System Dynamics Modeling for Policy Analysis

Threshold 21 (T21)

T21

INTEGRATED DEVELOPMENT MODEL

Andrea M. Bassi, Ph.D.
ICTP Trieste, 20 May 2011

End goal!

- Imagine a simulation model, customized to your country, that allows you to use inputs from climate models and simulate social, economic and environmental impacts of, among others, hurricanes and rainfall cycles.

- Then, imagine the same model allowing you to use climate data to support national development plans and inform budget allocation for climate mitigation and adaptation.

End goal! (2)

- This model should be well regarded by economists, social and environmental experts, and still be used by policy makers!
- Finally, you should be able to run scenarios, modify the structure of the model and carry out policy analysis, all using a graphical user interface – with no coding.
- OK… now we are ready to go!

Agenda

- Introduction to System Dynamics (SD) and Threshold 21: overview of the model
- Application of Threshold 21 Model to National Development Policy Options
- Interactive demonstration of past modeling experiences in several countries using T21

Some info about myself

- Deputy Director at the Millennium Institute
  - Working on sustainable development issues, mostly policy formulation and evaluation, with focus on energy and the environment, often in Africa
- Former Visiting Researcher at the Danish National Environmental Research Institute (NERI) and GRA at the Los Alamos National Laboratory

- Ph.D. and M.Phil. in System Dynamics: University of Bergen, Norway
- M. Sc. in Economics: LIUC University, Milan, Italy

Millennium Institute

- Established in 1983, MI is a not for profit organization based in Arlington VA, USA.
- Our goals are to develop and disseminate advanced analytical tools to support strategic planning on critical issues;
- Build capacity in countries to use our tools to help address critical issues;
- Develop a network of partners to inspire, endow, and implement more integrated planning towards a sustainable future.

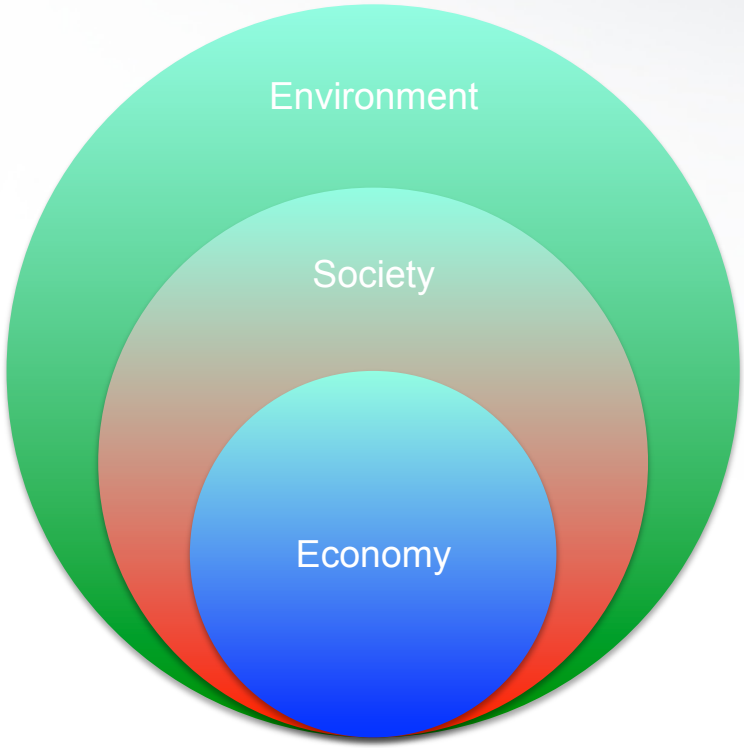
MI's Core Offerings

- Research in systemic and integrated national, regional and global models; sector models
- Capacity development and training for SD and medium and long planning specialists
- Visualization of synergies and implications of different policy options across and within sectors
- Provision of insight into interrelations (synergies and dissynergies) across and within critical issues
- Long term support to clients and partners for modeling, scenario analysis and policy design

Characteristics of MI projects

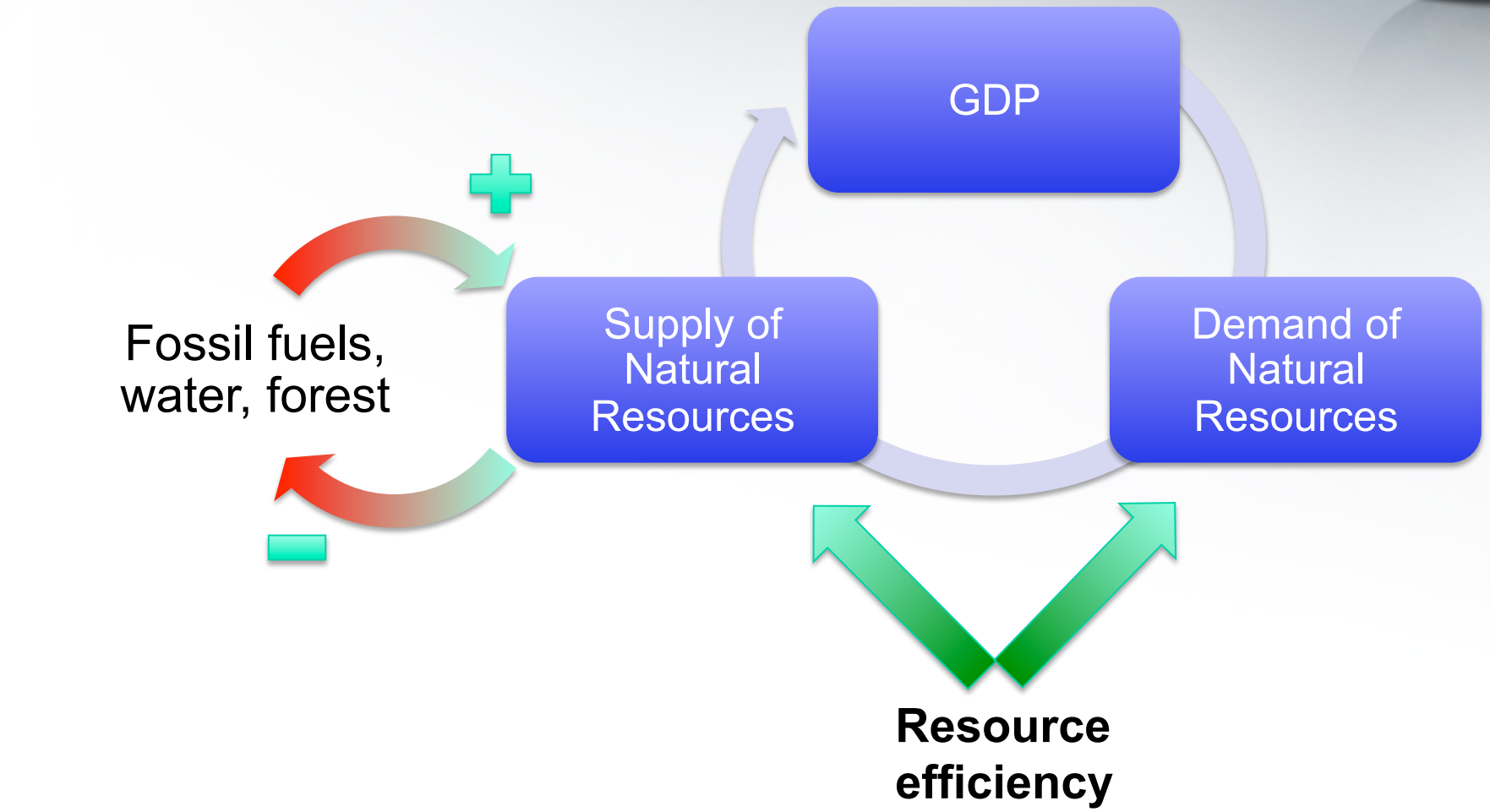
- Customized models (to local context) and analysis, focused on elaborated national vision and implementation policy
- Flexible, easy to learn and use software for the simulation of different scenarios
- Integration of different stakeholder from across government and interested parties in the modeling and policy dialogue process
- Local capacity development for modeling and integrated policy planning institutionalization

