C O M P L E X

Knowledge Based Climate Mitigation Systems for a Low Carbon Economy

Exploring low-carbon transitions by means of model integration

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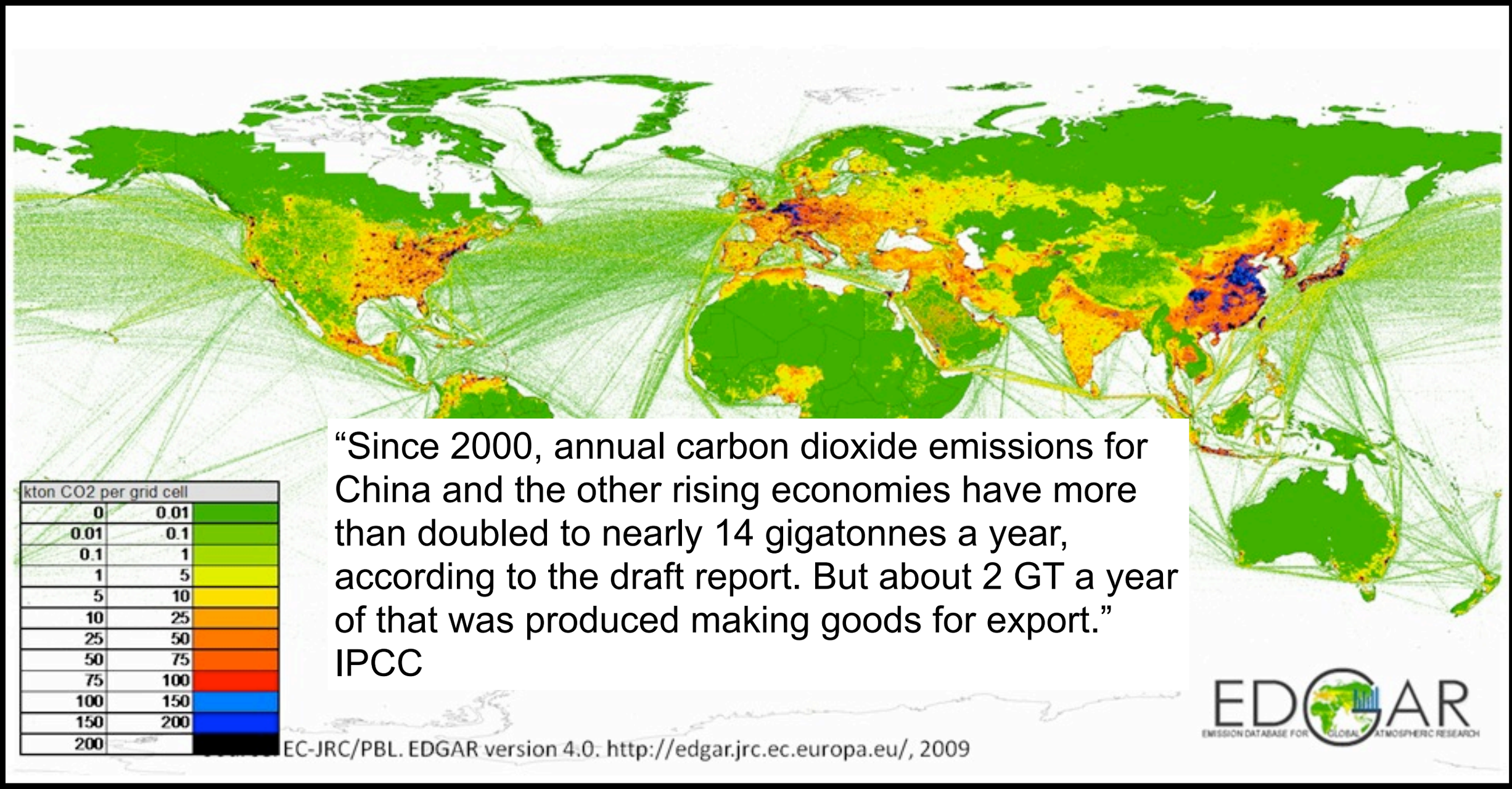
Problems with conventional economic models

- Developed for conditions of abundant natural resources
- Demand side economics
- Economic growth = main goal
- GDP = main indicator
- Systems at equilibrium, only marginal changes assumed
- No account for non-linear processes that result in regime shifts, bifurcations, and structural change

Problems with conventional economic models (cont.)

- Assuming spatially uniform systems (either local, or regional, or global) with little attention to multi-scale hierarchical processes spanning various scales of complexity and spatial arrangement
- Simple assumptions about human behavior (rationality and homogeneity in preferences)
- No account for adaptation and social learning.

