Developing and Linking Tools for ISA

Within an ISA cycle, combinations of tools are used to develop and test the visions in terms of consistency, adequacy, robustness and feasibility. Further, they are used to explore the implications of policy options and trade-offs between different pathways.

In the MATISSE project the work on tools had two distinct foci. The first is a focus on scenarios, which are covered elsewhere in this brochure (pages 11 - 14). The other is on models, in particular on simulation and conceptual models, both existing and new:
Interlinking and improving existing modelling tools. This involves the use of a portfolio of existing Integrated Assessment (IA)-models and other models in a more creative and coherent manner, while also linking, adjusting and improving them.
Developing prototypes of new ISA-modelling tools. This involves the development of new conceptual models and modules that are based on a new paradigm that is rooted in complex systems theory, evolutionary economics and multi-agent modelling. The aim is to develop stakeholder-oriented, explorative, and more integrated ISA-tools.

Existing modelling tools

Computer modelling tools are simplified representations of complex real-world phenomena. They are based on scientific theory and have a formal, mathematical structure. Existing modelling tools have been applied to a wide range of sustainability issues and have been used for policy-relevant sustainability assessments. These include bio-physical models, socio-economic models and integrated modelling approaches[1].

Within the ISA cycle of scoping, envisioning, experimenting and learning, computer simulation models are especially useful in three stages:

- Applications of certain models in previous ISA-type assessments can help in the scoping stage of a sustainability assessment to define the problem, pinpoint its key drivers and causal chains and identify potential trade-offs and synergies to provide guidance on which measures could be appropriate to tackle the problem.
- Extensive scenario development and analysis with existing and/or improved models are useful in the envisioning stage to map alternative futures.
- In the experimental stage, models are used to explore the potential of a range of policy options and transition pathways to solve the sustainability issues at hand. If models from different schools can be coupled, they may provide a comprehensive and consistent framework for understanding the potential interactions between social, economic and environmental processes.
- In the learning stage, the models can be updated based on past experiences, in preparation for the next ISA cycle.

The focus is, however, on the experimental stage in which models are of crucial importance.

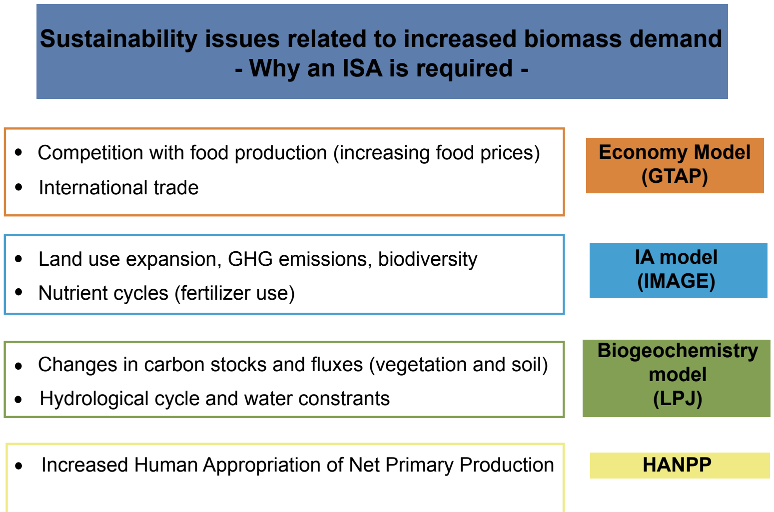
Linking existing modelling tools

An example of linking models is provided by the MATISSE efforts to define possible limits to sustainable biomass demand and supply for Europe until 2050, including global trade linkages and an array of policy options. Since increased biomass demand would have implications for biogeochemical cycles, water systems, material and energy flows, a variety of models is required and these must be linked (see next page). Four models have been linked within the MATISSE project. The results of linking the models and defining possible limits to sustainable biomass demand are relevant for the case studies on dematerialisation and sustainable mobility.

