Exploring low-carbon transitions by means of model integration

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There are various visions of our future, but most policy-makers and scientists agree that life will be substantially different in the post-fossil era. The cheap and abundant supply of fossil energy has led to unprecedented population growth and to staggering levels of consumption of natural resources, undermining the carrying capacity of nature. Eroding ecosystems, the end of cheap oil and climate change call for new policies to support societal transformations toward low-carbon alternative futures. This understanding has already been expressed in recent EU legislation, which requires that domestic GHG emissions be cut by 80% between 1990 and 2050. Energy is a major driver of change and an important 'currency' that runs economic and social systems and influences environmental systems. Being so used to the abundant and uninterrupted supply of fossil energy, we tend to forget the important role that it plays in our everyday lives. Non-marginal, abrupt changes, such as during the Oil Crisis of the 1970s or the sudden sharp rise in oil prices in 2008 remind us how vulnerable societies are with respect to energy.

There are several reasons why most of the conventional economic models are not well suited to treat the transitions that are already happening and will be only accelerating:

- They were developed for conditions of abundant natural resources, where economic growth could be considered as the main goal, and nature was seen as something to 'combat' and 'conquer';
- They were considering systems at equilibrium when only marginal changes were assumed, failing to account for non-linear processes that may result in regime shifts, bifurcations, and structural change;
- They were treating spatially uniform systems (either local, or regional, or global) with little attention paid to multi-scale hierarchical processes spanning various scales of complexity and spatial arrangement;
- They had very primitive assumptions about human behavior, mostly assuming rationality and homogeneity in preferences and decisions made, with no account for adaptation and social learning.

The FP7 COMPLEX project is designed to develop new modeling tools for managing step-change dynamics by working across a wide range of spatio-temporal scales, and integrating the knowledge of many stakeholder communities, for example in respect of land-use change driven by carbon-related technologies. In particular we will explore how model integration can be used to improve our understanding of future low-carbon economies and to analyze various decisions and policies that can facilitate the transition.

We are operating in a generalized 'socio-environmental model space' (Fig.1), which includes empirical models, conceptual stakeholder models, complex computer simulations, and data sets, and which can be characterized in several dimensions, such as model complexity, spatial and temporal resolution, disciplinary coverage, bias and focus, sensitivity and uncertainty, usability and relevance. In this space we are developing a 'model calculus' – a set of relationships and operations that can apply to individual models and groups of models. Our goal is to expand beyond traditional integrated modeling, which focuses on development of component coupling software tools, by providing integration tools to bring qualitative, conceptual, mental models of stakeholders together with the quantitative simulation models. This should allow the project to organize the models in various configurations dictated by particular policy goals and scenarios.

We are building a flexible system of integrated models and components that can be further modified and expanded to facilitate case-studies. These will be used to represent the climate-energy-economic system at different levels of spatial, temporal and structural detail and resolution, integrated with soft-systems approaches that take account of cultural and ecological patterns and unambiguously frame the spatio-temporal scale of reference. Greater transparency and accessibility will be achieved through enhancing documentation and communication of model functioning and strengths and limitations of various models and approaches.

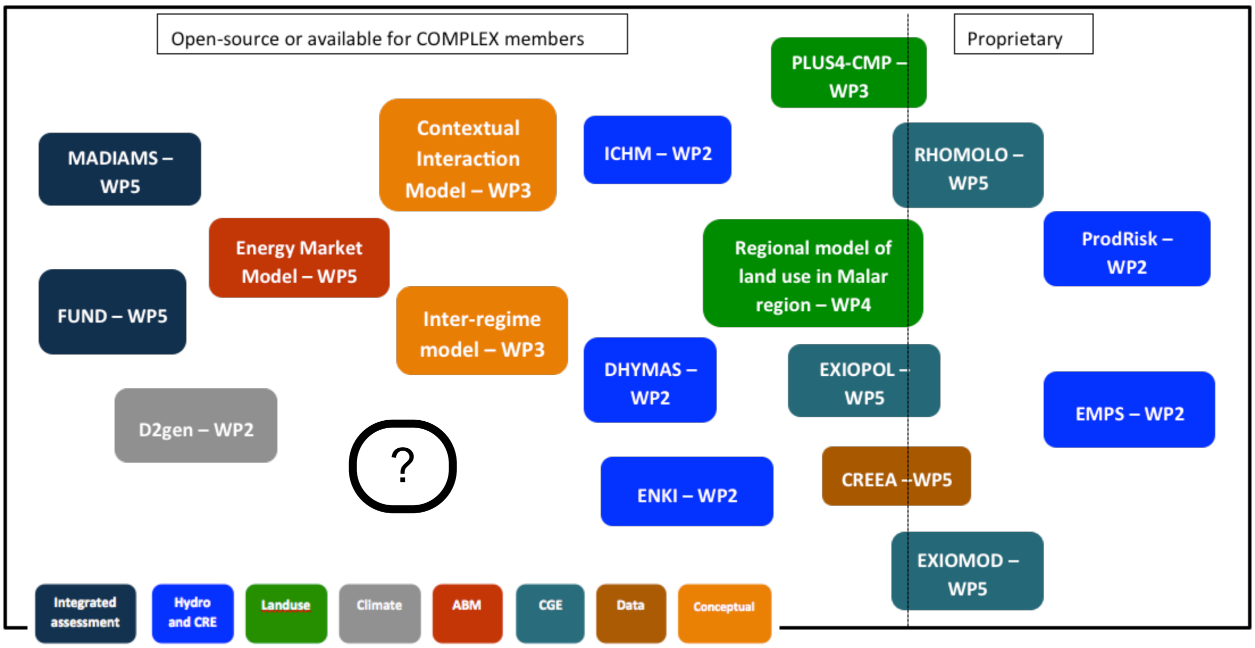

Fig. 1. COMPLEX model space representing the various types of models available for integration. The box with the question mark means that we do not consider the space complete, and use it only as a test bed when developing our tools.

This extensive model documentation following improved and enhanced meta model standards is an important first step that makes sure that models (both qualitative and conceptual) 'talk the same language' and can exchange information and knowledge at various stages of research. This also helps us create the ontology of the project, which can be further used for computer aided semantic mediation of models. This semantic mediation will include such functionality as consistency checks (checking for units, concepts, spatio-temporal resolution, etc.). This should also help to 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. This bears the promise of insight on the complex behavior of non-linear systems where regime shifts and non-equilibrium dynamics is usually better understood with simple models, while the more complicated models are easier to parametrize with data and can take into account more detailed information about particular systems and situations.