Approach – Methodology

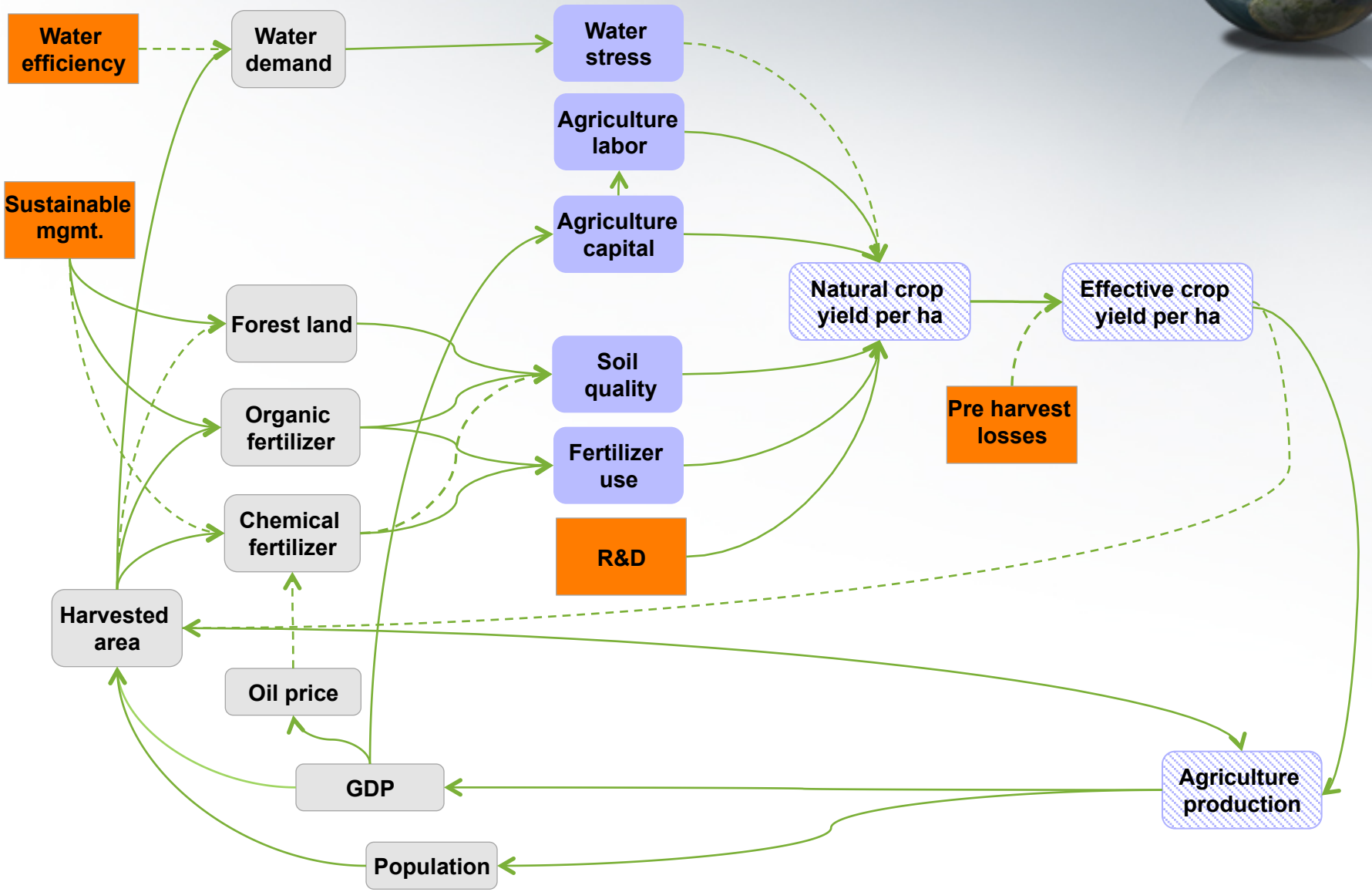


Society	Economy	Environment
Population	Agriculture	Land
Nutrition	Fishery	Water
Education	Forestry	Energy
Employment	Industry	Waste
Poverty	Services	Emissions
Public Infrastructure	Economic Accounts	Footprint

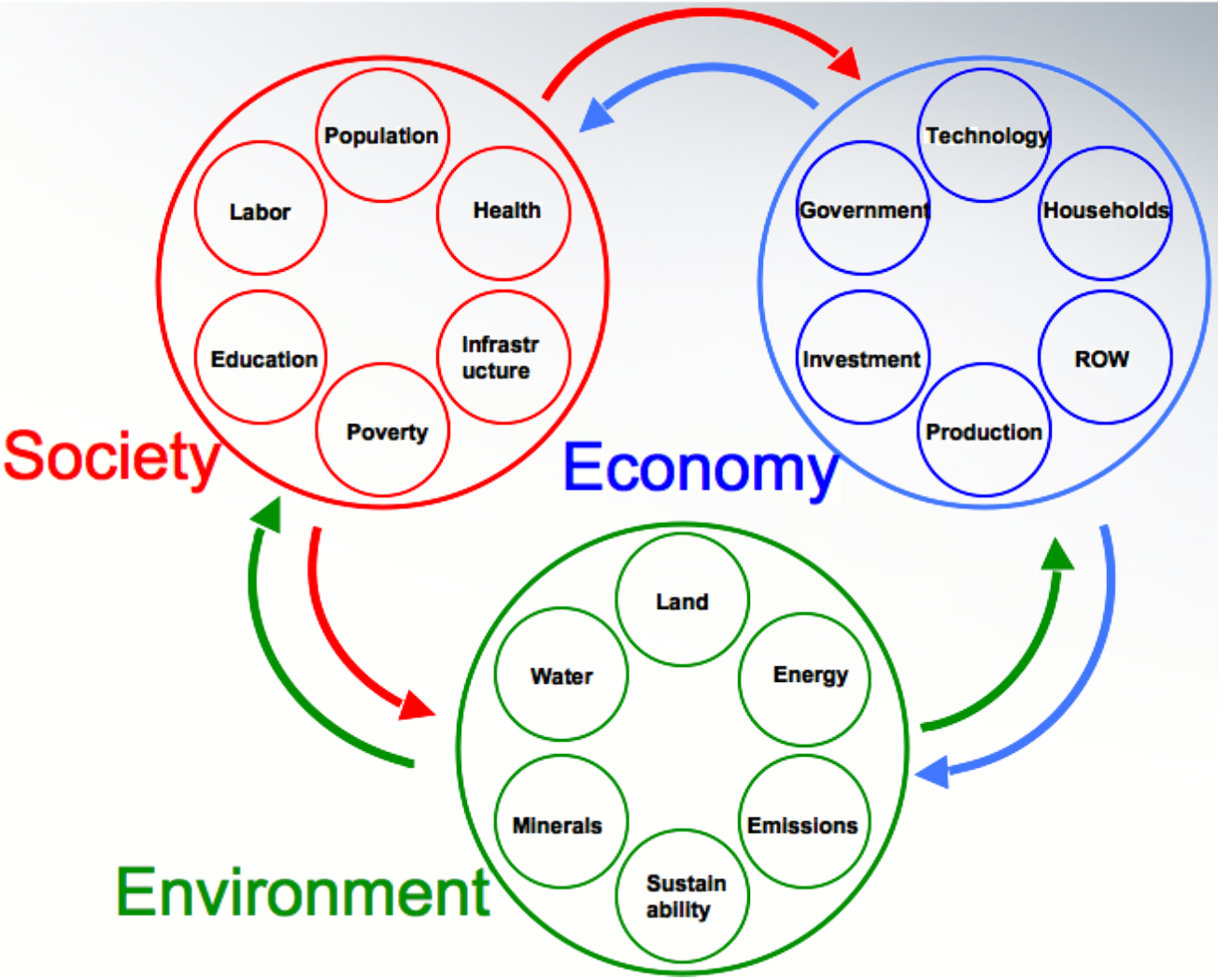
Approach – Methodology (2)



Approach – Methodology (3)



