Sustainability Scenarios for a Resource Efficient Europe

Final Report for the European Commission (DG Environment)

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Executive Summary

Context and scope

- The Europe 2020 Flagship Initiative "Resource efficient Europe" aspires "to support the shift towards a resource efficient and low-carbon economy that is efficient in the way it uses all resources”. It requires that the EC works to establish a vision for change by 2050.
- A vision must be owned by the organisation that will be promoting it, and this requires it be developed and debated internally. This study, carried out by Cambridge Econometrics, Sustainable Europe Research Institute (SERI) and Wuppertal Institute (WI), *assists* DG Environment as it develops the vision and *does not* provide the final vision itself. The scope of resource efficiency is vast; the scope of this project is limited to the resource domains of material use, energy/climate, land use/biodiversity and water.
- Specifically, the study
  - Suggests key elements for the overall vision, including targets
  - Suggests broad policy initiatives through which the elements of the vision could be achieved
  - Recommends modelling approaches through which potential policies aimed at achieving the vision can be assessed and progress can be measured.

Key elements for the vision

Headline vision

- There already exist many visions and scenarios for achieving resource efficiency, many of which share key features. Drawing on these, an overall vision for the EU could be summarised as ‘*dematerialisation, climate protection and rich biodiversity*’. Central to these visions is that strong de-coupling of economic growth from the use of renewable and non-renewable materials, water, land and energy has been achieved. This in turn brings other benefits, including the flourishing of biodiversity and negating the tradeoffs between reducing resource use and achieving growth.

Table 1: Key features of a headline vision for sustainability

KEY FEATURES OF A HEADLINE VISION FOR SUSTAINABILITY
The vision: Dematerialsisation, climate protection and rich biodiversity
Strong decoupling of economic growth from use of resources.
This leads to
- Living within the carrying capacity of the planet
- Biodiversity is well managed enabling it to flourish to the benefit of economies and societies
Headline targets
Primary material and energy use reduced by 80% by 2050
EU GHG emissions 80-95% below 1990 levels by 2050
Water abstraction to below 20% of available water
Further loss of worldwide biodiversity is halted by 2020

Visions for different resource domains

Vision for material use

The vision for material use can be summarised as '*steady-stocks society, balanced bio-economy and zero waste*'. Strong decoupling of economic growth from the use of materials leads to a reduction in material use. This in turn results in lower levels of waste, and waste and virgin material use is further reduced through re-use, recycling and improved design. Environmental fiscal reform and reformulation of accounting practices and financing mechanisms help bring it about.

Table 2: Key features of a vision for material use

KEY FEATURES OF A VISION FOR MATERIAL USE
The vision: steady stocks society, balanced bio-economy and zero waste Strong decoupling of economic growth from renewable and non-renewable materials results in a reduction in overall material use. There are no further increases in man-made physical stocks. This is enabled by collaboration, innovation and knowledge sharing.
Headline targets Absolute reduction in overall resource use of 30% by 2020 and 80% by 2050 Increases in total material productivity of around 5% pa Increases in the share of secondary metals in total consumption of metals Net imports of biomass to the EU reduced to zero by 2030
Possible policy actions Revenue-neutral environmental fiscal reforms Reform accounting standards to integrate positive and negative externalities of activities Develop innovative financial mechanisms that focus on longer-term sustainable investments Promote research and technology development and innovation

Vision for energy and climate

The vision for energy and climate can be summarised as '*energy-efficient and renewable-based low-fossil-carbon economy*'. Europe achieves a secure and sufficient supply of low-carbon energy, in part through substantial improvements in energy efficiency. An effective ETS and a global carbon price are important policy actions to bring this about, as is improved access to information which brings about changes in behaviour.

Vision for fresh water

The vision for fresh water can be summarised as '*circular water use and water engineering in harmony with ecosystems*'. Water demand management is in place to ensure appropriate allocation of water resources to users and the environment, taking a river basin perspective. All bodies of water have good ecological status or potential and their long-term stability is ensured. Key policy initiatives include transparent regulatory frameworks and pricing, knowledge transfer and implementing a global dimension to water governance.