CO_2 in Space



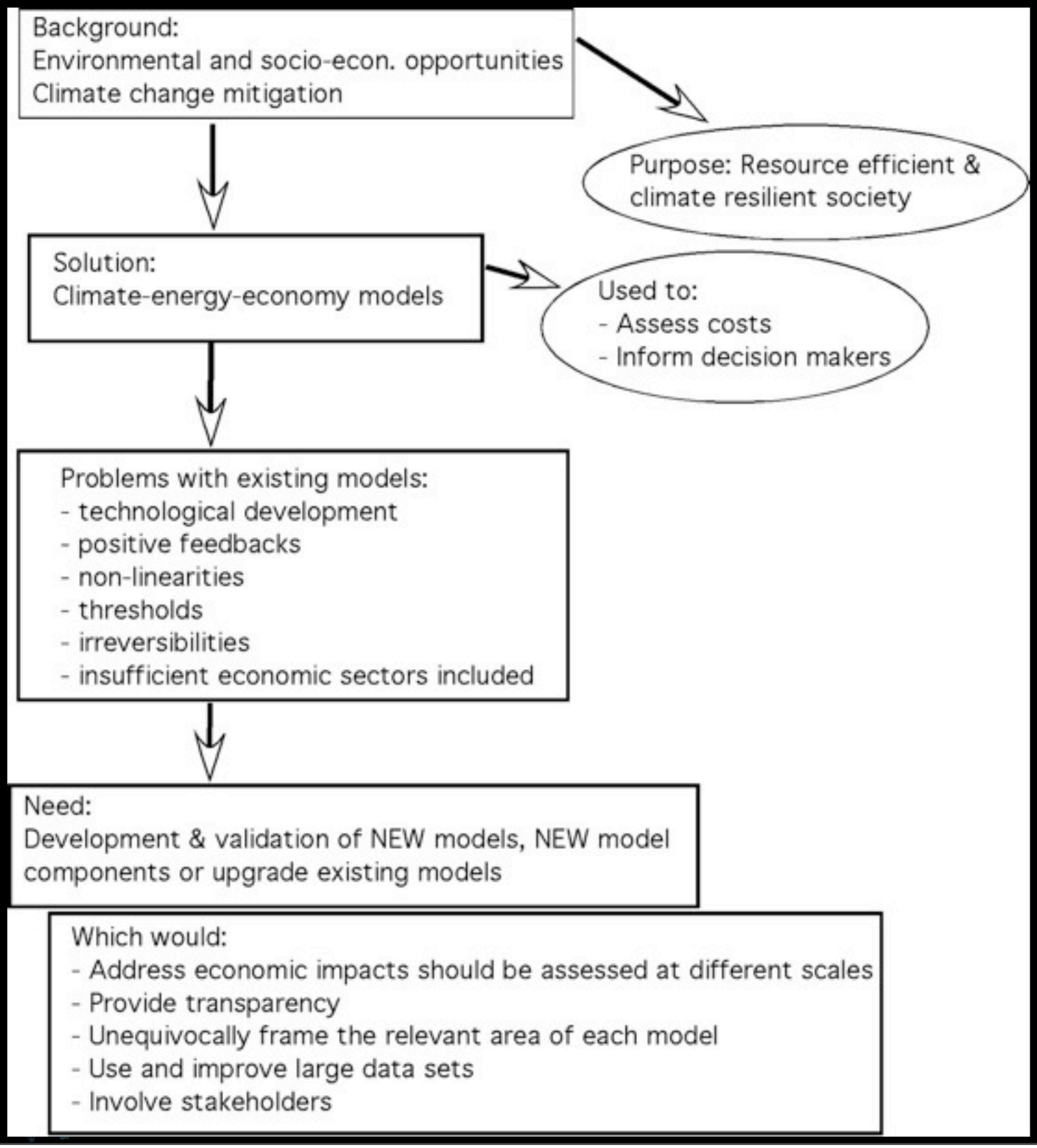
kton CO2 per grid cell		
0	0.01	
0.01	0.1	
0.1	1	
1	5	
5	10	
10	25	
25	50	
50	75	
75	100	
100	150	
150	200	
200		

"Since 2000, annual carbon dioxide emissions for China and the other rising economies have more than doubled to nearly 14 gigatonnes a year, according to the draft report. But about 2 GT a year of that was produced making goods for export." IPCC

EC-JRC/PBL. EDGAR version 4.0. http://edgar.jrc.ec.europa.eu/, 2009

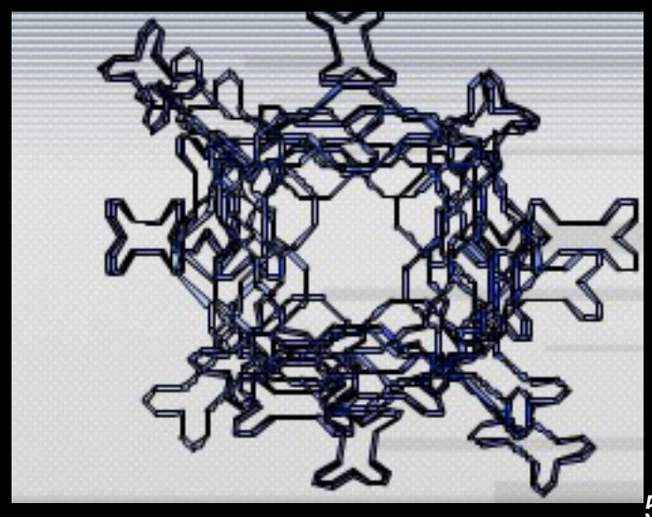
http://www.theguardian.com/environment/2014/jan/19/co2-emissions-outsourced-rich-nations-rising-economies