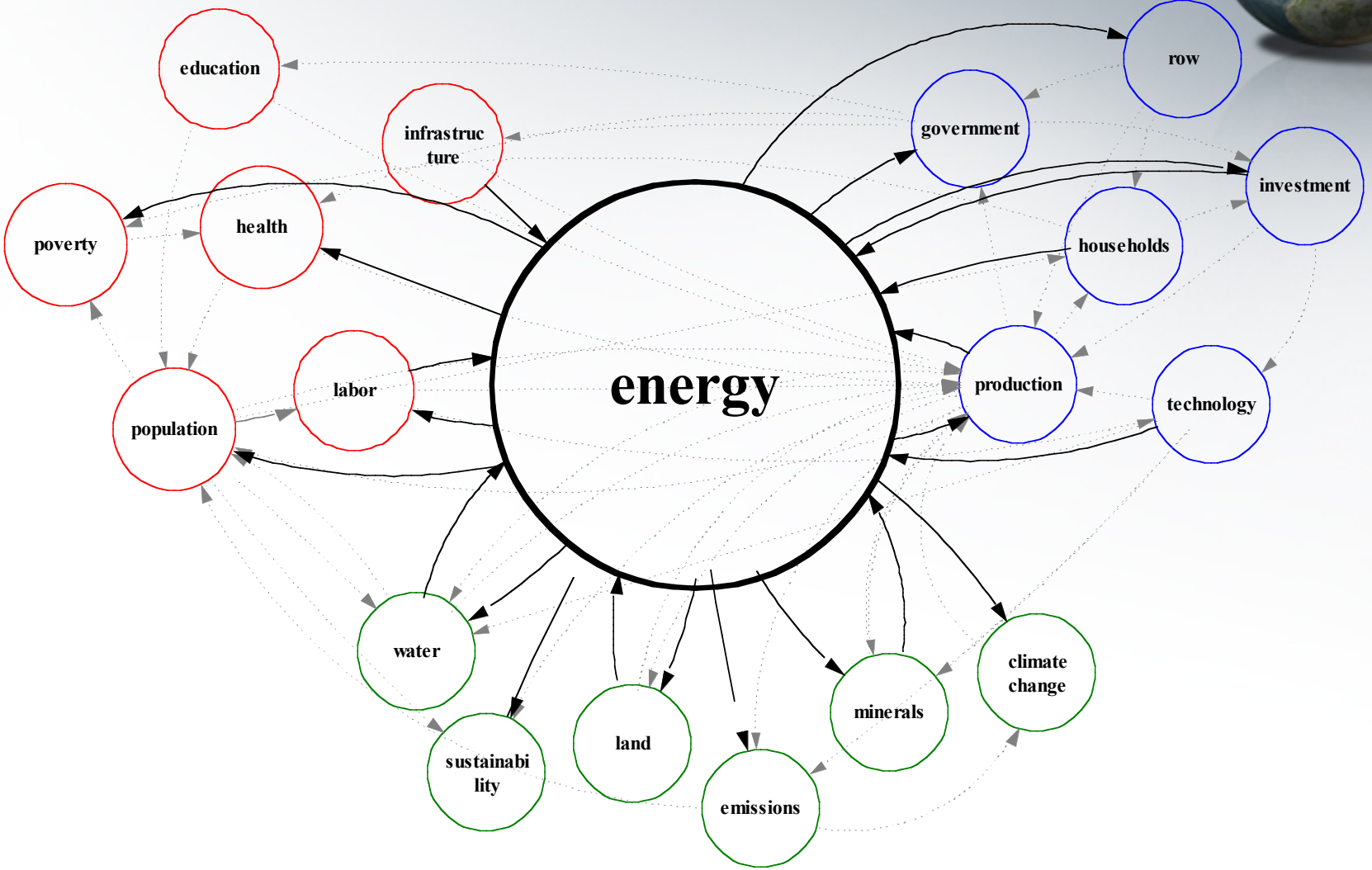
Architecture



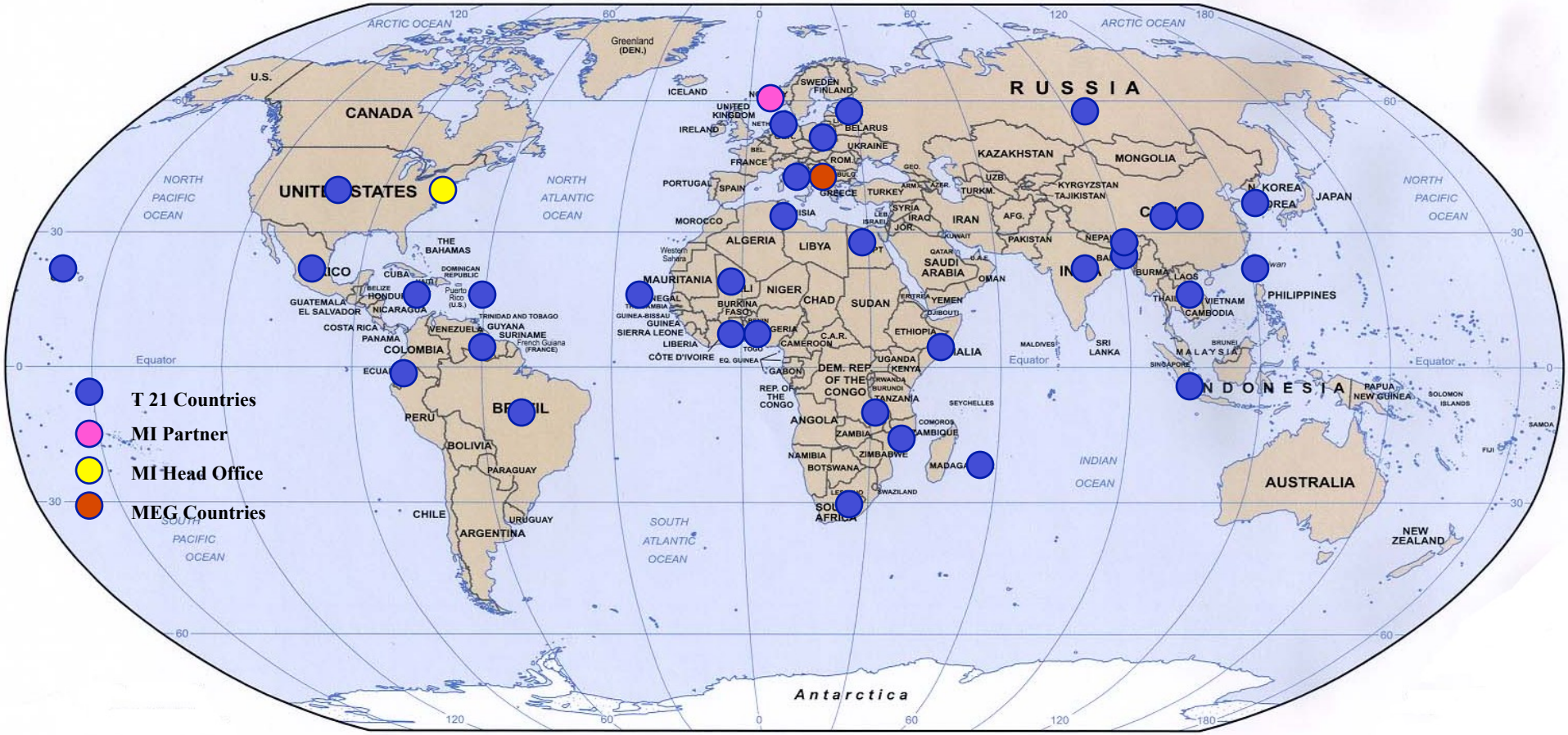
The Threshold 21 Approach

- **System dynamics methodology**
  - Based on existing sector analyses
  - Reflects observed real world relations
  - Analyzes cross-sector links and feedback loops
- **Composed of three main pillars**
  - Economic -- SAM, key market balances, and production
  - Social -- dynamics in population, health, HIV/AIDS, education
  - Environmental -- area specific issues and information
- **Adapted to priority goals and vision for each individual country** based on its own data, structure, and patterns of activity
- Highlights inter-sectoral feedbacks
- Calibrated against history to provide reality checks
- Generates multiple medium-to-long-term scenarios
- **Transparent and easy to use**

Energy Interdependencies



Applications Worldwide



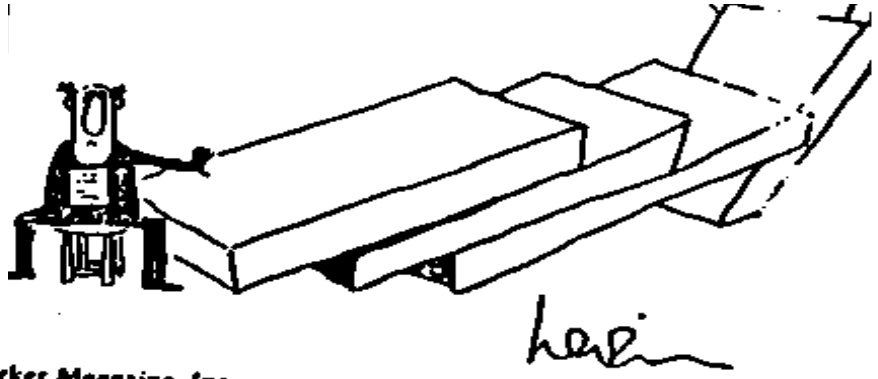
Motivation for System Dynamics

- Need to close the gap between the dynamic, all embracing integrated (system) thinking and certain existing sectoral static/linear tools (models)

  Such tools are required when facing critical issues such as the upcoming energy transition, climate change, food security, green economy because conventional modeling tools do not examine their broader causes and impacts

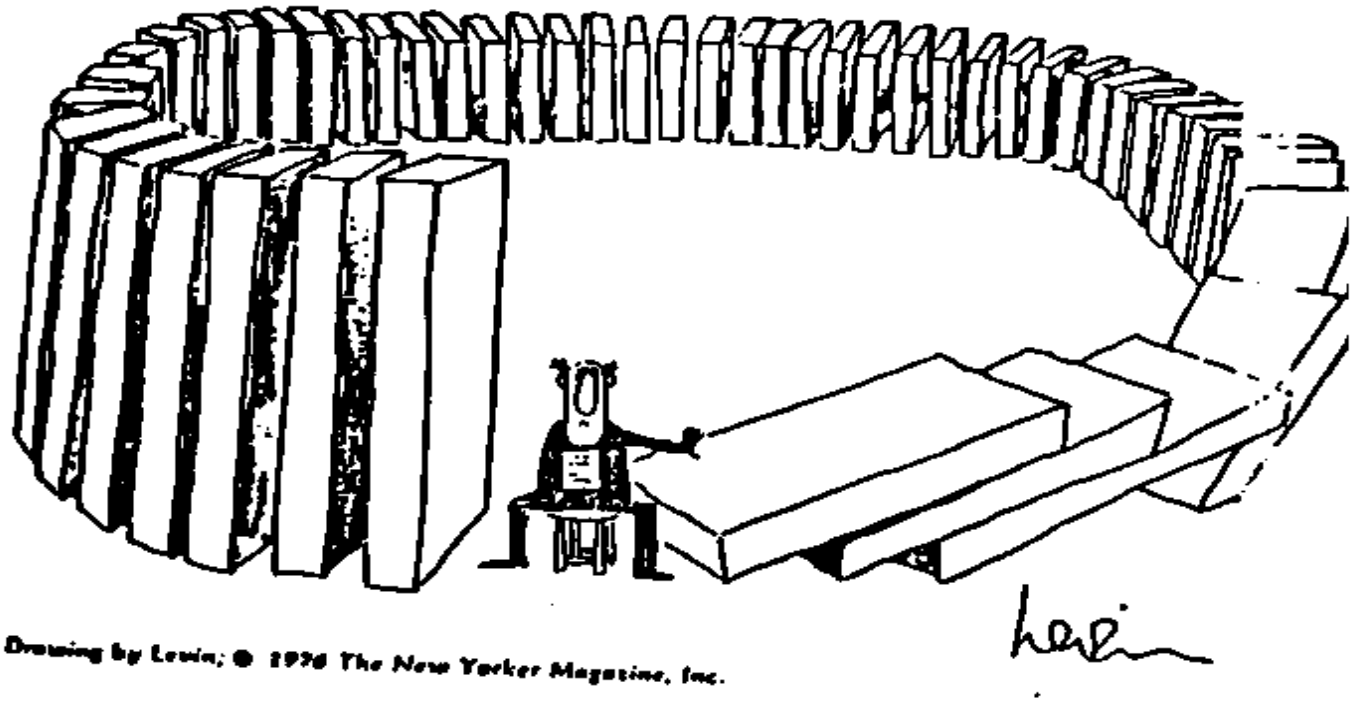
- Enormous efficiency gains (financial and natural resources) from promoting synergies and discouraging negative feedbacks

Why Take a Systemic View?