Table 3: Key features of a vision for energy and climate

KEY FEATURES OF A VISION FOR ENERGY AND CLIMATE
The vision: energy-efficient and renewable-based low-fossil-carbon economy A secure and sufficient supply of low-fossil-carbon energy is achieved Increases in energy efficiency result in an absolute reduction in energy consumption
Headline targets In 2050 GHG emissions including emissions embodied in EU trade fall to at least 80% of 1990 levels Renewables account for 20% of EU energy by 2020 and 80-95% by 2050 By 2020 energy efficiency is 20% higher than in 2000, and 80% higher by 2050 Net imports of biomass reduced to zero by 2030
Possible policy actions Ensure effectiveness of the ETS Establish a global carbon price Use higher energy taxes and parafiscal levies to reduce consumption Encourage lifestyle and production changes Improve availability of information on energy consumption

Table 4: Key features of a vision for fresh water

KEY FEATURES OF A VISION FOR FRESH WATER
The vision: circular water use and water engineering in harmony with ecosystem Comprehensive water demand management including all major users is in place to ensure proper allocation of water to users and the environment The long-term stability of freshwater bodies is ensured and negative environmental actions stopped Water management is based on a river basin perspective Member states take account of the principle of recovery of costs of water services, including environmental, ecosystems services and resource costs
Headline targets for the EU Net imports of embodied water reduced to zero Abstraction is below 20% of available renewable water resources All bodies of water have good ecological status or potential by 2015 Net imports of biomass reduced to zero by 2030
Possible policy actions Integrating the principles of integrated water management into water governance Improve efficiency of other factors of production to increase water productivity Provide stable and transparent regulatory frameworks Ensure water pricing acts as an incentive for long-term sustainable water use Pursue global dimension of water governance

Vision for land use, soil and biodiversity

The elements of the vision for land use, soil and biodiversity comprise '*sustainable human land use, stable soils and flourishing eco-systems*', with more diverse land management practices the norm, ecosystem services valued, maintained and enhanced and the increase in built-up land stopped. Better valuing of ecosystem services (also for their inherent biodiversity value), an expansion of protected areas (both land and marine) and improved forest management are possible policy initiatives that would help bring this about.

Table 5: key features of a vision for land use, soil and biodiversity

KEY FEATURES OF A VISION FOR LAND USE, SOIL AND BIODIVERSITY
The vision: sustainable human land use, stable soils and flourishing eco-systems
The management of land as a limited resource has improved, supporting biodiversity
Biodiversity is better managed
Use of agricultural land is limited and biofuels production is limited, and does not require land suitable for food crops, either within or outside the EU. Intra-EU improvements of land use and quality are not linked to deterioration elsewhere.
Expansion of built-up land has been stopped
Headline targets for the EU
Reduction of EU's global land use to its fair global per capita share by 2030
Net increase in built-up land reduced to zero
Net land conversion through urban sprawl, road infrastructure, mining etc reduced to zero
Nutrient balances in soils are stabilized
Possible policy actions
Preservation of biodiversity and ecosystem goods/services is mainstreamed in international policy fields
An EU sustainable spatial planning policy is in place by 2020
Expansion of protected areas on land and sea
Monitor global land use
Reduce post-harvest losses in the food chain
Provide disincentives for further urban sprawl through active spatial planning and revitalising urban centres

Prospective synergies in the pursuit of the domain-level visions

- The four material domains are clearly not isolated from one another. We anticipate that positive actions taken in one domain will on the whole provide favourable impacts for other domains. In other words, the visions may be implemented synergistically. The main interlinkage where the effect of improvement in one domain may lead to a trade-off in another domain unless the vision is fully-realised is between energy and land use through the pressure that biofuels could place on land use. Therefore, in this case in particular policies are required to ensure full scope of the vision.

Table 6: Key relationships between domain-level visions

KEY RELATIONSHIPS BETWEEN DOMAIN-LEVEL VISIONS					
	Secondary domain being influenced				
	Materials	Energy	Climate	Water	Land use/biodiversity/soil
Primary domain					
Materials		Synergistic	Synergistic		Synergistic
Energy	Synergistic		Synergistic	Synergistic	Trade-off
Climate				Synergistic	Synergistic e
Water		Synergistic	Synergistic		Synergistic
Land use/biodiversity/soil	Synergistic		Synergistic	Synergistic	

The vision assumes a global context

- In many areas, the EU-level visions are in some way dependent on a particular global context. For example, the overall vision rests on the assumption that global action is taken so that global warming is limited to below 2°C. There is also a further interdependency in that the EU will influence global targets. Examples from other domains include:
  - Millennium Development goal 7: providing 1.5bn people with access to improved water supply by 2015
  - further loss of worldwide biodiversity is halted by 2020

Visions for specific economic sectors

- The study also considers what a resource-efficient vision may involve for particular key sectors.

