon dioxide in the atmosphere.
  - To address climate change we must have a climate policy, a carbon policy.
    - Consumption, sustainability
  - Must have sustained management of “climate.”
    - Population?

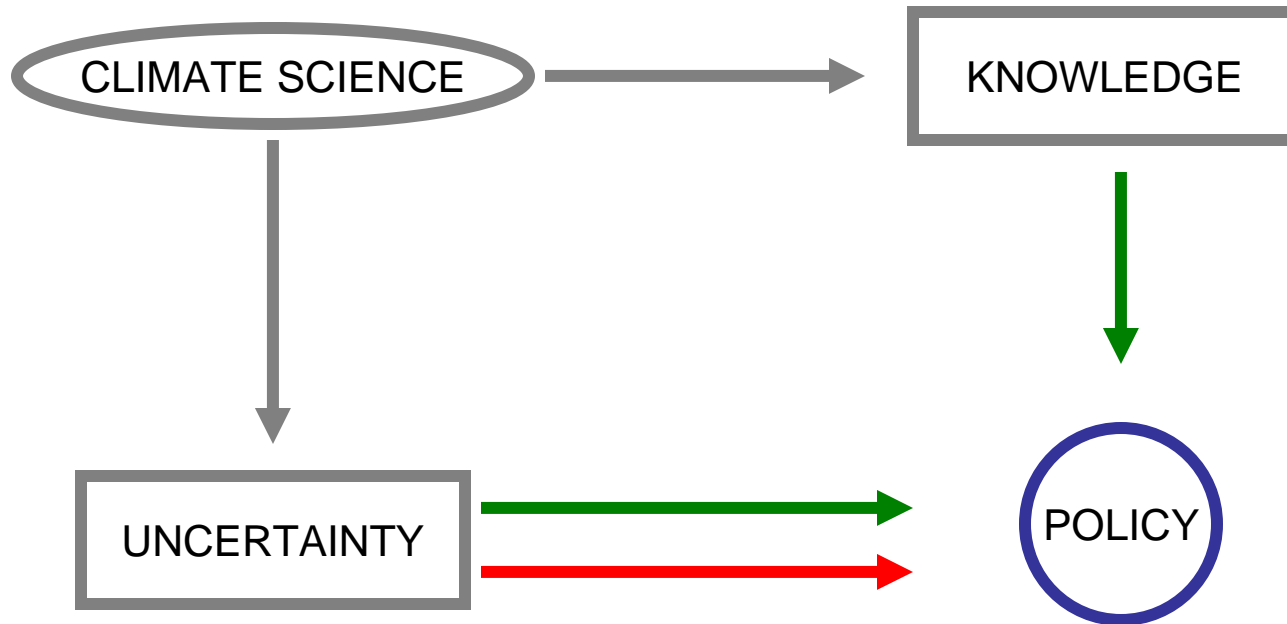


# Relationships: Building Perspective

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# Climate Science-Policy Relation



PROMOTES / CONVERGENCE



OPPOSES / DIVERGENCE



# Economics

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## U.S.: Codified economic growth and climate change

### SEC. 16\_\_\_. SENSE OF THE SENATE ON CLIMATE CHANGE. (2005)

(a) Findings.—Congress finds that—

- 1) greenhouse gases accumulating in the atmosphere are causing average temperatures to rise at a rate outside the range of natural variability and are posing a substantial risk of rising sea-levels, altered patterns of atmospheric and oceanic circulation, and increased frequency and severity of floods and droughts;
- 2) there is a growing scientific consensus that human activity is a substantial cause of greenhouse gas accumulation in the atmosphere; and
- 3) mandatory steps will be required to slow or stop the growth of greenhouse gas emissions into the atmosphere.

(b) Sense of the Senate.—It is the sense of the Senate that Congress should enact a comprehensive and effective national program of mandatory, market-based limits and incentives on emissions of greenhouse gases that slow, stop, and reverse the growth of such emissions at a rate and in a manner that—

- 1) will not significantly harm the United States economy; and
- 2) will encourage comparable action by other nations that are major trading partners and key contributors to global emissions.



## Economics and climate change

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- For the most part, the world has intertwined our responses to climate change with economic growth; hence, consumption.
- By our decision, climate change and acquisition and protection of wealth are linked together.

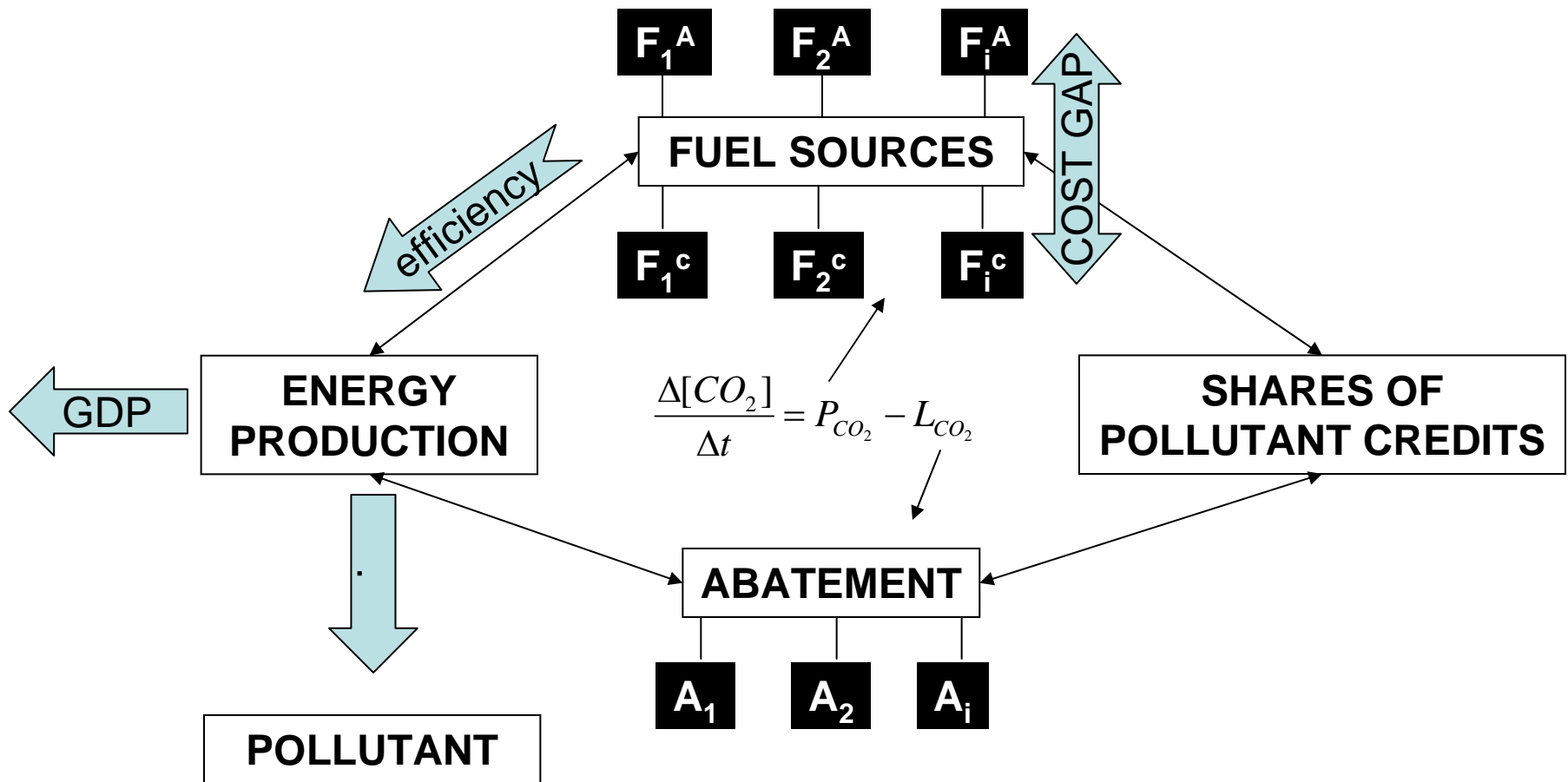


# The economics argument

- Comes to the conclusion that we must provide valuation to the environment, the cost of energy, the disposal of our waste.
  - Often collapses to the argument of a market versus a taxation problem.
  - The economics argument potentially provides the mechanism of policy (e.g. an environmental market), but it still does not compel policy.