Improving existing tools

A number of improvements have been made to the E3ME within MATISSE. These include extending the model to incorporate the cost of damaging externalities from air pollution and implementing a new module that links economic activity and demand for physical materials.

The case study on Agriculture, Forestry and Land Use (AFLU) has also developed and extended models to enable them to adequately represent the critical relationships linking the policy instruments designed to promote sustainability in the AFLU sector with a host of widely disparate sustainable development concerns. This has included development of a stochastic model to provide the joint distributions of the policy impacts using the expected impacts given by the



deterministic models as a reference. Methodologies have been developed for measuring costs of application of policy measures. Finally an Integrated Policy Assessment tool will provide the synthesis, albeit in a reduced form, of the modelling work undertaken.

New tools for ISA

A major goal of the MATISSE project was to develop prototypes of a new generation of modelling tools for use in ISA. This is a huge task that will likely take many years to complete! In this project we decided to focus our work in particular on developing a new modelling tool that can simulate socio-technical 'transitions' in the context of pathways towards a more sustainable future. By 'transition' we refer to a fundamental change in the structure and functioning of a whole system rather than incremental changes within a current system. So the switch from sailing ships to steam ships in the 19th Century might be an example of a transition, whereas gradual incremental improvements in the technology of sailing ships would not be.

We set out to develop protypes of a tool that would be able to capture the type of fundamental structural change that we postulate will be necessary to achieve sustainability (in Europe and elsewhere) during the course of this Century. To do this we first developed a guiding conceptual framework for transition modelling that provided a synthesis of available empirical evidence about previous transitions, on the one hand, and the emerging body of theory on socio-technical transitions on the other hand.

Concepts from the literature on socio-technical transitions were used to develop a structured narrative about the kinds of process involved in producing a transition. We conceptualised a transition as arising out of a dynamic interplay between a dominant (or 'incumbent') regime and set of competing niches. By the 'regime' we refer to a dominant set of practices, and also the actors and structures associated with that dominant set of practices. Thus the behaviour of many individual actors is aggregated using the concept of a 'regime'. Similarly 'niches' represents constellations of actors (and associated structures) grouped around new, novel or emerging practices.

The key dynamical patterns underlying a transition were then described by defining a minimal set of 'mechanisms' that could, in principle, reproduce the dynamical features of observed transitions. Examples of such mechanisms include that of the clustering of niches into one larger niche or the absorption of a niche by the regime in order to remove competition or gain new practices. We then developed the prototype transition model by developing algorithms for each of the identified 'mechanisms' and then allowing them to determine the dynamics of the interactions between regime and niches. In addition a background 'landscape' was described that represents the underlying, but powerful, currents that inexorably change the context of opportunities, challenges and problems facing both the regime and niches. Through differentiated response 'mechanisms' it is possible to explore how landscape 'signals' can either favour the regime, and stability, or niches, and an eventual transition.

In contrast to other assessment tools, the transition modelling tool developed within the MATISSE project highlights the complexity of interactions between actors and structures and the non-linear dynamics within social systems. The modelling framework developed in MATISSE is highly suited to exploring simulations of radical alternative futures because it is inherently able to simulate systems innovation and deep structural change. By simply including a niche in the model that has radically novel practices (and hypothesising why these may lead to success) the model simulates the dynamics of the emergence of novel societal structures in the context of transitions to sustainability during the course of this Century.

An application to the assessment of mobility in Europe

The conceptual framework for transition modelling developed in the MATISSE project has been used in initial modelling of a mobility transition. For this purpose, the regime is defined as *private mobility using petrol/diesel internal combustion engine (ICE) technology*. At time point 0 (year 2000), public transport is identified as an empowered niche. Other niches are: *hybrid-electric vehicles, biofuel-powered vehicles, hydrogen fuel cell vehicles, urban ICT-centred lifestyles, car sharing,* and *slow modes.* The model also includes simple consumer/citizen agents who provide 'support' (a broad concept that encompasses generation of resources and 'power' through market, political and cultural processes) to the regime and the various niches.