Drawing by Lorin; © 1976 The New Yorker Magazine, Inc.

To Avoid Unexpected Results!



Implementation (research)

Modeling the context in which issues arise in this research work involves:

- Studying global, regional and national issues and the understanding of how they impact domestic policy formulation.
- Incorporating energy, society, economy and environment into a dynamic modeling framework.
- Building models that serve to create dialogue and establish a mutual trust relationship across government policy making departments and other stakeholders.

Implementation (training & institutionalization)

The capacity and institutional development entails:

- Defining the needs of the client / partner and selecting the candidates for training
- Defining specific needs, developing curriculum and scheduling courses
- Supporting the client / partner in the design and implementation of a strategy to establish system dynamics based modeling and scenario analysis unit(s)
- Providing advice on institutionalization

Key Success Factors

1. Solid Model
    a) Data
    b) Participation
2. (Local) Modeling Capacity
    a) Training
    b) Practical use
3. Institutionalization
    a) Commitment
    b) Ownership (across departments, ministries)

T21 Fits into Planning Toolkits

- Macro models
  - Provide Macro Balances, MTEF, IFI discussions
  - Short term -- need longer-term, x-sector validation
- CGE Models
  - SAM, Detailed relations, Optimum effects
  - Comparative static -- need more transparent paths
- Threshold 21
  - Long term, Cross sector links, Transparent results
  - Not as detailed, builds on local data and input from other tools

Limitations of T21 approach

- Mid-long term approach: does not focus on short-term volatility
- National perspective: does not (often) consider diversity among different regions
- Medium-high level of aggregation: parameters are averaged by sector
- Requires active involvement of client in definition of model's structure

Main Objectives – capacity building

Analytical knowledge and skills:

- *SD method:* Basic knowledge of the System Dynamics method;
- *Behavioral analysis:* Ability to relate a system's behavior to the underlying structure;
- *Understanding complexity:* basic elements of complexity in common social, economic and environmental issues.

Main Objectives – capacity building (2)

Technical knowledge and skills:

- *Software:* Knowledge of basic modeling techniques with Vensim;
- *Modeling:* Ability of representing economic, social and environmental issues through simple simulation models;
- *Simulation techniques:* Ability to run and compare alternative simulation scenarios.

Application of Threshold 21 Model to Climate Change and National Development Issues

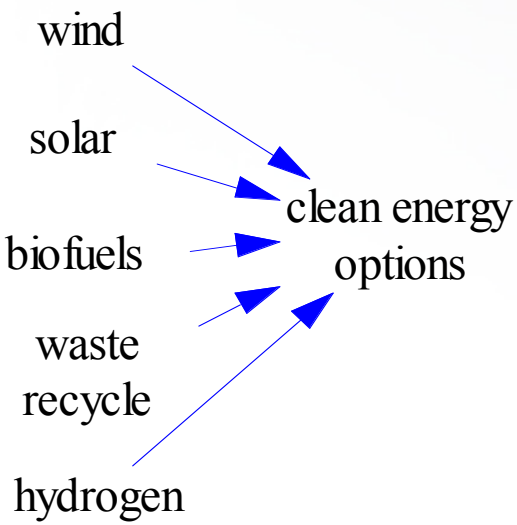
- National Development:
  - Vision to policy
  - Budget allocation
  - MDGs
- Climate Change
  - Mitigation
  - Adaptation
  - Sectoral and integrated policy and investment analysis

Some results

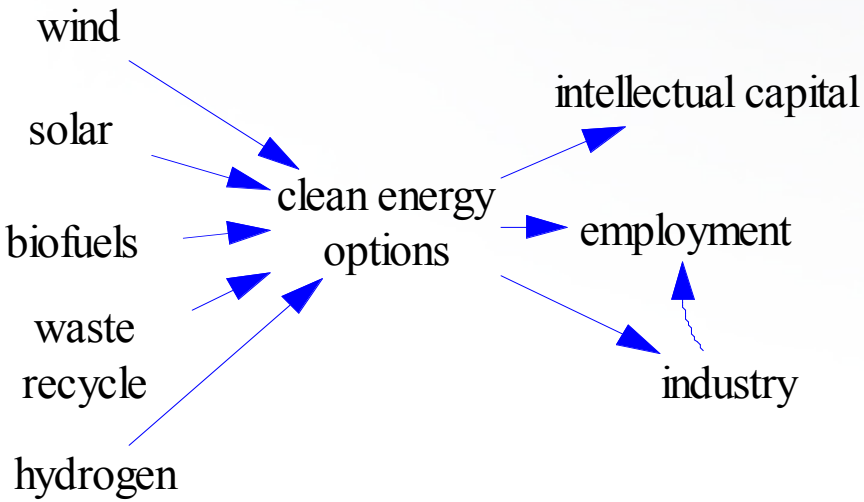
- Emergence of various unexpected side effects is likely;
- Elements of policy resistance arise over the medium and longer term due to the interrelations existing between energy and society, economy and environment;
- Side effects or unintended consequences may arise both within the energy sector and in the other spheres of the model; nevertheless, these behavioral changes influence all society, economy and environment spheres.

