European Commission

Concurrent Design Foresight

Report to the European Commission of the

Expert Group on Foresight Modelling

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Report to the European Commission of the Expert Group on Foresight Modelling

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GLOSSARY

BEPA	Bureau of European Policy Advisers
CSA	Chief Scientific Adviser
DG	directorate-general
EEA	European Environment Agency
EFFLA	European Forum on Forward Looking Activities
EFP	European Foresight Platform (previously the European Foresight Monitoring Network (EFMN))
ERA-Net	Networking of national research programmes in the European Research Area
ESPAS	European Strategy and Policy Analysis System
EEAS	European External Action Service
ERO	European Risk Observatory
ESA	European Space Agency
ESPON	European Spatial Policy Observatory Network
EU-OSHA	European Agency for Safety and Health at Work
FCM	fuzzy cognitive map
FTA	future-oriented technology analysis
IAM	integrated assessment model
GHG	greenhouse gas
JRC	Joint Research Centre
JRC-IET	Institute for Energy and Transport
JRC-IPTS	Institute for Prospective Technological Studies
MEP	member of the European Parliament
ORBIS	Open Repository Base on International Strategic Studies
SSM	soft systems methodology
STAC	Science and Technology Advisory Council
STOA	Science and Technology Options Assessment
TEKES	Finnish Funding Agency for Technology and Innovation

EXECUTIVE SUMMARY

Foresight addresses open and complex futures. The fast-changing and complex nature of many future challenges requires faster, more experimental and more adaptive forms of foresight processes. Expert and stakeholder participation and public engagement are increasingly important to draw on a broader pool of knowledge, to mobilise action and to enhance the legitimacy of foresight results. Foresight needs to be properly embedded into decision-making, both in process terms along the different phases of decision-making and in structural/organisational terms as a network across policy areas. This requires a rapid response capability, which can be delivered through the development of 'Concurrent Design Foresight'. This includes modelling and the recent Science and Technology Advisory Council report concludes 'the Commission needs multidisciplinary foresight activities, including modelling and simulation' (STAC, *The future of Europe is science*, October 2014, p. 19).

Modelling analysis in foresight processes

Since foresight addresses complex social processes, analytical models for anticipatory learning are required to simulate alternative future scenarios as a part of foresight processes. They should identify critical issues through identifying social and technical system structures, their interdependencies and possible paths of change into the future. The models should be used to play out alternative futures which arise from different scenarios of events and factors.

There will be no one model or even type of model that is suitable for all foresight activities. Non-numerical (qualitative) analytical models can structure the complexity of future challenges and serve as a platform for the mutual understanding, participation and integration of often conflicting perspectives. Numerical simulation (quantitative) models can be used to explore specific aspects or stylised systemic features in a fast and experimental way. They require a more explicit specification of variables, relationships and parameters, which can help to make understanding clearer.

A pilot foresight activity for sustainable transport

A foresight process is proposed, to be tested via a pilot Concurrent Design Foresight modelling platform with the objective of developing visions for the EU of a low-carbon transport future, identifying the possibilities for future developments and indicating areas for policy support. The process should be organised around a structured engagement of stakeholders.

Although transport is an activity fundamental to society, it is also accepted that it has negative impacts. The response of society so far is inadequate. Technologies already available — renewable energy and biofuels for power, new vehicle configurations for improved energy efficiency — do offer the possibility for dramatic reductions in CO_2 and other emissions. There are a complex set of influences on transport: lifestyles and culture reflect and reinforce urban form and transport-intensive economic structures. This means that a broad, integrated systems approach is needed to develop policies to support sustainable mobility. There are potentially multiple strategic benefits to EU society and industry.

Conclusions

Concurrent Design Foresight is a tool to support agile and adaptive foresight processes as a part of policy development. The 'wicked problems' faced by EU policy, such as climate change or ensuring the competitiveness of EU industry in the face of globalisation and new technologies, require a transdisciplinary, system-of-systems analysis as part of a participatory foresight process.

This should be supported by a new analysis capability. What is required is not a single 'definitive' foresight model, but rather a platform that supports Concurrent Design Foresight (enabling real-time interaction with stakeholders) through both non-numerical and numerical modelling. Such models are not currently available for policymaking in the European Commission.

The recommendation of this expert group is that the European Commission should develop a platform for analytical modelling to support Concurrent Design Foresight. A pilot Concurrent Design Foresight modelling platform and process is proposed, which will focus on developing visions for the EU of a low-carbon transport future, identifying the possibilities for future developments and indicating areas for policy support.

1. INTRODUCTION AND CONTEXT

Challenges for EU society and policy often reflect 'wicked' problems and changes in society. They are characterised by struggles over how to frame the issue and contradictory assessments of ends and means, i.e. complexity and ambiguity rather than just scientific uncertainty. These challenges are made even more difficult because social systems can also be thought of as 'wicked' systems: they are both complex and complicated, and these qualities interact to produce emergent behaviour (Andersson et al., 2014). Even when the structure is known, including the different actors, institutions and societal mechanisms, it is still not possible to forecast outcomes because of the complexity of social and technical systems with autonomy of actors and the possibility of conflicts of interests.

The forward-looking methods used to engage in a structured way with such complex, multidimensional and puzzling challenges are collectively known as foresight activities. Foresight assumes the future will be different from the present. It seeks to understand how breaks with the past might come from either crisis (an exogenous shock) or transformation (reorganisation within). A foresight process can enable such changes in social structures to be imagined and the implications for different policy fields to be discussed. An example of such a change is the new possibilities of internet-based social media (see Box 1.1 below).

According to 19th century sociologists — including Marx, Durkheim and Weber — modern societies are born when geographically distant social interactions become important in the economy and everyday life. Local interactions are increasingly replaced by geographically distributed linkages, and villages and their inhabitants start to deal with far-away people and cultures. In these classical accounts, space and spatial relations play a foundational role. A key claim of many leading social theorists, past and present, has been that different forms of social order are associated with different ways to organise social interactions in time and space. The emerging knowledge society can therefore be characterised as a new way to organise social time-space*,* based on the new information technologies.

Many key developments on the internet represent qualitatively new ways of organising social interactions and time-space. This means that they do not simply continue extant trajectories of development. On the contrary, they create new possibilities for social interaction that did not exist before. Ten years ago presidents did not tweet. There was no such thing as 'tweeting', and no facts or data that could have been used to predict the future impact of tweeting for society, the economy or politics. Twitter, introduced in 2006, is an example of such a game-changing disruption, but not the only one: Other examples could include Skype (2003), Facebook (2004), Flickr (2004), YouTube (2005), Google Maps (2005), Google Street View (2007), Spotify (2008) and Instagram (2010).

Box 1.1. The new possibilities of internet-based social media

Because the challenges are multidimensional and complex, it is essential that a whole-system approach be used. Foresight processes must identify the different levels and viewpoints of society and technologies that may be relevant, as well as the external influences that have an impact on decisions and outcomes.

Foresight uses a combination of hard and soft systems thinking to develop shared understanding of the challenge and provide insights into the dynamics of change, refreshing conventional wisdom on threats and opportunities, means and ends. This anticipatory intelligence underpins future-oriented strategy building and decision-making within all participating organisations. At the same time the foresight process of iteration of analysis, dialogue and design strengthens the capacity of the system to detect new signals of change and deal with unexpected changes in a proactive manner. New networks between diverse actors are formed and common ground and shared perspectives, as well as future-oriented attitudes, are fostered.

Currently, many foresight activities in the European Commission are undertaken within the directorates-general (DGs). Consequently, they are sector-specific and use diverse methods hindering an integrated view and therefore its comprehensive modelling. This reflects the structure of policymaking which is contained in clearly delimited areas of political responsibility. However, many of today's and tomorrow's challenges are cross-cutting in nature, and require impulses from different policy areas to be tackled successfully. As also stressed by Commission President Juncker

in his political guidelines, *A new start for Europe* (1), **there is an urgent need to overcome the silo structure of policymaking in the European Commission**. In addition to the pooling of multi- and transdisciplinary expertise (2), foresight has the potential to look at issues with a systems thinking approach, including building on interrelations and interdependencies. It can thus help build the necessary bridges between policy areas. An important element in foresight is the societal aspect, as innovation can only occur successfully when there is a buy-in by society, implying a process of responsible innovation (Owen et al., 2014). Bringing together the available foresight knowledge will therefore require a form of 'integrated foresight' (3). Such integration will contribute to enhancing the quality of evidence-based policymaking within the Commission, proactively identify future policy areas and develop a positive and inclusive agenda for research and innovation that reflects changing societal needs and aspirations.

There have already been activities to address this problem. The Science and Technology Advisory Council (STAC) of the former president of the Commission focused its activities on science and technology foresight. This includes modelling, and the recent STAC report concludes 'the Commission needs multidisciplinary foresight activities, including modelling and simulation' (STAC, *The future of Europe is science*, October 2011, p. 19). At the same time, a Commission Foresight Network, currently composed of 21 DGs, was created as an essential tool for transversal cooperation and forward-looking activity. A number of foresight and forward-looking activities already exist in various DGs, namely in the JRC, DG Research and Innovation and DG Communications Networks, Content and Technology. In addition, several new activities were launched at the level of the former Bureau of European Policy Advisers (BEPA) and Chief Scientific Adviser (CSA) Office concerning foresight. The main objective of these activities was to provide a better understanding of changes in the global and EU context, challenges, opportunities and trends that are relevant to the success of existing policies and can be **used by the Commission to anticipate and prioritise future policy areas**. However, the increasing awareness of the complexity of the policy issues faced by the EU and the understanding that sociotechnological structures are changing mean that this integration needs to be extended through the policymaking processes of the European Commission in a much more coordinated way.

1.1. The objectives of the expert group

The main aim of the Expert Group on Integrated Strategic Foresight Modelling is to deliver advice on how to develop models to integrate existing foresight evidence in a transdisciplinary manner that can be used by high-level decision-makers, Commission policymakers, other experts and possibly citizens themselves. The group decided to adopt a broad definition of models. The idea of a model is not just understood in the sense of analytical modelling, but also as the concept for the overall foresight process. Hence the report considers both models for foresight processes and models as tools for analysis to support foresight processes (see Box 1.2). The modelling and associated tools could even be used as a training tool or for educational purposes and for supporting societal dialogue.

The objective of the report is to propose how foresight modelling analysis and processes can be used for policy or other decision-making processes. This also implies that these tools include proper reflection on and integration of societal needs and concerns in foresight.

(1) http://ec.europa.eu/about/juncker-commission/docs/pg_en.pdf
(2) In Horizon 2020, transdisciplinarity refers to approaches and methodologies that integrate as necessary (a) theories, concepts, knowledge, data and techniques from two or more scientific disciplines and (b) non-academic and non-formalised knowledge.
(3) 'The art of integrated foresight'; *BEPA monthly brief*, Issue 62, 2013, pp. 6-7

This report differentiates between models for foresight processes and models for analysis to support foresight processes.
Models of process include concepts for the structure of a foresight process and also the associated models for the institutional structure or organisation which will initiate and undertake foresight studies. They describe the modalities of engagement of different actors and stakeholders, as well as the methodological steps to be followed. They tend to address also issues of how foresight is related to organisational change.

An analytical model is in general an abstraction of reality developed to understand the phenomena under consideration. In foresight, there are different kinds of formal structured methods of analysis in which can be considered as analytical models:

- Numerical models (e.g. the Hadley Centre Climate Models, the Fraunhofer ASTRA transport integrated assessment model) are what are conventionally considered to be 'models' in policy analysis.
- There are a series of non-numerical formal methods which can be considered as qualitative models (e.g. cognitive maps or mental maps of an issue, causal mapping, argument logic maps)

Box 1.2 Model Categories for Foresight processes and analysis

1.2. Structure of the report

The expert group has concluded that foresight modelling cannot be addressed in isolation; it must be considered as part of an interactive, iterative foresight process. The report therefore considers the current foresight structures employed in the European Commission and related institutions. It then reviews current ideas about foresight processes for policy development in the context of the EU, drawing in particular on the results of the European Forum on Forward Looking Activities (EFFLA). **Concurrent Design Foresight** is introduced as a concept which offers the necessary breadth of approach, the ability to allow for conflicting interests and opinions and the ability to react quickly, when necessary, to the needs of policy development. The potential for analytical modelling to support foresight activities is then considered and conclusions about the necessary attributes of models in foresight are drawn. A new platform for analytical modelling to support Concurrent Design Foresight is proposed. In order to illustrate the range of possibilities for analytical models in foresight, three contrasting cases of issues are briefly discussed: low-carbon housing in Chapter 5, 3D printing in Chapter 6 and sustainable mobility in Chapter 7. These are summarised in Table 1.1. Low-carbon housing is an example of an issue that is well defined as a goal in society, with a well-known technological structure and a clearly limited problem boundary. 3D printing is an example of a new technology which is developing rapidly. The current features of the technology are known, but it offers the prospect of changing social and economic structures in many different ways, such that the boundaries of the issue are open and the possibilities for EU society have to be discussed and created.

Table 1.1. Summary of cases discussed

Case study	Policy situation	Foresight role
Low-carbon housing	Well-defined goal Well-known technologies Clear problem boundary	• Reveal and contest assumptions about the future • Clarify policy options that might work in a variety of plausible future contexts
3D printing	New technology Uncertainty impacts on societal and economic structures Open problem space: no clear boundary	• Reveal and contest assumptions about the future • Structure uncertainty • Attend to ontological expansion • Forge shared and systemic understanding • Identify better questions that policymakers can address
Sustainable mobility	Clear idea of social issue	• Manufacture the foresight client/policy actor(s)

	Multiple systems/policy areas Different and sometimes opposing perspectives	• Reveal and contest assumptions about the future • Structure uncertainty and attend to ontological expansion • Create and sustain collaborative action-learning

Sustainable mobility is an example of a concept in society where there is a clear idea of a social issue, but where there are multiple systems involved: people and products that require transport and mobility, technologies for providing transport, the built environment and lifestyles with cultural ideas of the meaning of transport. This case provides an excellent example of a highly relevant issue in EU policy with multiple points of view and aspects of society to be considered. It requires a system-of-systems approach, which takes into account the differing and sometimes opposing perspectives. We therefore propose a **pilot foresight process and modelling activity** to address sustainable mobility as the next step in developing foresight in the European Commission.

CHAPTER 2: OVERVIEW OF FORESIGHT IN EUROPEAN INSTITUTIONS

Key Messages

1. A wide range of foresight projects, different in nature, scope and objectives, are conducted across the EU institutions. In the Commission, DG Research and Innovation is the main foresight player. The JRC, DG Communications Networks, Content and Technology, other DGs and the former BEPA and CSA Office are also involved in different forms of foresight. The European Parliament hosts the Science and Technology Options Assessment (STOA), and the Council sets up high-level groups using foresight on key policy issues. Decentralised agencies such as the European Environment Agency (EEA) and European Agency for Safety and Health at Work (EU-OSHA) also conduct foresight activities.

2. EU and Commission foresight projects fit into a quantitative-qualitative spectrum. Technical quantitative models are used to provide policy analysis with numerical input, such as projections and impact assessments. Qualitative exercises involve more exploratory and participatory initiatives. An opportunity is now emerging to expand the scope and usefulness of foresight modelling; this is the object of this report.

3. Foresight work in the Commission (and the EU) has traditionally been done in 'silos'. In response to this environment, the Commission has set up foresight networks, workshops and knowledge platforms that ensure communication and coordination across DGs and EU institutions.

2.1. Overview of strategic foresight activities in the Commission, other EU institutions and Member States

This chapter aims to provide a swift overview of how foresight studies are currently conducted in the EU. It is not within the purview of the present report to provide a full-scale, exhaustive, detailed study about foresight in the EU, as its object is to discuss the potential use of integrated foresight modelling by policymakers. This chapter is therefore meant to be introductory, providing some context to the report and some guidance for external actors who want to interact with the European Commission on foresight topics.

The chapter draws on literature, both internal and external to the EU. It is complemented by interviews with EU foresight practitioners with hands-on experience in a range of different foresight projects inside the EU ([4]). It also includes feedback from a workshop held with Commission officials to discuss the draft report.

2.1.1. Definition of foresight in the EU context

Foresight can be defined as 'a systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building process aimed at enabling present-day decisions and mobilising joint actions' (FOREN, 2001). Using this definition, we include for consideration in this chapter, along with activities conducted by dedicated foresight units, other future-oriented activities such as technology roadmaps. Chapter 3 provides more background and details on the nature and evolution of foresight.

2.1.2. Foresight activities in the European Commission

The EU has a long tradition of foresight activities. Long-term planning is integral to EU activities, as shown in the 7-year multiannual financial framework and framework programmes for EU research and technological development. Over the last 20 years, the number and scope of foresight projects conducted within EU institutions have increased steadily. EU foresight projects encompass different

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([4]) We are grateful to the following EU foresight practitioners who kindly accepted to be interviewed:

- Theodoros Karapiperis, PhD, Head of Unit, Science and Technology Option Assessment (STOA), Directorate for Impact Assessment and European Added Value, Directorate-General for Parliamentary Research Services, European Parliament;
- Nikolaos Kastrinos, Team Leader, Foresight, Unit A6 — Science policy, foresight and data, DG Research and Innovation;
- Domenico Rossetti di Valdalbero, PhD, Principal Administrator, DG Research and Innovation;
- Fabiana Scapolo, PhD, Head of Sector, Foresight, Foresight and Behavioural Insights unit, Joint Research Centre.

scopes, objectives and methods, from major scenario projects, to vision exercises, to horizon scanning, to technology roadmaps, to one-off foresight workshops or conferences.

Foresight projects carried out in the European Commission often involve several DGs. DG Research and Innovation is the most prominent initiator of foresight activities, with funding from the framework programmes. The former BEPA under President Barroso (formerly the Cellule de Prospective under Jacques Delors) and the Joint Research Centre (JRC) have a tradition of doing foresight activities.

We list the DGs and other key producers of foresight within the European Commission below ([5]).

- **DG Research and Innovation**

DG Research and Innovation supervises important interdisciplinary foresight projects. These projects are carried out either by high-level expert groups or through collaborative projects which bring together different universities over several years to answer a specific research question. Foresight projects are funded under different DG Research and Innovation research themes.

Examples of projects include the following ([6]).

- Collaborative project 'Forward-looking analysis of grand societal challenges and innovative policies' (Flagship, 2013-2015) ([7]), funded under the 'Socio-economic sciences and humanities' theme, aims at developing a set of scenarios of long-term socioeconomic evolution in the EU.
- In the ongoing collaborative project Foodsecure ([8]) (2012-2017), an interdisciplinary research consortium is tasked with providing analytical tools and strategies to assess and address the future of global food and nutrition security.
- Another collaborative project, 'Future prospects on transport evolution and innovation challenges for the competitiveness of Europe' (FUTRE, 2012-2014) ([9]), was funded under the 'Transport' theme. The aim is to produce scenarios of transport innovations and their implementation, as well as options for research policy, in order to address the issue of competitiveness for EU transport industries and service providers.
- The Recreate network (Research Network for Forward-Looking Activities and Assessment of Research and Innovation Prospects in the Fields of Climate, Resource Efficiency and Raw Materials) ([10]), a coordination action launched in 2013 and planned for completion in 2018, brings together key stakeholders in the fields of Climate action, resource efficiency and raw materials with the objective of providing evidence to support Horizon 2020's Challenge 5 ([11]).
- The expert group exercise *Global Europe 2050*, completed in 2012 ([12]), was funded under the 'Socioeconomic sciences and humanities' theme and tasked an expert group with building three scenarios depicting alternative pathways that the EU could follow to 2050.

DG Research and Innovation is also a major user of foresight. As part of the innovation union initiative, DG Research and Innovation EFFLA ([13]), a high level expert group to bring together existing studies and data to improve the evidence base of research and innovation policies. Following on from EFFLA recommendations, a recently established unit (DG Research and Innovation Unit A6) has the mission of leading foresight for research and innovation policymaking, and for example also concretely supporting the decision-making procedures of Horizon 2020, with the long-term objective of being a reference on foresight for strategic programming within the European Commission and vis-à-vis the Member States (Burgelman et al., 2014).

- **Joint Research Centre**

With the first activities in technological foresight starting in 1989 in the Institute for Prospective Technological Studies (IPTS) ([14]), the JRC is a long-standing provider of foresight intelligence, performing foresight studies and developing methodological guides, training courses and networks on foresight. The JRC organises a regular international conference on future-oriented technology

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([5]) *Source:* Dreyer, I., Stang, G. and Richard, C., 'Foresight in governments: practices and trends around the world ', 2013; interviews.
([6]) For more examples, see DG Research and Innovation's latest report on *European Union research in foresight*, 2014 (http://ec.europa.eu/research/social-sciences/pdf/project_synopses/research_in_foresight.pdf).
([7]) http://flagship-project.eu
([8]) http://www.foodsecure.eu/About.aspx
([9]) http://www.futre.eu
([10]) http://www.recreate-net.eu/dweb
([11]) Horizon 2020 is the European framework programme for research and innovation.
([12]) Available at: http://ec.europa.eu/research/social-sciences/pdf/global-europe-2050-report_en.pdf
([13]) http://ec.europa.eu/research/era/effla_en.htm
([14]) https://ec.europa.eu/jrc/en/about/ipts/what-we-do

analysis (FTA) and manages the sharing platforms Forlearn ([15]) and Forsociety ([16]), aimed at exchanging foresight resources between practitioners, users and policymakers.

Recently, a new unit was established at the JRC that focuses on innovation in public policy through foresight, horizon scanning, policy labs and behavioural sciences. The new unit is exploring the possibility of integrating these disciplines into a policy lab for innovation in public policies intended to better engage stakeholders and citizens and improve the effectiveness of EU policies.

The Foresight and Behavioural Insights unit at the JRC works in close cooperation with policy DGs to provide rich, forward-looking information and stimulate innovation on priority policy issues that are of interest to other DGs. Two recent foresight exercises conducted by DG-JRC are 'Industrial landscape vision 2025 for early standardisation', requested by the former DG Enterprise and Industry ([17]) and 'Tomorrow's healthy society — research priorities for food and diets', at the request of DG Research and Innovation ([18]). Two other foresight studies, on food security and on the transition to a sustainable economy, are nearing completion.

The JRC-IET (Institute for Energy and Transport) also provides projections on topics such as the adoption of future transport technologies, the potential of low-carbon technologies, or the evolution of energy systems.

- **Former Bureau of European Policy Advisers**

BEPA was in charge of providing strategic thinking and policy advice to the European Commission. The original bureau was set up in 1989 under the title Cellule de Prospective, and has been conducting foresight analysis on different topics in collaboration with other DGs (DG Research and Innovation, JRC).