FP7: COMPLEX

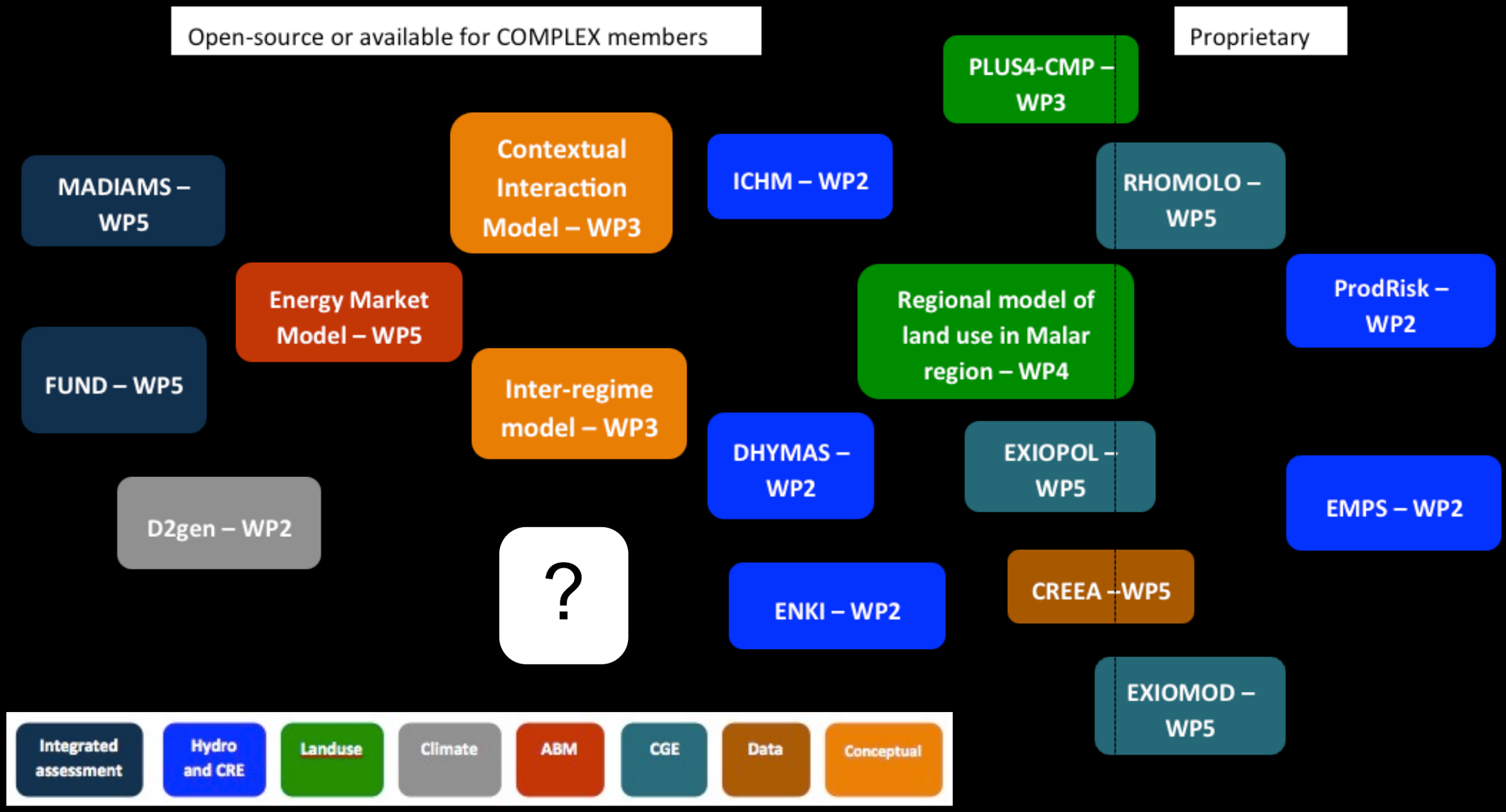


- Knowledge Based Climate Mitigation Systems for a Low Carbon Economy

- http://www.complex.ac.uk/

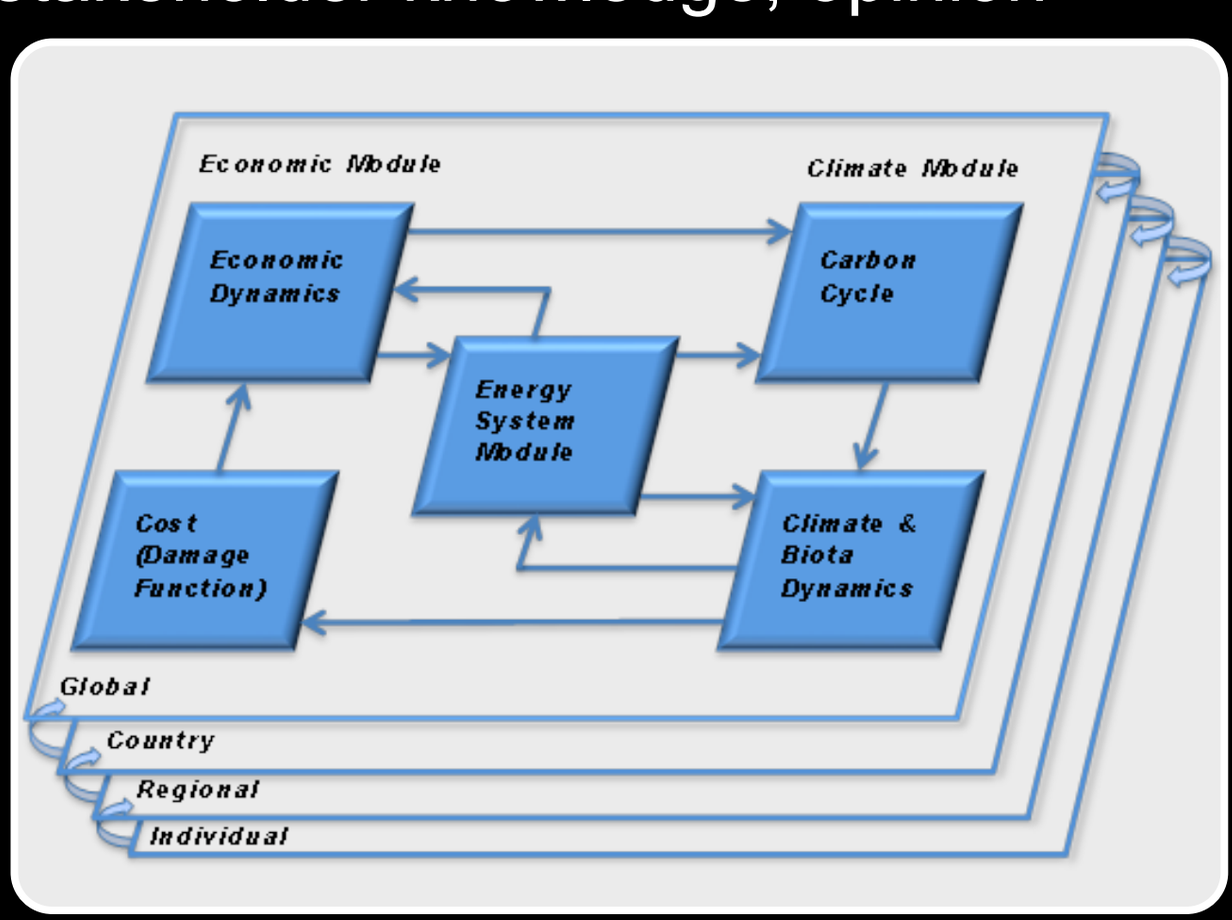


COMPLEX model space



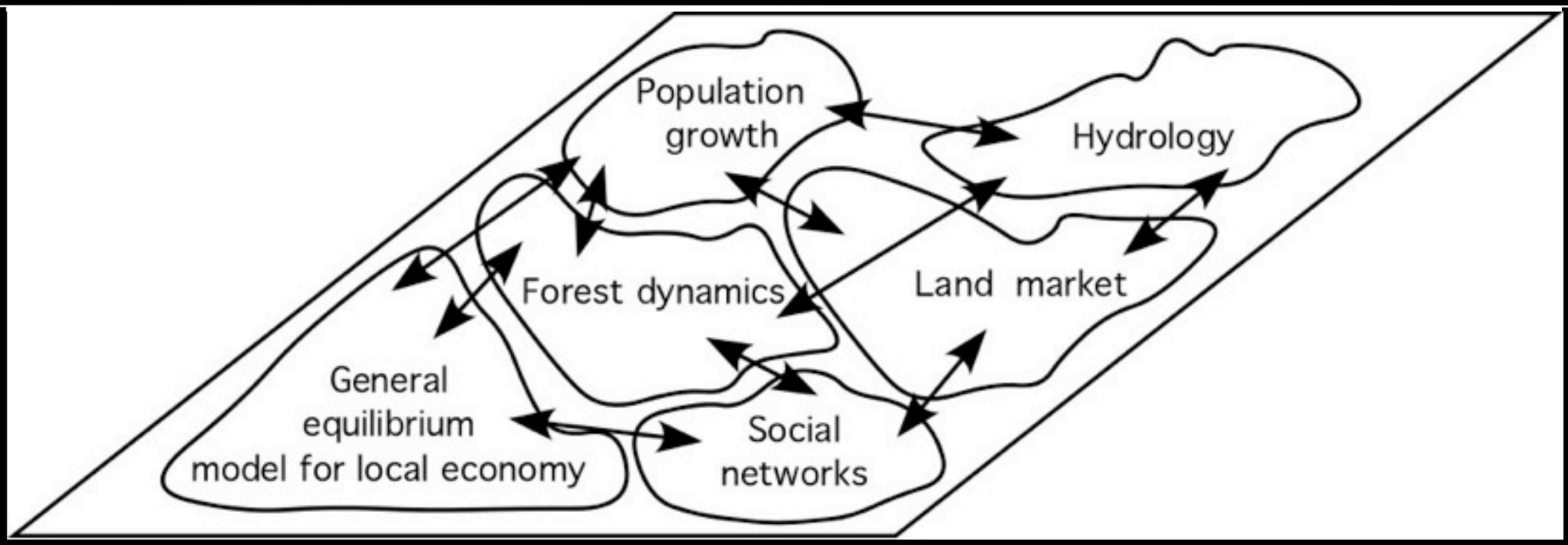
WP6: Integration of models

- Goal: build and analyze the hierarchy of models, which are developed and applied within this project and beyond
- Operate in a generalized ‘socio-environmental model space’ (empirical models, conceptual models, complex computer simulations, and data sets)
- Integrate qualitative models of stakeholder knowledge, opinion and scenarios
- Explore the different models along the complexity continuum to understand how information from more aggregated qualitative models can be transmitted to more elaborated and detailed quantitative simulations, and vice versa.