Case Study: Lolland, Denmark

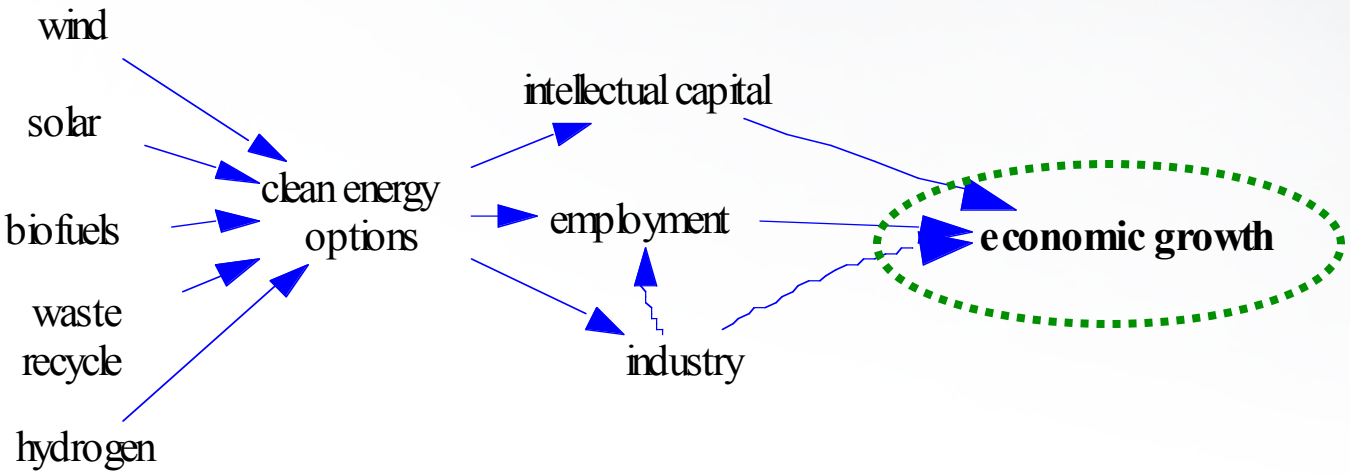
Clean energy options…



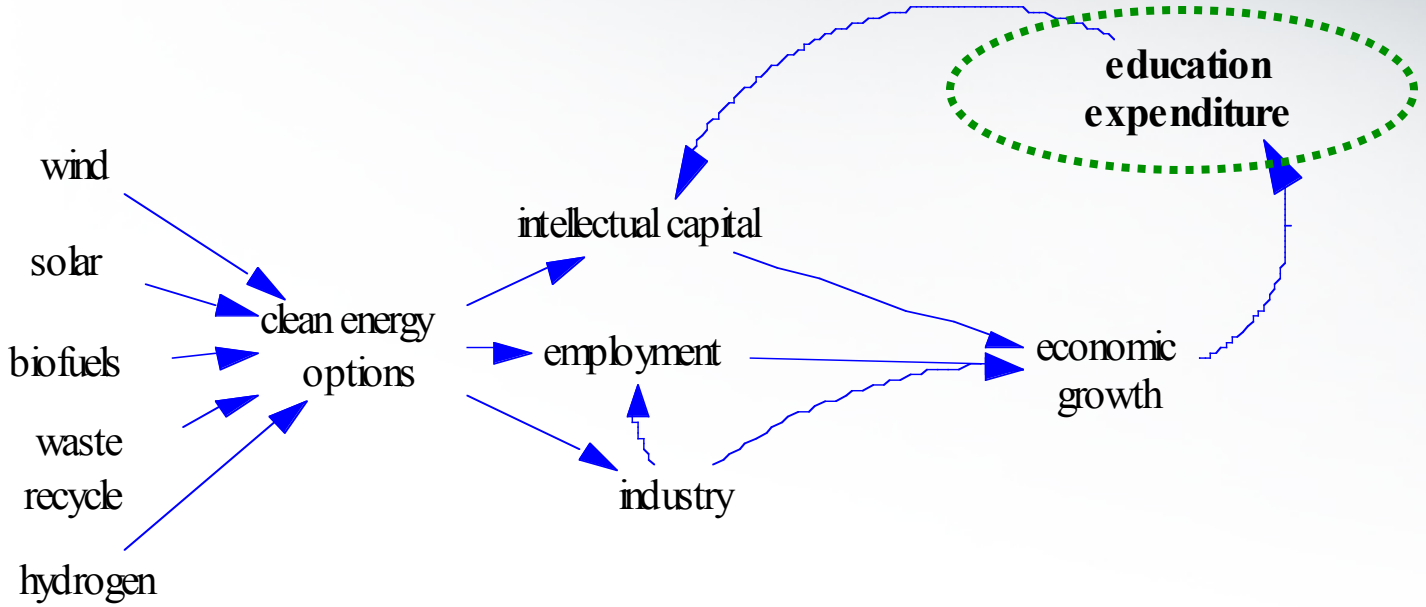
… create positive effects…



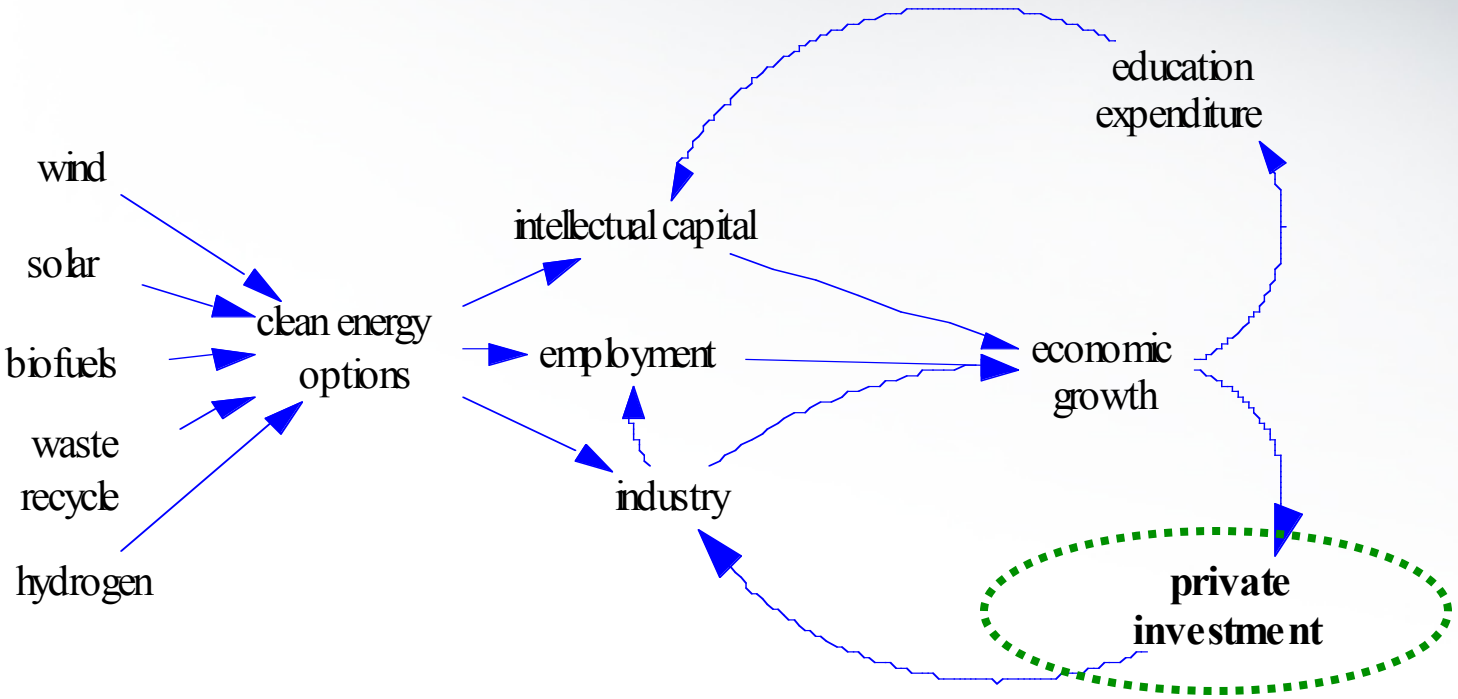
… on the drivers of economic growth…



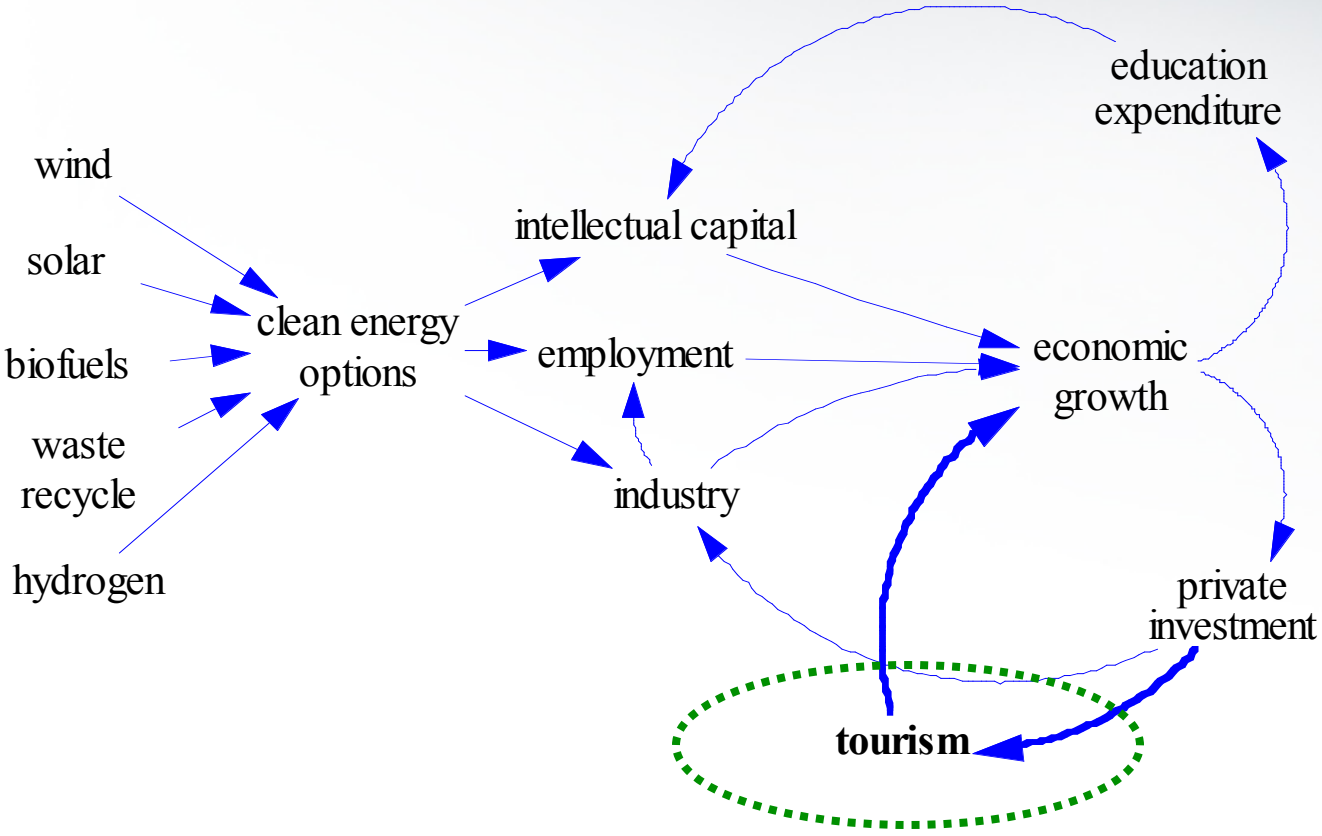
… but require to retain talents…