BEPA co-steered the interinstitutional European Strategy and Policy Analysis System (ESPAS), together with the European Parliament, the Secretariat-General of the Council of the European Union and the European External Action Service (EEAS). This project is aimed at strengthening the capacity of the European Union to identify and analyse long-term trends and policy priorities ([19]).

- **DG Communications Networks, Content and Technology**

In 2011, DG Communications Networks, Content and Technology created Futurium, 'the digital agenda for Europe', a participatory web platform that uses foresight methods as a way to engage citizens in policymaking to co-create preferred futures. Participants can imagine and contribute surprising future developments to the horizon for 2050, as well as their own visions, and can host local events ([20]).

Futurium was initially set up to host future-oriented policy ideas, and has since been meant to be an experiment for participatory policy design (Accordino, 2013). The content collected on Futurium informed the Horizon 2020 framework ([21]).

- **President Barroso's Science and Technology Advisory Council**

STAC was chaired by the CSA and was asked by the former president to focus its second report on foresight (STAC, 2014). The report includes themes such as future living, health, interactions, learning, natural resources and manufacturing ([22]).

The president, with the help of STAC, also initiated a high-level foresight conference titled 'The Future of Europe is Science', on 6 and 7 October 2014 in Lisbon, supported by the JRC ([23]). In preparation for the conference, a Eurobarometer was initiated by DG Research and Innovation and the CSA Office surveying 28 000 citizens about their views on priorities for the next 15 years in science and technology ([24]).

([15]) http://forlearn.jrc.ec.europa.eu/index.htm
([16]) http://forlearn.jrc.ec.europa.eu/guide/A2_references/forsociety.htm
([17]) http://www.manufuture2013.eu/images/MF/presentations_PDF/Scapolo_Churchill_W25.pdf
([18]) http://ec.europa.eu/health/nutrition_physical_activity/docs/ev20120614_co04_en.pdf
([19]) http://europa.eu/espas
([20]) http://ec.europa.eu/digital-agenda/futurium
([21]) https://ec.europa.eu/digital-agenda/futurium/sites/futurium/files/DF_final_report.pdf
([22]) See also the minutes of STAC meetings at: http://ec.europa.eu/commission_2010-2014/president/advisory-council/documents/minutes_4th_pstac_meeting_071113.pdf and http://ec.europa.eu/commission_2010-2014/president/advisory-council/documents/minutes_5th_pstac_meeting_310114.pdf
([23]) https://ec.europa.eu/jrc/en/event/conference/future-europe-science-october-2014?search
([24]) Special Eurobarometer 419, *Public perceptions of science, research and innovation*. Survey requested by DG Research and Innovation and coordinated by DG Communication (Strategy, Corporate Communication Actions and Eurobarometer unit).

- **President Barroso's Chief Scientific Adviser**

One of the roles of the CSA Office was to coordinate foresight for science and technology within the Commission. In this respect, an internal network was put in place of about 230 foresight experts across 21 DGs. It delivered cross-disciplinary thematic briefs for the president, his cabinet, STAC and ESPAS, as well as relevant Commission services. The CSA Office also co-initiated the present report with DG Research and Innovation.

- **Other DGs**

Other DGs are regularly engaged in thematic foresight processes. In contrast with the DGs listed above, their foresight activities tend to be focused on their own theme of interest. Below is a non-exhaustive list of such DGs with project examples.

- DG Regional and Urban Policy: the European Spatial Policy Observatory Network (ESPON) completed a foresight study of Europe in 2050, *ET2050 — Territorial scenarios and visions for Europe* ([25]), with the objective of establishing targets for territorial planning policies.
- DG Energy published the *Energy roadmap 2050*.
- DG Energy, DG Climate Action and DG Mobility and Transport jointly produced *EU energy trends to 2030*.

2.1.3. Foresight activities in other EU institutions

The other EU institutions also conduct foresight activities.

- **European Parliament: Science and Technology Options Assessment**

STOA, created in 1987, is a panel of members of the European Parliament (MEPs) that coordinates technology assessment studies and projects, carried out by external experts, for use by the committees of the European Parliament. The goal of STOA is to expand MEPs' range of ideas through objective, fact-based, unbiased analysis of policy options. This includes exploring the consequences of policy choices into the future. The STOA Panel is assisted by the STOA Secretariat, a service within the Scientific Foresight Unit.

The newly created Scientific Foresight Service, within the same unit, will develop in-house expertise on long-range trends and forward-looking policy issues in the fields of science and technology. Besides awareness-raising on future trends in science and technology, the service will develop futures studies with the aim of empowering MEPs to work towards desirable future scenarios and avoid undesirable future scenarios by providing legislative options.

- **European Council**

The European Council has requested a number of foresight activities, usually in the form of high-level task forces tackling specific themes. In 2007, the European Council requested the creation of a working group to identify key issues that would affect the EU in the future and develop a response. The results of these reflections were published in 2010 in the report *Project Europe 2030 — Challenges and opportunities — A report to the European Council by the Reflection Group on the Future of the EU 2030*, known as the Gonzalez report.

- **Council of the European Union**

The High Level Group on Innovation Policy Management was created by the Council in 2011, and in its second phase used foresight to support its blueprint recommendations for a European Union innovation ecosystem.

- **Decentralised agencies**
  - The EEA uses scenarios to explore environmental uncertainties ([26]). It powers an Environmental Scenarios Information Portal showing forward-looking outputs such as scenarios, outlooks projections, trends and assessments ([27]). Its latest *European environment — state and outlook* (SOER) was published in spring 2015.
  - EU-OSHA, through the European Risk Observatory (ERO), also uses foresight as a way to monitor new and emerging risks in occupational safety and health.

([25]) http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/ET2050.html
([26]) http://www.eea.europa.eu/themes/scenarios/intro
([27]) http://scenarios.ew.eea.europa.eu/reports

2.1.4. Foresight activities in Member States ([28])

Many Member States have active governmental foresight systems, among which Finland is widely recognised among the global foresight community as one of the most advanced and effective national foresight systems attached to the Prime Minister's Office. EUISS (2013) reviews foresight activities around the world.

Government foresight models are distinct across Member States, and it is not within the scope of this report to explore the specificities of each national foresight system ([29]). Dreyer et al. (2013) provide several axes of analysis: level of funding, in-house or external skills, degree of centralisation, departments involved, regularity and nature of foresight exercises. France, the Netherlands and the United Kingdom have centralised systems, while foresight bodies in Finland, Germany, Italy and Switzerland are decentralised. In EU Member States, foresight analyses and policymaking tend to be separate, while some emerging countries (e.g. Brazil, China, India) tend to set government goals in accordance with a vision for the future.

Member States have also joined resources to conduct foresight studies. At the regional level, Nordic foresight projects brought together Denmark, Finland, Iceland, Norway and Sweden. At the EU level, since 2008, Member States have been able, through joint programming initiatives (JPIs), to agree on and implement shared research agendas about key issues shaping the future of the EU. JPIs increasingly use visioning, horizon scanning and other foresight methods to orient and program research agendas, as well as to explore topics of interest (Meissner et al., 2013).

The United Kingdom government futures toolkit (HMG, 2014) surveys approaches to foresight, with a similar structure and set of activities to the EFFLA. It surveys foresight methods and their application to the different activities and phases in a foresight process, including the 3 Horizons and Delphi approaches.

2.2. How modelling is used in EU foresight: quantitative and qualitative foresight, two edges of a spectrum

2.2.1. Foresight in the EU: quantitative, qualitative and hybrid approaches

A typology of foresight methods used in EU institutions has been developed, placing foresight projects on a scale from the most qualitative to the most quantitative. In practice, three main approaches to foresight can be identified: qualitative, quantitative and hybrid (Rossetti, 2010).

Traditionally in foresight practice, including in EU institutions, quantitative and qualitative approaches have tended to respond to distinct objectives and have distinct advocates. This is the case in the EU, as described below.

2.2.2. Foresight modelling in the EU: the quantitative edge

In the Commission and other EU institutions, the term 'modelling' is currently mostly understood and used in its quantitative or numerical sense. Foresight modelling is used to provide foresight results (such as scenarios or trends) with quantitative projections. Foresight models are thus mostly used in a predictive sense.

In practice, impact assessments and technology maps regularly use existing models to assess options and strategies. Models include general equilibrium models (GEM-E3), econometric models (Nemesis, E3ME) and partial equilibrium models (Primes, POLES). In other foresight projects, specific models are developed for and about the question studied. Those models are constructed based on datasets from the past, allowing users to extrapolate past trends or change parameters and values to yield different variants ([30]). The DG Research and Innovation project Foodsecure is one example of a project developing ad hoc quantitative tools. Other examples include Simpatic ([31]), looking at the impacts of research and innovation policies, and Milesecure ([32]) analysing the future of EU low-carbon energy security.

([28]) This chapter focuses on foresight as policy support at the European level. We therefore do not provide details on the diversity and profusion of foresight work done by global and national non-governmental organisations, think tanks and corporations.

([29]) For more details about foresight in each Member State, see forthcoming study by DG Research and Innovation — Science, in collaboration with Inno, Innova and Manchester Business School, on anticipatory governance in Member States.

([30]) Further analysis of numerical models is provided in Chapter 3 of the present report.

([31]) http://simpatic.eu

detailed numerical input. This means that technical models are run to provide answers to specific policy questions, particularly in impact assessments and technology roadmaps.

The main obstacle that may prevent quantitative projects from supporting policymaking resides in the complicated and specialist nature of the models. The difficulty of explaining the 'black box' with all its implicit assumptions often results in a lack of legitimacy in the eyes of the recipients — both policymakers and the larger public.

Models are also included in hybrid approaches. In current EU activities, qualitative outputs such as scenario narratives are produced first and then illustrated by figures derived from one or more quantitative models, usually borrowed from previous research. Examples include Flagship, Global Europe 2050, and 'Challenges for Europe in the world of 2030' (AUGUR) ([33]). The main advantage of hybrid approaches is in bringing together experts with significantly different backgrounds in an exchange of views, which tends to yield more innovative ideas. However, it requires a higher time investment in order to enable experts from different horizons to acquire a common language.

2.2.3. The other side of the spectrum: qualitative and participatory foresight

Qualitative projects encompass trends, horizon scanning, visions and scenarios. One example is the JRC-led foresight exercise 'Industrial landscape vision 2025 for early standardisation' ([34]), which developed a detailed vision, narrative and conceptual model of the future industrial landscape in 2025. Qualitative exercises are usually based on desk research, workshops and conceptual analysis. They are used to look beyond quantifiable facts and forecast-based extrapolations to maintain the future as an open story. Working with different assumptions about the future enables access to tacit knowledge — which is often transmitted in the form of stories or narratives and contributes a different way of knowing — intuition and imagination. These projects are deemed successful when they help gather new narratives and clarify the different interpretative frames that are inherent in any decision-making about a novel situation. They help popularise social and political concepts. They may suffer from a perceived lack of legitimacy compared to exercises that directly support decision-making with numbers.

Although not all of them include stakeholder participation, qualitative projects tend to involve participatory approaches more often than quantitative projects. The extent of participation of external and internal stakeholders varies across projects, those with narrow focuses involving fewer participants. Currently, external participants include mostly academic experts, although other actors may be represented in formal foresight processes, for example consumer organisations ([35]). Open foresight platforms such as Futurium are participatory by nature.

2.3. Sharing processes and results: connections and communication between foresight units (inside and beyond the Commission)

Coordination and communication across DGs currently occur through a range of networks of foresight practitioners and platforms of foresight tools and knowledge.

2.3.1. Foresight networks within the Commission and between EU institutions and Member States

One example is the abovementioned network of foresight experts set up around the former CSA office. Another is the network of foresight correspondents of Horizon 2020 involving the 10 DGs tasked with research activities, which is coordinated by DG Research and Innovation unit A6. The network aims to coordinate and stimulate foresight activities across Horizon 2020, cross-fertilise the use of foresight results and promote mutual learning. Members of this network discuss their foresight plans and present their projects to each other. Attendees from other EU institutions are invited as well, for example the European Environment Agency ([36]).

In the European Parliament, one of the goals of STOA is to maintain communication both between the Member States and between Member States and the public at large. Therefore, outreach is a key intrinsic activity. STOA participates in forums and hosts public events, with a range of guests from universities or EU institutions.

([32]) http://www.milesecure2050.eu
([33]) http://www.augurproject.eu/spip.php?rubrique30
([34]) https://ec.europa.eu/jrc/en/research/foresight/ilv2025
([35]) *Source:* interviews.
([36]) *Source:* interviews.

2.3.2 Foresight training and communication of projects' results within European 2.3.2. Foresight training and communication of projects' results within EU institutions

As mentioned in Section 2.1.2, DG Research and Innovation created EFFLA to bring together existing studies and data and involve public and private stakeholders to improve the evidence base of research and innovation policies. After EFFLA had fulfilled its mandate by providing advice on how to incorporate foresight in strategic programming, EFFLA experts were incorporated into a broader High Level Group of Research, Innovation and Science Policy Experts (RISE). EFFLA's advice has underpinned the recent structuring of foresight coordination and communication in DG Research and Innovation and across Horizon 2020. For example, DG Research and Innovation offers foresight training, such as foresight awareness and foresight essentials (methods).

Foresight results are often communicated both within the Commission and to the larger public through conferences and seminars. For example, DG Research and Innovation holds 2- to 3-hour conferences where the conclusions of a specific foresight project are presented for comments to a range of DGs. Longer workshops, involving different Commission groups, have foresight and subject matter experts describe the results of their work. The objective of these workshops is to explore and exploit the results of research. For quantitative projects, these workshops are spent teaching how to understand the model and use its results. Minister-level seminars, where members of different Member States are invited, for example members of the Competitiveness Council, are also held around foresight studies.

Efforts have also been put into platforms where foresight projects, methods and results can be shared both within and beyond EU institutions. For example, the European Foresight Platform (EFP) (previously the European Foresight Monitoring Network (EFMN)) aims to bring together practitioners to 'share their knowledge about foresight, forecasting and other methods of future studies' ([37]). It also linked to the iKnow weak signals scanning system and is now including IPTS's ForLearn. The Open Repository Base on International Strategic Studies (ORBIS), powered by ESPAS, hosts the reports of prospective studies done in EU institutions or Member States ([38]). ERA-Net and the Futurreg project are other examples of sharing platforms, with different objectives (Kuosa, 2011).

2.4. Conclusion

This chapter provided a short overview of foresight activities conducted in the Commission, other EU institutions and Member States in order to set the context for the following chapters. There are already a large number of different activities in the Commission and other EU institutions which support policymaking. However, most of these activities are based on approaches which emphasise a particular point of view and which cannot take into account the structural changes that would be required to address the complex, systemic problems that foresight activities are intended to address.

In an increasingly complex, uncertain and unpredictable context, policymaking requires cross-disciplinary inputs, creative thinking and places for experimentation. EFFLA has already pointed out the benefits EU policymaking would gain from having a 'centre of future-oriented strategic thinking' (EFFLA, 2012) which could directly contribute to policy implementation. In particular, a foresight approach based on multidisciplinary and multi-stakeholder perspectives may be able to reduce the prevalence of silo thinking in policy formation. The Concurrent Design Foresight approach incorporating foresight modelling that this report proposes are intended to support this objective.

([37]) http://www.foresight-platform.eu
([38]) http://europa.eu/espas/orbis

CHAPTER 3: INTEGRATED FORESIGHT PROCESSES

Key points

1. Foresight is dealing with open and complex futures. The fast changing and complex nature of many future challenges requires faster, more experimental and more adaptive forms of foresight processes.

2. Expert and stakeholder participation and public engagement are increasingly important to draw on a broader pool of knowledge, to mobilise action and to enhance the legitimacy of foresight results.

3. Foresight needs to be properly embedded into decision-making, both in process terms along the different phases of decision-making and in structural/organisational terms as a network across policy areas.

4. Modelling has two important functions in next generation foresight: qualitative, often conceptual modelling allows the structuring of the complexity of future challenges and serves as a platform for mutual understanding, participation and integration of perspectives; quantitative modelling can be used to explore specific aspects or stylised systemic features in a fast and experimental way.

The purpose of this chapter is to develop a conceptual framework for foresight activities in the EU that can serve as a common background for positioning the roles that different types of analytical modelling can fulfil in the context of foresight processes. The framework should take into account the changing nature of emerging policy challenges and the need to make foresight a more effective input into policymaking.

The framework shall thus build on: (a) existing approaches to conceptualising foresight processes; (b) an analysis of key emerging challenges for foresight; and (c) insights into the embedding of foresight into (political) decision-making. This latter aspect seems crucial given the context in which the expert group is operating and supposed to contribute (Section 3.1). On this basis, some crucial requirements will be set out that need to be met by the integrated foresight process framework that we subsequently want to propose as our reference point (Section 3.2). Finally, this integrated foresight process framework suitable for the policymaking context of the Commission will be introduced and explained. Different types of process and analytical models will be positioned in relation to this framework (Section 3.3).

3.1. Process perspectives on foresight

3.1.1. Definitions of foresight in the literature

The notion of foresight became prominent in the late 1980s, with the launch of the British foresight programmes (Martin, 2010). Since then, several definitions have been proposed. According to the EFP, foresight can be defined as 'a systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building process aimed at enabling present-day decisions and mobilising joint actions. It can be envisaged as a triangle combining 'thinking the future', 'debating the future' and 'shaping the future' ([39]). Other definitions give more prominence to the open character of the future, and thus stress the notion of scenarios rather than that of vision. Even if the roots of foresight are in technology foresight, it is nowadays mainly applied to exploring and shaping change in social systems, to which the biological model of change applies (i.e. self-organisational and self-referential) rather than the physical (i.e. mechanistic) one (see Chapter 4).
Very common is the reference to the 'five C's' as typical characteristics of foresight processes (Irvine and Martin, 1984), as shown below.

- **Concentration on the future.** The exploration of scientific-technological developments and socioeconomic demand requires a 'systematic attempt to look into the future of science, technology, economy and society. It is not focused on a single, most probable future but on several possible scenarios.

([39]) http://www.foresight-platform.eu

- **Communication.** Joint processes of exchange, learning and engagement among stakeholders and the public aim to broaden the participants' horizons and to develop shared perceptions of challenges and options.
- **Consensus and conflict.** A shared understanding of future challenges and options can be achieved by way of participatory processes of intelligence gathering and scenario building. On this basis, consensus is often sought on normative orientations, such as visions or areas of strategic research, likely to yield the greatest economic and social benefits. However, transparency about diverging goals and conflicts of interest is also a useful outcome of foresight.
- **Commitment.** Early involvement in foresight can help mobilise actors and stakeholders in line with the shared visions and priorities identified, and thus facilitate joint and coherent action.
- **Coordination.** Through shared perceptions of challenges, visions and priorities, the coherence across different actors' strategies can be enhanced. Foresight is an instrument for coordinating present-day decisions in view of future challenges and visions.

Underlying these key characteristics of foresight are a number of fundamental assumptions about change processes in society that reflect a constructivist understanding of how the future unfolds.

- **The future cannot be predicted, but is open and malleable.** As a consequence, foresight tends to rely on scenario building and adaptive strategies as means for dealing with uncertain future challenges. It rejects the approach of trying to forecast the future on the basis of models that essentially reflect the past, also because foresights puts the emphasis on the longer term when structural and even disruptive changes are likely to occur.
- **The influence of individual actors is limited.** Entrepreneurial personalities can make a difference, but the systemic understanding of innovation that underpins much foresight work implies that often a range of technological, social and institutional changes are needed to realise a desirable scenario. Shaping the future thus requires coherent and coordinated action by an equally broad range of actors and stakeholders, a process that can be facilitated by shared problem perceptions, orientations and visions.
- **Moving from visions to concrete actions is crucial.** As shared visions are not enough to make change happen, the definition of joint as well as individual agendas for action is central to foresight. Mobilisation and activation of actors and stakeholders by way of participation in foresight processes is thus a key tenet of foresight thinking.

This understanding of how the future can be shaped implies that foresight relies on the participation of stakeholders to combine future exploration by way of scenarios with normative considerations about the goals and visions to be pursued. In other words, not only the pathway towards the future needs to be debated, but also the target. This has consequences for the use of certain types of modelling approaches, in particular those focusing on the assessment of future options, because the key dimensions for assessment as well as their relative importance is subject to continuous scrutiny. As regards the relationship with modelling, nowadays a synergetic view prevails. Modelling can be a useful input to the foresight process at different stages, but can also be informed by foresight-type processes. Broad conceptual, often qualitative models allow better and more comprehensive structuring of the issues at stake, whereas quantitative models contribute to exploring and assessment-specific features of the issue.

- Foresight aims to anticipate, explore and assess alternative future developments as well as the options for action to deal with these alternative futures.
- Foresight also contributes to mobilising actors and stakeholders who influence today's decisions and thus shape future trajectories.

3.1.2. How the future is conceptualised and how it is addressed by foresight

Exploring the future can be done in different ways. There are different core conceptual models of how the future unfolds, which can be distinguished in terms of the extent of variation they assume with regard to the two dimensions of structures and relationships, as shown below.

1. Extrapolation assumes essentially the continuity of both existing structures and past relationships.
2. Forecasting deals with the changing of relationships under conditions of structural continuity. This is often reflected in the nature of system dynamic models used for forecasting. Major changes can only be imposed exogenously, and they do not alter the underlying system structure.
3. Foresight is more flexible because it allows structural change in a system or ontological expansion (Tuomi, 2013) to be explored. New elements can come into play, and thus also new relationships. However, it is restricted in its scope by the creativity of what its

participants can imagine and formulate as scenarios, visions and roadmaps for planning. This has serious implications for the possibilities and limitations of planning under conditions of fast and disruptive change. Associated with the notion of ontological expansion, this model of the future focuses on the unexpected and unimaginable, such as the 'black swans' (Taleb, 2007). In this framework, the future cannot be planned, but requires robust and agile/adaptive (some prefer 'resilient') structures and relationships, or continuous learning and adaptation towards ambitious higher-order goals.

Note that foresight under unpredictable uncertainty and in situations involving novelty will need to reveal, contest and clarify assumptions about what will be the same, as well as shifting and genuinely different — and these are likely to vary by different interests and perspectives of stakeholders — including science which often contributes contradictory assessments using the same evidence base.

In recent debates, this last type of perspective has attracted growing attention. More and more future challenges are seen as either giving rise to or requiring structural or even disruptive change. The climate-change debate is an example of a challenge that is regarded by many experts as requiring such significant changes. Emerging and converging technologies are sometimes assigned a transformative potential that is hard to imagine (e.g. 3D and 4D printing; see Chapter 6).