Friday, April 4, 14

Integrated modeling



- "Integrated modeling is a systems analysis-based approach to environmental assessment. It includes a set of interdependent science based components (models, data, and assessment methods) that together form the basis for constructing an appropriate modeling system" *

* EPA (2008). White Paper on Integrated Modeling for Integrated Environmental Decision Making: http://www.epa.gov/crem/library/IM4IEDM_White_Paper_Final_(EPA100R08010).pdf

Problems (software angle - doable)

- Written in different languages (conversion is time-consuming and error-prone)
- Code is not well-documented or easy to understand and reuse
- Models have different geometry, dimensionality (1D, 2D or 3D)
- Models may use different types of grids (rectangles, triangles, polygons)
- Each model has its own time loop or "clock"
- Mismatched numerical schemes (explicit vs. implicit).

Peckham, S. 2010. CSDMS Handbook of Concepts and Protocols: A Guide for Code Contributors. http://csdms.colorado.edu/wiki/Help:Tools_CSDMS_Handbook

Problems (modeling angle - iffy)

- Are models software?
- Components built by different teams, at different time, at different places. Built for different goals and purposes.
- Teams use different languages. Need to communicate assumptions. Metadata, metamodels and standards.
- What are the modeling paradigms used? Are they compatible? How do we calibrate integrated models?
- What are the scales? Resolutions? Time, space, structure.
- Propagation of error and uncertainties.
- What are models? Modeling is art or science? Beware of “integronsters”

The complexity curse

- With integration, models are becoming even more complex
- “A complex model may be more realistic yet at the same time more uncertain”*
- Complex models are hard to test
- Complex models are hard to communicate
- Complex models are hard to trust
- Complex models are hard to calibrate
- In environmental modeling calibration is a must.

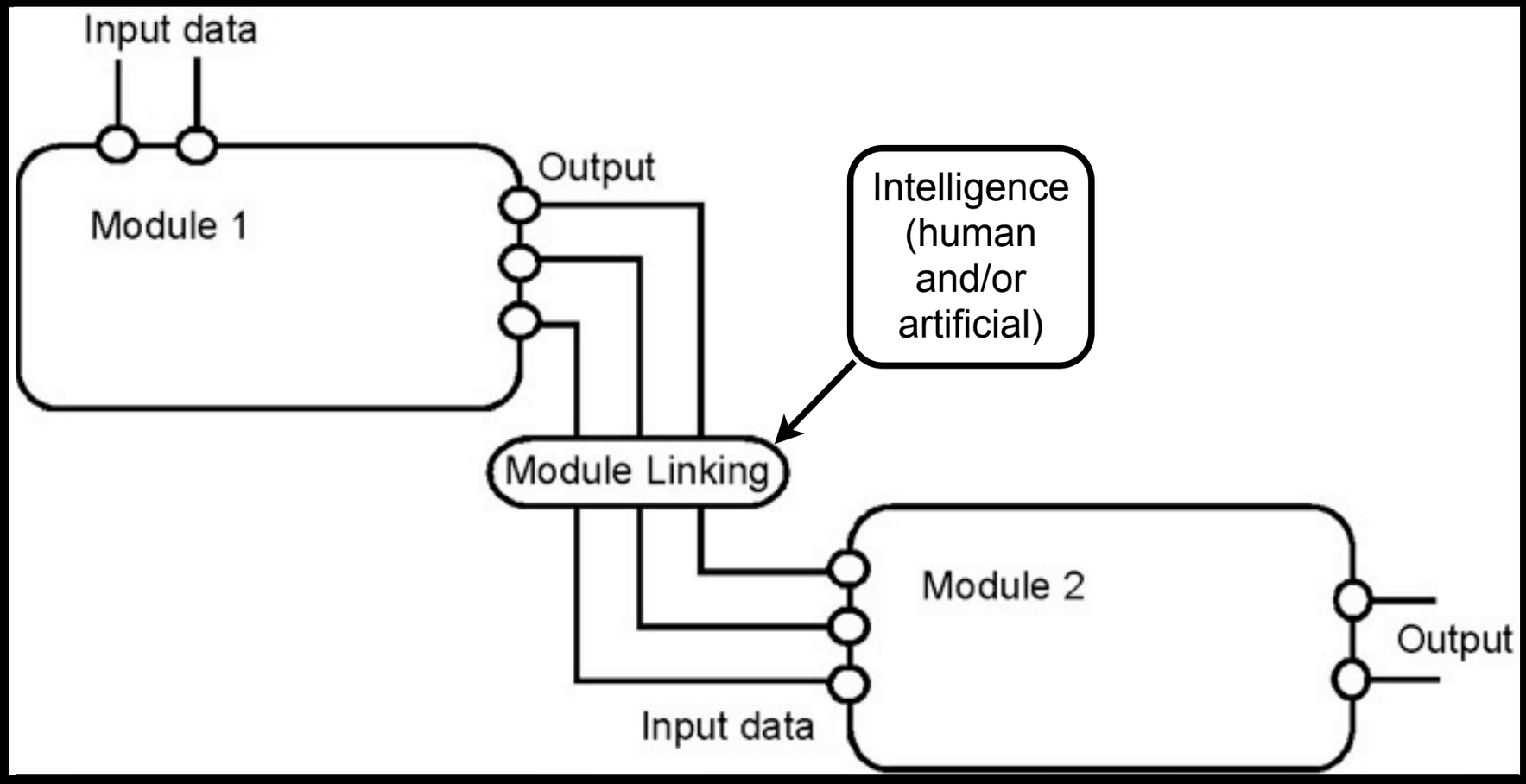
* Oreskes, N., 2003. "The role of quantitative models in science," in Models in Ecosystem Science, Ed: C. D. Canham, J. J. Cole, and W. K. Lauenroth (Princeton: Princeton University Press), pp. 13-31.