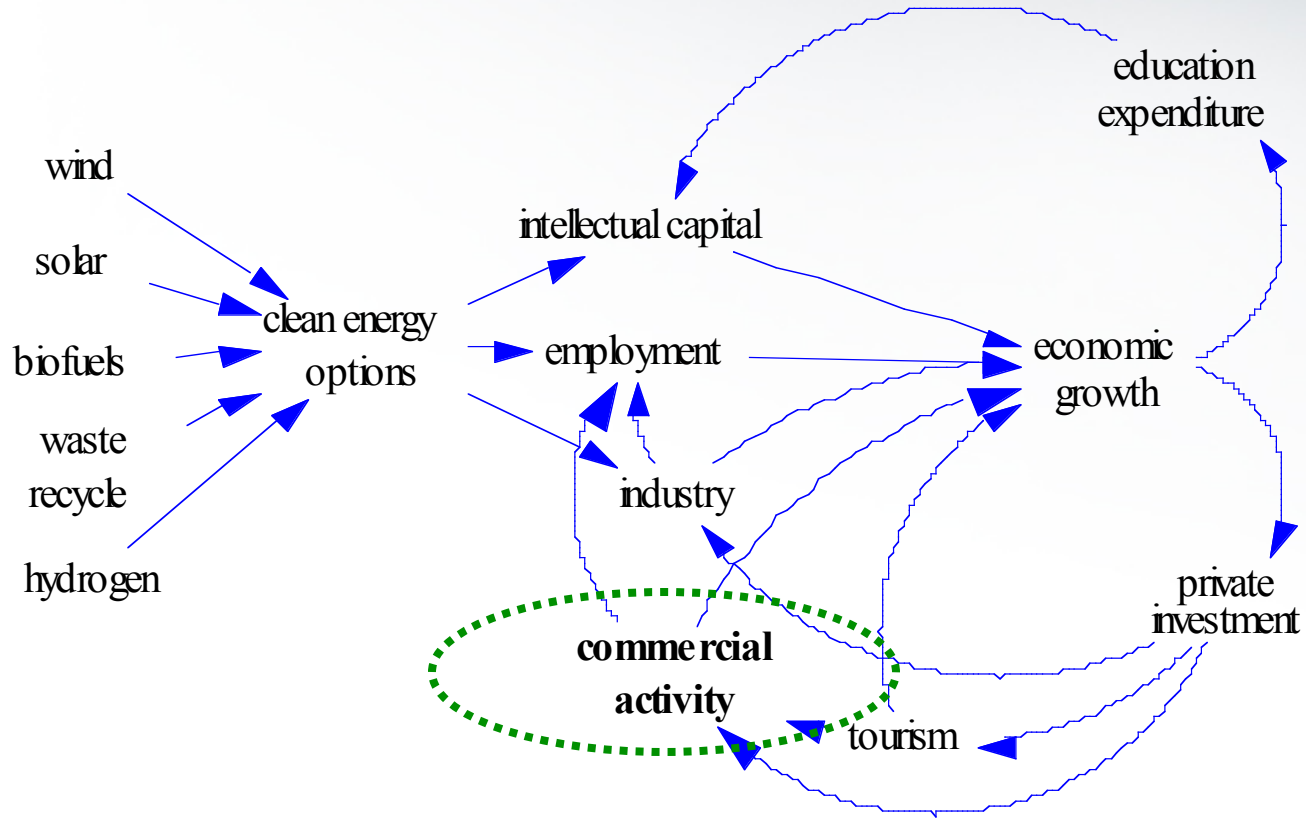
… while stimulating investment…



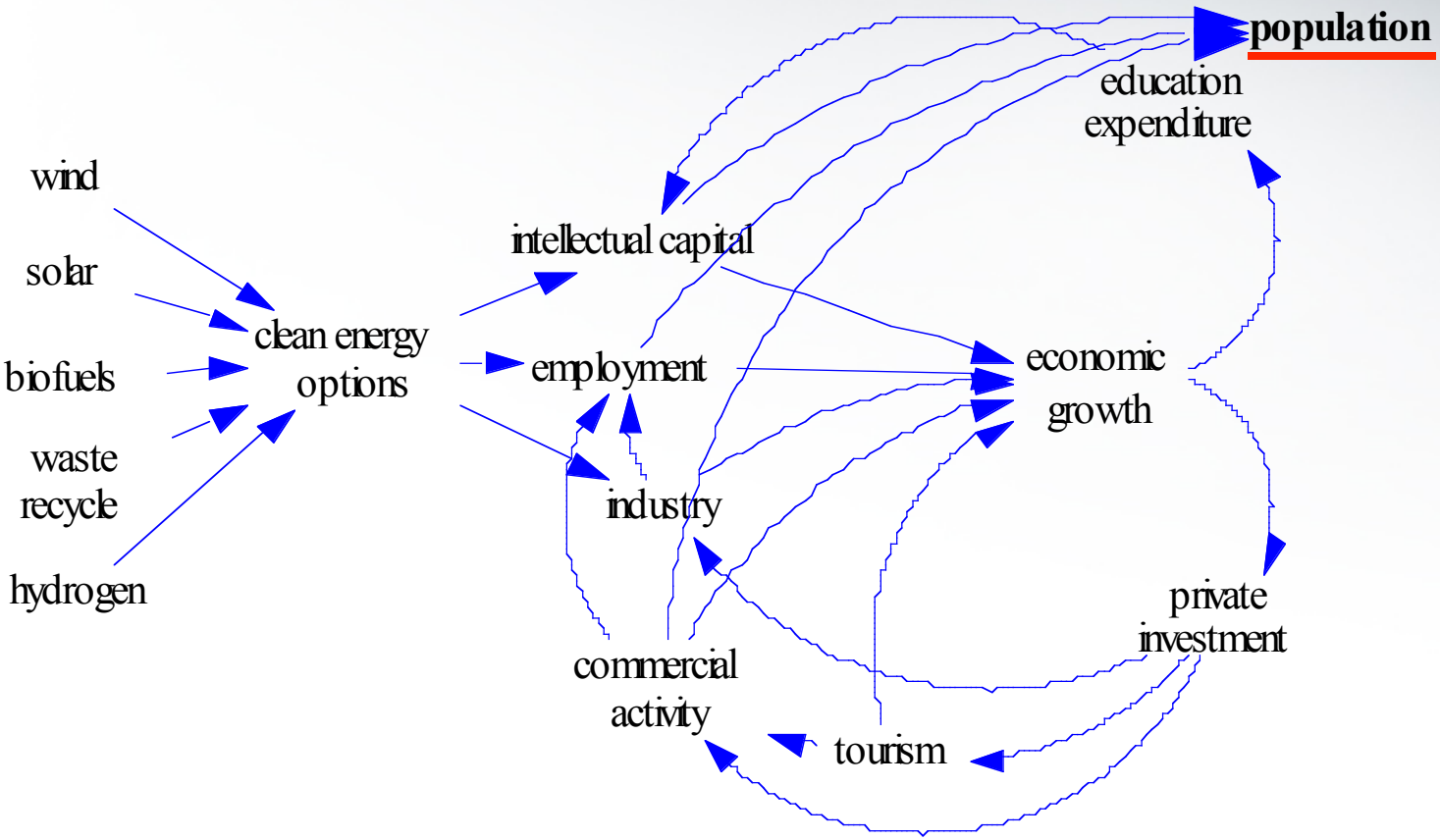
… for the industry and tourism, among others…



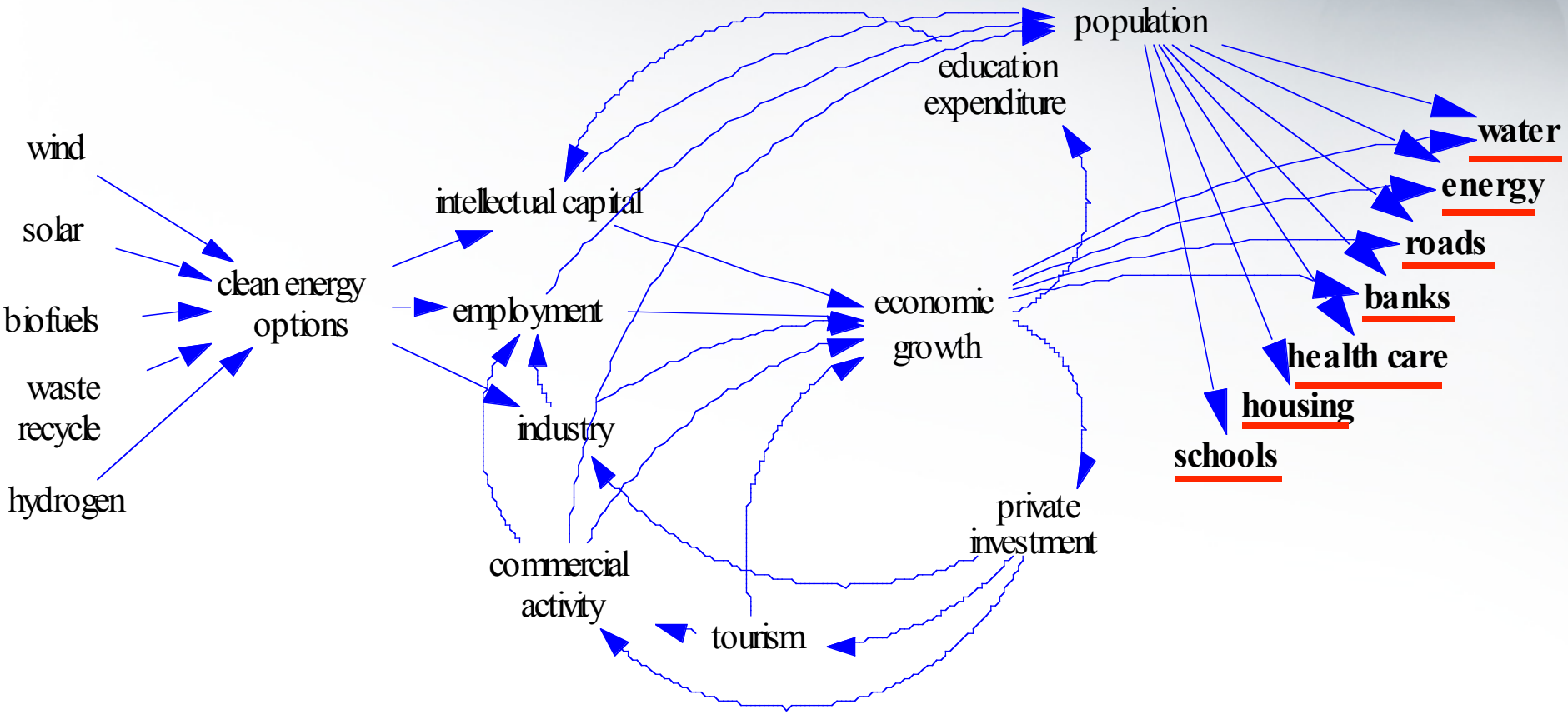
… adding commercial services…



… to finally result in demographic changes…



… and higher needs to sustain economic growth.