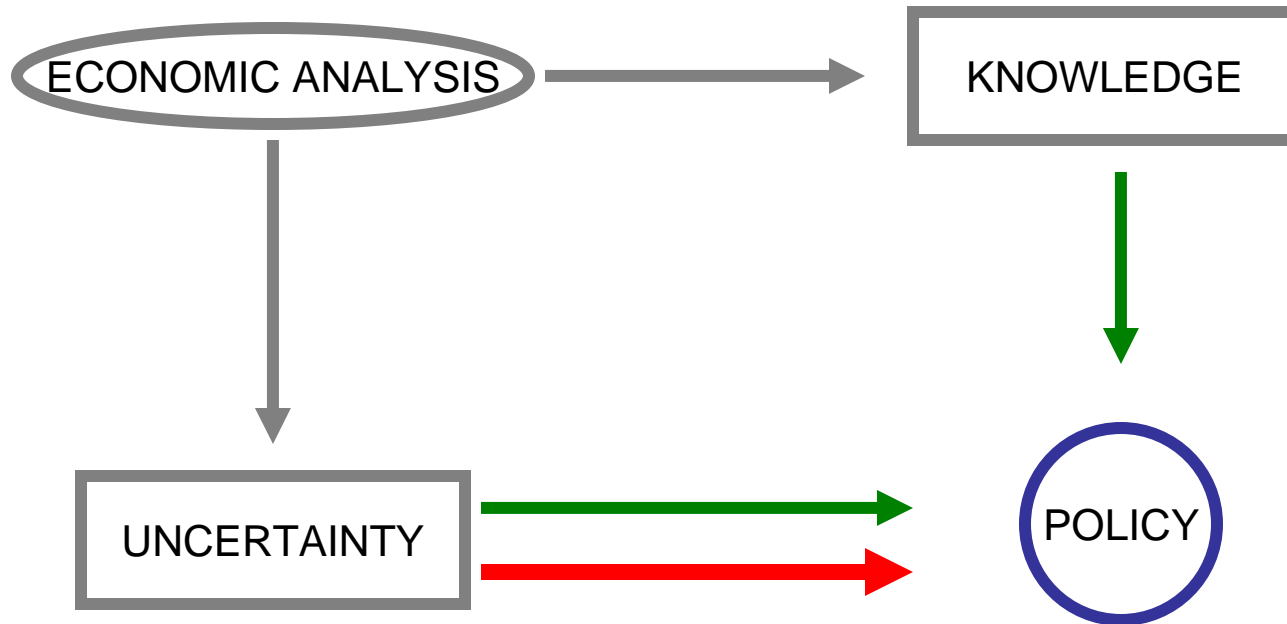
# Environmental pollutant market as policy mechanism







# Economics-Policy Relation



**PROMOTES / CONVERGENCE**



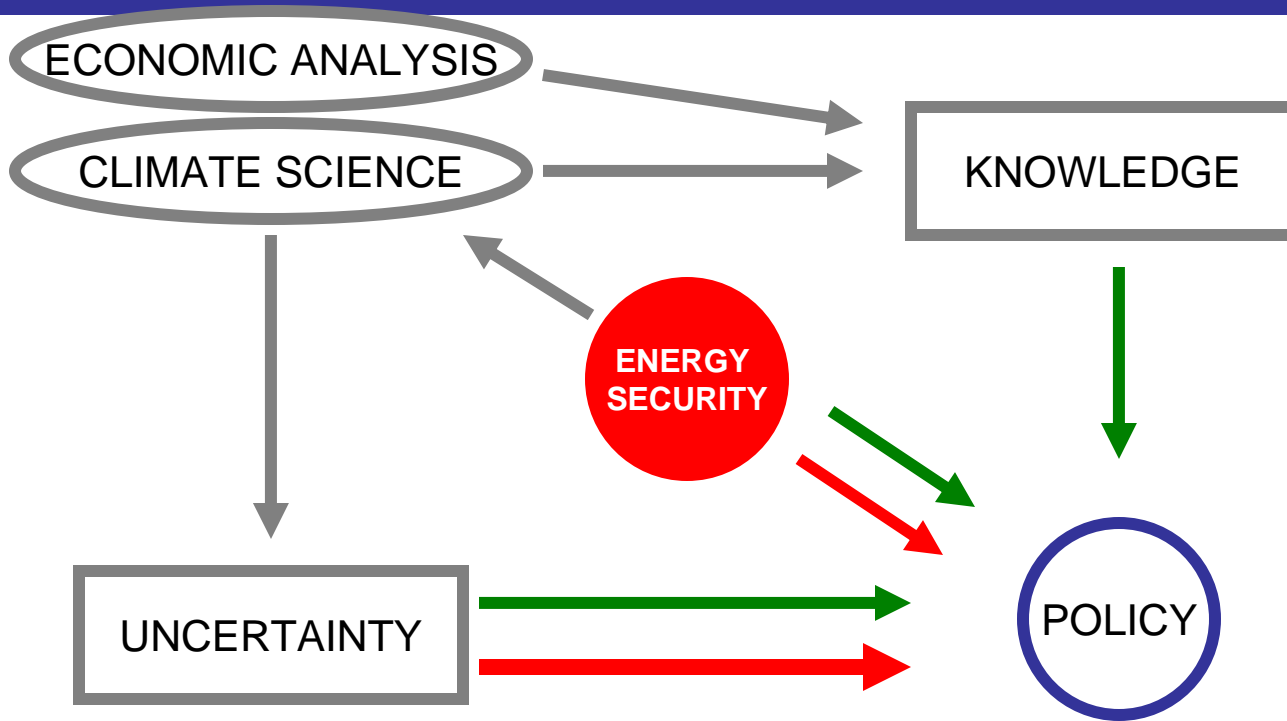
**OPPOSES / DIVERGENCE**

Economic analysis is not the compelling catalyst to converge the development of policy – at least on the global scale.

Different story on the local scale.