Voinov, A., and C. Cerco. 2010. Model integration and the role of data. Environmental Modelling & Software 25, no. 8: 965-969.

Candidates for integration

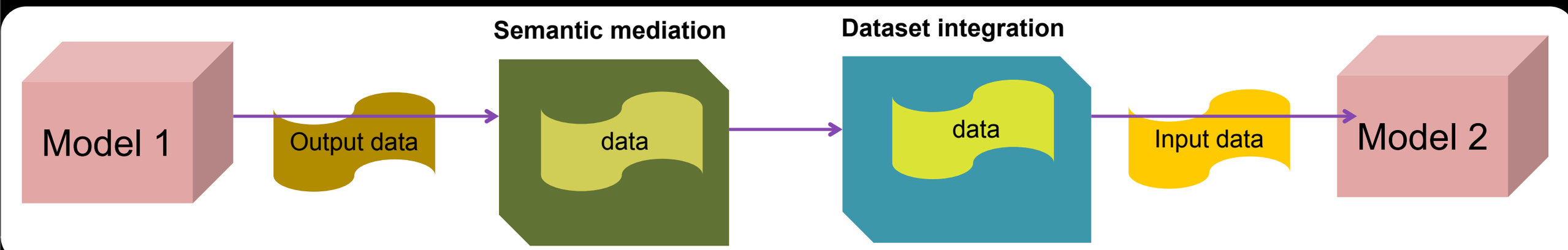
- FUND - Integrated assessment model (IAM)
- EXIOMOD - Country level Computational General Equilibrium Model (CGE)
- RHOMOLO - NUTS2-region level CGE
- Agent-based model (energy market in NUTS2)
  - Supply-side: diffusion of low carbon energies (LCE) among heterogeneous firms
  - Demand-side: behavioral change at household level
- MADIAMS - System Dynamics (SD) model

Model coupling



SOA in COMPLEX models

- For loose coupling of models with some intermediate data processing:
  - semantic mediation
  - dataset integration