T21's Contributions -- 1

- Coordination within and across sectors
  - Relation of infrastructure amd transport systems to economic, social and environmental results
  - Synergies between education, health, labor productivity, and growth, regionally and nationally
  - Impacts of investments and policies on resource security, employment structure, women's roles, and the environment
  - Potential gaps or barriers in cross sector exchanges
  - Improving cooperation among sectors and departments by analyzing joint outcomes

T21's Contributions -- 2

- Understanding endogenous changes over time
  - How will the population age structure evolve
  - When will the better educated nationals be prepared to take on higher skilled jobs
  - When will energy or water constraints become more binding and where
  - How will agriculture programs affect food security and the environment
  - How will industrial diversification affect demand for resources, labor, infrastructure

T21's Contributions -- 3

- Improving government management of growth
  - Tracking financial balances over time related to economic and social development and constraints
  - Determining more effective timing and coordination of programs
  - Adapting lessons learned from 'model' countries to each new country's situation
  - Monitoring progress toward the Vision and adjusting to unexpected changes
  - Improving risk management by examining effects of exogenous shocks

T21's Contributions -- 4

- Strengthening broad support for the path chosen to reach the goals of Mission and medium term plan
  - Help different agencies cooperate by demonstrating the integrated results over time
  - Involve public and private sector stakeholders in productive dialogues
  - Expand knowledge base for the economy and society and help identify indirect causal relations
  - Build public confidence in the process and monitor progress.

T21 Has Helped Many Others

- GM models for emerging markets
- USA Model and CAFE standards, climate policy
- China Model and GHG emissions
- Jamaica Model and Natural disasters
- Assisting UNEP on the Green Economic Report
- Dealing with Climate Change in countries like Bangladesh, Mauritius, USA, Denmark, Kenya, Namibia (ongoing)
- Helping Mali and Mozambique determine how to achieve their development goals
- Supporting Italy and Denmark on environmental policy

Why new insights?

- Results emerge from a combination of:
  - Integrated “spheres”;
  - The representation of feedback, nonlinearity and delays;
  - A participatory and transparent approach.

The approach used contributes to the representation and understanding of the context (social, economic, environmental and political) in which issues arise and within policies are formulated and implemented.

Jamaica case study: extreme events

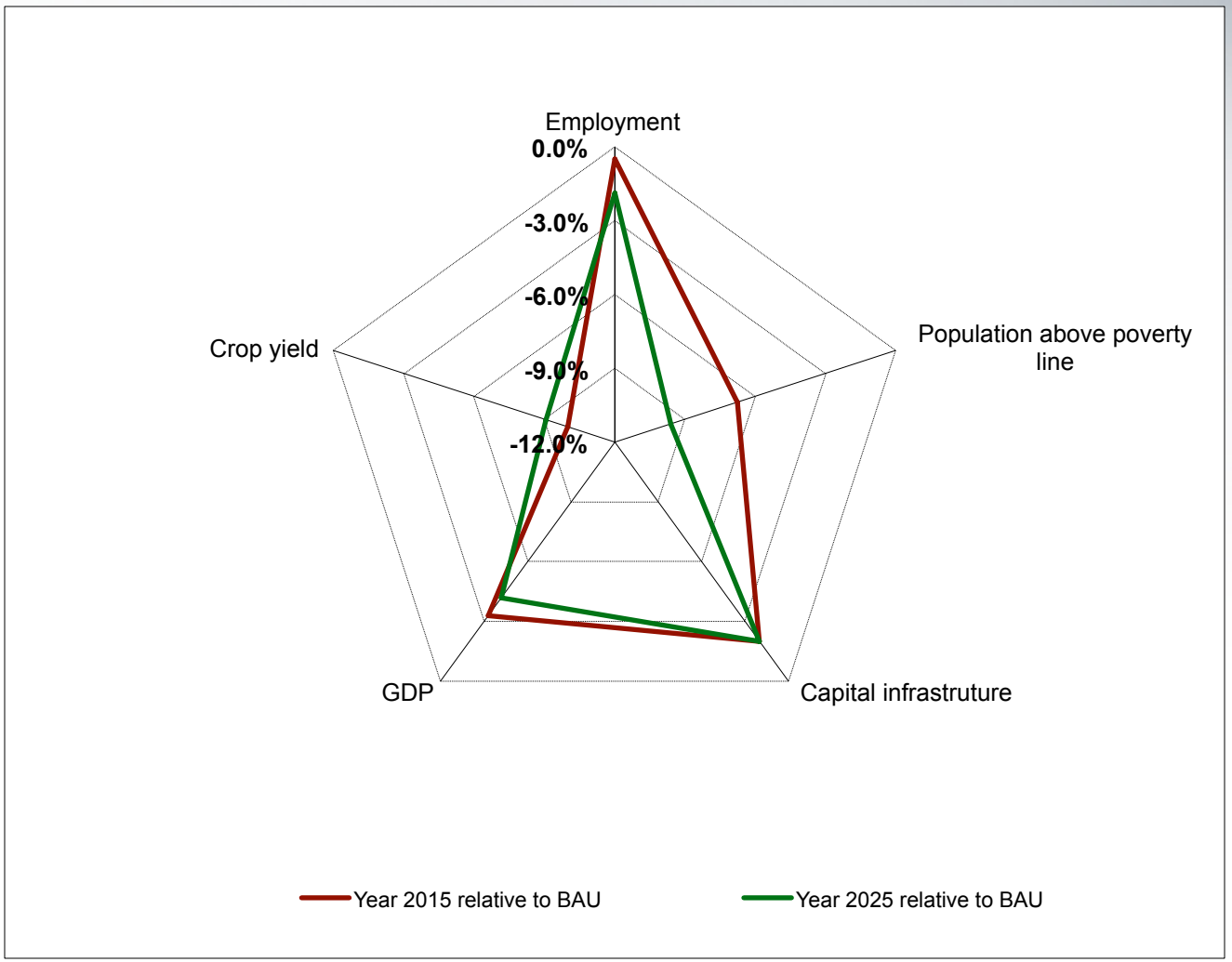
- Simulation of the direct and indirect impacts of natural disasters, namely hurricanes. Direct impacts include repercussions on tourism, agricultural production, industry and service production, government relief expenditures, and human deaths.

Jamaica case study (2)

- **Capital loss** is estimated at about 2% for all economic sectors, and the simulated hurricane is projected to generate a 10% **reduction in crop yield** (or approximately 1,500 tons) in 2015.
- Employment, impacted by capital disruption and a **lower amount of tourists** reaching the island, is projected to be about 25,000 and 50,000 units below the baseline scenario in 2018 and 2030 respectively -a 2.5% **increase in unemployment** by 2030.
- The population will be also directly impacted by the hurricane in terms of **deaths**, which are estimated to be in the range of 30 people, and is dependent on population levels at the time of the hurricane.
- To counter the negative impacts of the hurricane, **more land** will be used to support agriculture production (therefore requiring **more water**).
- Private investments are supported by the natural disaster **insurance payments**, reaching 25B and 87B Jamaican Dollars in 2015 and 2025 respectively (assuming that 20% of properties are insured). Further, the government is projected to allocate about 18B and 62B Jamaican Dollars to **disaster relief projects** in the two years following the hurricane, respectively 2015-16 and 2025-26.