# An integrated picture?



PROMOTES / CONVERGENCE



OPPOSES / DIVERGENCE

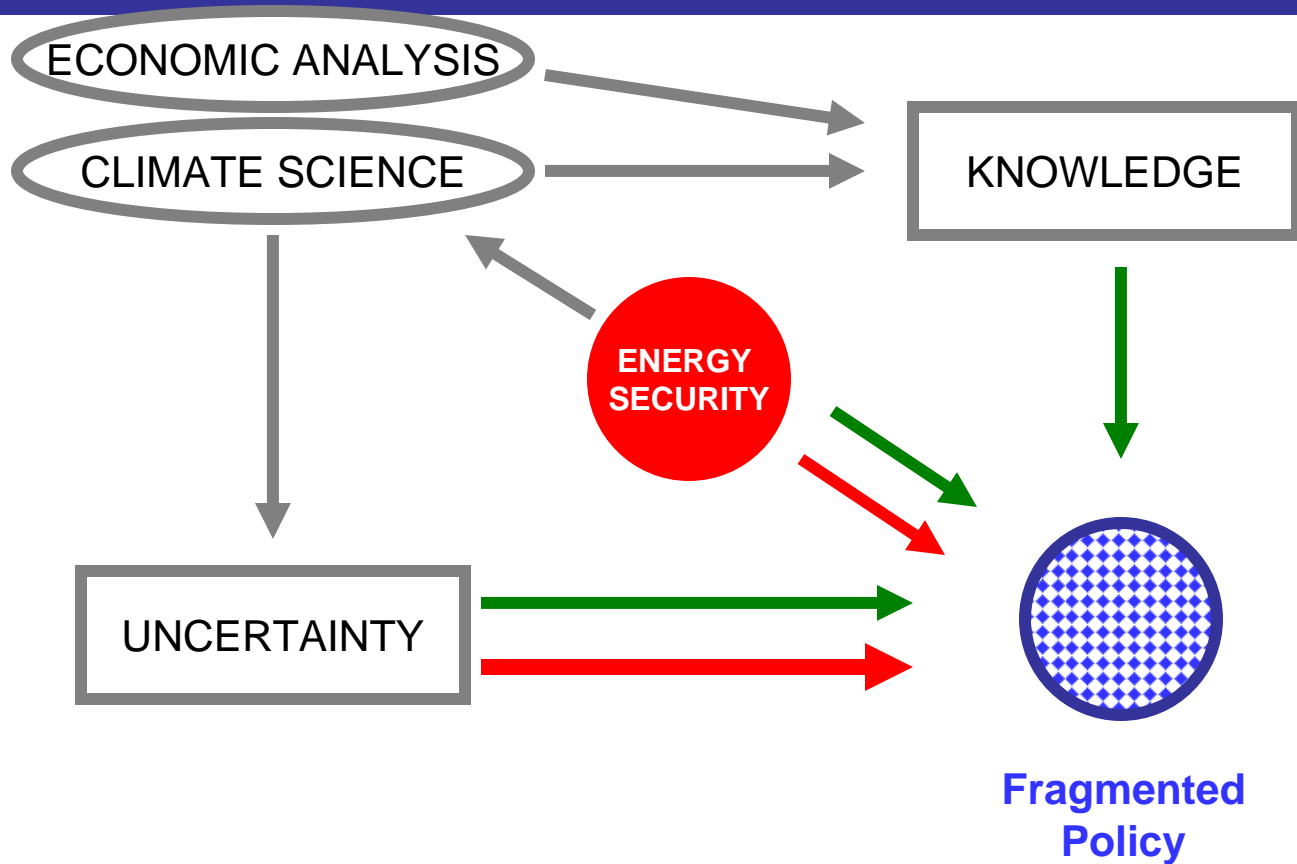


## Think about policy again

- As all of these pieces are brought to bear on policy, the fragmentation of those interests begins to show up in policy.



# An integrated picture?



 **PROMOTES / CONVERGENCE**

 **OPPOSES / DIVERGENCE**



# Fragmented Policy

- Represents the real, rational interests of different elements.
  - short-term, long-term; local, global; poor, rich
- As a whole, however, does not work together,
- may collectively work against, for instance, mitigation of climate change.
- Fragmented policy becomes, perhaps, an accelerator or more integrated, more federal or global policy.

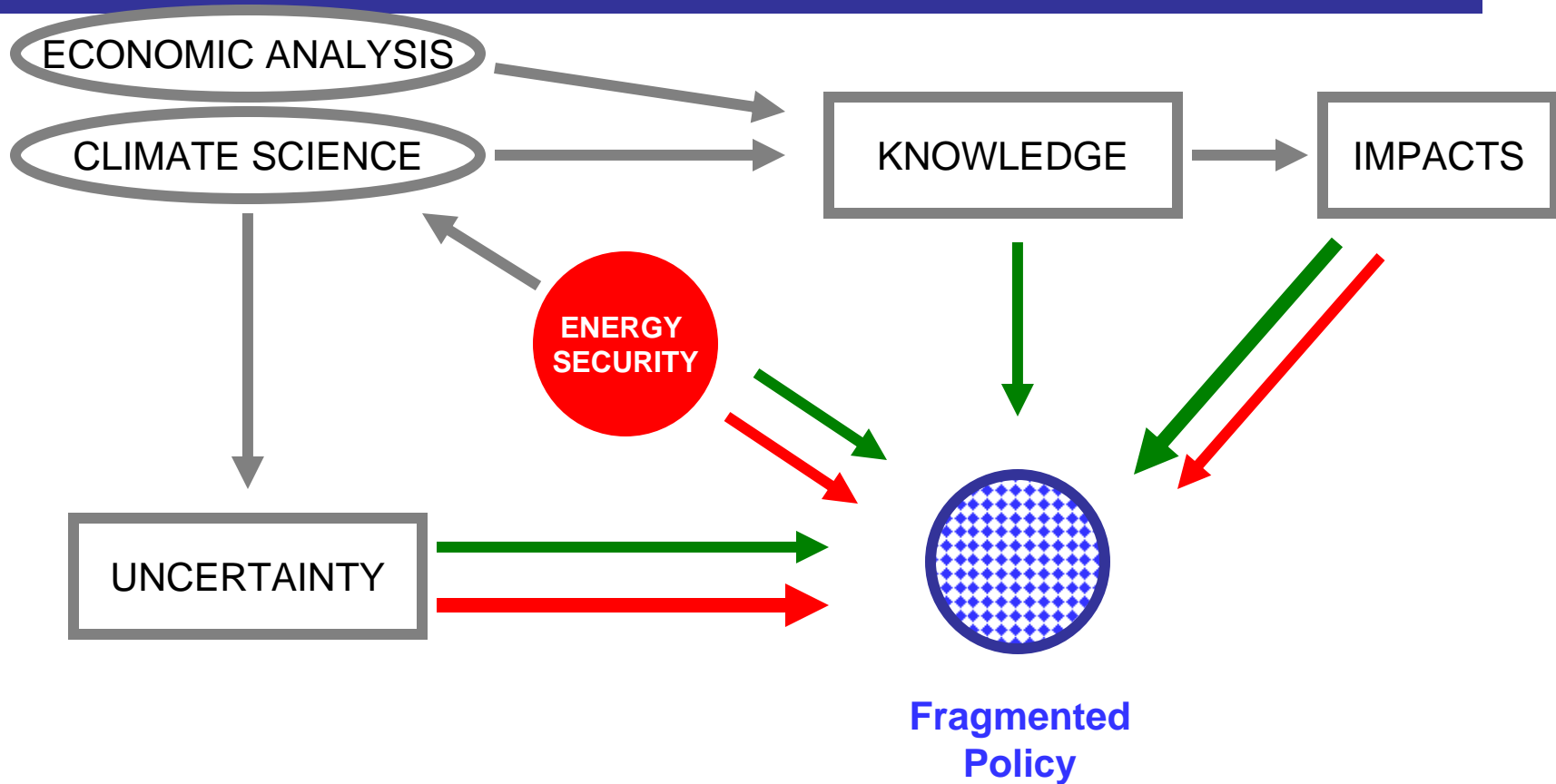


## What about Impacts?

- The knowledge that comes from climate science suggests a set of impacts
  - Agriculture
  - Forestry
  - Fisheries
  - Public health
  - Water resources
  - ....



# An integrated picture?



PROMOTES / CONVERGENCE



OPPOSES / DIVERGENCE



# Impacts

- 
- Heat waves as an example of an impact.





## Lessons from heat waves

- Existing problem with existing system to address the problem
  - Weaknesses in the system often associated with population stress, by vulnerable population, highly (anti) correlated with wealth and education
- Strongly dependent on extreme events, not the average
  - Hence want to know how extreme events will change
- Not clearly and distinctly addressed by efforts to mitigate greenhouse gas emissions
  - Motivator for “Kyoto like” policy?



## Lessons from heat waves

- Strongest levers for addressing the problem are
  - Societal capability (social integration, structure, communications)
  - Environmental warnings and alerts
  - Education (first responders, general public, ....)
  - Engineering (air conditioners, green spaces, ...)



Imagine your job was to reduce deaths from heat waves

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POPULATION

CONSUMPTION

ENERGY

CLIMATE CHANGE

**It's going to get hotter!**

MITIGATE CLIMATE CHANGE

or

USE MORE ENERGY

or

...