Numerical modelling may be very suitable for extrapolating and forecasting future developments, but it often reaches limits once structural and disruptive changes are considered. The complexity of the issues at stake can be of such a magnitude that many different features need to be modelled in interaction, implying that uncertainties (and thus error margins) superpose, while qualitative and structural changes are even harder to quantify (see Chapter 4).

Over the past decades we could observe a shift in emphasis from the first two approaches of thinking about the future to the latter two approaches, obviously also in response to the recognition of the growing complexity, uncertainty and ambiguity of the phenomena under study. This shift is also reflected in the different generations of foresight (with their respective underlying conceptualisations of the future). Even if the term 'foresight' was only invented in the late 1980s, it is applied in retrospect to earlier generations of future anticipation, as follows.

- First generation (1970s):
  - technology identification and forecasting;
  - technology Delphis.
- Second generation (1980s):
  - anticipation of new technologies and markets;
  - technology and market Delphis, key technology studies, etc.
- Third generation (1990s):
  - 'real' foresight combines outlooks on technologies, markets and societal developments;
  - sociotechnical scenario thinking for devising collective strategies;
  - mobilisation of actors and stakeholders ('rewiring the innovation system') ([40]).
- Fourth generation (2000s):
  - developing adaptive planning and strategies to cope with different future scenarios;
  - combining collective processes with intraorganisational strategic foresight.
- Fifth generation (2010s):
  - focusing on how to deal with grand challenges as key demand-side drivers of change;
  - horizon scanning and identification of weak signals to anticipate the unexpected;
  - systemic foresight.
- Sixth generation (currently emerging):
  - dealing seriously with ontological expansion and the impossibility of anticipating the unexpected;
  - designing foresight aiming to simultaneously explore and experiment with emerging and future developments.

In particular with regard to the last two generations, there are still major methodological and conceptual challenges to be tackled in order to be able to develop informed advice for policymaking. The steering philosophy that would be suitable in the age of ontological expansion merits attention. Neither normative orientations nor the ability to anticipate future developments can be taken for granted, implying that both future exploration and its assessment need to be continuously renegotiated in a process of goal-oriented modulation (Kemp and Loorbach, 2006).

([40]) This notion was coined by Martin and Johnston (1999).

What this look at the different generations of foresight shows is that there are different modes of approaching the future, and corresponding processes and methods to be used accordingly. More recent modes do not necessarily replace older ones, but rather complement them, either to tackle new types of challenges that were less prominent in the past or to take into account a better and sometimes more complex understanding of the challenge in question.

This implies that, depending on their suitability for the problem at hand, different foresight generations with their respective methods may be relevant to consider in our process-oriented framework, if we want to position the contribution that modelling can play.

- Different approaches to foresight have been developed over the past decades, suitable for the exploration of different kinds of future challenges. The nature of the challenges determines the choice of methodology.

3.1.3. Emerging challenges for foresight

While acknowledging that not all future issues may require the latest generation of foresight to be applied, it is important to be aware of the nature of the conceptual and methodological challenges that the most recently emerging developments in science, technology, economy and society raise for foresight.

- The limits to anticipating the future in view of fundamental uncertainty and complexity are growing (Tuomi, 2013). This implies the need to explore and simultaneously realise qualitatively new horizons, and to rely on comprehensive, interdisciplinary thinking as an essential element of exploring and experimenting with the future.
- As a consequence of the previous point, defining the goals and targets is equally difficult, and assessments of emerging developments are hard to make in the absence of a good understanding of the nature of these developments (Collingridge, 1980).
- Participation plays a key role for realising the claim not only to anticipate alternative futures, but also to shape the future, and thus to engage society in the foresight process. Participation is also key for the coordination and orientation functions often assigned to foresight. The challenge is to avoid dialogue fatigue and to enable not simply more but more effective participation. This in turn requires clarification about the governance model: who decides and on what basis, at key stages in the process of generating foresight, what is attended to and what is left out (Henrichs et al., 2010)?
- Complex and multifaceted future challenges require interdisciplinary and multiperspective strategies to be tackled. A shared conceptual platform is thus needed, on the basis of which the dialogue and coordination of activities can take place in order to avoid local and segmented responses to cross-cutting challenges.
- The relationship between foresight and decision-making can take different forms along a spectrum ranging from inspirational to instrumental. If the intention is to integrate foresight more tightly into decision-making in order to enable more responsive or even anticipatory governance, then issues of cooperation and coordination across policy areas need to be addressed, as well as matters of institutionalisation in contrast to the ad hoc implementation of foresight on a project-by-project basis.
- An important aspect of the link between foresight and policy link concerns the tracing of impacts of foresight. Ultimately, the legitimacy of foresight as central policy supporting instrument depends on the ability to demonstrate its benefits. This is very difficult to do in practice, not the least due to the process nature of foresight.

- Recent changes in the nature of emerging challenges, which tend to occur faster and sometimes even in a disruptive way, but at the same time are highly complex, require novel forms of foresight. Foresight needs to become quicker, more experimental and more adaptive.
- Better ways of connecting this new type of fast, experimental and adaptive foresight to policymaking need to be devised. This will require procedural and organisational adjustment to policymaking.

3.1.4. Beyond phases of foresight processes

We will now consider the more operational side of how foresight processes are implemented.

Sequential phases
There are different ways of sequencing foresight processes; different process phases. This can be done on the basis of the available foresight literature. One example is taken from Saritas (2011):

- information to understand complex interactions between products, services, users and other stakeholders in multiple contexts in which these products and services are used;
- intelligence through scanning to explore novel ideas, unexpected issues and shocks, as well as persistent problems or trends;
- imagination in a holistic innovation ecosystem by integrating foresight, creativity and design for scientifically possible, technologically feasible and socially desirable futures;
- interaction with the systematic involvement of stakeholders in an inclusive process with long-term perspective for the analysis of different perspectives and their social relations in the system;
- effective implementation for a successful transformation/transition programme.

It is important not only to refer to standard sequential perspectives of how to do it, but also to emphasise the recursive and learning processes that need to underpin systemic foresight processes or even an institutionalised foresight system.

Systemic foresight processes
In view of the emerging challenges for foresight, and in particular the need for an open conceptual platform to integrate diverse perspectives on complex issues, a systemic framework seems to be a useful foundation for the conceptual modelling of emerging future challenges. It could serve as a platform for the positioning of more specific, also numerical modelling attempts, but cater equally for disruptive and transformative change processes with a highly uncertain outcome. Systemic foresight provides a broad framework for foresight as a process of interaction between the process in the narrow sense and its context.
The systemic foresight model suggests a learning system, which structures a systems-based debate to formulate the basic mental acts. These are not phases in the narrow sense, but rather building blocks (Saritas, 2011), as shown below.
1. Systemic understanding.
2. Systems synthesis and modelling.
3. Systemic analysis and selection.
4. Systemic transformation.
5. Systemic action.

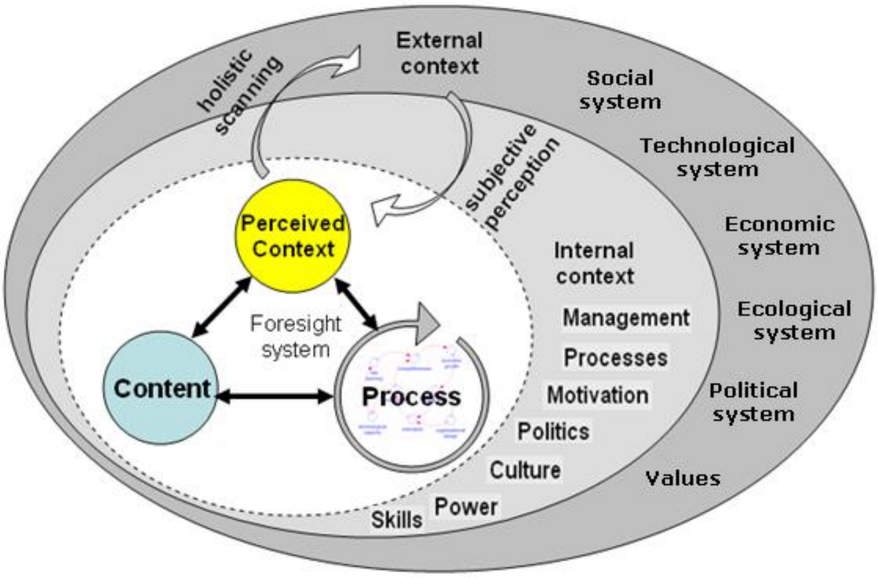

Figure 3.1: Systemic Foresight Model

Source: (Saritas 2011)

Design foresight processes

Design foresight processes build on, but go beyond, systemic foresight processes. As a response to the problem of ontological expansion, design foresight approaches have been suggested that are based on the use of an experimental technique to actually explore and realise actions on the future (Tuomi, 2013).

3.1.5. Participation and public engagement in foresight

In general, engaging experts, stakeholders and citizens is recognised as being essential to foresight processes. A crucial question is nevertheless who actually participates in these processes, and what is the benefit and value of participation. Broadening participation has become easier, not least through the various options offered by information and communication technologies, but in the practice of most EU projects, participation is limited to organised or institutional stakeholders (e.g. public bodies, trade associations, trade unions, non-governmental organisations/organised civil society) and scientific experts. The direct participation of ordinary people is the exception rather than the norm, in spite of introducing citizen initiatives as a bottom-up policy instrument in the Lisbon Treaty (European Union, 2005). EU foresight will have to seriously consider the broadening of its participation base to citizens, especially when dealing with the challenges to EU society which touch upon normative issues and the future way of life of EU citizens. In this context, it is relevant to note that the Commission has started to foster more inclusive participation in research and innovation policy via Responsible Research And Innovation (RRI), the process of aligning research and innovation to the values, needs and expectations of society. RRI aims to engage the whole of society, including citizens and civil society, in the research and innovation processes. RRI means that societal stakeholders work together in science education, the definition of research agendas, the conduct of research, the access to research results and the application of new knowledge in society, in full respect of gender and ethics considerations. This approach has recently given rise to the Rome declaration, which calls on all stakeholders to further promote RRI in an integrated way ([41]).

A broadened understanding of participation as public engagement can have four different functions, which in essence also apply to foresight.

- **Public validation.** The most common function of public engagement is validation of results and choices, and there are plenty of instruments available for this purpose: public consultations, conferences, funding programmes, etc. Stakeholders and the public in general are called to be informed, validate and implement new policies.
- **Awareness raising, education and behavioural change.** Stakeholders and the public are called on to take part in the decision-making process to consider and understand the implications of different decisions, and modify their future behaviour accordingly. A relevant example for foresight is the sustainability of public pension scheme in Italy (led by the Unipolis Foundation). Citizens and representative bodies have been involved in a process to become aware that the public pension is financially unsustainable and citizens need to add a private pension scheme. The change is a long-term process, but an effective strategy requires citizens to change behaviour from the beginning, increasing savings and activating a private pension scheme.
- **A source of knowledge.** Public engagement can be a source of inputs to enrich the knowledge base of policymakers or even to modify the frame of the question. The European Commission is open to inputs from institutional stakeholders/lobbyists. EU policies, including those geared towards social innovation or social entrepreneurship, have been mainly designed by stakeholders. The public, on the contrary, is almost ignored. One of the few examples in which ordinary people were included was the project Voices. It engaged 1 000 ordinary people, randomly selected but respecting certain criteria of representation of nationality and social categories, to define the Horizon 2020 2014-2015 work programme priority on 'Waste: a resource to recycle, reuse and recover raw materials' ([42]). This function has the potential to build legitimacy and public trust in the decision-making process. However it needs a large scale of participation. Voices could not reach a critical mass because it did not leverage the potential of ICT. CAPS, a new funding programme of DG Communications Networks, Content and Technology, aims to overcome the problem of bridging public engagement and ICT ([43]). At the international level, the

([41]) http://www.sis-rri-conference.eu/wp-content/uploads/2014/12/RomeDeclaration_Final.pdf
([42]) For further details see http://www.voicesforinnovation.eu
([43]) See https://ec.europa.eu/digital-agenda/en/caps-projects

revision of the millennium development goals post-2015, led by UNDP in 2013, is a good example. It engaged 2 million people in the world ([44]).
- **Ensuring the presence of outliers.** Historically poets, artists and philosophers have provided the most visionary options for the future. More recently hackers have performed the same function, even managing to influence policymaking, as in the case of legislation on copyright in the EU and the United States. Outliers broadly speaking can be a source of inputs and innovation because they do not belong to the mainstream and are less influenced by peer pressure. Projects like Edgeryders have tried to engage this peculiar community to extract inputs for policymaking ([45]). It has been very effective to engage young people, but the European Union struggles to deal with innovators on the edges because of its historically grown hierarchical, institutional and formal structures and procedures. If the European Union does not want to miss the new generations of radical innovators it will have to develop new forms of engagement — the example of Skunkworks projects might be useful to consider — especially as policy innovation labs.

These four functions are important to consider in the context of future EU-level foresight, and will need to be brought to bear in different phases of such processes.

- A broad understanding of participation is necessary, useful and possible in the context of foresight. The need for specific expertise and representation needs to be complemented by public engagement to enhance the legitimacy of proposed actions and the robustness of foresight.

3.1.6. Purposes, roles and functions of foresight for policy: the issue of embedding in the policymaking process

Beyond basic definitions, there are several different perspectives on the purposes and roles of foresight for policymaking, including the main claims of what foresight can achieve and what its limitations are. More broadly speaking, this is about the realisation of anticipatory governance, understood as the embedding of forward-looking features of various kinds into the processes and structures on the basis of which policies and collective strategies are developed, legitimised and implemented.

The embedding of foresight into policymaking thus goes far beyond merely informing policy, and comprises at least the following six main functions (based on da Costa et al. 2008).

- **Informing policy**, i.e. generating insights regarding the dynamics of change, future challenges and options, along with new ideas, and transmitting them to policymakers as an input to policy conceptualisation and design. This includes horizon scanning as an instrument of early warning and anticipation of the unexpected.
- **Facilitating policy implementation**, i.e. enhancing the capacity for change within a given policy field by building a common awareness of the current situation and future challenges, as well as new networks and visions amongst stakeholders. Better coherence of policy implementation across different agencies is one of the benefits of this FTA function.
- **Embedding participation into policymaking**, i.e. facilitating the participation of stakeholders and civil society in the policymaking process, thereby improving its transparency and legitimacy, and ultimately coherence with stakeholders' strategies.
- **Supporting policy definition**, i.e. jointly translating outcomes from the collective forward-looking processes into specific options for policy definition and implementation. In a multi-policy setting as typical for most grand challenges, policy coordination in its different facets is a major benefit of this function.
- **Reconfiguring the policy system**, i.e. changing structures and processes in a way that makes the policy system more apt to address long-term, complex social challenges, for example the grand challenges.
- **Symbolic/legitimising function**, i.e. indicating to the public that policy is based on rational information and transparent processes.

In individual foresight activities, the emphasis is often put on some of these functions only, and this obviously has consequences for the methodology of such foresight activities, but also — and of equal importance — for the relationship between foresight and policymaking. In recent years, the traditional reservoir model of conducting foresight activities that provide a stock of forward-looking thinking on which policymaking may draw in case the necessity arises (e.g. in a sudden crises) has been superseded by the desire to ensure close connection between foresight and decision-making

([44]) See http://europeandcis.undp.org/blog/2014/01/30/what-if-post-2015-were-already-here
([45]) See https://edgeryders.eu/page/home-mb-ano

almost in real time. Such closer integration and embedding of foresight into decision-making requires other organisational models than individual projects and programmes only, namely a reasonably stable, yet flexible, form of institutionalisation of foresight, which enables cooperation across the silos of EU policymaking. This requires novel organisational solutions (e.g. networks of foresight practitioners and decision-makers) as well as the enhancing of absorptive capabilities on the side of decision-makers and of communicative skills among foresight practitioners. The emerging approach of design foresight may further enhance the need for close and swift interaction between foresight and decision-making.

EFFLA has developed a process model that could serve as inspiration for the institutional embedding of foresight into decision-making (see Figure 3.2). While the model was developed with particular attention to DG Research and Innovation, its core elements can easily be reframed for other policy domains and levels. It argues that the main deficits and barriers with regard to a more forward-looking and strategic approach to policymaking in the European Commission resides in the lack of systematic foresight in the early phase of decision preparation, to be realised by enhancing strategic intelligence, and in particular sensemaking functions, which not only analyse the issue but also to come to a common understanding of possibilities and goals before the formal phases of decision-making involving the Parliament and the Council are entered.

This circular model of a revolving process should not be interpreted too rigidly. It is geared to the highly formalised processes of decision-making for EU framework programmes. As a generic model of how to embed foresight on a regular basis into policymaking processes, room for flexibility and shortcuts need to be foreseen in order to allow for adjustments and targeted initiatives once sudden crises or events occur.

Moreover, in case of fast-changing and disruptive developments, there is also a need to speed up the process of policy learning. While foresight and modelling may help explore and simulate policy impacts, the insights from the pilot application of novel policy instruments need to be fed back quickly into the policy design process, at best almost in real time. The idea of concurrent design coming from engineering design, in which the process is accelerated through conducting the activities in the four elements simultaneously, can be an effective approach to achieve this acceleration. The concept of policy labs as a means of piloting and accelerated learning can also be understood as a shortcut in the foresight and decision-making cycle.

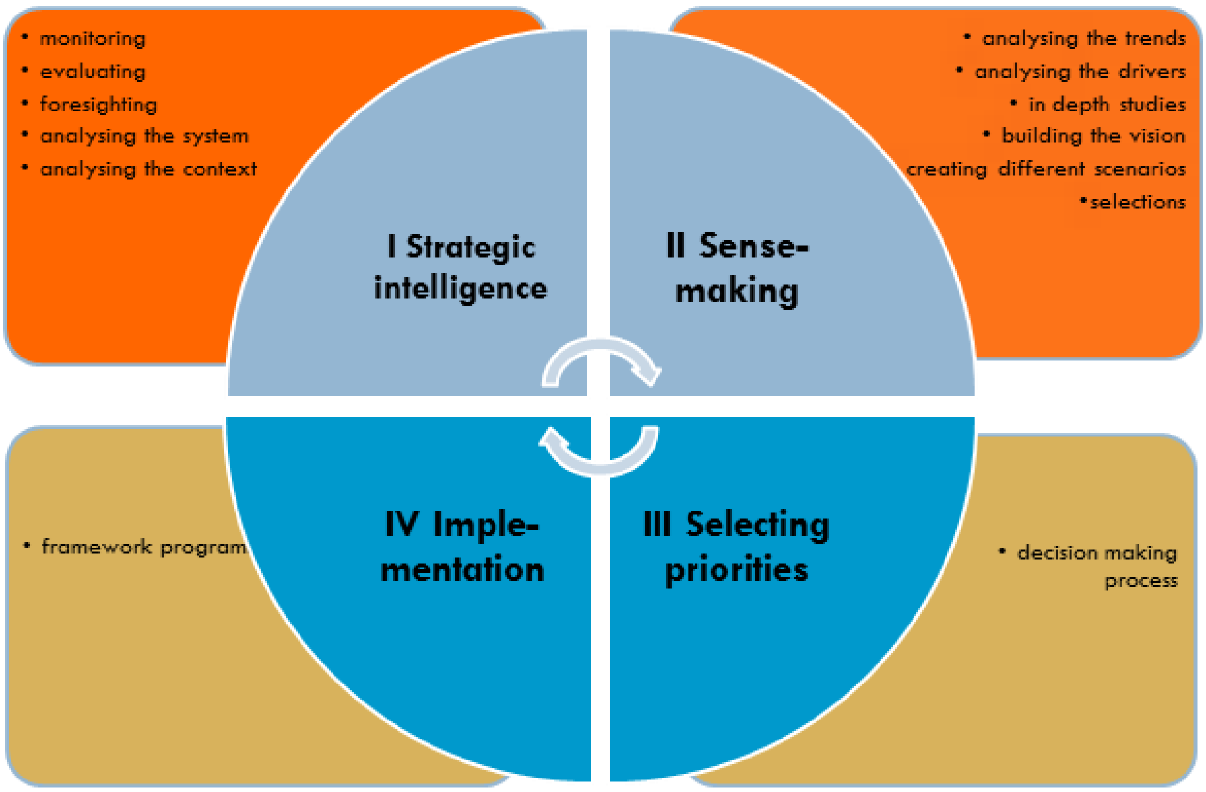

Figure 3.2: Foresight and decision-making cycle

Source: EFFLA (2012)

Seen from the perspective of this interconnected foresight and decision-making framework, the largest deficit in current policymaking must be seen in the sensemaking phase. There is a broad range of inputs from different sources of strategic intelligence available, but processing these inputs and turning them into a proposed policy strategy, priority or action could be enhanced in terms of transparency and rationality by explicitly applying different types of foresight approaches and methods. Collective narratives can serve as useful tools to support sensemaking processes that involve a broad range of stakeholders and citizens (Lane, 2014). Modelling can help in structuring the issue, its elements and relationships very explicitly, possibly even by quantification. Under the specific assumptions they make, models allow experimenting with specific partial aspects of the issue, or in a rather stylised fashion with the overall dynamics. Sophisticated gaming environments can be used to facilitate the sensemaking process, and visualisations can support communication between the different participants.

While these considerations may help envisage in which direction the embedding of foresight into decision-making should evolve in the future, it is important to stress that there are still important aspects in need of further clarification, as shown below.

- **The positioning of appropriate different foresight approaches in the context of the decision-making cycle.** Guidance is still needed regarding the kinds of foresight and modelling approaches that are needed at the different stages of the decision-making process.
- **The integration of stakeholder participation and citizen engagement during the foresight and decision-making cycle.** Different types of stakeholders need to find a place in this process model, but not all stakeholders necessarily need to be part of all phases. In fact, strategic intelligence as an information-gathering activity may require different types of inputs from stakeholders to sensemaking, whereas the final selection of priorities tends to rely on formalised consultation processes anyway. There is also much still to learn about citizens engagement in government-centred foresight processes, even though activities such as the TEKES (Finnish Funding Agency for Technology and Innovation) or DG Communications Networks, Content and Technology's Futurium project have piloted novel forms of participation. In the private sector, new approaches to forward-looking problem-solving have also been developed and tested (von Hippel and von Krogh, 2013).
- **The specification of the role for different forms of modelling in different phases of the cycle.** Similar arguments as for participation and engagement apply to modelling. Different types of modelling can contribute to enhancing the systemic character of foresight and the quality and transparency of policymaking. Modelling is likely to be particularly useful in the context of strategic intelligence and sensemaking, but the possibilities and limitations of different techniques and tools need to be made transparent in order to assess the validity of results and thus their suitability as a foundation for sensemaking. Chapter 4 will provide some first indications in this regard.