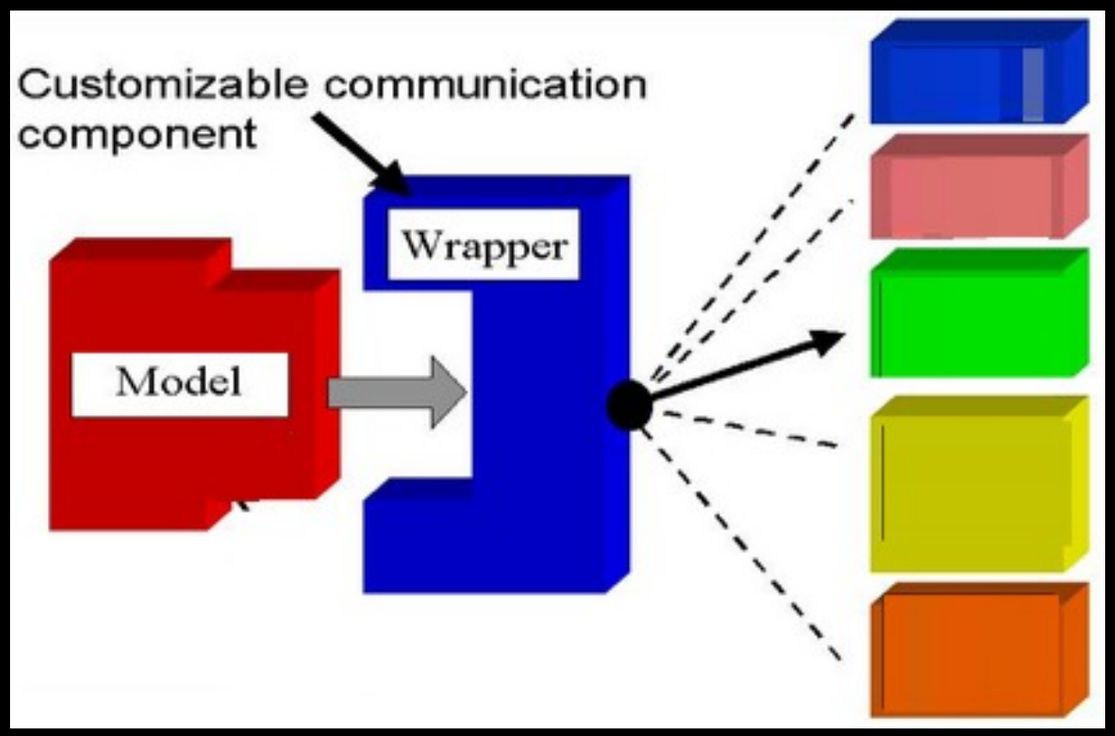


- Allowing communication between all models can produce integronsters
- Need integration rules that glue the models together and provide checks and balances for their joint execution
- Potential involvement of humans in the integration process

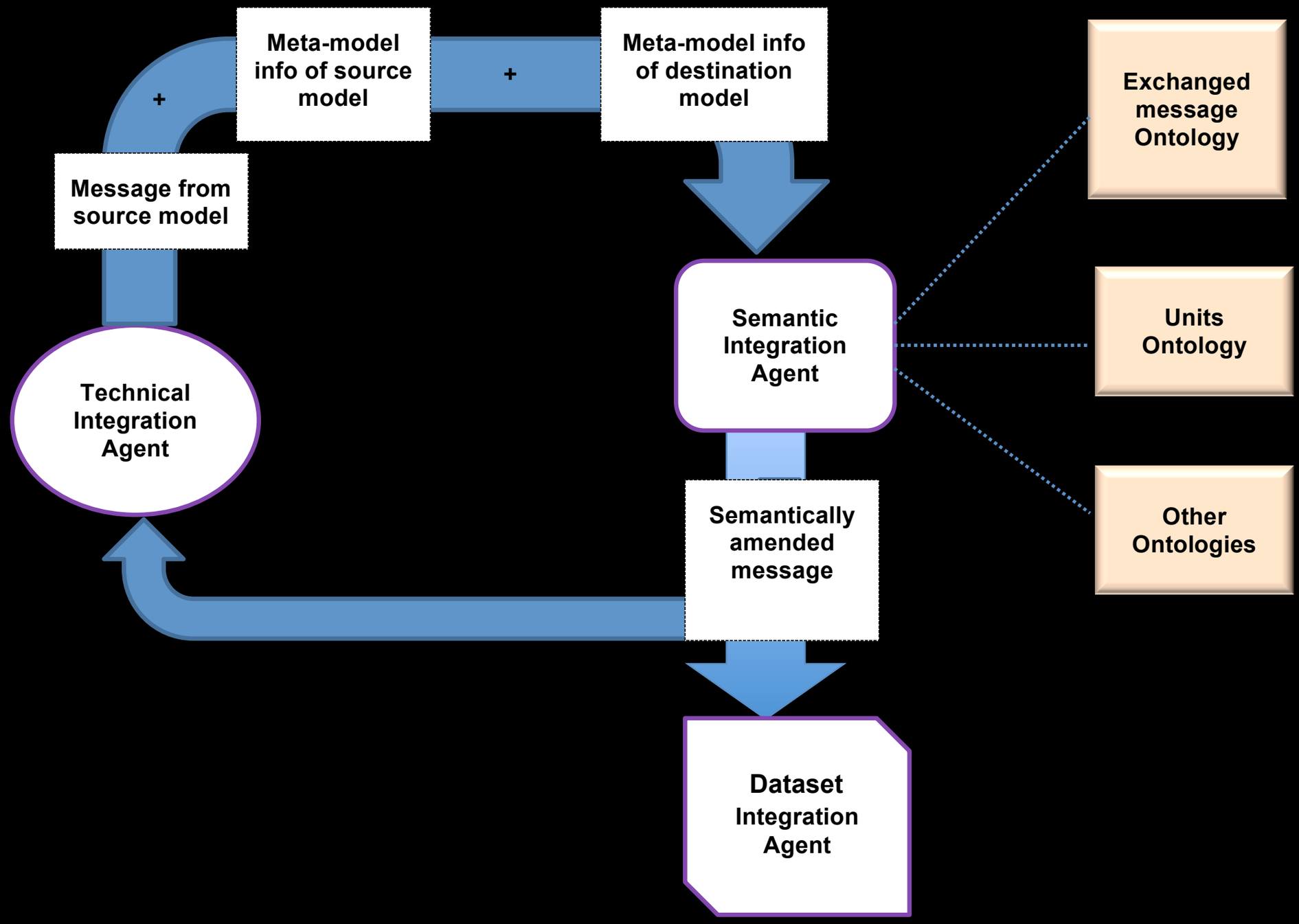
Why SOA for COMPLEX models?