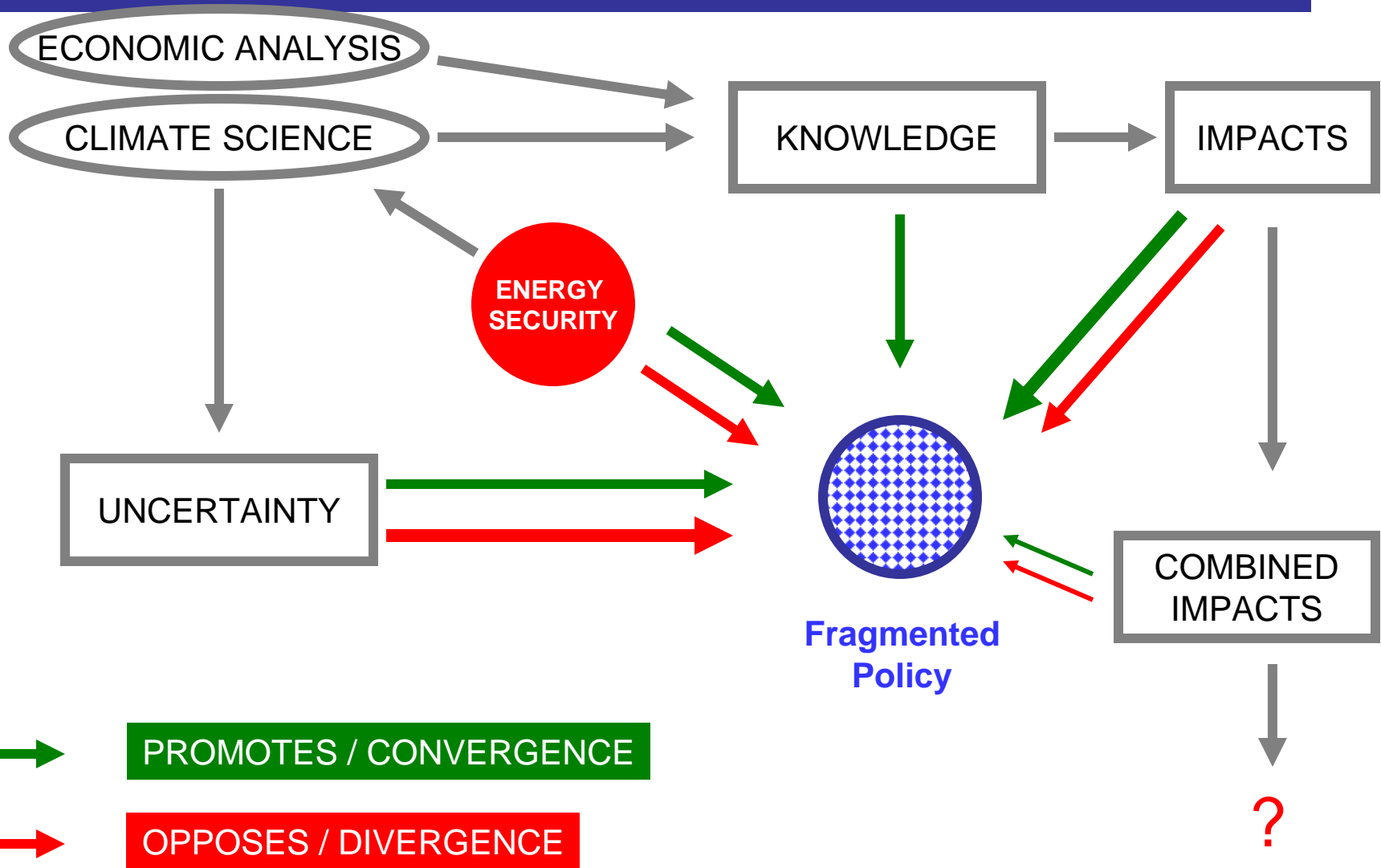


## Systematic or combined impacts

- Water resources, public health, agriculture, taken in isolation rich countries can imagine that they have technological and engineering solutions to these problems, but
- what about their combined impacts?
  - e.g. water in energy production, agriculture, industry and domestic consumption



# An integrated picture?





# There are important elements still missing

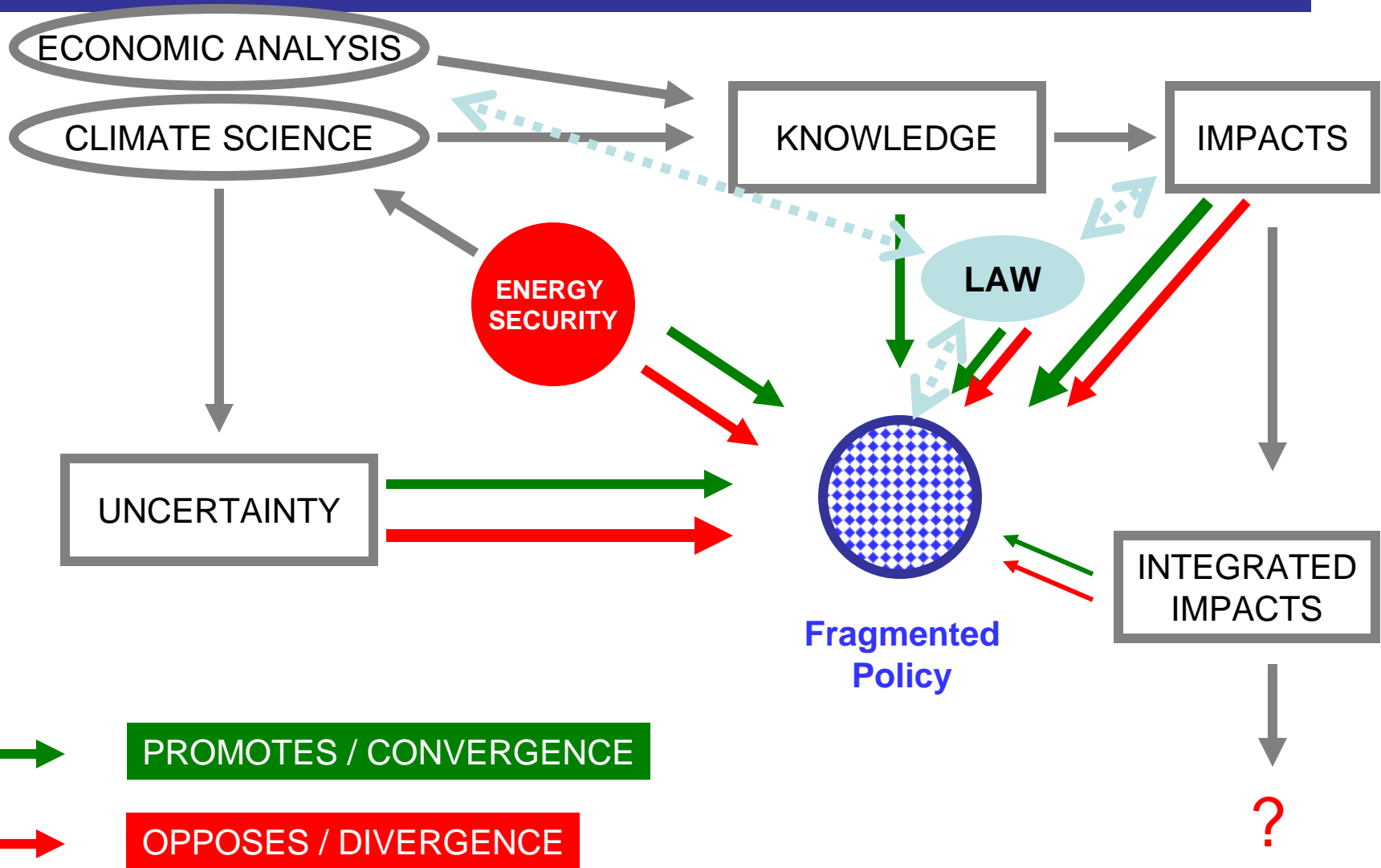
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- Law

- Law offers a possible entry into the “system.”
  - Links policy and *de facto* laws
  - Links economic windfalls and losses
  - Links impacts
  - Links ethical considerations
  - ....
- Promotes, perhaps, policy