- Foresight needs to be properly embedded into the process of policymaking, and these links need to be developed from the outset rather than after the production of a foresight report. Foresight can play an effective role in each of the different phases of decision-making.
- Given the complex nature of many future challenges, touching upon different policy areas and levels, foresight should be effectively institutionalised as a network across the boundaries of different policymaking entities, reaching out to expert and stakeholder networks. A dedicated entity within an organisation can then serve as a knowledge hub and entry point.

3.2. Current and future requirements for integrated foresight

Against this backdrop, some requirements for foresight in the context of the EU institutions, and the European Commission in particular, can be formulated; requirements that can be used to develop functions for different types of analytical models in the context of an integrated foresight process framework that can reflect the needs of an increasingly fast-changing, complex and uncertain world (see Table 3.1). It is important to underline that a comprehensive framework for the embedding of foresight into decision-making not only needs to consider analytical models of a qualitative, quantitative or exploratory nature, but also the organisational and process dimensions of bringing foresight effectively to bear on decision-making. Organisational and process models thus need to be considered as important complements to the analytical models.

Table 3.1: Functions of different types of models in an integrated foresight framework

Analytical models	**Functions of models in an integrated foresight framework**
Non-numerical (qualitative) foresight analysis models	Conceptual metalanguage for: - scoping - dealing with normative issues; - integrating results; - interorganisational communication. Comprehensive understanding of future developments and impacts: - capturing systemic inter-dependencies; - exploring qualitatively and structurally different futures; - exploring potential impacts chains.
Numerical (quantitative) analysis models	- Checking consistency. - Exploring low-uncertainty (e.g. physical) relationships. - Understanding complex mechanisms.
Process models	
Exploratory models and tools	- Scanning weak signals. - Exploring the unexpected with the help of narratives.
Models for foresight processes	- Dealing with ontological expansion. - Enhancing resilience. - Enhancing adaptivity.
Structural and organisational models	- Building competencies. - Networking agents. - Policy coordination in a multi-policy setting

With this broad understanding of models in mind, the following requirements can be proposed.

1. Devising policy strategies in a faster-changing world, where qualitatively new and disruptive developments are bound to happen, policymaking needs to become faster, more adaptive and more resilient. Creativity, visionary thinking and experimentation have to be part of this new approach to policymaking, as does a widening of the space of policy alternatives to be considered. There is an obvious tension, however, between this claim for speedier, real-time foresight and policymaking processes on the one hand, and on the other the reality of formal decision-making in the EU institutions, with which foresight needs to be synchronised in order to become effective.
2. An integrated foresight process is needed to underpin and inform such resilient policymaking processes. It needs to cater for both traditional foresight and modelling activities and for real-time and experimental design foresight approaches.
3. The ability to handle complexity has become increasingly important. Quantitative numerical approaches can help in exploring simplified patterns of complex system behaviour. They can also be used to handle reasonably stable relationships and to check consistency in specific and focused domains. By forcing the analyst to be explicit about assumptions, they can also help structure issues and systems. However, relying on numerical models alone would obscure the inherently uncertain nature of many of the change processes ahead of us.
4. Qualitative modelling approaches provide a systematic and at the same time comprehensive foundation to understanding and debating future developments across organisational and disciplinary boundaries. They also serve as a framework for interpreting and positioning more specific or simplified future explorations of both a qualitative and a

quantitative nature. Their particular strength is thus to be comprehensive, and they can be supported by numerical models in specifying conceptual relationships where suitable.

5. Under conditions of fundamental uncertainty, exploratory models and tools (e.g. horizon scanning), which are based on principles of experimental and design foresight, are needed, in addition to traditional foresight methodologies and modelling, in order to anticipate, co-develop and handle radically new developments in real time. They should become integral parts of policymaking processes from monitoring and strategic intelligence to implementation.
6. Methodological diversity is thus called for in the context of foresight, but based on a common conceptual basis in order to facilitate the integration of different types of future-oriented insights as part of a sensemaking process. This is particularly important when knowledge needs to be integrated across disciplinary or organisational boundaries.
7. Foresight and foresight modelling need to rely on solid evidence where possible. The involvement of specialist experts with their respective in-depth understanding of specific areas is crucial here, but it must be complemented by the knowledge of generalist experts able to integrate knowledge into a more comprehensive picture. Non-formalised knowledge from societal actors can also add to this picture, and the common sense of citizens is often a valuable reality check in this regard.
8. The engagement of stakeholders is essential in foresight for a number of reasons: for tackling normative aspects of foresight, for exploiting their knowledge and understanding of interests in society and for enabling their mobilisation in support of shared problem perceptions, vision and strategic agendas, but also for identifying potential lines of conflict. In fact, the expectation of finding a full consensus about future options among all stakeholders must be abandoned and replaced by the recognition of conflicting views. Stakeholder involvement is crucial for handling such potential lines of conflict early on in the process. In addition, creative thinkers can bring in valuable outside-the-box impulses that challenge established wisdom.
9. Collective narratives play an important role in making the conceptual thinking behind these foresight models more accessible and thus open to a broad range of stakeholders and the public. Arts, creative writing, science fiction and gaming can be useful to facilitate the translation needed between conceptual thinking and engagement of a broader audience.
10. Foresight is increasingly conducted in a multi-policy setting. This requires better cross-cutting collaboration without consensus across different policy domains, in a network across organisational boundaries. Such collaboration requires the overcoming of structural barriers in public administration and policymaking, but also a common conceptual language for exploring future developments and integrating different perspectives. This kind of language can be provided by conceptual foresight models, and it needs to be supported by network-type organisational settings for multi-domain policymaking.

3.3. Foresight in support of policymaking — Concurrent Design Foresight as an integrated foresight framework

An integrated process-based foresight framework needs to take into account different purposes of foresight, the procedural nature of foresight and the embedding of foresight into policymaking. As captured in Figure 3.3, such a framework — building on the four phases of strategic intelligence, sensemaking, strategy and priority setting, and implementation — then provides the background for positioning different modelling approaches, in line with the requirements formulated in the previous section. The key features of this framework of 'Concurrent Design Foresight' can be summarised as follows.

- Foresight should not be understood as a single-step activity, but rather as a regular and recursive process. It needs to be closely tied to the cyclical process of policymaking and policy learning and to interconnect organisational structures to be fully effective. It must be capable of reacting very quickly to policy development needs. This requires the application of a new concept in foresight processes: Concurrent Design Foresight.

The concept of concurrent design comes from engineering design. It is intended to speed up design processes by simultaneously including all the phases of design with a series of rapid iterations between all the interests involved — scientists, interest groups, policymakers and civil society — on a timescale of weeks rather than months or years. The expert group considers that this approach must also be applied to foresight processes if they are to respond to requests from policy developers in a useful timescale.

Box 3.1 Concurrent Design: application to foresight

Against this general backdrop, the role of different kinds of modelling can then be specified in more detail, as follows.

- Different types of modelling need to be distinguished in the context of foresight. Qualitative analytical modelling is particularly useful in a context of distributed policymaking that nevertheless requires coordinated action (as in the case of most grand challenges). A conceptual metalanguage is needed to enable communication and mutual understanding of future challenges and to design potential solutions across organisational boundaries. In other words, by using qualitative models a common conceptual basis can be established that allows being explicit and transparent about the elements and relationships considered in different policy domains. Qualitative models thus provide important inputs for effective policy coordination. Based on explicit and appropriate simplifications of comprehensive qualitative models, quantitative analytical modelling techniques can be used to explore general system dynamics, but also to analyse selected aspects of future change in depth. Other modelling approaches and tools are needed to anticipate — to the extent possible — disruptive developments, and they equally need to be integrated in a transparent manner into the qualitative modelling framework. The common conceptual language provided by qualitative modelling is thus key to the concurrent design approach to policy-oriented foresight.
- The different modelling elements as distinguished in this integrated process-based foresight framework not only consider analytical models (qualitative, quantitative and exploratory), but also take into account process and organisational models. These are essential for ensuring the effectiveness of foresight in the context of policymaking. They are also important for dealing with those features of the future that cannot be explored in an analytical and/or participatory way, such as, in particular, the ability and resilience to respond to the unexpected.
- While some building blocks of foresight need to draw on specific expertise, the effectiveness of foresight in the policymaking context depends on a multidisciplinary systems approach which is embedded in decision-making and interactions with stakeholders and the public. This is crucial for addressing normative issues associated with foresight, but also for exploring qualitatively novel futures, which benefit from outsider perspectives.

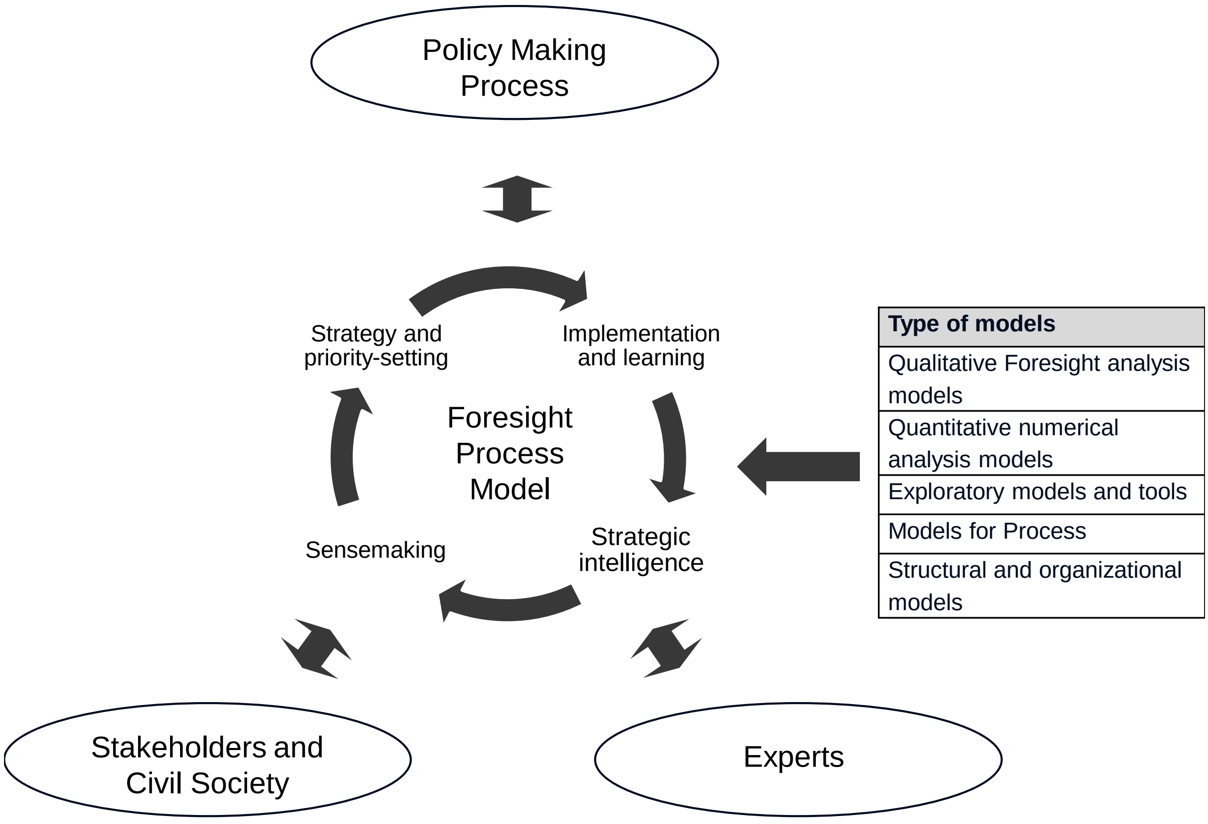

Figure 3.3: A framework for foresight activities, showing the different types of models in support of foresight for policy anticipatory governance

Chapter 4: Modelling analysis in foresight processes

Key points

1. Foresight requires analytical models for anticipatory learning to simulate alternative future scenarios as a part of foresight processes that have the goal of co-developing knowledge about policy issues for the future. They should identify critical issues through identifying social and technical system structures, their interdependencies and possible paths of change into the future. The models will be used to play out alternative futures which arise from different scenarios of events and factors.
2. Non-numerical (qualitative) analytical models can describe the current system structure and can help to develop understanding of possible paths into the future. They can contribute to all the four elements of a foresight process, but are often particularly suited to system analysis in strategic intelligence and sensemaking.
3. Numerical simulation (quantitative) models can also describe a current state and explore future states, but require a more explicit specification of variables, relationships and parameters. Possible ranges of outcomes that are internally consistent with a particular set of assumptions can be generated. They are mainly used for detailed policy analysis, but simple models can also deliver rapid exploratory system analysis of different futures and different perspectives on an issue.
4. There will be no one model or even type of model that is suitable for all foresight activities.
5. **The recommendation of this expert group is that the European Commission should develop a support platform for analytical modelling to support concurrent design foresight processes.**

4.1. Introduction

As explained in Chapter 3, foresight is increasingly conducted in a multi-policy setting, in particular with a view to tackling social challenges that can be characterised as 'wicked problems': complex, dynamic and ambiguous. As stated in Chapter 1, Box 1, this report differentiates between models for foresight processes and models for analysis to support foresight processes. An analytical model is in general an abstraction of reality developed to understand the phenomena under consideration. In foresight, there are different kinds of formal structured methods of analysis in which can be considered as analytical models:

- numerical models (e.g. the Hadley Centre climate models, the Fraunhofer ASTRA transport integrated assessment model) are what are conventionally considered to be models in policy analysis;
- there are a series of non-numerical formal methods which can be considered as qualitative models (e.g. cognitive maps or mental maps of an issue, causal mapping, argument logic maps)

Foresight modelling is not forecast-based planning, because the ambition is to address complex, dynamic and ambiguous issues, whose outcomes cannot therefore be predicted in detail. This requires a change in approach from analysis for knowledge about the future to analysis for knowledge to influence the future. Intervening effectively in any given situation benefits from understanding what is going on and what might happen next. This means that there are two different situations benefiting from different modelling approaches: learning and intervening.

Foresight modelling aims at generating new ideas and social capital and contributing new possibilities and options for action. It also aims at enabling faster and more effective social learning processes, engaging different perspectives, learning from disagreements, clarifying tactical knowledge, exposing group thinking where one idea is believed to be the only realistic possibility, testing deeply held assumptions, reframing challenges, etc. It is not a stand-alone activity but is embedded in some wider purposeful intervention, for example interactive strategy, adaptive policy or goal-directed transition management. It also recognises that pervasive complexity, uncertainty and ambiguity mean that overreliance by decision-makers on approaches with predictive modelling may actually be misleading, restricting attention to what can be measured about the past and present rather than what really matters or might matter more and/or could and should be different in the future. Fortunately there are many approaches to modelling that can be used to appreciate, understand and effectively address the most significant challenges faced by societies today. If we

want to understand innovation-intensive societies and the impact of new innovations on economy and society, we have to use approaches that are able to model the unexpected and which embrace ambiguity and unpredictability. In modelling, it is easy to fall back on an existing historically legitimised consensus which, by definition, misses those developments that are essentially new and which has a disruptive impact on society and economy.

Foresight activities that contribute to the different phases of a foresight process discussed in Chapter 3 include: problem clarification and definition of the social-technical system to be influenced; trend analysis; scenario development; identification of the possible future range of possibilities given the current system state; development of visions of the future including consistency checks; roadmaps of how to get to a chosen scenario in the future. Analysis models can contribute to all these activities, as indicated below.

- Non-numerical (qualitative) formal models can describe the current system structure and state. With the inclusion of dynamic processes they can help to develop understanding of possible paths into the future. They can contribute to all the four elements of a foresight process, but are often particularly suited to system analysis in strategic intelligence and sensemaking (see Figure 3.2)
- Numerical simulation (quantitative) models can also describe a current state and explore future states, but require a more detailed specification of variables, relationships and parameters. Model building necessarily involves the identification of the relevant variables and their interconnections. This then enables the sociotechnical system to be mapped into the future, given assumptions about the exogenous variables. Hence, possible ranges of outcomes that are internally consistent with a particular set of assumptions can be generated. Simple numerical models can also deliver rapid exploratory system analysis of different futures and different perspectives of an issue. They can statistically analyse historical data to determine trends.
- They can generate quantitative scenarios and associated outputs for communicating scenarios and visions.
- Models can be used to show stakeholders the influence on system outcomes of changing assumptions about parameters, for example oil or carbon prices or temperature rise, which can support the development of scenarios in stakeholder processes.
- A model can combine different sets of information in a consistent way, for example in integrated assessment models combining environmental and economic analysis.

In an era of big data, some are optimistic that real-time data mining combined with continued increases in computational power and speed will enable more reliable predictive modelling. However, being able to run the modelling process faster and deliver more detail does not guarantee better outcomes. Achieving this requires the worlds of theory and practice to be effectively bridged in a co-production of knowledge. In the foresight philosophy of non-deterministic, still emerging and open multiple futures, this bridging needs to be done in a way that effectively grapples with problematic situations or enables the management of unprecedented large-scale transitions in the context of unpredictability and uncertainties. This involves avoiding premature foreclosure of the situation framing, resulting in a limited action space and instead engaging with different perspectives to widen the framing of issues, to expose assumptions made in the framing of the issues and to enable the reframing of the challenges, including the discovery of new possibilities and options for action.

This chapter discusses the requirements for analytical foresight models. It then considers numerical modelling and non-numerical modelling in turn.

4.1.1. What are the general characteristics needed for foresight models?

Foresight modelling should provide a way to develop a deeper, i.e. systemic, more shared and contestable understanding of the way the world works. The use of multiple models and modelling approaches provides an effective way to open up the future as a conceptual space in the present and in a way that enables differences in perspective to be revealed, related and respected.

At the EU level, the importance of dialogue between science and society has been recognised and led to specific initiatives, such as the RRI cross-cutting theme and the 'Science with and for society' objective within Horizon 2020 ([46]). This objective follows the 'Science in society' and 'Science and society' programmes of the seventh and sixth EU framework programmes for research respectively. Many studies and public opinion surveys have revealed the importance of trust for fostering this dialogue ([47]). One key component for achieving trust is honesty about (scientific) uncertainty, and

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([46]) http://ec.europa.eu/research/swafs/index.cfm
([47]) *Europeans and biotechnology in 2010 — Winds of change?*, European Commission, Brussels, 2010.
Biobanks for Europe — A challenge for governance, European Commission, Brussels, 2012.

this is a fundamental requirement for the use of modelling in foresight. This also implies that the assumptions that have been made in the model design and that the mechanisms that are driving the results are clear. Thus transparency is another key component.

The objective of foresight modelling, to contribute to foresight processes for policy development, means that modelling activities will be part of an overall foresight process, as discussed in Chapter 3. This also implies that the modelling activities must be able to respond in accordance with the process timescales, sometimes producing an assessment in a timescale of weeks rather than months or years.

Concurrent design modelling as used in engineering design is a modelling approach that covers part of these requirements. Once a specific issue and the resulting system to be studied has been identified, it introduces a rapid development modelling process which combines the necessary disciplines in an iterative process to arrive at a joint solution.

There are different ways to use modelling that aim at different objectives and which require different styles of implementation. In particular, we can differentiate between probabilistic, possibilistic and constructivist approaches to foresight-oriented modelling (Tuomi, 2013b). Probabilistic approaches have the goal of assessing the probabilities of a series of clearly defined alternative outcomes. This is associated with the idea of risk of bad versus good outcomes, in particular in numerical modelling. Possibilistic approaches try to show a range of possible outcomes where the uncertainties cannot be unambiguously defined. They use more general representations of uncertainty than probability, such as fuzzy cognitive maps (described below), to represent uncertainties that cannot be rigorously specified in quantitative terms. This enables a formal assessment of the plausibility of scenarios, where the probability cannot be rigorously specified (Ramírez and Selin, 2014). Constructivist approaches use modelling with the express purpose of influencing the future through engagement with a decision process to influence the course of future events.

4.1.2. Applying the constructivist approach: anticipatory modelling for learning

The constructivist approach upon which foresight is based holds that the future is not waiting to be discovered. Here the social and the Newtonian worlds are different. Society constructs the future based on our narratives that describe where we came from and where we are heading. Modelling an unpredictable world requires that we move from trend extrapolation towards creative design-oriented foresight processes that allow us to implement designs for social change and learn in the process. In this respect, foresight modelling is different in its purposes and practices to modelling that seeks to reduce or remove uncertainty in decision-making and assumes that all decision outcomes can be calculated in advance and thus rational choice enabled.

Modelling is a specific way to encode observed phenomena of a system under study into another (often formal) system, making inferences in this other system and decoding the outcomes back to the observable characteristics of the world. Therefore, modelling is a mapping between a world and another (in sciences, formal) system, which includes rules for encoding observations, making inferences and translating the inferred outcomes back to predictions. In some very specific cases the formal system is a system of numerical equations; in general it is not. A generic theory of modelling is known as category theory, which is now increasingly used in foundational studies in mathematics, logic and sciences. Based on category theory, Robert Rosen described in great detail how different types of sciences rely on structurally different modelling approaches. A key outcome of this work is the idea of an anticipatory system (Rosen, 1985):

> A system containing a predictive model of itself and/or its environment, which allows it to change state at an instant in accord with the model's predictions pertaining to a later instant.

In Rosen's work, analysis of the example 'It's raining outside, therefore take the umbrella' does involve a prediction. It involves the prediction that 'If it is raining, I will get wet out there unless I have my umbrella'. In that sense, even though it is already raining outside, the decision to take an umbrella is not a purely reactive thing. It involves the use of predictive models which tell us what will happen if we don't take the umbrella when it is already raining outside.

A key observation of Rosen was that classical physics (and also quantum mechanics) leads to modelling approaches that are not anticipatory, whereas biological systems require models that are anticipatory. These two lead to structurally different models. Even the simplest biological systems have hardwired predictive models that make them anticipatory systems. Linear equations and systems of linear equations (and approximations based on them) are unsuitable for modelling those aspects of biological systems that make them alive. Biological systems have relational models, where the system has emergent characteristics that do not exist at the level of their components. As complex biological systems, this anticipatory method of modelling for decision-making is commonly used in decision-making by people. This anticipation is what foresight is

intended to support — to provide methods of analysis that use predictions of future changes to change current decisions.