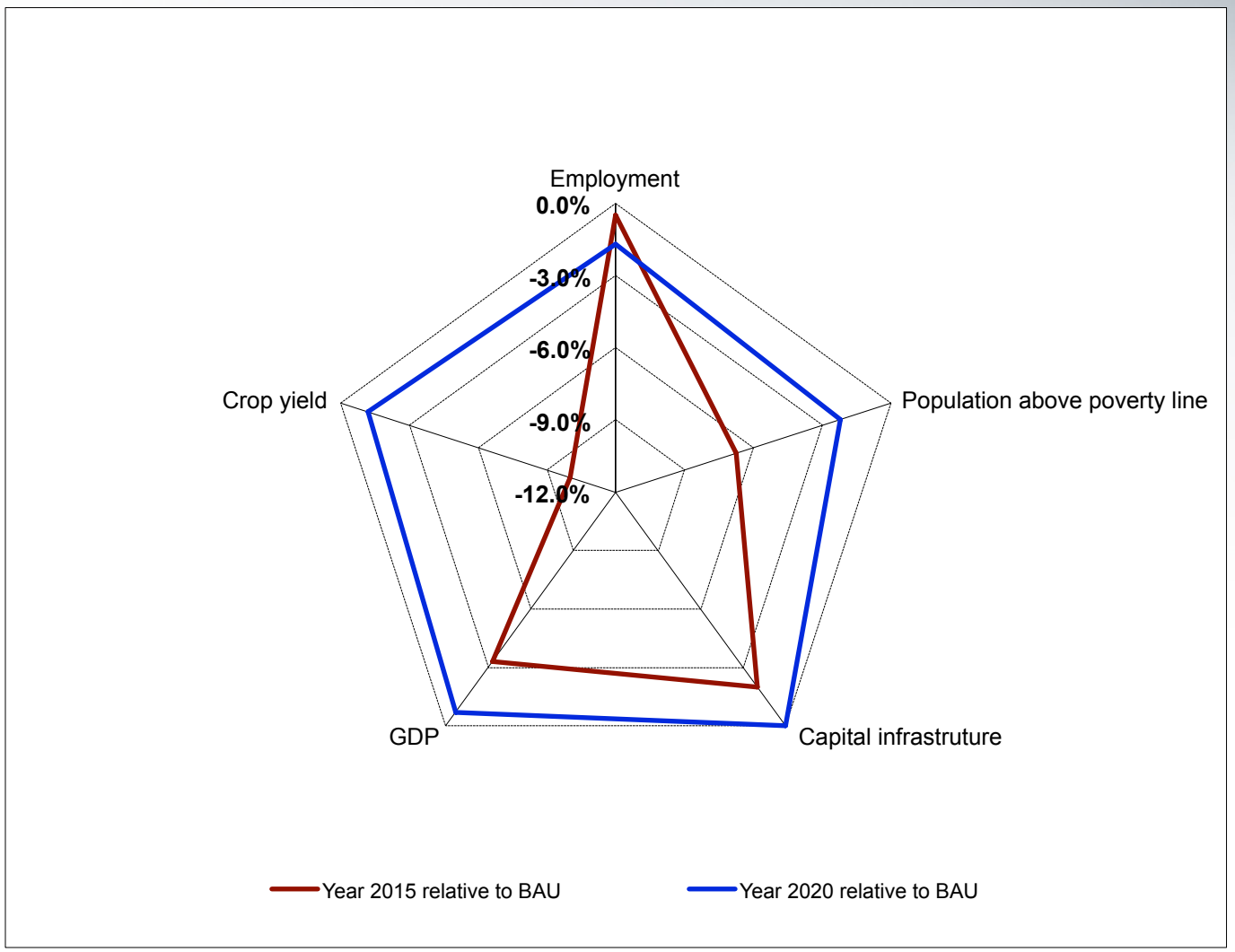
Jamaica case study (3)

- Figure 1: impact of the two hurricanes, in 2015 and 2025 (crop yield and poverty are highly impacted)



Jamaica case study (4)

- Figure 2: impact of first hurricane and recovery, after 5 years (poverty and employment lag behind but are mostly recovered)



Thank you for your attention

For more information please contact me at

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Or visit

www.millennium-institute.org

Some publications

- Bassi, A.M., and J.D. Shilling, **"Informing the US Energy Policy Debate with Threshold 21"**. Technological Forecasting & Social Change (2009), In Press.
- Bassi, A.M., R. Mistry, **"Assessing Water Management Options on Maui: applying an integrated approach to inform community conversations and policy debates"**. Environmental Science and Engineering Magazine, Fall Issue 2009.
- Yudken, J.S., A.M. Bassi, **"Climate Change and US Competitiveness"**. Issues in Science and Technology, Fall Issue 2009.
- Bassi, A.M., and J. S. Yudken, **"Potential Challenges Faced by the U.S. Chemicals Industry Under a Carbon Policy"**. Sustainability 1(2009)592-611. *Special issue on "Energy Policy and Sustainability".*
- Bassi, A.M., A. E. Baer, **"Quantifying Cross-Sectoral Impacts of Investments in Climate Change Mitigation in Ecuador"**. Energy for Sustainable Development 13(2009)116-123, doi:10.1016/j.esd.2009.05.003
- Bassi, A.M., Schoenberg, W., Powers, R., **An integrated approach to energy prospects for North America and the rest of the world**, Energy Economics (2009), In Press, doi:10.1016/j.eneco.2009.04.005
- Bassi, A.M., Yudken, J.S., Ruth, M., **Climate policy impacts on the competitiveness of energy-intensive manufacturing sectors**, Energy Policy 37(2009)3052–3060, http://dx.doi.org/10.1016/j.enpol.2009.03.055
- Bassi, A.M., **"Analyzing the role of integrated, dynamic, national development planning models to support policy formulation and evaluation"**. The 3rd OECD World Forum on "Statistics, Knowledge and Policy", October 27 – 30, 2009, Busan, Korea.

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Some publications (2)

- Musango, J., A. M. Bassi, A. Brent, **"South African Energy Model: A System Dynamics Approach"**. 2009 International System Dynamics Conference (ISDC), July 26 – 30, 2009, Albuquerque, NM, USA.
- Balnac, K., C. Bokhoree, P. Deenapanray and A. M. Bassi, **"A System Dynamics Model of the Mauritian Power Sector"**. 2009 International System Dynamics Conference (ISDC), July 26 – 30, 2009, Albuquerque, NM, USA.
- Bassi, A.M. and A.E. Baer, **"An Integrated Approach To Measuring The Environmental, Economic And Social Impacts Of Investments In Climate Change Mitigation In Ecuador"**, in *Rio 9: World Climate and Energy Event: Proceedings of the International Conference*, S. C. W. Krauter, Rio de Janeiro, March 2009. ISBN: 978-85-62366-01-7
- Bassi, A.M., **"An Integrated Approach to Support Climate Policy Formulation and Evaluation"**, in IOP Conference Series: *Earth and Environmental Science* 6 392007, March 2009. DOI: 10.1088/1755-1307/6/39/392007.
- Bassi, A.M., and S. Magnoni, **"Analyzing strengths and weaknesses of existing and proposed financial mechanisms for climate change mitigation and adaptation to inform the UNFCCC talks at COP15"**, Beyond Kyoto: Addressing the Challenges of Climate Change, March 5-7, 2009, Aarhus, Denmark.
- Bassi, A.M., A. Drake, E.L. Tennyson and H.R. Herren, **"Evaluating the Creation of a Parallel Non-Oil Transportation System in an Oil Constrained Future"**, 2009 TRB Conference: Annual Conference of the Transportation Research Board of the National Academies of Science, Engineering, and Medicine, January 11-15, 2009, Washington DC, USA.

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Some publications (3)

- Report: Bassi, A.M., **"Systems Modeling of Long Term Energy Policy, Mauritius"**. Prepared for the Ministry of Renewable Energy and Public Utilities, Republic of Mauritius, and UNDP Country Office Mauritius and Seychelles, Port Louis, August/October, 2009.
- Report: Yudken, J.S. and A. M. Bassi, **"Climate Policy Impacts on the Competitiveness of Energy-Intensive Manufacturing Sectors"**. National Commission on Energy Policy, Bipartisan Policy Center, April 2009, Washington DC, USA.

Other selected papers currently submitted for publication:

- *Oct 09* - Bassi, A.M., **"An Integrated Approach to Climate Policy Formulation and Evaluation"**. *Currently submitted to Regional Environmental Change.*
- *Aug 09* - Magnoni, S., A.M. Bassi, **"Creating Synergies from Renewable Energy Investments, a Community Success Story on Lolland, Denmark"**. *Currently submitted to Energies.*
- *Aug 09* - Bassi, A.M., J. Harrisson, R. Mistry, **"Assessing Water Management Options on Maui: Applying an Integrated Approach to Inform Community Conversations and Policy Debates"**. *Currently submitted to Sustainability.*
- *Jun 09* - Bassi, A.M., and S. Magnoni, **"Elaborating a coherent and adequate financial structure for a post Kyoto framework".** *Currently submitted to Earth and Environmental Science.*
- *Jun 09* - Bassi, A.M., and J. S. Yudken, **"Analyzing the Role of Externalities on the Impacts of a Climate Policy on U.S. Energy Intensive Manufacturing Sectors"**. *Currently submitted to Environmental Research Letters.*
- *Jun 09* - Bassi, A.M., **"Reflections on the Validity of Integrated System Dynamics Simulation Models"**. *Currently submitted to Journal of Future Studies.*

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Comments by Main Users

- **"It has been my dream since ten years to get the the PIOJ departments to work together…now its happening with T21; With T21 I can see team building and networking across the ministries and government agencies and effective communication"**
  Wesley Hugh, Director Planning office Jamaica
- **"I want that T 21 planning team in my office"**
  Président Amadou T Touré, Mali
- **"MI's T21 analytical tool is essential for effective national development strategies"**
  Ed Cain, Carter Center
- **"MI's long-term, integrated perspective is essential"**
  Pablo Guerrero, World Bank
- **"We need to use this tool at the Headquarters, in our embassies and help our country partner acquire it"**
  Dutch Ambassador Ton Boon von Ochsee
- **"MI's integrated dynamic models have been vital for GM's sales forecasts"** Paul Ballew, GM

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