# An integrated picture?



PROMOTES / CONVERGENCE

OPPOSES / DIVERGENCE



## Important elements that are still missing

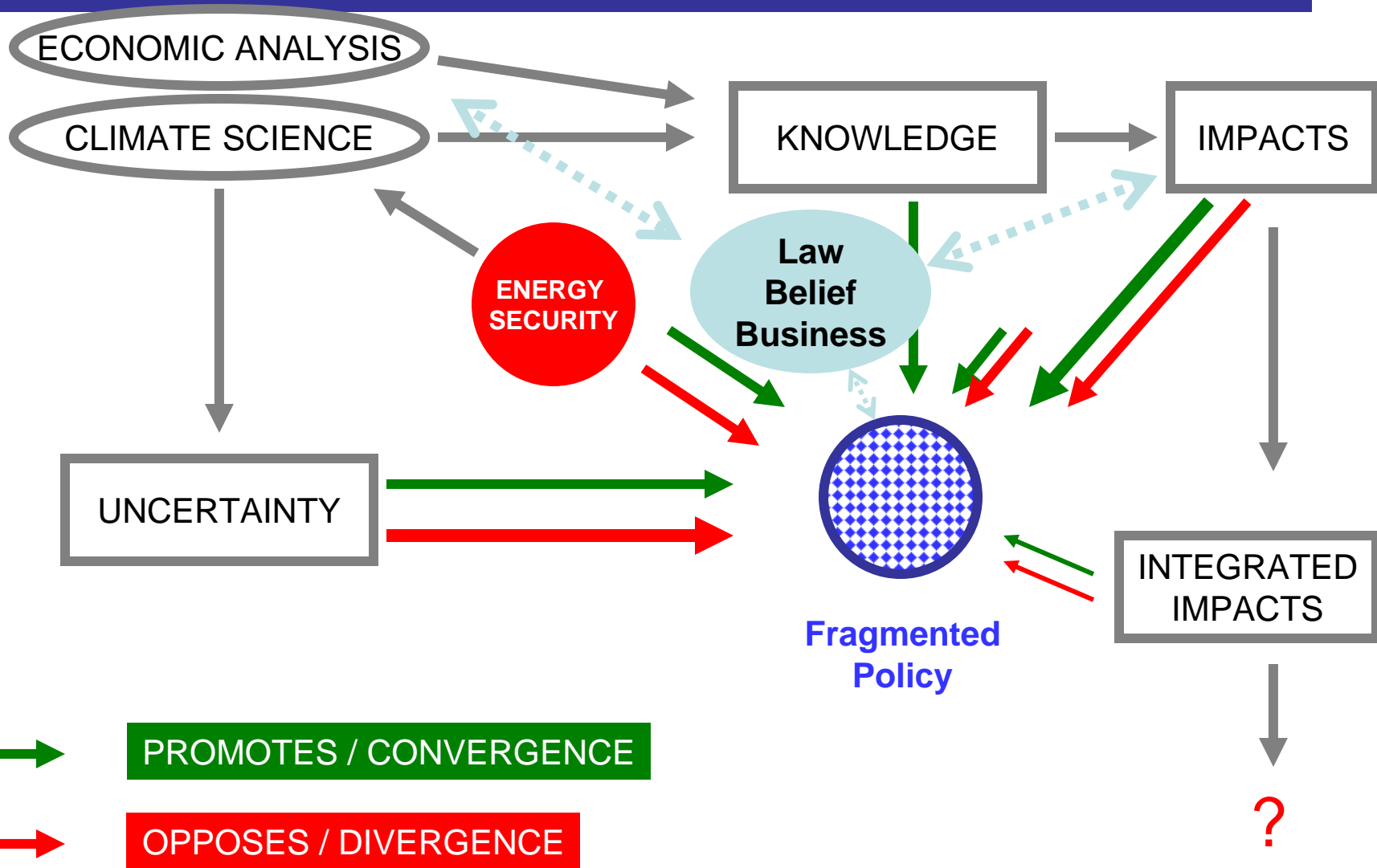
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- **Belief system**
  - religion
  - ethics
  - value systems that are, in principle, different than money
- **Business**
  - value systems that are, in principle, money





# An integrated picture?





# Some attention to business

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# Business

- Business has often been posed as the villain in climate change discussions
  - But business is far from uniform in motivations, practices, and beliefs
- Business is core to the economy, core to consumption, core to energy use
  - Ultimately business is a core element of the solution set; it is connective.



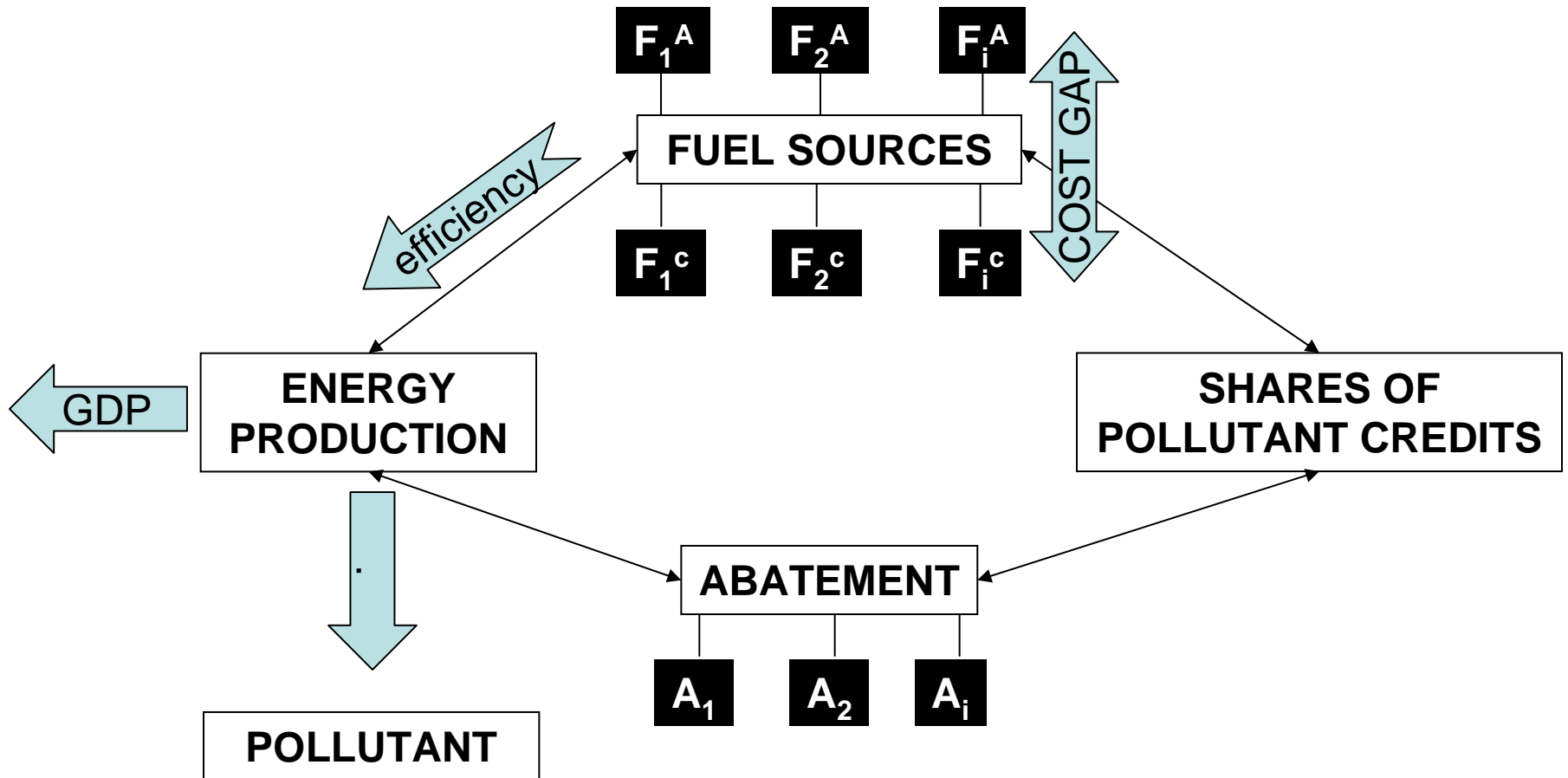
## Revisit the environmental market

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- If we look at how the different communities communicate with each other, then communication is often most effective through valuation, that is, money.
  - Money is, abstractly, the standard of communication.