For policy formulation and analysis, scientifically robust modelling is essentially a process that facilitates the creation and construction of models that expand the space of policy alternatives. This leads to design-oriented foresight, agile modelling and foresight methods that can change their practical and theoretical approach in the course of a foresight process, and experimental policy development. When innovation matters, the future cannot be modelled by running well-established models and asking what-if questions in the context provided by the model. (In innovation theory, this corresponds to parametric innovation and the optimisation of dominant designs.) Instead, what-if needs to be asked on a higher conceptual level: 'What if this (alternative) model were an illuminating model of the world that could generate new possibilities for thought and action? Does this model help us make sense and understand possible futures and expand our space of possible action?' (In innovation theory, this corresponds to disruptive innovation and exploration of alternative designs that may become new dominant designs.)

It should be noted that, historically and empirically, this constructive, generative and design-oriented approach to modelling has been highly successful and has had an extraordinary impact. To quote Alan Kay (Xerox Parc, 1972), 'The best way to predict the future is to invent it.' This is the (constructivist) approach used by those inventors that actually have changed the world, our societies and our futures in recent decades. Scientists who use conventional predictive modelling have been also important and influential; they, however, cover only part of the field.

Modelling in the foresight context therefore becomes an effort of constructing alternative descriptions of the world in the future, analysing their potential implications and implementing experiments that look most promising, with an explicit intent to learn in the process. This is how business innovators do their foresight.

This requires anticipatory modelling.

4.2. Models as numerical tools

Here we consider models as numerical tools. We note that the wider use of models as a framework for organising knowledge in a comprehensive way, or for providing an integrated systems perspective of the problem area, is still a valuable basis for the development of models as numerical tools.

We will discuss models here with the climate change and energy systems development issues in mind, as these provide illustrations of both advantages and problems associated with modelling efforts in the context of future studies. There are two model perspectives that are of relevance for foresight: (i) models as numerical tools; and (ii) models as conceptual frameworks of interacting subsystems.

We note also that a model as a numerical tool may serve a more conceptual role, without claiming any forecasting or strong predictive capabilities. A numerical model trying to capture all relevant aspects of the system at hand, if well formulated and presented, provides a framework that includes a variety of mechanisms and associated parameters, which can serve as an organised description of the system. Parameters can be presented with uncertainty ranges and unknown parameters can be highlighted, clearly indicating where uncertainties are present in the system view. Even mechanisms for which one is uncertain how they can be formalised could be placed in the structure. The main purpose for such a model would be to organise the knowledge of the problem area in a systematic way.

4.2.1. Models of subsystems

The use of simple models, i.e. models that focus on an isolated subsystem and only one or a few mechanisms, is relatively uncontroversial. In such a situation, the model is, through its simplicity, often both transparent and easy to use in an exploratory way. Uncertainties are easier to understand. It is clear that the model provides limited information on the studied issue and that other sources of knowledge are also needed for a comprehensive assessment of the problem.

For simulating interconnected systems into the future, system dynamics modelling is the modelling approach that is generally relevant. Agent-based modelling is useful when there are many elements in a system that can be modelled as acting in a relatively simple way, but in which the behaviour and decision-making varies between the elements, for example different national policies on renewable energy. A common approach in many studies, especially when combining subsystems in a larger context, is various types of optimisation or equilibrium economics modelling (often including dynamic features such as recursive dynamic equilibrium models), as is discussed below.

Another type of modelling which has been developed in the recent literature is social network modelling, which describes the contacts between people (or other social agents) and has also been used in a dynamic structure — termed a network evolution model — that mainly looks for network changes until some stable state has been reached (Toivonen et al., 2009).

4.2.2. Integrated assessment models

The situation becomes more involved when one becomes more ambitious and includes several interconnected systems in the modelling approach. This typically leads to an integrated assessment model (IAM), which is a type of model that has been extensively used in the context of climate change and for discussions on policies to reduce increased global warming. These are models that integrate important parts from the climate system, the energy system and the land-use system, as well as other parts of the economic system.

The use of models as numerical tools that integrate knowledge and data from several systems and disciplines has exploded since the 1980s, clearly illustrated by the development of IAMs in the context of climate, energy and the economy. In this sense, models are developed to enable systems thinking and provide a clear, contestable and consistent framework that relates variables in the system via well-established relations (i.e. statistically relevant/evidence based causality and/or correlations). Such a model can then be used to project the business-as-usual future and provide a basis to aid the construction of possible scenarios that reflect deep uncertainties relating to the issues of concern/challenges in hand. The model-based projection, often referred to as a baseline, reflects future assumptions that are consistent with respect to the underlying model. The alternative scenarios, in contrast, can reflect assumptions that challenge the underlying premises of the model, recognising that formal modelling involves the reduction of complexity to quantifiable parameters and, even further, to those parameters about which there is sufficient evidence to inform dynamic developments and causal relations.

Van Asselt (2004) defines IAMs as 'computer models/modelling frameworks that ideally describe the causal chain(s) of a specific issue (vertical integration) and the linkages and interactions among different issues (horizontal integration).' She further identifies the distinction between (i) optimisation vs. simulation models and (ii) sets of (connected) models versus an integrated model.

Questions asked in the context of climate change can be exemplified by the following. How can policies be designed so that climate change is slowed down at a reasonable cost? What are the technological options and the resource constraints that are critical for a transition to a fossil-free energy system? How can unintended effects from policies be avoided or mitigated? (The last one refers, for example, to the effect of biofuel policies on food prices.) These are questions that have engaged researchers and policymakers for several decades. The problems at hand are exacerbated by the fact that the changes in some of the systems involved occur at vastly different timescales — from centuries for the climate system, to decades for the energy system, to years for the agricultural system.

When combining models of such vastly different subsystems, one needs to keep track of where the uncertainties are, in terms of both the mechanisms and variables that are chosen as the basis for the models and the specific parameters (and their time dependence). In the energy and climate context it is clear that the underlying uncertainties are of very different kinds, both between and within the systems. Examples of variables and laws used in many IAMs and their respective subsystems are as follows.

- Climate: more or less well-based physical relations.
- Energy: technical characteristics on energy conversion processes (efficiencies, costs, life time, etc.), primary energy resource availability, future demand for energy services, emissions from energy use.
- Economy: capital and labour, production functions, output for consumption and for investment (also to energy sector), possible feedback from climate.

It is clear that the uncertainties are of different orders of magnitude. Depending on what question one asks and what one wants to use the IAM to help provide an answer to, the weakest point in the integrated model may be the part (or combination of parts) that determines the uncertainty of the model result.

The use of different types of numerical models used for assessment of policies and societal development is not unproblematic, and there is a broad range of literature in the area. The complexity of the integrated system composed of both natural and social subsystems makes predictions problematic. The awareness of this difficulty is not new. Henry L. Moore stated in 1917, in the introduction to his work *Forecasting the yield and price of cotton* (Moore, 1917):

> An eminent economist has recently told us that economists no longer talk so confidently as they once did of forecasting and social phenomena, and that, confronted with the

complexity of social relations, 'the sober-minded investigator will be slow in laying too much stress on single causes, slow in generalisation, slowest of all in prediction.' An equally distinguished statistician has warned his colleagues of the dangers of using refined mathematical methods in the treatment of loose data supplied by our official bureaus. These are authoritative warnings, and I have not been unmindful of them as the successive theses of this essay have been developed. But the ultimate aim of all science is prediction; the most ample and trustworthy data of economic science are official statistics; and the only adequate means of exploiting raw statistics are mathematical methods.

4.2.3. Strengths and weaknesses

The place of modelling in foresight is closely connected to the extensive work that has been done in investigating problems and solutions for how modelling can and should be used in integrated assessment. After the pioneering IAM development that was started at the National Institute for Public Health and the Environment (RIVM) in the Netherlands, with the IMAGE and TIMER models ([48]), a substantial body of literature dealing with uncertainties and practices in integrated assessment modelling ([49]) was established during the 1990s and onward. But if one looks at the publications in the area today, such a critical and careful view on how to use integrated assessment models and their results is to a large extent lacking (Hedenus et al., 2013).

In the perspective of simulation models, the requirement for a model to work well in a specific problem context is that the key characteristics and mechanisms are known, and that the parameters of the model can be estimated to a sufficient degree of accuracy. Depending on what system variables one wants to predict and what certainty one is aiming for, the uncertainty about the basis for the model may be more or less critical.

Most models involving the economic system, or parts of it, assume the system to be in equilibrium or to be well characterised by an equilibrium state. In fact, most IAMs in the climate change context are based on core assumptions of equilibrium, homogenous representative agents and rationality. Even though this may work well for some situations it is clear that this is not a good tool in general. However, simulation models, such as system dynamics models, may be formulated so that the laws of motion are not directly based on the underlying mechanisms. Instead there are aggregate variables that develop over time according to empirically derives relations or heuristic rules. The TIMER model of RIVM is one such example.

There is increased interest in so-called agent-based models for developing IAMs, where the mechanisms are modelled on the level of agents in the system that take decisions. Whether this approach will work better as a basis for IAMs is too early to assess. For separate subsystems of society the approach has been successful, one prominent example being the modelling of traffic in urban systems; but it should be noted that the success to a large extent depends on the limited choices that the agents have in their actions, which determines the dynamics of the system.

4.2.3.1. Consistency

One of the main advantages with models as support for integrated assessment is the relations provided between key variables of the system. If the relations are well known and certain, like conservation of energy, then there is a strong constraint in how the variables of the system may develop over time. This is a key reason why there are aspects of the energy system, connecting primary energy sources with demand via energy conversion, which can be understood even far into the future. Similar but less strict constraints may be used for the modelling of land-use and food, resources and materials, etc. Also, connections between critical systems may have a more or less well-known physical description. The aggregate emissions of CO_2 from society has a relatively well-established response in the atmospheric CO_2 concentration, but the response in terms of temperature increase, as quantified by the climate sensitivity, is much more uncertain.

But, if correctly implemented, the model provides a consistent description of (present and future) variables in the system; that is, consistent with respect to the relations that are built into the model. If the relations are known this is fine, but when there is uncertainty about the relations (or the underlying mechanisms) then that uncertainty must be dealt with when assessing the value of the model results.

([48]) See, e.g. http://themasites.pbl.nl/models/image
([49]) See for example, van Asselt and Rotmans (2002); van der Sluijs (1997, 2002); Walker et al. (2003)

4.2.3.2. Uncertainty and transparency

Computer simulations of large, complex, interconnected systems have been successfully developed in physics and in disciplines where physical laws provide a secure basis for the mechanisms in the model. Highly relevant examples are found in meteorology and climate science. But in physics also, uncertainties and hidden assumptions may make the model results less trustworthy. In the context of astrophysics and simulation of a supernova explosion, but with a broader relevance in mind, the famous physicist Leo Kadanoff asks:

> How does the power of argumentation provided by exploratory simulations compare to that of rhetorical or order-of-magnitude discussions? Since the simulations must include everything to make a star go boom, they provide an internal check of consistency and completeness not available through words. On the other hand, some intermediate steps in the argument may have their weaknesses hidden in unexamined computer processes. Words may be better than computer output for showing up weak arguments. Computer arguments often force us to rely upon the integrity and care of the investigators. So computers provide a useful but dangerous tool for the exploration of complex systems.

So the question is, how can we design and use models in order to be honest and clear about their weaknesses — the inherent uncertainties — at the same time as the models provide new insights about the problem area that is addressed?

When using simple models or models of well-defined subsystems, it is often clear how the uncertainty of model assumptions and parameters affects the results. If the model is described in a transparent way, it should also be clear how other systems, which are not part of the simple model, influence the modelled system. This of course means that the results are expressed under certain assumptions on how other systems behave and develop.

Here there is a choice on whether one should model the systems in isolation and explicitly deal with the different points of connection in between them, or whether one should build an integrated model of the whole system. The latter approach leads us to the IAM. A fundamental problem arises when one connects models (of subsystems) where the uncertainties associated with the results produced by the separate models are of different kinds and different orders of magnitude as discussed above. With the integration of the models into a single large model, there is a risk that the transparency is lost and that the uncertainties are less easy to identify and quantify.

When we consider integrated models there are other uses one needs to consider. In the example of climate change we have complex interactions between the energy system, society and the climate system, and many linkages are not well known. The most critical connections are the socioeconomic ones that take place in the future.

Because of this level of complexity, model results must be interpreted with care and all uncertainties in the whole range from model structure to parameters must be taken into account. Sensitivity analyses are increasingly being used, but that does not deal with the assumptions made on model structure, which among other things in general assume some basic development usually free from sudden events or discontinuities. Given these caveats, one may still consider such an IAM to generate, to some extent internally consistent, pictures of possible future development of the system. The characteristics of these pictures, depending on different sets of assumptions on important driving factors such as climate policies, resource availability and technological development, may provide qualitative insight on how policies and other assumptions interact.

For a comprehensive discussion on uncertainty in the context of IAMs, see the work by van Asselt and Rotmans (2002). They state the following.

- Not all uncertainties can be adequately addressed with existing methods and tools. This especially holds true for uncertainty in model structure and uncertainty due to behavioural and societal variability, value diversity, technological surprise, ignorance and indeterminacy.
- Uncertainty is usually treated as a marginal issue, as an additional physical variable, as a mathematical artefact. The current methods merely involve evaluation of the impacts of certain uncertainties, i.e. uncertainties for which estimates or probability distributions are available.
- Current methods give no indication of the magnitude and sources of the various underlying uncertainties and the aggregated uncertainty measures are difficult to understand for decision-makers and other audiences.

To conclude, models as numerical tools may have an important role in foresight modelling, but this requires one to be well aware of the vast limitations of the precision in modelling results that in general is the case. The numerical models give one perspective (or several since there are different modelling options) on the problem at hand. As a good basis for discussions several models should

be used, each with clearly stated mechanisms and assumptions, and this should then be complemented with non-numerical modelling approaches as discussed in the following section.

Even if the aim is to build an IAM, it would be of high importance for clarity and transparency that the construction is made in a modular way. This means that models of subsystems are constructed so that they can be run and studied separately, and even that one can switch between different types of sub-models (including different mechanisms and different modelling techniques). The key point in this process is to keep the assumptions and the uncertainties clear so that a set of transparent analysis tools can be provided.

4.3. Non-numerical models

Non-numerical models are, like numerical models, abstractions of reality developed to understand the phenomena under consideration. A non-numerical model has the main objective of identifying the ontology (the structure) which determines behaviour (i.e. observable phenomena). Non-numerical, inquiry-led model building therefore helps to frame numerical analysis.

Non-numerical modelling has been extensively discussed in sociology. Hedström and Ylikoski (2010) review non-numerical modelling in the social sciences. They argue that, in social theory, the development of general theories to explain social phenomena require 'mechanisms' as causal links. Following Bhaskar (1978), these mechanisms require 'causal agents' which in the social sciences are always individual actors, such that the link between phenomena or state to another is an action. This is known as 'methodological individualism'. Hedström and Ylikoski (2010) also argue that states are influenced by collective social phenomena, which cannot be directly traced back to individual actions, which is then 'weak methodological individualism'. The problem in social science analysis is that these mechanisms are often unobservable. Hedström and Ylikoski (2010) then provide an example of qualitative reasoning, starting from the case of the 'self-fulfilling prophecy' — if there is a rumour of insolvency of a bank, such that some savers withdraw their savings, thus strengthening the rumour and leading more savers to withdraw, a bank that was solvent will become insolvent. This postulates a system with actors whose actions determine the state of a social system.

Most social phenomena involve several mechanisms, such that a system approach is required. Using Coleman's boat model (Coleman, 1986) they propose three types of mechanisms: Situational mechanisms, which explain how macro events affect individual actors (macro-micro mechanisms); action formation mechanisms, which explain how an individual assimilates macro events and determines actions to be taken (micro-micro mechanisms); and transformational mechanisms, which explain how individual actions combine to generate macro-level outcomes (micro-macro mechanisms). The first two mechanisms are individual and the third is social. They summarise the proposed approach as having four core elements, as shown below.

1. Explanations based on actions.
2. Explanations in the social sciences are most usefully directed at a limited range of phenomena and should not try and establish universal laws; rather they are causal patterns that are initiated under unknown conditions, in contrast to the general laws of natural science (from Elster, 1989).
3. The mechanisms have to abstract from non-essential factors and identify the necessary determinants of phenomena.
4. The explanations should use the principle of reduction, a detailed explanation directly linking the actors and phenomena through precisely specified actions.

Non-numerical modelling in foresight analyses will almost always address social as well as physical phenomena. This implies that, as well as requiring anticipatory models in the sense of Rosen, they should have the objective of identifying these explanatory mechanisms to provide the theory of the anticipatory models. Identifying the particular mechanisms and how they interact through qualitative system analysis can lead to an understanding of possible future outcomes and the factors which can influence these outcomes. This theorising of structure can be undertaken using so-called causal loop analysis — in technical terms a directed graph, which shows phenomena of interest and the directions of influence between each phenomenon. This is then a qualitative system model, with the feedbacks shown as positive (the level of population determines the demand for food, more population increases the demand, so the interrelation goes from population to food demand and is positive) or negative (an increase in the price of oil reduces economic output).

4.3.1 Non-numerical Modelling Methods

There are a large number of methods used for qualitative problem analysis. Table 4.1 lists some of the main methods.

Table 4.1 Non-numerical methods and process tools for Foresight Analysis

Non-numerical methods	
Causal mapping	Based on systems theory, the identification of a system as variables or objects and the causal links between nodes.
Argument Maps	An argument map is a graphical representation of a logical argument. Nodes are statements (assertions i.e. arguments) and lines join one argument to another to show that an argument supports or detracts from the other node i.e. argument. This is graphically the same as a causal loop analysis, but representing logical relations instead of system states and their feedbacks.
Cognitive Maps	A cognitive map is a mental map, a spatial representation of the outside world that is kept within the mind, until an actual manifestation (usually, a drawing) of this perceived knowledge is generated.
Conceptual models	These tend to be more descriptive, rather than data rich. They can take the form of diagrams, rich pictures, landscape visualisation and stories. Conceptual models can useful in developed shared understanding of a situation in a way that reveals and respects different perspectives. Furthermore, conceptual models can reflect qualitative and quantifiable understanding
Rich Pictures	Typically, rich pictures follow no commonly agreed syntax, usually consist of symbols, sketches or "doodles" and can contain as much (pictorial) information as is deemed necessary.
Process tools	
Group Model Building	'A process in which team members exchange their perceptions of a problem and explore questions such as: what exactly is the problem we face? How did this problematic situation originate? What might be its underlying causes? How might the problem be effectively tackled?'(Vennix, 2001 p.3).
Search Conferences (Jimenez, 2008).	A search conference is a group learning process which works through five stages: 1. Exploration of the contextual environment 2. Analysis of the current situation 3. Design of the ideal desired state of the system 4. Identification of obstacles and opportunities to reach the desired state of the system 5. Selection and design of courses of action

Causal maps are the result of causal loop analysis. Argument maps define what the argument is about (key aspects, as perceived by the different stakeholders); the foresight process can then to use modelling/simulation/ design tools to draw conclusions and to find alternative designs (policy models). One important source for errors is that we tend to forget what the basis for opinions was, and record-keeping of the design rationale might be useful to mitigate the problem. Cognitive mapping is the implicit and mental mapping the explicit part of the same process. In most cases, a cognitive map exists independently of a mental map. Rich pictures are part of the soft systems methodology toolkit (see Box 4.1) and provide a mechanism for learning about complex or ill-defined problems by drawing detailed (rich) representations of them.

There are also process tools which are useful for foresight activities. Group modelling has been developed because it is teams, rather than individuals, that usually determine the performance of modern organisations. Differences in viewpoint can be very productive in developing useful and useable models of novel and puzzling situations. The search conference provides a social space where reflection and design can be accomplished in an environment free of self-imposed constraints.

4.3.2. Hybrid methods

Fuzzy cognitive maps

Fuzzy cognitive map (FCM) modelling was originally intended to make complex political, economic or social problems accessible for a wider audience. FCM model building is a multistep process that captures causal knowledge in the form of cognitive maps, formally describes these maps as adjacency matrices and applies neural network computation to refine the model and analyse model results (Jetter and Kok, 2014). FCM modelling uses a mix of non-numerical and numerical approaches. It enables the inclusion of multiple and diverse sources to overcome the limitations of expert opinions, it considers multivariate interactions that lead to nonlinearities and it aims to make implicit assumptions (or mental models) explicit. They are useful for integrating expert, stakeholder and indigenous knowledge by creating scenarios that bridge the gap between quantitative analysis and qualitative storylines.

Scenario planning

Scenario planning involves the construction of a limited set of plausible, relevant and challenging stories about the future. The emphasis is on what might happen ([50]). Plausibility is not a derivative of probability and deductive reasoning. Instead, plausibility offers an alternative basis for logical reasoning based on adbuctive and inductive reasoning to provide a guide to the future and redirect attention from business-as-usual thinking, enabling conventional wisdom to be exposed and tested as necessary to enabling anticipation of less familiar, unexpected and novel developments (Ramirez and Selin, 2014). Plausibility instead encourages attention to be redirected to what might be different about the future, i.e. structural breaks and disruptions that are novel and uncomfortable and involve thinking through the unthinkable.

Soft systems methodology (SSM) is an approach that is able to integrate systems ideas, dialogue and action orientation into a coherent whole (see for example Checkland and Poulter, 2008). It proposes a disciplined process to create clarity in a complex, problematic situation. SSM allows people to step back from the rush to solve problems and the messiness of the actual challenge and think about ways of organising in an idealised realm. It is a process that takes differences between the world views of people affected by the situation explicitly into account. The purpose is to come to a joint agreement about what actions are desirable and feasible that may lead to an improvement, however modest, in the situation. SSM can be of great help to a group of people who jointly want to agree on how to deal with a problematic situation they are all affected by but of which they may have a very different understanding. What SSM does is make these differences in framing very explicit and then seek an accommodation between these differences in deciding upon actions to bring about improvement.

The power of SSM derives from the willingness to make differences in the framing of problematic situations very explicit. SSM assumes upfront that clashing worldviews are always present in human affairs. Rather than pretending that these differences are not there, it takes the disagreement as a source of insight, energy and creative tension. The temporary move away from the messiness of the real problem by pulling the enquiry away from the actual situation and thinking about it from an idealised, single-worldview perspective means that SSM creates a more relaxed and disciplined setting to deal with urgent challenges. Like any methodology, SSM also has weaknesses, as indicated below.

— The focus on feasibility — in SSM the interventions are limited by what is deemed culturally and politically feasible. They do not emerge from a visionary perspective that radically wants to transcend the existing challenges.

— Process-wise it is sometimes difficult to convince participants to go along with the discipline of developing multiple activity models, each of which is associated with a different purpose for the system. In acute problematic situations people are often so hungry for structure that they are happy to stop after a first activity model has been generated. Going beyond that to explore other worldviews (and hence to increase complexity) may require considerable persuasion skills from a facilitator.