- Once implemented, a computer-based model is a composition of two major parts:
  - interface that defines inputs, outputs and parameters of a model,
  - implementation which defines the model equations.
- Wrapper is a program or script that sits between a model and the model space

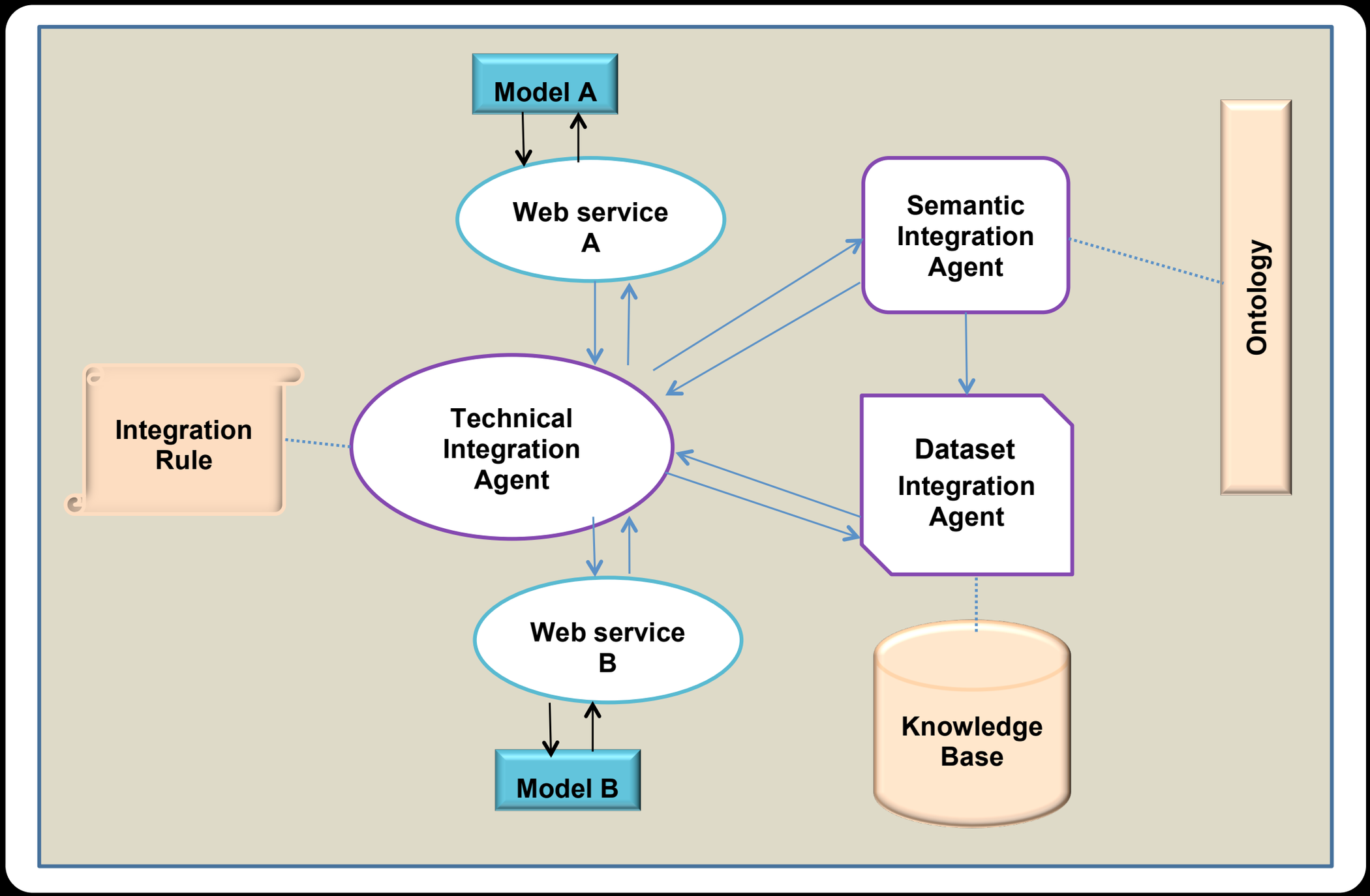
Developing wrappers as a calling interface to existing code to assure language interoperability and to convert existing models into interoperable components.



Semantic integration agent



Technical integration agent



Technological imperative

- Make models more like software and modeling more like science, less like art;
- Focus on standards for data, model input and output, and interfaces. Adopt existing and develop new ones;
- Develop standards for model conceptualization, formalization, and scaling;
- Semantic technologies, ontology engineering;
- Metadata, markup languages;
- Require good documentation, including examples and test cases;
- Ensure transparency, portability, and reusability, and include procedures for version control, bug tracking, regression testing, and release maintenance.

Social imperative

- Collaborative, open source research and modeling
- Modeling with stakeholders
- Put the ‘user’ upfront, understand their needs and behavior
- Toolboxes and model repositories for participatory modeling
- Integrating conceptual models
- Integrating numbers with ideas
- Visualizations and perceptions - learn from media and commerce

Next steps

- Identifying models which are available for integration,
- Identifying possible model coupling,
- Identifying integration scenarios and use cases,
- Making selected model accessible to integration team,
- Documenting meta-model information using our template,
- Testing the technical integration.