# Elements of environmental pollutant market





## Some Resources on Business and Climate Change

- Readings
  - [Hoffman: Pew Corporate Strategies 2006](#)
  - [McKinsey: Global Business Survey 2008](#)
- Web portals
  - [U.S. Climate Action Partnership](#)
    - [CAP Call for Action](#)
  - [CERES: Coalition of Investors, Environmental and Public Interest Groups](#)
    - Click Publications: Look at 2003 and 2006 Corporate Governance



# Climate Action Partnership

- Account for the global dimensions of climate change;
- Create incentives for technology innovation;
- Be environmentally effective;
- Create economic opportunity and advantage;
- Be fair to sectors disproportionately impacted;  
and
- Reward early action.



## One interesting view into business

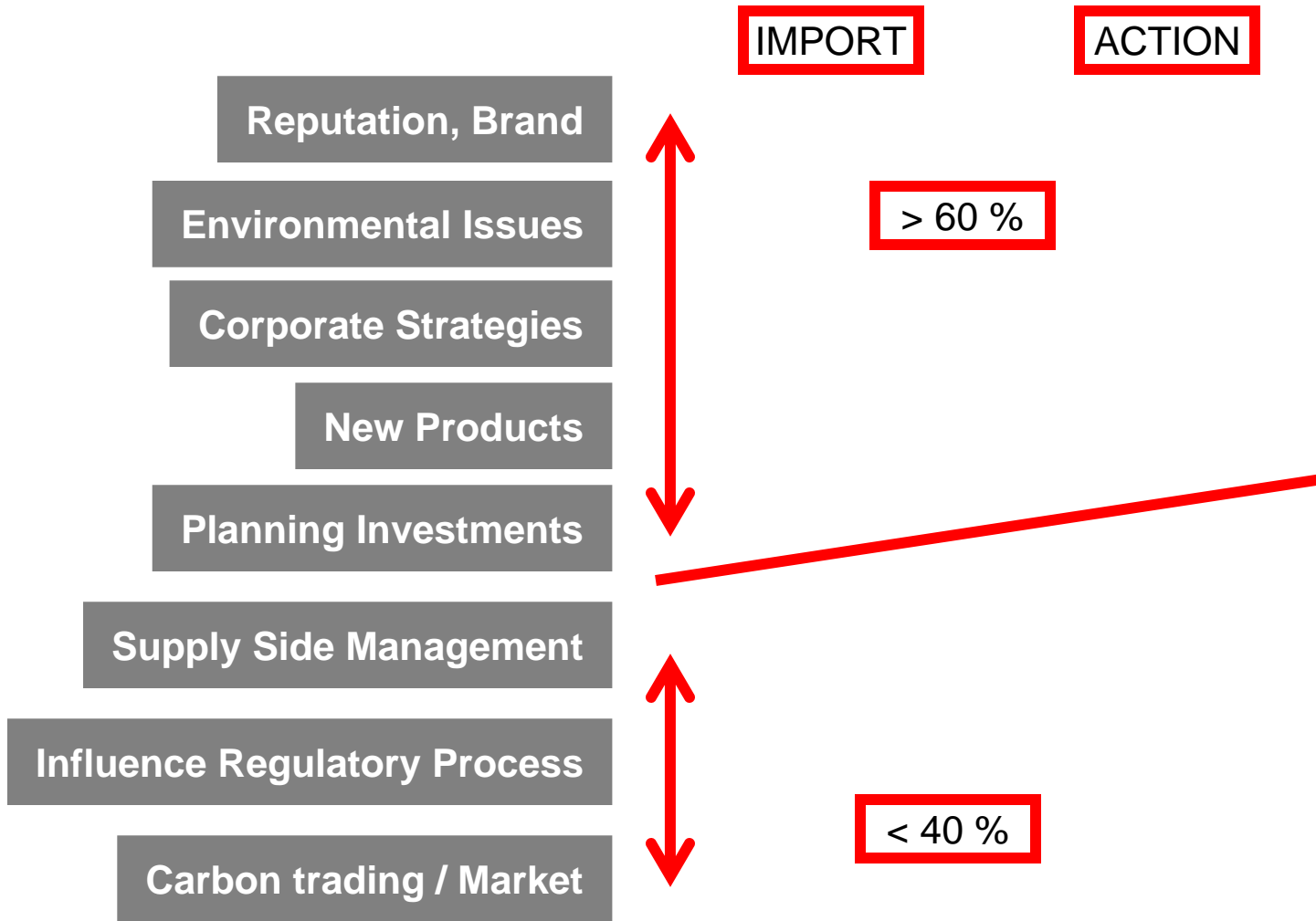
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- McKinsey *et al.* Global Survey
- > 2000 Corporations Respond
  
- This report defies me when I try to take graphics from it!





# Summary of 2008 McKinsey Report





# Geographic Sector

	IMPORT	ACTION
Asia: NOT China and India		
China	> 60 %	> 30 %
Europe		
India		
Latin America	~ 50 %	< 30 %
North America		



# Business

- 
- Business effective accelerator of policy?
    - Policy risk greater than “climate” risk
  - Remember business, like all of us, act in self-interest



# Summary

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# A useful idea?

- We arrive at a situation where there are four overarching communities:
  - Science
  - Business
  - Government
  - Non-governmental organizations
- For the most part the elements of the community behave rationally within their community.
- When the communities interact, they can appear irrational to each other.
- With the consideration of the attributes of time, space, and wealth, rationality can often be defined and lead to solution paths.
- These are “biological” not “hierarchical” relationships.



# Climate change versus other challenges

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- Climate change sits in relationship to other challenges such as food security, AIDS, malaria, energy security, etc., etc.
- Parallel, prioritized approaches to these problems are needed.
  - Think about [Bjorn Lomborg](#).



## What are some of the robust conclusions?

- Long-term solution will require decoupling energy use and greenhouse gas emission, and hence, economic success with greenhouse gas emission.
  - Population?
  - Consumption?
- Energy security will compel the use of more coal and oil. Therefore, “removal” of CO<sub>2</sub> from the atmosphere will be required.
  - Sequestration
  - Other?



## What are some of the robust conclusions?

- If the “Market” emerges as the ultimate policy mechanism, then it will require development.
  - Valuation of efficiency
  - Marginal cost of alternative energy sources
  - Viable, verifiable abatement choices
- What we do in the near term matters
  - Efficiency: but need valuation of efficiency
  - Avoided deforestation
  - Technology incentives: (Marginal rate of returns.)
  - Tax policy (to value efficiency and to bridge the marginal cost of alternative energy choices.)





## What are some of the robust conclusions?

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- Get honest and responsible about geo-engineering.
  - We are, *de facto*, geo-engineering no matter what we do.
  - Develop a “climate impact assessment” capability.
- Focus an element of climate science on the applied sciences of resource management and adaptation.
  - Science investigation of non-science questions.



## Energy-Economy-Climate Change

- Because of the global reach of Energy, Economy, and Climate Change, solutions need to be woven into the fabric of our behavior.
- Solutions need to be able to evolve from the near-term to the long-term.
- Solutions need to address both local and global attributes of the problem.
- Solutions are impacted by wealth
- There is no one solution; we need a portfolio of solution paths.



# Class Specifics and Projects

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## Where have the students come from?

- School of Natural Resources and Environment
- School of Business
- School of Public Policy
- Literature, Sciences and Art
- College of Engineering
- School of Law
- School of Public Health



# Lectures and Project

- Lectures by me and guest lecturers
- Project
  - To provide a knowledge-based analysis of a complex problem.
  - Purpose of the analysis
    - Inform an agency head, government official, a corporate manager so that a decision can be made.
    - Set the foundation for a research program, an initiative, a business plan.



## Some Aspects of the Project

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- Students become aware of what is knowledge and what is advocacy.
  - Advocacy clearly separated from what is known.
  - If an advocate, be fully aware of that fact.



# Approaching Complex Problems

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- What are pieces of the problem?
  - Brain storming
  - Mind maps
    - Write down all of the things that you can think of associated with the problem
- Do not try to define the relationship between the pieces of the problem.