— Whilst it is founded on a set of simple, clear ideas, SSM embodies a logic that people do not easily make their own. It may take a while before they really get the logic of the approach. In

([50]) There are many different ways of building scenarios (Wilkinson and Kupers, 2013, 2014; Ramirez and Wilkinson, 2014). Van der Heijden (2005) notes four different approaches: deductive (drivers-of-change starting point, often called the 2×2 matrix method), inductive (holistic/creative thinking/narratives starting point), official (incremental method: official future starting point) and (normative) vision-based building methods. Sohail (1998) introduces the 'critical method' or causal layered analysis. Bezhold (2009) introduces the 'four archetypes' method.

terms of implementation, an SSM-based project may take anything between an afternoon and 6 months. Given the requirement that people only participate who have first-hand experience of the problematic situation and who can take responsibility for intervening in it, the number of participants will usually vary between 10 and a few dozen.

BOX 4.1: Soft systems methodology

4.4. Other approaches used in foresight modelling:

Clay models: design prototyping

A designer builds a physical representation (traditionally in the automobile industry from clay) of what a new product, service, system, etc. might look like and refines the design through a series of iterations with the end user. This approach to physical modelling can use many different materials e.g. clay, Lego blocks, etc. The physical rendering of the new 'product' supports a process of co-design and coproduction of something that does not yet exist i.e. a creative process involving ontological expansion.

Serious gaming

A serious game or applied game is a game designed for a primary purpose other than pure entertainment. In situations of stress or incomplete information, research has shown that people do not necessarily make decisions in a logical way (Klein, 1999). This is a big reason why simulations, exercises and games are so important. Scenario-based policy discussions are an effective way to inject foresight into policy discussions. are an example of Not only do the impart some of the hidden complexities that make up tactic knowledge by they also embed patterns into the memory of participants which can be recalled later for making decisions in real life situations. The players become agents in the problem environment. The 'serious' adjective is generally used to refer to products used by industries like defence, education, scientific exploration, healthcare, emergency management, city planning, engineering, and politics. Serious games are simulations of real-world events or processes designed for the purpose of solving a problem ([51]). This builds on the experience of the gaming industry, the 'Four Keys to Fun,' a model used by game developers worldwide.

4.5. Conclusions

Foresight models will usually be developed as part of a foresight process, organised to address a particular issue. Foresight requires models for anticipatory learning, which use a model of the future to simulate alternative future scenarios as a part of foresight processes that have the goal of co-developing knowledge about policy issues for the future. The modelling process must be rapid to fit with the timing of foresight stakeholder processes and to enable the EU foresight organisation to respond to urgent policy concerns.

Models as numerical tools may have an important role in foresight modelling, but this requires one to be well aware of the vast limitations of the precision in modelling results that in general is the case. The numerical models give one perspective (or several since there are different modelling options) on the problem at hand. As a good basis for discussions several models should be used, each with clearly stated mechanisms and assumptions, and this should then be complemented with non-numerical modelling approaches.

There is also a wide range of non-numerical analytical tools, such as causal mapping, that can be used to help define the scope of an issue. Processes such as group model building and serious gaming can also provide alternative ways to explore and understand complex policy issues.

([51]) Some examples:

- Eco-based marine spatial planning: a game to explore policy options for all countries on the North Sea for joint planning of wind turbine parks, and in the process to identify conflicts with other functions of the North Sea (sand supplies, fishing, ecology, defence, shipping routes, etc.) and conflicts between countries. See http://www.sciencedirect.com/science/article/pii/S096456911300104X
- Electricity market game: explores the evolution of the power generation portfolio (including the issue of generation adequacy) under different regulatory regimes/policy interventions. See the flyer: http://emg.tudelft.nl/emg_flyer.pdf
- SimPort: originally the work of a PhD student in the next generation infrastructures programme, Geertje Bekebrede. The game was developed for the port of Rotterdam, to explore the planning challenges (e.g. the emergence of path dependencies) for the second Maasvlakte, the 2 000-hectare port extension. See http://www.simport.eu

This discussion has shown that there is a wide range of analytical modelling approaches that can be relevant for foresight activities. Therefore, it is not possible to propose a single modelling approach that should be developed for the European Commission's foresight activities. However, Chapter 3 identified the need for a new approach to foresight for the EU: Concurrent Design Foresight. This also requires a new approach to modelling activities. This new approach must deliver models, both numerical and non-numerical, with the following characteristics:

— they must be part of a process of development of pro-active visions and solutions, allowing for changes in the structure of society;
— through anticipatory learning, they should contribute new possibilities and options for action;
— they must support a wide-ranging analysis of the issue, with the inclusion of conflicting perspectives;
— they must be quick to develop and use;
— their structure and assumptions must be transparent to the stakeholders in a foresight process.

The European Space Agency's (ESA) concurrent design modelling platform is an example of such an approach, but in a more limited engineering design context. Therefore a new development is required. **The recommendation of this expert group is that the European Commission should develop a platform for analytical modelling to support Concurrent Design Foresight processes.**

Chapter 5: Low-resource housing: a test case and potential for backcasting services

Key points

1. Low-resource housing should be considered in the larger context of urban planning and the related infrastructure (mobility) and societal integration needs of its inhabitants.
2. The building and construction industry is the biggest single consumer of material resource in most national economies, as well as the major consumer of energy and water and the biggest waste producer.
3. These resources are largely embodied in the load-bearing structures and can be preserved through reuse and service-life extension strategies of the structures with technological upgrading of the envelope, greatly increasing resource efficiency
4. The overall resource consumption of housing is influenced by the energy and water consumption of its users during utilisation. As these latter diminish (zero-energy housing), the importance of the embodied resources increases.
5. Foresight analyses could address specific topics such as ecodesign, redesign with foreseeable technologies, hydrogen houses and densification of housing.

5.1. Introduction

Chapter 5 sets the boundaries of a foresight case study on low-resource housing and briefly considers the potential roles of analytical models. Section 5.2 defines the system context of housing and its boundaries; section 5.3 analyses the resource consumption of housing proper; section 5.4 clusters the factors influencing housing units and their resource consumption into four fields, illustrated in a star diagram; and section 5.5 proposes possible modelling/backcasting topics. These provide examples with clear boundaries to the issue to be considered.

5.2. Identifying and defining the systemic context of housing and its boundaries

This section shows the main issues of housing in a general systemic and societal context.

5.2.1. The societal role of housing units

Housing represents shelter and security in Maslow's pyramid of basic human needs. The standard of housing is directly linked with the standard of living of the inhabitants. The degree of sophistication of housing thus changes with the economic situation of a society. In an affluent society, user needs fade away and lifestyle issues take over, dominating the resource consumption pattern. Higher income often means larger average surfaces per person, more (water- and energy-consuming) sanitary equipment and a higher (indoor) comfort, achieved by more heating and cooling. Housing can be designed for social integration. By building social housing units for the elderly on top of commercial centres in the United Kingdom, a synergy of animation and control has been created.

Some of the EU housing stock is part of the cultural heritage, in urban and rural sites. This can cause clashes of policy demands between maintaining the heritage and reducing energy consumption or installing new technologies, such as photovoltaic solar panels.

5.2.2. The systemic context of low-resource housing — space and time

The systemic resource consumption of housing units is influenced by space and time issues.

Space issues are defined by the character of the site where the housing is located (land or water based, on wheels, in an urban or remote location), which determines the climate conditions and the legal (regulation, planning policies) and economic conditions. Refurbishing housing stock is a low-resource strategy and often a cheaper and faster one than replacing stock by new construction. Repair and refurbishment work is carried out by local small firms (SMEs); it is labour intensive and uses much less material, energy and water resources (and produces only a fraction of the greenhouse gas (GHG) emissions) than replacement new construction. The smart management of housing stocks is a low-resource housing strategy, which also contributes to creating a low-resource (resource efficient) economy.

Time issues are subjected to constant change, such as user needs (demographic changes) and personal preferences on the one hand, and societal integration issues (accessibility to community services, connections to networks, interactions between housing and society) on the other. Technology is a major factor which changes over time. For example, when local solutions become cheaper than centrally produced ones, a change in consumer preferences can lead to stranded

capital and technology lock-in. The same impact can have many sufficiency solutions (waterless and zero-energy solutions). The specific resource consumption diminishes with a longer building service life; doubling the service life halves the specific resource investment.

5.2.3. The impact of housing density on resource use

Housing density is one of the key factors in the use phase for several systemic issues of resource consumption: low housing density tends to lead to autonomous solutions (for instance supply of resources and waste management); high housing density often leads to centralised integrated solutions. Population density normally parallels housing density; it determines the systemic resource consumption of housing, such as mobility (transport) or accessibility (internet). Housing density influences the feasibility of centrally produced network-distributed resources (water, energy) and waste elimination services, and thus the choice between centralised and stand-alone solutions (for instance fixed-line versus mobile telephone services; or electricity grid versus micro-electricity production).

Housing density also heavily influences the interface with the environment. High density leads to urban accumulation effects, which call for reflecting roofs, green roofs and green alleys (replacing pavement with grass and trees) and water run-off to help manage excess storm water and extreme heat ([52]). Low housing density facilitates natural ventilation without air conditioning but also creates the conditions for wildfires in dry weather.

5.3. The resource consumption of housing proper ([53])

This section shows the resource consumption issues of housing in a narrow view. Traditionally, the resource consumption over the life cycle of a housing unit was characterised by construction, use and demolition phases, for which there have been recent trends for reduction in resource use (see Table 5.1).

Phase	Resource use	Recent trends for resource reduction
Construction	Managed by professionals of the construction industry and characterised by high material, energy and water consumption, which are embodied in the resulting housing unit	Extending the service-life of the housing stock
Use	Influenced by user preferences and dominated by energy and water consumption	Minimising the heating/cooling losses through better insulation of the envelope (facades and roofs) and reducing the electricity consumption by increasing the efficiency of lights and technical equipment
Demolition	Energy and emission intensive	Industrialising the deconstruction process with the objective of recovering components and materials in a near zero-energy process e.g. Ana Hotel in Tokyo

Table 5.1 Phases in housing lifetime and influences on resource intensity

Modern building design with zero energy consumption in use, or even better plus-energy buildings — which produce more energy than they consume — have become the ultimate vision of architects. They also reduce the demand for public security in emergency situations (no people blocked in lifts and the supply of street lighting in blackouts).

([52]) ACEEE news release of 18 June 2014: ‘To protect public health, many major cities confront urban heat island effect’.

([53]) Three kinds of resources are consumed by housing units.

- Material, energy and water are used during construction and embodied in the finished housing unit; water and energy are also used during use and in the demolition phase.
- Ground: if built on land, this resource is occupied (no longer available for other uses) but not consumed; the quantity used per person is correlated with the housing density.
- Finances: housing (the combined value of land property and physical buildings) is one of few investments which keeps or even increases its market value over time. Housing therefore does not consume capital resources and is a preferred investment of, for instance, life insurance companies, which will let the housing units to tenants. But housing units can also come into the focus of financial speculators.

With regard to material resources, the building sector is the major consumer of resources in industrialised economies; about half the national material resource flow goes into the construction and building sector. In the EU, ceramic materials (bricks, concrete and increasingly glass) are dominant; the production of these materials is fossil energy and GHG intensive. Timber constructions are common for housing in Scandinavia and the USA, but the use of timber has traditionally been limited to low-level housing (one or two storeys) by fire legislation. In a typical building 80 % of the total energy input is embodied in the load-bearing structure; the remaining 20 % in the envelope (roof and facades), the technical equipment and interior partitioning and decoration. This means that the refurbishment of a building becomes more energy efficient than new-build replacement. Refurbishment will preserve up to 80 % of its original energy investment and GHG emissions ([54]), technological upgrading of the envelope (to high insulation) makes energy sense and, in near zero-energy buildings, the energy capital of the load-bearing structure becomes the largest energy item over the building's lifetime. Preserving this investment through service-life extension is therefore the smartest option to reduce energy consumption and GHG emissions.

5.4. Clustering the factors influencing housing units and their resource consumption

This section groups the issues or factors of resource consumption of housing into major topics: siting, construction and use, summarised in Table 5.2. The information is also presented in a star diagram in Figure 5.1. The star diagram identifies four analytical domains: siting, physical construction, use and (societal) integration. For each domain the main topics are listed, and for each topic the key factors are derived. For example, siting defines the climate, which leaves a choice of microclimates (with regard to humidity and temperature).

The design heavily influences, even predetermines, later flexibility and adaptability to changes in use and technology. A systems design allowing technological upgrading to later best-available technologies can substantially reduce resource consumption over the life of a housing unit. Material requirements during the use phase depend heavily on the options to adapt the interior to changes in user structures (family structures, mobility of individuals in ageing societies) and on the options to upgrade housing unit stocks in line with technological progress. Urban planning with systemic optimisation (such as the Japanese hydrogen highways) can optimise the systemic resource consumption of housing units.

A number of other factors can also heavily influence the resource consumption of housing units. Sufficiency strategies were used in the past to some degree (micro-hydro power, windmills) and have recently again gained in importance. Positive contributions to societal integration can be made through inclusive design, inclusive technology and design for adaptability to changes in user needs.

([54]) The EU construction 2020 action plan was introduced in 2012 to promote opportunities available in energy- and resource-efficient renovation and slash trade obstacles in the single market.

Table 5.2 main factors influencing the resource consumption of housing units.

Siting

- Microclimates (hot/cold, wet/dry, including trees and gardens — a factor which has lost its importance with the advance of indoor climate technology).
- Natural opportunities (hydro energy, geothermal energy, wind and solar energy) and hazards (exposure to radon emissions, floods, windstorms, mudslides, earthquakes).
- Legal and technical requirements (land-use zoning laws, building codes, subsidies, mandatory connections to networks).
- Economic conditions (land prices, capital costs, demand and supply of housing, demographic and family structures).

Construction

- A choice of low or high rise and density of the housing estate.
- A load-bearing structure: choice of materials.
- An envelope (roof and facades) and internal divisions; technical equipment, such as heating, ventilation, air conditioning (HVAC); energy, communications, IT and water networks; vertical transport systems (lifts), energy recovery, water reuse/zero water.

Use

- Use as residence, work space, dual use.
- Energies (mostly heat, cold and light), room temperature, cooking and other equipment.
- Water (for sanitary, food/drinking and cleaning purposes, gardening).
- Materials (repair and maintenance, adaptations to changes in use).
- Thermal insulation of the envelope using best available technology, such as vacuum insulation panels (VIPs).
- Vertical mobility services, such as lifts to accommodate ageing populations.

Societal integration into networks

- Accessibility (delivery services for food, goods, postal and digital mail, internet), mobility (human power, public and shared transport, individual vehicles).
- Access to community services (health, education, culture, religion, sport and digital services).
- Utility networks (electricity and gas grid, water and waste water networks, waste collection and disposal, hydrogen highways, latest communication (fibre optics)).
- Outreach plus energy buildings, housing units integrated into other functions.
-

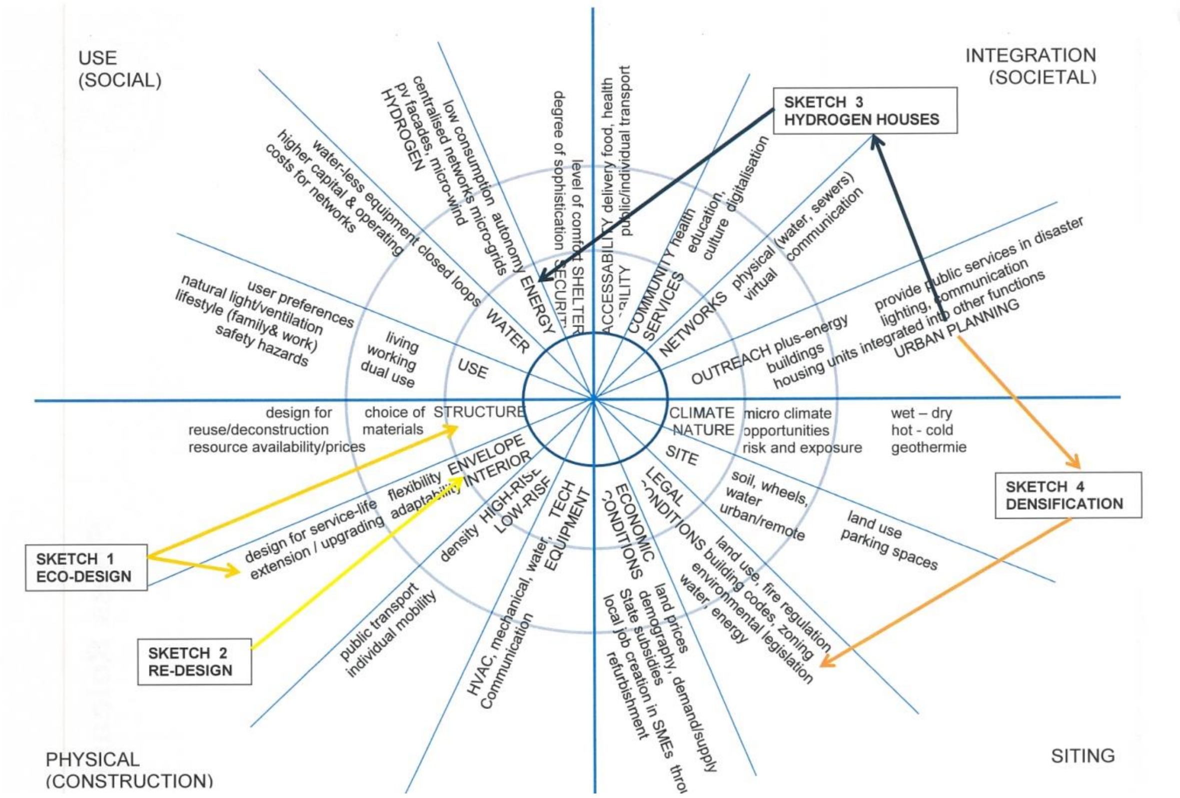

Figure 5.1 Factors in energy use in housing

5.5. Possible foresight topics

This section sketches some possible proposals which could be used to test the findings of Chapters 3 and 4 in the context of low-resource housing. Ecodesign and redesign propose technology-fix options of integrating technological progress into new housing design (1) and into upgrading existing housing stock (2). Technologies which can be retrofitted into existing housing and included in the construction of new housing include novel elements of the building envelope (roofs and facades) with a substantially improved insulation performance, such as triple-glazed windows, vacuum insulation panels; low-carbon heating and cooling systems with a high system efficiency, such as combined heat and power generation (co-gen) plants, using geothermal energy or fuel-cell hydrogen systems; solar hot water circuits for sanitary hot water, common in China even for tower blocks; solar photovoltaic elements integrated into facade panels and windows; interactive homes; smart electricity meters, which in turn enable goods-as-services business models of the performance economy based on pay-per-use (rent-a-wash of washing machines).

(1) Ecodesign — Integrating the results of technology foresight into new building design by 2030/2050 — and look back

Systems design of new buildings offers an opportunity for low-resource housing through a modular design concept of elements according to function and expected service life: load-bearing structures that use standardised components; an envelope consisting of elements which can be easily exchanged or upgraded; an interior layout which allows for flexibility and adaptability in use; technical equipment which can be easily changed or updated, such as integrating solar photovoltaic panels into the facades of new buildings, enabling future updates using existing wiring.

(2) Redesign — Integrating the results of technology foresight into technological upgrading of housing stock (for instance with regards to use energy and water efficiency) and look back ([55])

([55]) A German study came to the conclusion that 'the ambitious climate protection goal (of the German government) can only be reached whenever buildings require less energy for heating, which in turn depends on the availability of low-cost strategies for renovating buildings to make them more energy-efficient. Possible solutions include making more extensive use of prefabricated building components, which will enable significant cost savings to be achieved in renovation projects, and also the use of novel inexpensive materials' (Fraunhofer ISI, *Energiesysteme Deutschland 2050*; and Röthlein, B. 'Protecting the climate pays off', *Fraunhofer magazine*, No 2, 2014, p. 22 et seq.)

In an average year, the new construction volume corresponds to about 2 % of housing stock. It would thus take 50 years to renew the existing housing stock with a more energy and water efficient one. Technological upgrading of the housing stock enables acceleration of the transfer to an energy and water efficient stock. In addition, it prevents waste and saves an equal amount of resources needed for renewing stock through demolition and reconstruction.

(1) Hydrogen houses — Designing new urban planning policies for low-carbon districts

An urban planning policy can be combined with a vision of how to introduce hydrogen as a new zero-carbon energy in a systemic way ([56]). This approach may be useful in rural areas where high-density housing is not desirable for societal reason for instance in case of cultural heritage.

(2) Densification of suburban housing stock

Housing density has a direct impact on land-use. A high density can be achieved by both high-rise and low-rise buildings. Le Corbusier's *unités d'habitations*, for example, have the same number of dwellings per hectare as settlements of terrace houses commonly found in Britain. However, these two extremes of housing density differ substantially with regard to, for instance, social problems and ownership.

The density of existing housing stock can be increased horizontally by building more of the same, such as villas in the gardens of existing villas, and vertically by increasing the number of floors of existing stock.

Densification allows the introduction of new urban planning concepts into existing housing districts, such as changing the age structure (providing studios for elderly and students), new transport, cultural and shopping facilities.

An increased density of housing has a strong influence on the economic feasibility of networks and infrastructure, including transport (taxis and car-sharing, public transport) and cable-based services (fibre optics), health and education services. The higher the (passenger) volume, the better the offer (frequency) of public (transport) networks. Also, densification demands an adaptation of the public networks (water, waste water and storm water run-off), which allows the resilience of existing districts to be increased at little additional cost. In addition, there are a number of systemic resource consumption factors to be considered. In regions where climate change brings higher temperatures and potential water shortages, increasing the density will reduce the risk of wildfires and may positively influence public security. Densification means fewer gardens and trees (and swimming pools) and may thus reduce the water consumed for plants and lawns. On the other hand, higher housing density may create an urban heat-island effect.

5.5.1. Use of foresight modelling in the four sketches

The first two proposed analyses of the implementation of new technologies into new buildings and upgrades of existing stock can be usefully modelled by physical and economic models of energy demand and potential investment costs, showing potential benefits in terms of both resource savings in energy and water flows and also operating costs. When combined with, for example, a model of building stocks and technology changes through time, time paths of emissions, resource and cost savings could be generated with dynamic energy economics models including systems dynamics models. These analyses would be able to use the current modelling techniques such as dynamic energy cost minimisation models, system dynamics simulation models of building stocks and changes, agent based models of technology uptake and behavioural change for energy and resource savings.