The consumer/citizen agents are associated with a set of 'practices'. Practices are broadly defined and include technology production and consumption, transport service provision and use, and infrastructure provision and use. The least number of practices has been identified that can differentiate the various niches, empowered niches, and regime and that impact on the environmental, social and economic mobility criteria identified earlier.

These practices are: CO_2 emissions [gCO_2/pkm]; cost acceptance [€/y]; private mobility [pkm/y]; public mobility [pkm/y]; ICT use [percent]; and built environment [mixed vs. single zone use; percent].

Figure 1 shows where consumer agents and the regime and niches are located in a chosen two dimensional subspace of the full 'practice space'. This indicates the (dis)similarity between agents according to their respective interests and activities; in this figure the difference is in respect of accepted cost and CO_2 emissions. In contrast to most economic models, consumer/citizen preferences and choices are not assumed to be static; rather they respond to changing landscape conditions and the changing power of agents. Runs of the transition model thus show how the

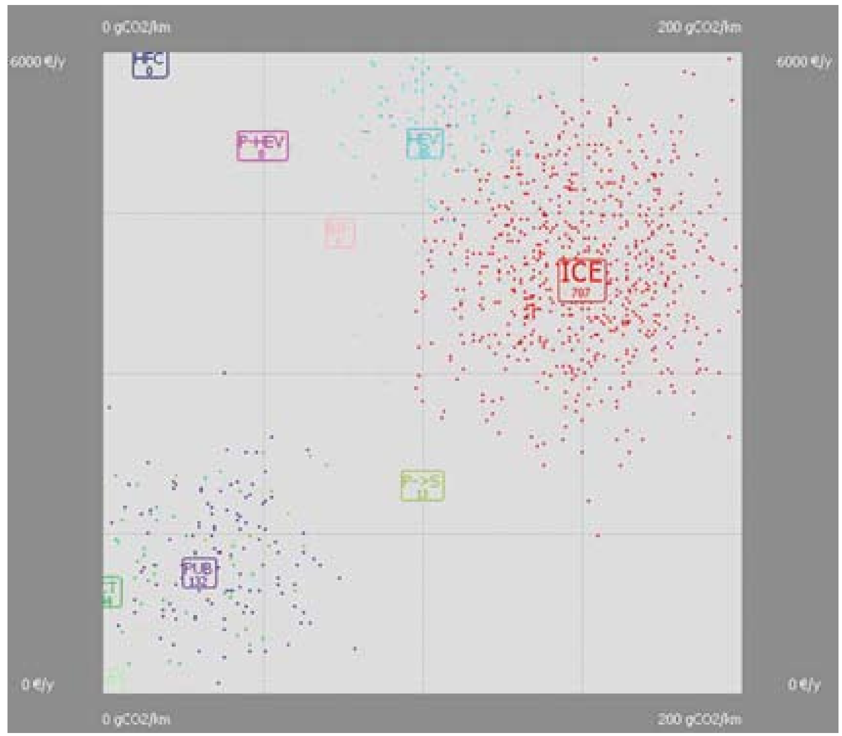


Figure 1 Screen-shot of the mobility transition model showing the 'practice space' - multidimensional axes, which represent the practices listed above; here, only cost and CO_2 emissions are shown. (Dots represent consumer/citizen; ICE (Internal Combustion Engine) = private ICE mobility; PUB = public transport; BIF = biofuel vehicles; HEV = hybrid-electric vehicles; P>S = car sharing; HFC = hydrogen fuel cell vehicles; ICT (Information and Communication Technology) = urban ICT-centred lifestyles; SLW = slow modes).

distribution of consumers shifts across this practice space.

Landscape trends and policy interventions are considered as exogenous 'signals' which affect agents – both directly (via adaptation) and indirectly (via change in consumer/citizen practices which in turn affects support for agents). Landscape signals in the mobility application are:

- Growing consumer/citizen concerns about climate change and emissions;
- Increased use of ICT (intrinsic value of car reduced);
- Rising fuel costs.