# Consider heat waves and human health

AUGUST FOOTBALL PRACTICE

HEAT STRESS INDEX

URBAN HEAT ISLAND

1995

HOT WEATHER

COOLING CENTERS

EMERGENCY ROOM

ELDERLY

GREEN ROOFS

LINDA RONSTADT

EXTREME HUMIDITY

PARAMEDICS

MEXICAN BORDER

EXTREME DRYNESS

HEART DISEASE

CHILDREN ON PLAYGROUND

CLIMATE CHANGE

2003

FLAWS IN CURRENT SYSTEM

MARTHA AND THE VANDELLAS

NIGHTTIME TEMPERATURE





## From the pieces of the problem

- Look for organizing notions and concepts. A way to group things.
  - Function
  - Discipline, like climate, public health, etc.
  - Related behavior
- The organization is not unique
  - For example high heat is likely a member of more than one group: physical climate, health threat, air quality, electrical demand
    - Avoid trying to make unique assignments of the pieces to groups.
    - Relationships are more “biological” than “hierarchical”



# Draw your first picture of elements of the problem

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HEAT-RELATED  
ENVIRONMENTAL  
PRODUCTS  
(e.g heat index)

Policy

ENVIRONMENTAL  
OBSERVATIONS and  
FORECASTS

HUMAN HEALTH AND  
PHYSIOLOGICAL  
INFORMATION

COMMUNICATIONS  
of PRODUCTS

ACTIONS BASED  
ON PRODUCTS  
and  
COMMUNICATIONS

Research and  
Validation



Think about the organization of the problem as a whole.

---

- What are you trying to achieve?
  - In a complex problem all of the pieces can be brought together towards several possible conclusions.
- What you are trying to achieve helps to define relationships between the pieces. It helps to set priorities



## Heat Wave System: Basic elements

Rethink your first picture. Start to separate your groups into roles.

ENVIRONMENTAL  
OBSERVATIONS and  
FORECASTS

HUMAN HEALTH AND  
PHYSIOLOGICAL  
INFORMATION

HEAT-RELATED  
ENVIRONMENTAL  
PRODUCTS  
(e.g heat index)

COMMUNICATIONS  
of PRODUCTS

ACTIONS BASED  
ON PRODUCTS  
and  
COMMUNICATIONS



## And thus to an end.

- The projects place the element of science-based information in relation to the other considerations.
- The separation of advocacy and preconceptions often leads to far different conclusions than originally thought.
- The interface between “science,” “policy,” “business,” and “value systems” is often rationalized and there is one or more possible paths forward.



# 2008 Class Projects

- 2008 Climate Change Projects
  - Energy, Water, Climate Change, and Economic Development of the Navajo Nation
    - Narrative      Presentation
  - Exxon and BP: An Analysis of Two Companies' Approach to Climate Change
    - Narrative      Presentation
  - Iron Fertilization in the Ocean: Environment and Business Opportunity
    - Narrative      Presentation
  - Biofuel and Hybrid Buses in Ann Arbor: A Consideration of the Cost of Climate Change
    - Narrative      Presentation
  - Carbon Management Initiative: The Integration of Carbon Management into the University of Michigan Curriculum
    - Narrative      Presentation

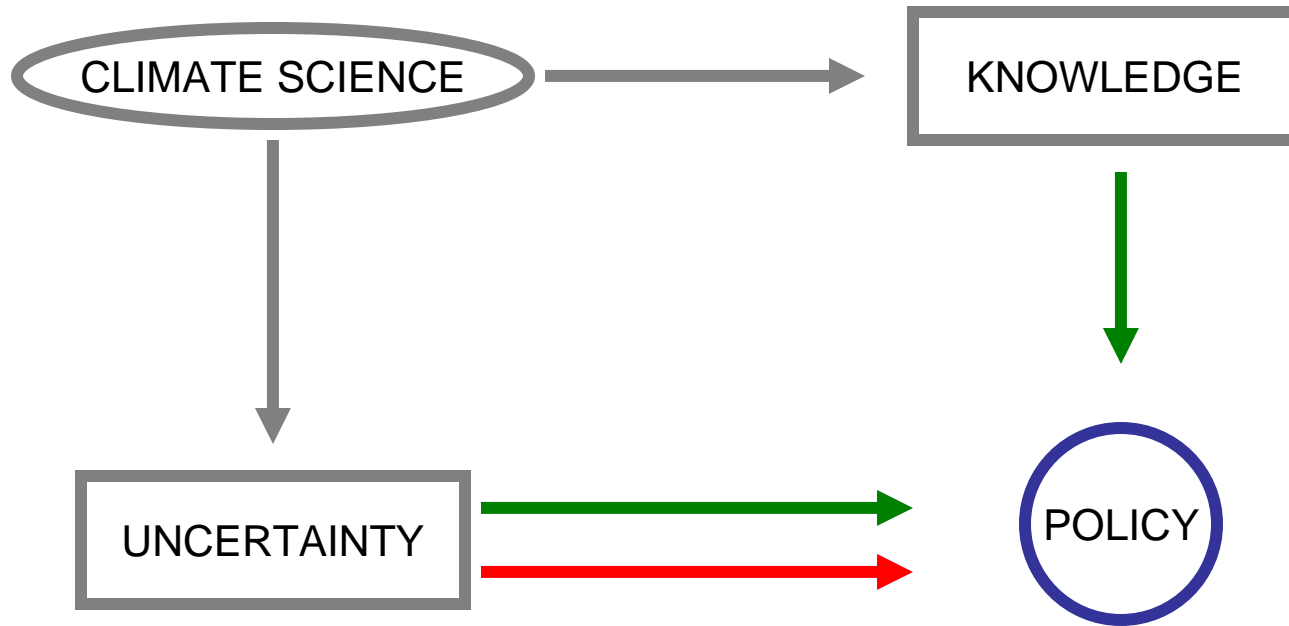


# A Few Nuanced Viewgraphs

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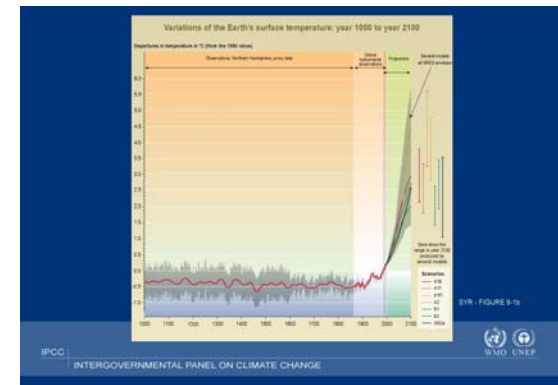
# Climate Science-Policy Relation