A foresight analysis could be undertaken into how an urban planning policy can be combined with a vision of how to introduce a new energy system or increasing housing density. A foresight process to develop visions of a new urban structure resulting from a new energy system could be informed firstly by a qualitative modelling of alternative ideas for a new urban system. This could lead into

([56]) The Japanese hydrogen highways start by selling hydrogen fuel cells to individual housing units, complete with individual hydrogen storage tanks, along certain roads. Once this has been achieved, the house owners are encouraged to buy hydrogen fuel cell-powered automobiles. This strategy overcomes the obstacle of a lack of public hydrogen fuel stations in the initial phase, as the car drivers can refuel their cars at home. Hydrogen buses along the hydrogen highways and a system of hydrogen refuelling stations complete the urban planning process. The world's largest 'hydrogen town' project celebrated its foundation on 11 October 2008 with the first installation of a residential hydrogen fuel-cell system in Maebaru City, as part of the Fukuoka Prefecture's plan to realise an eco-friendly hydrogen-energy society.

quantitative modelling of the energy implications and cost implications of the new technologies of the visions. The densification of housing does not involve new technologies to the same extent; rather, it involves the consideration of planning rules and their social impacts. This would then also require a foresight process with a qualitative system model, where the implications for social relationships could be discussed with residents and stakeholders for existing equivalent urban structures. Quantitative modelling could assess the potential energy savings from the different scenarios of density, using current data for a relatively simple, rapid assessment. The question of network efficiency versus regional sufficiency could also be a modelling topic ([57]).

([57]) El Hierro in the Canary Islands has become the first world region to produce all its energy itself from renewable resources (hydro and wind power), including electricity for its electric vehicles.

Chapter 6: Modelling the future: the case of 3D printing

Key points

1. All policy development uses implicit models of the future.
2. Ideas, such as the revolutionary impact of 3D printing, can become highly popular when they fit existing models; viral ideas, however, are always retrospective and they miss true novelty.
3. When the models are made explicit it is easy to evaluate and debate them and find missing evidence.
4. Foresight can use different types of models, and better foresight results when the model matches the issue.
5. Transformative innovation requires models and design-oriented foresight that are able to embrace unpredictability.

3D printing is an example of a new technology that has potentially radical consequences for the economy and society. This case is used to illustrate implications for analytical models on foresight and to provide an example of causal mapping and argument maps.

3D printing can make digitally designed unique products available at low cost and enable highly distributed systems of production that effectively utilise local knowledge and address local needs. During the last year, 3D printing has made headlines as full-sized houses are now constructed using 3D printers, open 3D designs for working guns have appeared and disappeared on the internet, prosthetic robot arms can now be printed for 50 dollars and less and 3D printers move from industrial design labs to supermarkets and Christmas wish lists. The cheapest 3D desktop printers cost today less than EUR 600, and 1 kilogram of plastic filament used to produce objects costs about EUR 30-50. Hobbyists have websites and cloud platforms where they exchange designs, ideas and knowledge, and high-quality 3D printing businesses that turn digital material into plastic and metal are rapidly appearing in all EU countries.

In July 2014, members of the inter-DG European Commission Foresight Network produced a 5-page brief on the future trends, expected impact and emerging policy issues of 3D printing. In the present chapter we reconstruct from this document some of its underlying models. As the document was produced by a six-person team with members from different disciplines and DGs, it integrates several conceptual models of 3D printing and its future impact. The brief text reflects the final outcome of a collaboratively generated consensus model. In this chapter we reconstruct parts of this model from the text of the brief with the intent of making its underlying assumptions explicit, at the same time highlighting the potential benefits of systematic modelling. For the full text, we refer to the report itself. We then put this discussion in the context of different ways of doing foresight and strategic and institutional sensemaking. The use of the qualitative techniques of causal mapping and argument maps is illustrated.

6.1. The overall setting: expected trends

The brief starts by reviewing the expected trends in technology and applications. It expects that there will be technical progress in two of the current key technologies, layering and materials, that will lead to improved prints and lower costs. This will lead to higher market take-up, which will further lead to a lower cost of 3D printers. As a consequence, the production of complex goods can be decentralised, localised, and even located at home. We schematically draw this partial model in Figure 6.1.

The brief, obviously, does not try to paint a full picture; instead, it highlights a few key messages relevant for high-level policymakers.

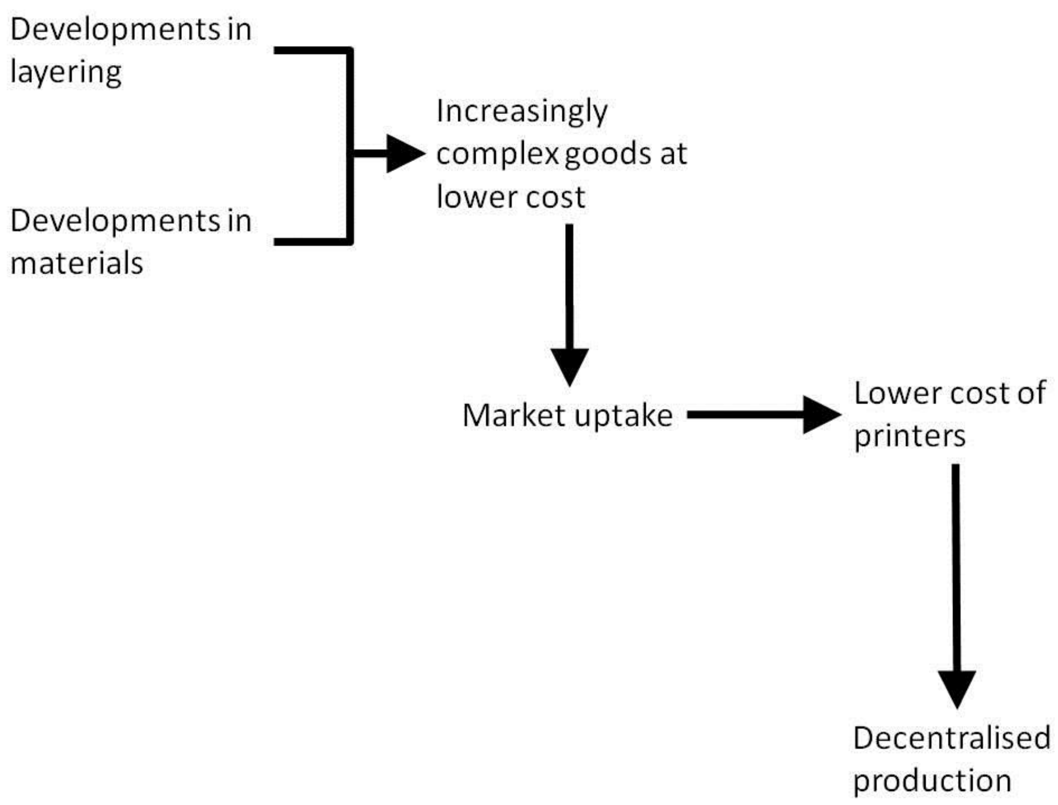

Figure 6.1 Expected impact of technology trends

6.2. The perspectives in use

The report describes the overall expected impact in and for the EU using five perspectives: society, economy, governance and policy, environment and climate, and safety and security. Each of these is described in the brief using one or two paragraphs of text.

The expected impact on society, as described in the brief, is shown in Figure 6.2. The brief states that 3D printing will enable mass customisation of goods, leading to a change of consumption patterns with unique products being delivered to individuals to the point that that it could impact the sense of ownership of goods by individuals. 3D printing is expected to lead to a similar democratisation of production as we have seen in software and content creation.

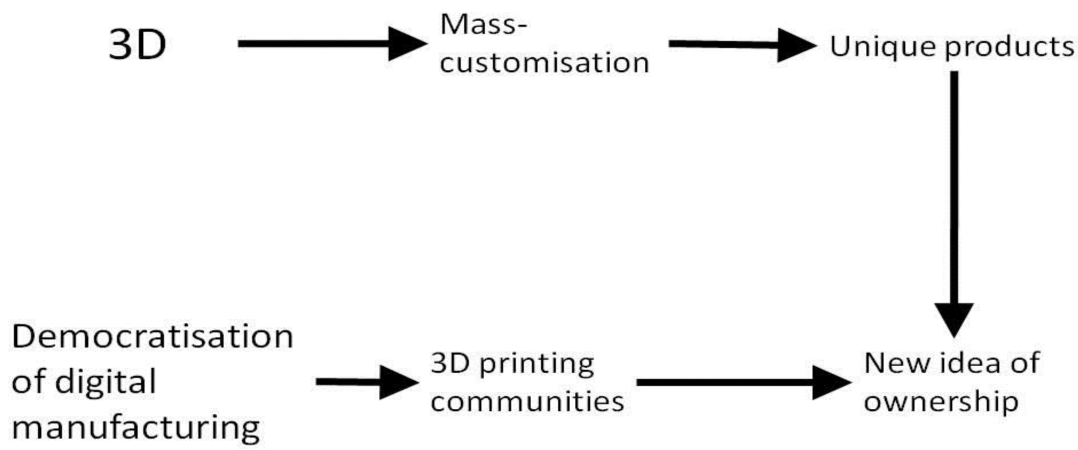

Figure 6.2 Expected impact on society

The economic perspective focuses on the direct and indirect impact of 3D printing on the labour component of manufacturing costs, as well as on the transformative impact of 3D printing on global logistics. According to the brief, 3D printing will reduce the share of labour cost in manufacturing to near zero. This will lead to a new global division of labour, as low labour-cost countries will lose their competitive advantage. As 3D printing diffuses more widely, low-skilled assembly and operational jobs will disappear in manufacturing. 3D printing will also have an impact on logistic costs, as production will be increasingly local. This will have a considerable impact on the shipping industry, although the overall effect is still unclear. As 3D printing requires digital models embodied in software, there will be major growth opportunities in tailor-made engineering and design services. This partial model is schematically shown in Figure 6.3.

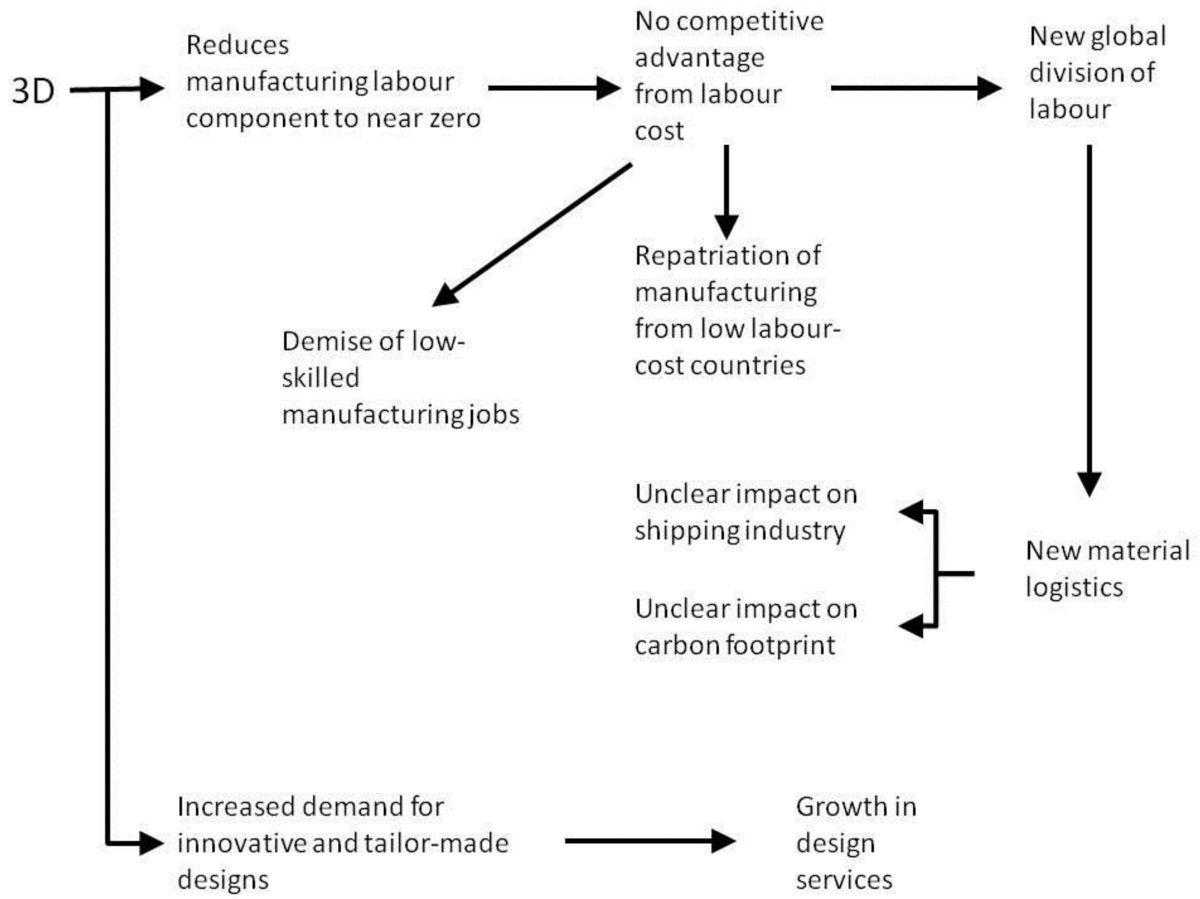

Figure 6.3 Expected impact on the economy

In addition to the social and economic perspectives, the brief discusses governance and policy issues, impact on the environment and the climate, and safety and security, including product liability issues. For these we refer to the original text.

The brief gives a very compact picture of some of potentially important implications of the rapidly expanding use of 3D printing. It does not try to provide a comprehensive analysis or detailed review of its topic. Instead, it essentially puts the theme of 3D printing on the agenda, highlighting it as a potentially important topic for further discussion and study. However, it also clearly shows that we use implicit models also when they are not made explicit. In contrast to most policy-related briefs, it is based on the work of a multidisciplinary team and it synthesises ideas from contributors that have different backgrounds and different perspectives. It is therefore interesting to reflect upon the generated models.

6.3. Reflection: issue dimensions and causal logics

The first question in all modelling efforts is what we include in and exclude from the domain under discussion and modelling. The brief uses five impact dimensions: society, economy, policy, environment and safety. Commonly used approaches in foresight studies and business environment analysis include the variations of the STEEPLE approach, where Social, Technological, Economic, Environmental, Political, Legal and Ethical dimensions of the external environment are analysed. Using this terminology, the brief uses a STEEP approach, with an added emphasis on safety and security, as well as on the governance dimension.

The description of technology trends adopts a view that developments in technology will lead to lower unit costs and lower cost of equipment. Recent decades have seen similar developments in particular in digital products and computing. This view, however, represents a rather deterministic model of technology development. Among innovation and technology scholars, the idea that technical advances drive economic change has been effectively contested during the last four decades or more. An alternative starting point would be that there is limited demand for unique products until the conditions for a new logic of production slowly emerge as a result of social, institutional and cultural change. According to literature on techno-economic transformations, new transformative multipurpose technologies generate over-optimistic expectations, and the materialisation of their productive potential often requires several decades.

An interesting possibility is that 3D printers can be used to produce components for 3D printers, creating a potentially viral dynamic of diffusion. This dynamic would still be based on a relatively straightforward technology push view, but it actually may resemble what we have seen in the last five decades in the software and semiconductor industries. In 2009, when the demand for 3D printers exceeded the production capacity of MakerBot Industries, it paid its customers to use their 3D printers to produce components for the printers.

A common problem with technology push models is that they are almost always historically wrong. The applications that will drive technology development are rarely what we expect them to be. The telephone, for example, was marketed for its first decades mainly as a broadcast medium, as well as a means to put children to sleep, and the social use of the phone was essentially invented by Midwestern American housewives some 40 years after Bell had his first telephone patent. In fact, although Bell's first telephone patent mentions that the invention can also be used to transmit notes and noises of all kinds, it was basically about a method to send two telegraph signals using the same copper wire. Since then, the telephone has been invented several times, and technologists have rarely been able to guess what the next driver will be.

6.4. Return of manufacturing to EU and the demise of manufacturing jobs: the argument

The partial models in the brief are short causal narratives that use a linear model of causality. It is therefore easy to extract the underpinning models as logical arguments. This makes it easy to locate possible structural problems in the models and pinpoint needs for further evidence.

A partial sketch of the argument about repatriation of manufacturing capacity to the EU is shown in Figure 6.4, where we use the online Agora-net mapping tool, developed to debate complex policy issues. Agora-net represents arguments as logical inferences that are derived from supporting premises, making premises and the logic explicit and open to collaborative debate.

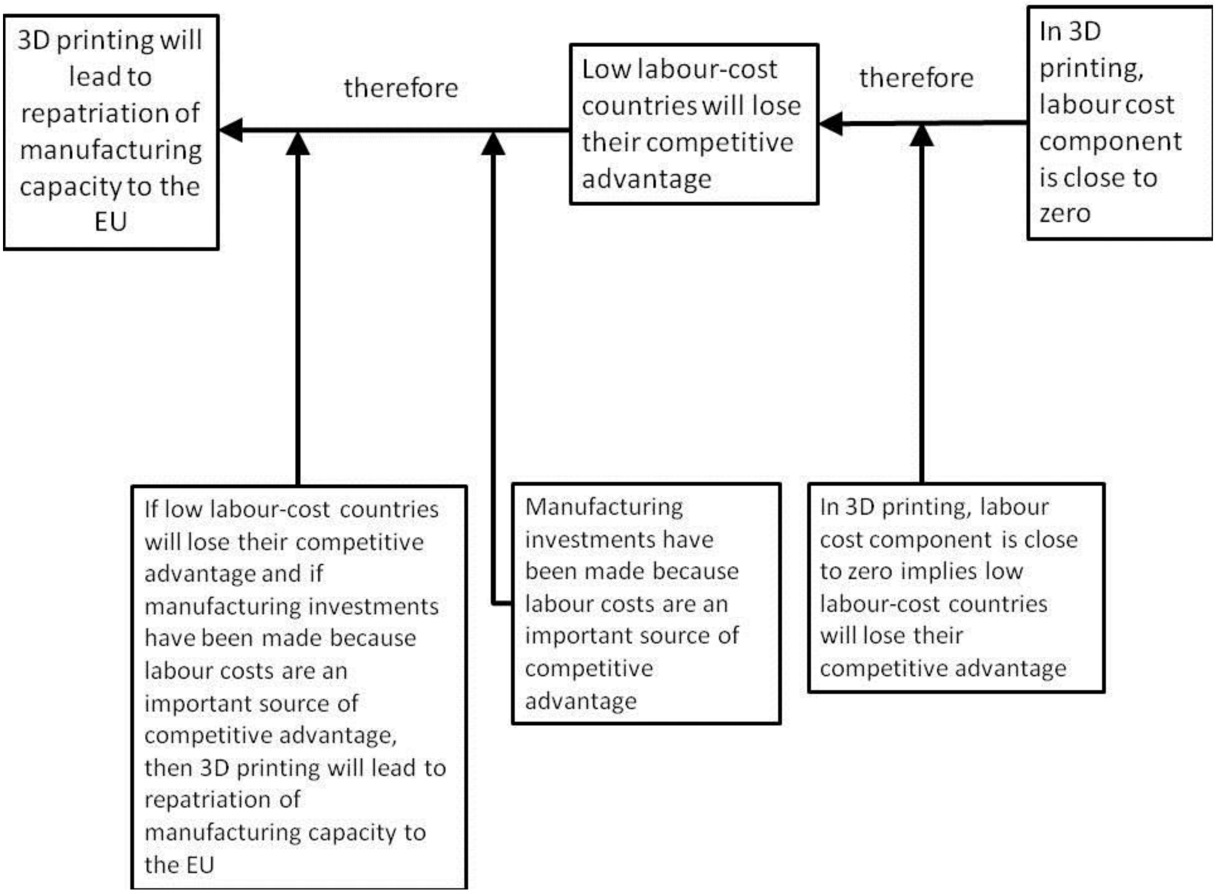

Figure 6.4. Repatriation of manufacturing: argument map

Using tools such as Agora-net, it is possible to make causal and inference models and their assumption explicit. For example, the brief expects that technical progress will lead to the production of increasingly complex goods at lower unit cost. This argument may look reasonable. It, however, is not the only possible one, and it could therefore provide an interesting departure

point for debate. Literature on mass customisation emphasises the importance of standard product platforms and promotes market segmentation as a means to increase prices. Manufacturing unit costs do not necessarily reflect product prices, as can be seen from the fact that some of the biggest mark-ups are on bottled water, perfumes and diamonds. In general, literature on disruptive innovation, technological paradigms and creative destruction points out that transformative technologies do not only change relative prices but also the underlying logic of production. Production unit costs are difficult to forecast also because many contextual things that are left out from the model influence relative costs. In Figure 4, argumentation could be added, for example, about the impact of possible expansion of conflicts in Europe and Arab countries, the decline of the middle-class associated with rising unemployment rates on both blue-collar manufacturing and programmable white-collar jobs and, for example, the impact of Ebola and superbugs on consumption, values and globalisation.

6.5. Three models of foresight

In general, foresight uses three different perspectives on causality. In probabilistic foresight, input change leads to a well-determined output. As we understand that models are partial, knowledge imperfect and surprises can happen, the future is framed in the context of expectations. The predictive models in natural sciences and the equilibrium models in economics both provide such probabilistic foresight. This model of anticipation also underpins our everyday action. It has been argued that such probabilistic foresight is a general capability for all living beings and that it, indeed, separates inanimate objects from animate beings. Even the simplest forms of life are based on internal models that can anticipate the consequences of action, and living systems, therefore, have been characterised as anticipatory systems.

Human beings, however, are also able to use narrative models of causality, where we rely on metaphors, analogues and prototypical storylines. In the narrative mode, listeners and speakers play on a field of shared expectations. Narrative causality, therefore, is highly culture dependent. Against the background of shared beliefs and context, a narrator can tell a story that makes sense.

This leads to a possibilistic model of foresight. Instead of aiming to predict the future and the impact of current developments, it aims at creating a richly structured and nuanced understanding of an issue at hand. A common method that uses this causal model is the scenario method. In scenarios, a small number of key dimensions are used to generate substantially different contexts where narrative stories about possible futures can be told. For example, scenarios of 3D printing futures could be based on different contexts created by separating possible worlds where the EU faces an era of a new cold war or where market-based globalisation continues without a break. Another possible contextual distinction could be made between worlds where production is based on the reuse of materials, or where production is based on renewable materials ([58]). These two axes of distinction would lead to substantially different settings where different stories about 3D printing would make sense. In a scenario approach, the dimensions that create different contexts are not about 3D printing, per se; instead they put the technology in a field of alternatives where it can have very different meanings and implications.