Figure 2 shows the dynamic output of a 'model experiment' using the initial distribution in the mobility system of consumer and niche/regime practices shown in Figure 1. This output shows system changes impacting on an indicator of the 'strength' or 'power' of the regime and niches. In this case, the prevailing private-ICE regime is replaced by a hybrid-electric regime; there is initial growth of the hydrogen niche after 2025. The results from this example run should not be considered a prediction, but rather an indicative simulation of radical social change processes using novel -modelling techniques. Initial tests show the model is capable of reproducing the transition patterns we expect to see, including slow development of niches, followed by a more rapid 'take-off' and then replacement of the regime, as well as failed transitions in which the regime adapts.

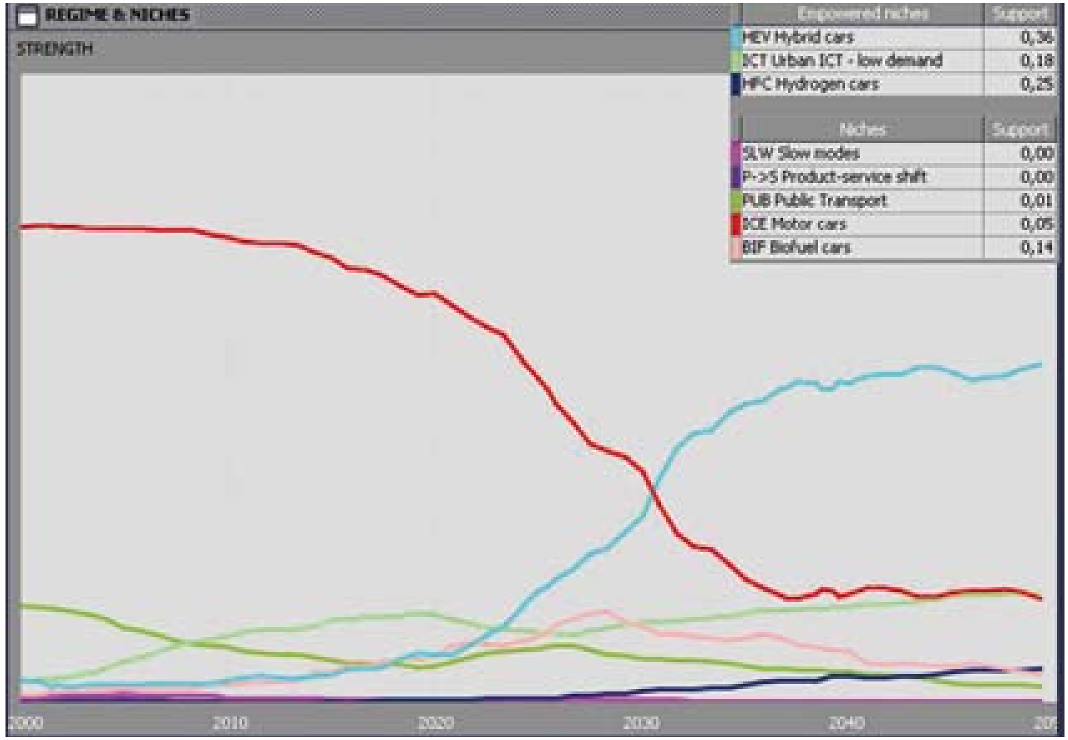


Figure 2. Screen-shot of a model run in which the prevailing mobility regime (of privately owned ICE vehicles) is replaced (by a hybrid-electric regime). The x-axis represents time (2000 to 2050); the yaxis represents the strength or power of the niches or regime (defined here as the support obtained from consumers; where support is distributed across all niches and the regime and always sums to 1).

[1] Lotze-Campen, H. (2007): Review of experience with existing models and their suitability for Integrated Sustainability Assessment (ISA) MATISSE Working Paper 16 . Available at www.matisse-project.net

Further reading

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