PROMOTES / CONVERGENCE



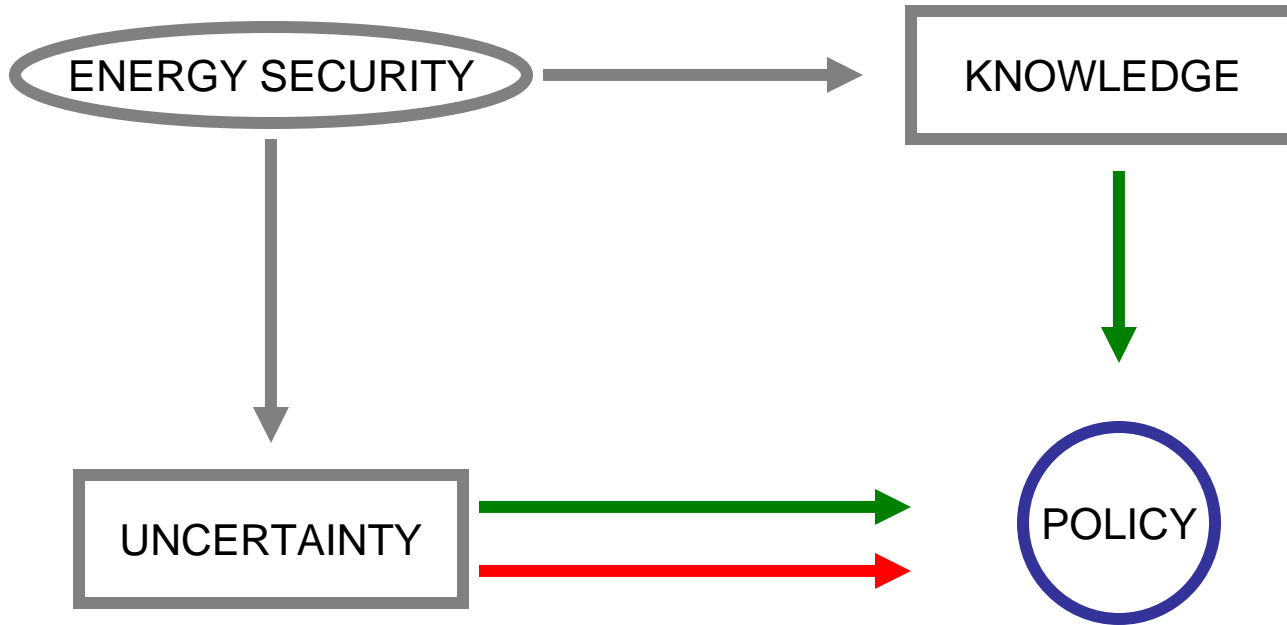
OPPOSES / DIVERGENCE







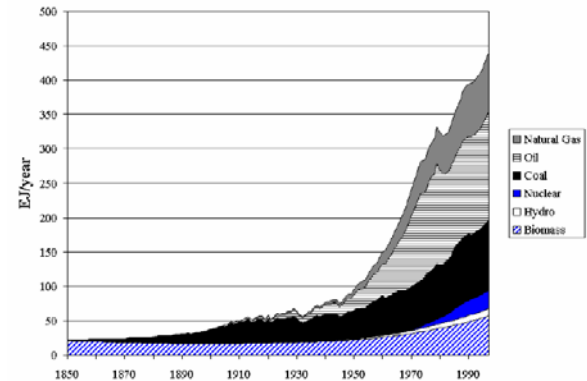
# Energy Security-Policy Relation



PROMOTES / CONVERGENCE

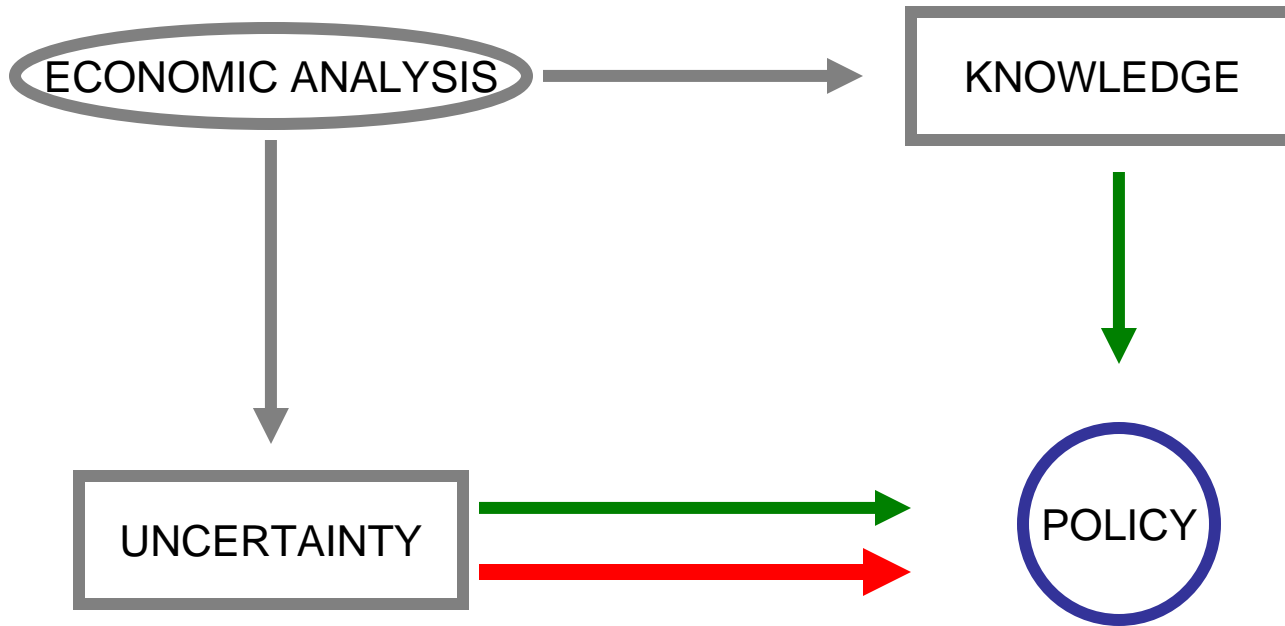


OPPOSES / DIVERGENCE





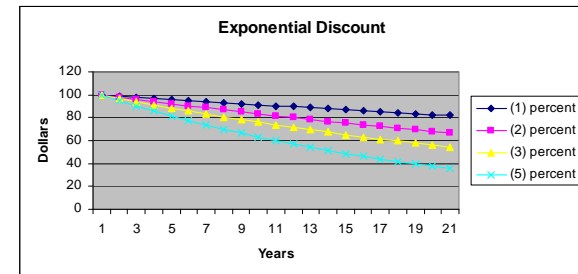
# Economics-Policy Relation



**PROMOTES / CONVERGENCE**



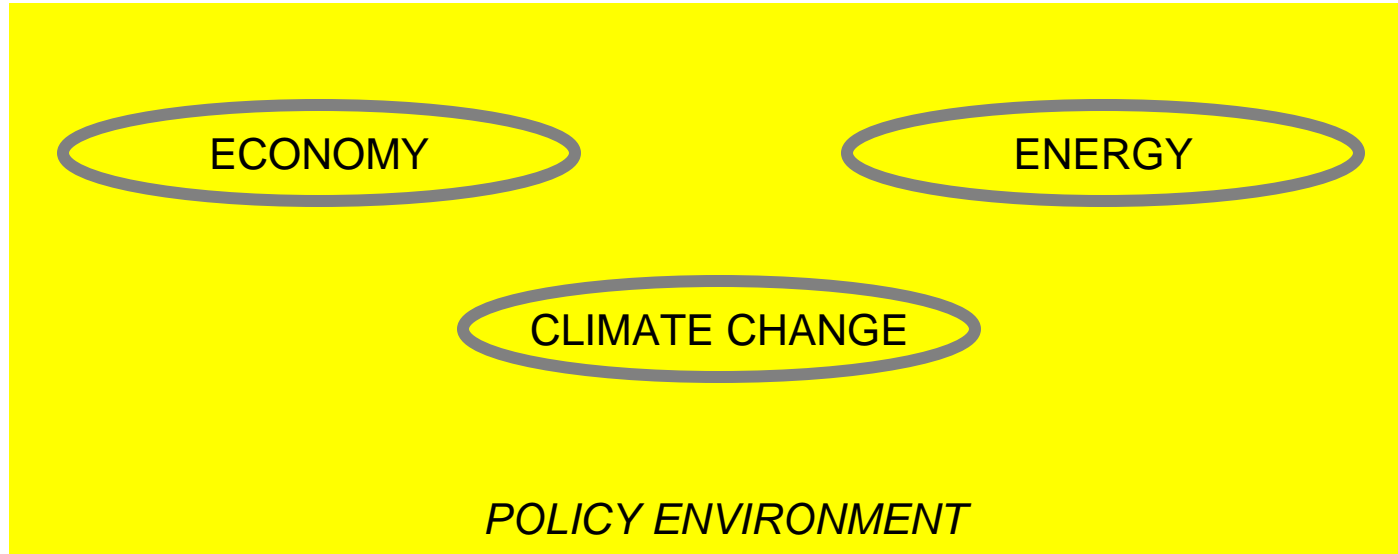
**OPPOSES / DIVERGENCE**





# Energy-Economy-Climate Change

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WHAT IS THE POLICY ENVIRONMENT IN WHICH OPTIMAL RESULTS CAN BE ACHIEVED?