A third causal model underpins design-oriented foresight. Design-oriented foresight is influenced by innovation research that has highlighted the point that many key uses of technology are essentially invented by users and are unpredictable in the historical context. Innovation creates things that did not exist before, and often we do not have concepts at hand that could be used to describe what the innovation will become when adopted by its future user groups. Descriptive concepts, therefore, have to created and developed before possible futures and future impact can be discussed and analysed. This means that foresight becomes focused on active creation of futures instead of knowing and predicting them.

In the context of design-oriented foresight, we start from the assumption that we cannot yet really know what 3D printing is and what it will become. We are in the same position as Bell when he filed the first patent on telephone, missing the most transformative uses of the emerging technology, interpreting the future with concepts that made sense in the prevailing but disappearing context of telegraphy. Applying this design-oriented approach in 3D printing, we would aim to invent new ways this still unclear and ambiguous technology could provide progress and benefit for society. The aim of design-oriented foresight is not to know the future; instead, it is to generate new possibilities and opportunities that expand the space of policy design and implementation in substantial ways. From the traditional epistemic focus of foresight we move towards a more ontological view, where the future is actively created through well-structured imagination and experimentation.

([58]) 3D printed objects are now commonly made of plastics produced from corn starch and other easily available renewable and biodegradable materials.

The design-oriented view is partly justified by historical studies that have shown that when qualitatively new technical possibilities emerge, a large variety of product concepts are developed and experiments are done to figure out what the new thing is about and what its true potential is. After a period of intense experimentation, a dominant design emerges that subsequently becomes the practical definition of the new product category. At that point, the key product characteristics are clearly defined, and innovation can focus on process and product improvements.

Research on product cycles, disruptive technologies and dominant designs, however, highlights the point that technical trajectories can be used to predict developments only when a dominant design exists and innovation is dominantly incremental. Historical trajectories provide little guidance in important technological transitions. Digital manufacturing, 3D printers and the new division of labour between communication networks and production potentially represent such a transition.

6.6. Why 3D printing looks a big thing?

The case of 3D printing is also an illustrative case of why some ideas can rapidly become highly popular and well recognised among top-level policymakers. This question has been extensively studied in research on strategic sensemaking. We sometimes misinterpret critical information and use a wrong mental map, sometimes with fatal consequences ([59]). More generally, when we interpret strategic signals, we always use existing models to make sense of them. As Mircea Eliade described in his famous 'eternal return' (Eliade, 1991), the world becomes a meaningful place to the extent that it repeats cultural archetypes. We do not see pure facts or data; instead we see meaningful and interpreted facts and data (Tuomi, 2000). As a result, information that does not fit an archetypical pattern remains noise and is rapidly forgotten and replaced by invented facts that are known to characterise archetypical patterns. Organisational memory and collectively shared mental models therefore strongly amplify interpretations that fit an existing pattern. Because of this, they effectively filter out things that are new.

The current very broad publicity around 3D printing, therefore, also indicates that it fits well with a common model of progress, change and unfolding future. 3D printing is not anymore a topic for experts; instead, it is a daily topic in news media, popular books and policy discussions. An important factor for the viral diffusion of the idea that 3D printing will revolutionise the world is that we already know how such a revolutionary story would look. A salient key characteristic of the industrial age — the factory — is in this model combined with the ideas of individualisation and open communities on the internet, and these are wrapped up in a box on a desktop near you.

This viral combination of old and new drives cycles of hype. Because innovation can create things that did not exist before, such a viral dynamic, however, only captures essentially backward-looking aspects of the change. This is an important reason for the fact that future-oriented visions rarely capture things that we retrospectively can call critical or salient.

Rapidly diffusing ideas require a widely shared mental model. This does not mean that hype would be just an empty bubble. It means, however, that the dominant view on a viral idea tends to miss the key elements of the emerging phenomenon. The appropriate policy reaction to such a phenomenon, therefore, is not to dismiss it as hype or to make it an augur of the future. Instead, the appropriate approach is to reflect upon the model that has made the phenomenon popular and create a more refined model that captures some key aspects of it.

([59]) A classic example is the case of the Mann Gulch firefighting disaster analysed by Karl Weick (1993).

CHAPTER 7: FORESIGHT MODELLING FOR SUSTAINABLE TRANSPORT

Key points

1. Although transport is an activity fundamental to society, it is also accepted that it has negative impacts. The response of society so far is inadequate.
2. Technologies already available — renewable energy and biofuels for power, new vehicle configurations for improved energy efficiency — do offer the possibility for dramatic reductions in CO_2 and other emissions.
3. There are a complex set of influences on transport: lifestyles and culture reflect and reinforce urban form and transport intensive economic structures. This means that a broad, integrated systems approach is needed to develop policies to support sustainable mobility.
4. There are potentially multiple strategic benefits to European society and industry.
5. A foresight process is proposed with the objective of developing visions for the EU of a low-carbon transport future, identifying the possibilities for future developments and indicating areas for policy support. The process should be organised around a structured engagement of stakeholders.

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7.1. The need for a foresight process for sustainable transport

This chapter introduces sustainable mobility as a theme for a pilot foresight model and process. Although transport is an activity fundamental to society, it is also accepted that it has negative impacts. Dramatic reductions in emissions are necessary if climate change goals are to be achieved. Technologies already available — renewable energy and biofuels for power, new vehicle configurations for improved energy efficiency — do offer the possibility for dramatic reductions in CO_2 and other emissions. In spite of these technological developments, the response of society so far is inadequate to solve these problems.

Sustainable mobility is arguably one of the most difficult policy areas for the EU. Amongst very many studies, both national and EU, it was the topic of one of the United Kingdom foresight studies, Köhler (2006). The problem for policy is how to promote economic growth while reducing environmental impacts. Most policy analysis does not consider dramatic changes. This is not always necessary: for example, congestion and the associated pollution is a location- and time-specific problem which can be considerably reduced by conventional measures such as congestion charges (as in London), road pricing, fuel taxes, etc. However, achieving GHG emissions reductions of, for example, 60 % for the United Kingdom will require much more in the long run. Also, radical changes to the transport system cannot be implemented quickly. The current dependence of most countries on fossil fuel-powered road transport is a fundamental part of the way we lead our lives, and transport has long-lived, cost-intensive infrastructure. Lifestyles and culture reflect and reinforce urban form and transport-intensive economic structures. Therefore, a wide-ranging system approach that can identify issues in the different fields and propose policy for system transformation is required. In other words, a Concurrent Design Foresight approach.

There are further issues which are of major concern for EU policy, as indicated below.

Social and economic issues

The EU's automobile sector is one of the largest industrial sectors, with 12 million jobs and a turnover of EUR 500 billion. At the same time, it is part of a global, mature industry. Its competitiveness is therefore a major concern for EU policy. At the same time, road transport can be argued to be inefficient, as private cars are only used for 5 % of their lifetime.

Road transport has a high cost to society: 30 000 people die and 200 000 are injured per year on the roads of the EU. More than 100 billion hours are lost in traffic per year in the EU, representing a GDP loss of 1.5 %. There is a major environmental impact. Some 25 % of GHGs come from the transport, sector and there is also a high level of air pollution (gases and particles), contributing to 350 000 premature deaths from health impacts annually in the EU.

Multifaceted strategic benefits

These multiple issues mean that there is potential for multiple benefits to EU industry of strategic importance for EU policies to promote sustainable mobility. These include strengthening the competitiveness of the EU's automotive industry through helping the sector to anticipate existing trends. This involves supporting the development of new technologies and markets in the ICT sector, such as boosting hyper-connection within cars (telework, 5G communications), space-based services and supercomputing capacity for fleet management. A further aspect is support for automation and robotics: progress in man–machine interfaces or in autonomous decision-making

Potential societal benefits

There are also multiple potential benefits for EU society. In terms of sustainability, these include opportunities to boost recycling and the closed-loop economy. Equality of access to mobility may be improved for children and disabled and elderly people through such things as automated vehicles. A further change in the direction of sustainability could be a move towards a society based on sharing affordable mobility services and not on pure consumerism and (car) ownership.

Strategies for sustainable transport

Directed processes of change — transitions — to new forms of transport are required in terms of transport systems, the structure of the built environment and lifestyles and culture. This requires the consideration of how to initiate social and economic processes that will transform transportation. Policy must provide the direction and processes while realising that the ability to control outcomes in detail is limited.

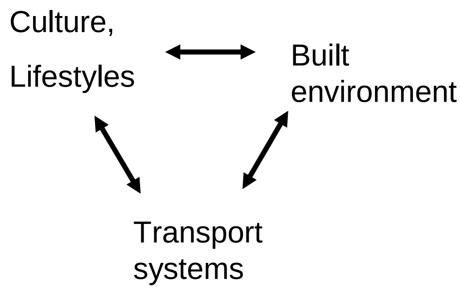
What is also needed is an incorporation of current transport scenarios into a vision of the future which describes societies and economies — ways of living, the built environment, leisure and culture. There is very little of this type of work that is carefully thought through. An important aspect of the limited time horizon of analysis and policy is that there are few plausible and specific visions of very low-emission transport systems. This makes it very difficult to create a debate about socially acceptable and politically feasible ways of achieving large-scale changes. This has the unfortunate consequence that policy measures to reduce either emissions or transport activity are often perceived to be unrealistic, because they are perceived to involve penalties on current behaviour that are unacceptable to large sections of society. However, it is important to note that transport policy has undergone a change in direction in many countries. Policies have (partly) moved from a predict-and-provide approach, where the objective is to build enough new infrastructure to meet future increases in demand, to attempts to restrict the use of motor cars. This moves policy into a much more difficult area, because it is trying to change the direction of transport behaviour instead of just following the trend of society.

This introduction demonstrates that if mobility can be changed to be sustainable, it will make a major contribution to EU society in many ways. However, this requires a transformation in the system of provision of transport to enable a break in the trend in which increased transport activity outweighs technology development for emissions reduction. Transport involves multiple social and economic systems, such that if effective policies are to be developed, a multidisciplinary systems approach that includes the lifestyle aspirations of EU citizens is necessary.

7.2. Structuring the theme

Figure 7.1 is a simple representation of the aspects of society leading to transport use. Lifestyles include mobility behaviours and these are reflected in the built environment. Transport systems are a part of the built environment and their use is also an expression of individual identity and culture. Therefore, in order to reduce emissions, the built environment, lifestyles and technologies must all be considered in a holistic analysis.

Figure 1 Influences on transport behaviour



The simple structure of Figure 7.1 is expanded in Figure 7.2, which adds two sets of factors that will have a decisive influence on future transport: changes in transport demand and new, ICT-based technological possibilities for the future.

These major determinants themselves have multiple aspects, a few of which are shown in Figure 7.2. The policy domain is not shown directly in Figure 7.2, because it potentially has impacts on all of these aspects, through for example town planning, innovation policy for transport or environmental policy for transport. Figure 7.2 shows the five main social/technical systems interacting with each other. These five main systems all consist of multiple factors interacting within each social system, but also with the policy domain. The issue of sustainable mobility is therefore structured as a system of systems, requiring the multiple disciplines to address issues ranging from lifestyles through transport economics and the structure of demand to automation.

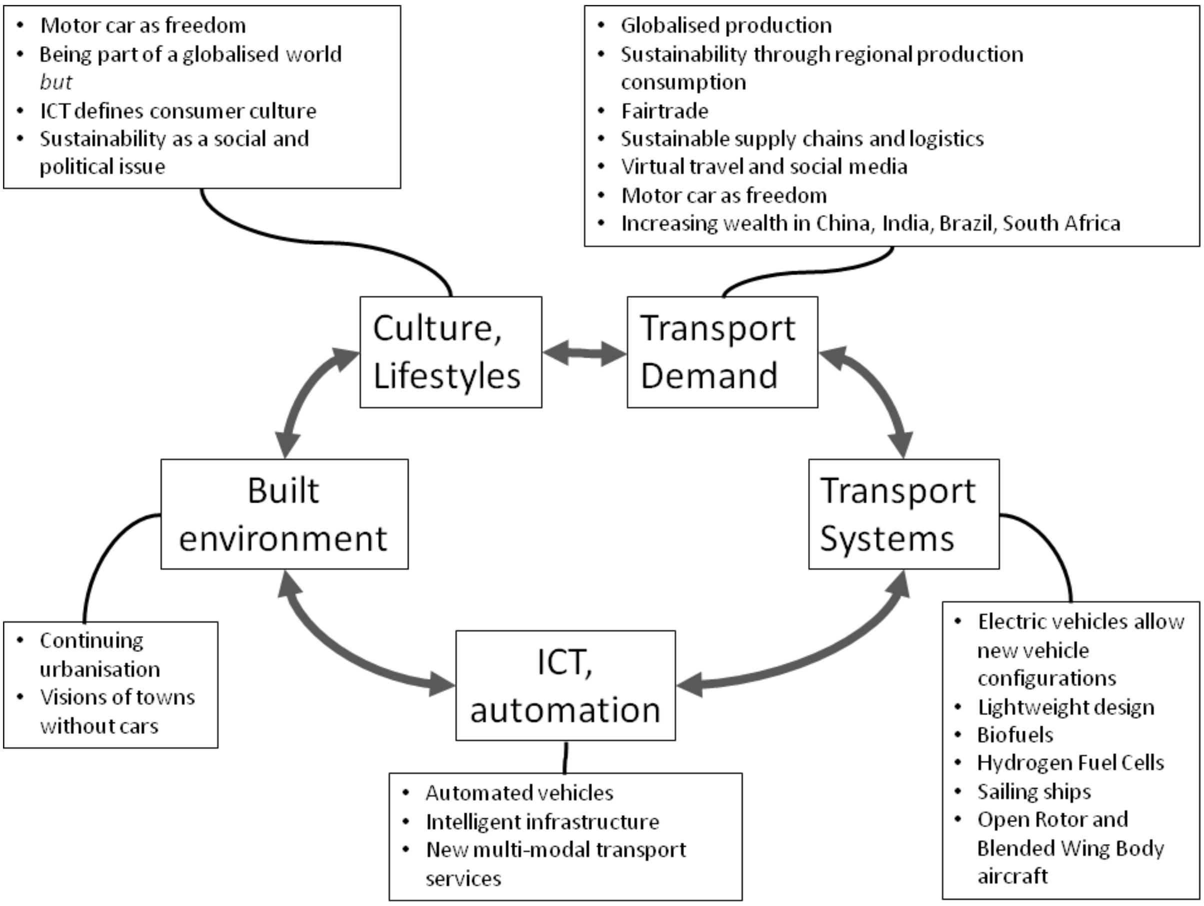


Figure 2 Determinants of future transport

7.3. A sustainable transport foresight activity

This discussion shows that this is a very important and also suitable topic for a foresight modelling process. The theme of sustainable transport is a major concern in both EU policy and innovation in the Union, relevant to major sectors of the EU economy. It concerns multiple interrelated aspects of society. It is also a major element of lifestyles and consumption and has major impacts on social well-being. It is a complex, many-faceted problem, involving normative social choices as well as engineering developments.

A foresight process is proposed with the objective of developing visions for the EU of a low-carbon transport future, identifying the possibilities for future developments and indicating areas for policy support. The process should be organised around a structured engagement of stakeholders, including from civil society.

7.3.1. Protocols of stakeholder engagement

Stakeholder engagement is a practice that has got traction in the last 10 years, especially in advanced democracies. Citizens and intermediary bodies expect to have a greater say in the decisions that affect their lives and future, especially in the long run. However, this is more than consultations on decisions or options already designed by the experts. These consultations tend to leave people frustrated and tend to be comfortable ground for lobbyists only.

A genuine stakeholder engagement is an open process with an open agenda. Questions and answers on the chosen issue are defined by participants. There are several well-known cases. They span from the citizen assembly set up in Iceland after the financial meltdown in 2011 to redraft the national constitution, to the open consultation run by the Italian minister for regional development to redesign public transport in rural areas, combining big data and town hall-like meetings with local communities. The field is not really codified yet. It is still practice in the making.

However, we can identify a set of principles and steps for a genuine stakeholder engagement that increases expertise fed into the process, and fosters its legitimacy with all the stakeholders in the community.

It starts with a learning phase. All the members involved in the process — elected, selected and chosen by lottery — receive training in the issue(s) in question. In this phase members learn about the options and hear arguments from experts and interest groups. They are free to raise questions and seek further guidance. A team of experts — better a mix of local and non-local — provides the training with the support of facilitators. The choice of the experts is a challenge and can influence the path. Experts should represent a wide variety of forms of knowledge, i.e. not just academic/technical experts but also experts from creative industry such as artists, designers and innovators.

Then a public hearing phase follows: the members attend public meetings and engage with all stakeholders. An online platform should allow everybody to feed into the process with all possible media — not just in writing — for instance telling stories, role-playing, drawing and animation. Different people are comfortable expressing themselves with different media.

However, the internet should not be deemed the only medium for mass participation. For instance, in Glasgow 2020 — a project of civic participation to imagine the city of the future — the wish campaign invited people to make a wish for the kind of city they wanted in 2020. Freepost postcards were distributed in public buildings around the city — people could write their wishes on the postcards and send them back.

Finally, in the deliberation phase, the members reflect upon and summarise all the inputs, consider the options and reach decisions. Even this phase requires the support of facilitators to consider the implications of different decisions.

All stages of the process have to be transparent and possibly recorded, with the records accessible online, and supported by facilitators to ensure that all voices are heard.

It is better to know in advance that this is a time consuming process for all participants. Something between 6 and 12 months is normally required. This is not a method for all situations, especially when a quick decision is demanded. Forcing the speed of the process could seriously undermine its legitimacy, and therefore its purpose.

Moreover, the most challenging and delicate part of the process is striking a balance between citizens and experts. In principle citizens should focus on values and end goals, and leave to experts the decisions on the possible and adequate means. Ideally, citizens, adequately informed, will give final validation to the decision on the means.

7.3.2. Foresight modelling for sustainable transport

A foresight modelling platform will support the process with both numerical and non-numerical analyses. Workshops with stakeholders will develop a system map of the problem field, with social and technical system elements and their positive and negative feedbacks over time. An exploratory analysis will develop scenarios of technological change and potential environmental and social benefits. The structure of the modelling will be developed as part of the process. It will start from the system map and employ current data for an initial calibration.

Chapter 8: Conclusions and recommendations

Policy challenges such as maintaining the competitiveness of EU industry or climate change have to be addressed in combination with changes in social and economic systems. To grasp the opportunities, policymaking needs to be integrated across traditional policy silos. Foresight in the EU should enable the integration of policy development to meet such challenges. It can thus help policymakers to expand their space of opportunities and options.

It is a tool to keep the future as an open space for policy development. This includes modelling and, as the recent STAC report concludes, 'the Commission needs multidisciplinary foresight activities, including modelling and simulation' (STAC, *The future of Europe is science*, October 2014, p. 19).

Foresight needs to be properly embedded into decision-making, both in process terms in the different phases of decision-making and in structural/organisational terms as a network across policy areas. Sensemaking functions which not only analyse the issue but also come to a common understanding of possibilities and goals are the weakest part of strategic policymaking activities in the European Commission. Foresight modelling should be particularly directed at supporting these sensemaking activities.

The fast-changing and complex nature of many future challenges requires faster, more experimental and more adaptive forms of foresight processes. It requires a transdisciplinary, multi-stakeholder system-of-systems analysis. Expert and stakeholder participation and public engagement are increasingly important to draw on a broader pool of knowledge, to mobilise action and enhance the legitimacy of foresight results. The expert group recommends that innovative foresight structures and models for analysis are necessary to meet these goals. Concurrent Design Foresight and modelling can be such a tool, delivering agile and adaptive foresight processes as a part of policy development.

Concurrent Design Foresight requires models for anticipatory learning to support the rapid development of alternative future scenarios as a part of foresight processes. These include qualitative analytical models as well as numerical simulation models. Such models are not currently available for foresight in the European Commission. There will be no one model or even type of model that is suitable for all foresight activities. Therefore, what is required is not a single definitive foresight model for the EU, but rather a platform that supports Concurrent Design Foresight through both non-numerical and numerical modelling.

The recommendation of this expert group is that the European Commission should develop a platform for analytical modelling to support Concurrent Design Foresight.

To initiate the development of such a capability for the new EU foresight activities that are being developed, the expert group proposes a pilot foresight process and modelling activity to address an important current policy issue. While other topics could be investigated, sustainable mobility is considered to be particularly suitable for a pilot study because the theme of sustainable transport is a major concern in both EU policy and innovation in the EU, relevant to major sectors of the economy. It concerns multiple interrelated aspects of society. It is also a major element of lifestyles and consumption and has major impacts on social well-being. It is a complex, many-faceted problem, involving normative social choices as well as engineering developments. Furthermore, there is a rich variety of assessment and data already available.

A pilot Concurrent Design Foresight modelling platform and process is proposed, with the objective of developing visions for the EU of a low-carbon transport future, identifying the possibilities for future developments and indicating areas for policy support.

The platform for modelling should be developed as part of the process, with functionality to support the process by using different foresight methods — visualisation and conceptual mapping tools and also numerical scenario analysis using a simple simulation tool. This pilot activity should undertake a non-numerical conceptual modelling exercise to determine the issues and necessary sociotechnological systems to be considered. The development of visions of sustainable transport futures should be supported by a simple numerical simulation tool. These non-numerical and numerical analyses should be based on a participatory process to build explorations of alternative futures for sustainable transport.

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This report of the Expert Group on integrated strategic foresight modelling aims to provide advice on how to develop a modelling tool that can integrate knowledge and data from forward-looking activities like foresight, in a transdisciplinary manner that could be used by policymakers.

Forward-looking activities have the potential to explore issues via a systems-thinking approach. Integrating the available knowledge into such a system approach requires the development of integrated foresight methods. Such methods can support the Commission in its efforts to enhance the quality of evidence-based policymaking. These methods can proactively identify future policy areas and develop an inclusive agenda for research and innovation that reflects changing societal needs and aspirations.

The report considers the current foresight structures employed in the Commission and related institutions, and reviews current ideas about foresight processes for policy development. Concurrent Design Foresight is proposed as a concept that offers the necessary breadth of approach, the ability to allow for conflicting interests and opinions, and the ability to react quickly and in response to the needs of policy development.

The expert group concludes that policymakers would benefit from a platform that supports Concurrent Design Foresight, enabling real-time interaction with stakeholders through both non-numerical and numerical modelling. The expert group therefore recommends that the Commission develop such a platform.

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