Construction and housing

- The vision can be summarised as '*resource-light, energy-efficient buildings built using closed resource use cycle through re-use, renovation and urban mining'*. This vision helps support the visions for resource use (net increase in stocks through reuse of resources), energy (energy-efficient homes to reduce energy consumption), water (as with energy) and land use (reducing expansion of sealed land, reducing need for road infrastructure and reducing resource extraction and construction and demolition waste disposal).

Agriculture and food

- A vision for agriculture within the context of the material-level visions is '*low-impact agriculture produces health diets*'. It links to materials (reducing biomass waste, in particular farm to fork), energy/climate (improving energy efficiency, changes in diet, reduced livestock farming and associated emissions, elimination of import of biomass as feed), land use (increased productivity and changing diets lowers need for land and materials/nutrients), and water (changing practices to lower use of water). The feed conversion efficiency in animal production is significantly improved and so has animal welfare benefits. Fish stocks have regenerated through a strong control system of fish catches and an absolute reduction of fish consumption.

Industry and manufacturing

- The material-level visions lead industry and manufacturing to be *'dematerialised services-based, closed-loop industry'*. This links to material use (dematerialised products, re-engineering to design for sustainability including repair, reuse and recycling), energy and climate change (energy-efficient products and production processes reduce energy demand).

Transport and mobility

- A consistent vision for transport is summarised as '*safe, land and material-efficient, low-carbon and low-volume transport*'. It links to energy and climate change (reduced road transportation reduces energy demand, greenhouse gas emissions and air pollution), land use (reducing need for new transport infrastructure diminishes land-cover change) and material use (reducing demand for transport infrastructure and equipment reduces use of metals and other materials).

Modelling to support the resource-efficiency initiative

Existing modelling tools can assess key elements of the comprehensive sustainability strategy, but do not work within a single framework

- Quantitative analysis has a vital role to support the development of a vision and in developing policy actions through which to achieve it. There are a wide variety of tools already available and these do allow all of the individual elements of the sustainability vision to be modelled. However, there is considerable variation in the number of existing models covering each domain; for example, there are many different energy models but relatively few models focusing on material use.
- The main deficiency that existing models have is that they are limited in assessing all the key elements of a comprehensive sustainability strategy or vision within a single framework. This means that the key linkages between resource types are largely missing. Also, although economic links to the resource domains generally exist, the feedback links from the resource to the economy are much more limited, if present at all.

Developing a comprehensive framework will require linking different models

- Figure 1 sets out the sort of comprehensive framework needed to model all the key elements of a sustainability scenario in a systematic way. We do not see the framework comprising of a single integrated model but rather involve the linking of different models in such a way as to allow the complexity with which the interactions between the domains are considered to remain relevant to the scope of the analysis. We identify four key ways to achieve this.

Establishing a state of art in modelling material demands

- The linkages between the economy and energy demand are well understood and are common in economic models. It is important that the treatment and status of modelling material demands becomes to be seen in the same way. Work is underway, but a state of the art in modelling material demands needs to be established and expected on the part of policy makers. It can draw on practices and concepts already used in energy modelling.

Flexible modular specifications

- Central to the framework is a representation of the economy that links suppliers and users of resources. Disaggregation (sectoral and resource) should provide as much detail as can be reasonably supported by the available data. There are grounds for enhancing the treatment of some key sectors through a more specialised approach. Examples of where this already happens within more partial models, include energy supply (identifying individual power stations), transport (different modes are more detailed than identified in economic data), agriculture and water use. Others, such as construction, cement or steel production, could be added (marked in grey in Figure 1). So, economic models should move towards a modular position where specific and detailed treatments of key sectors can be brought in and out according to the requirements of the analysis, while not leaving oversight and developing the capacity to detect problem shifting between sectors.

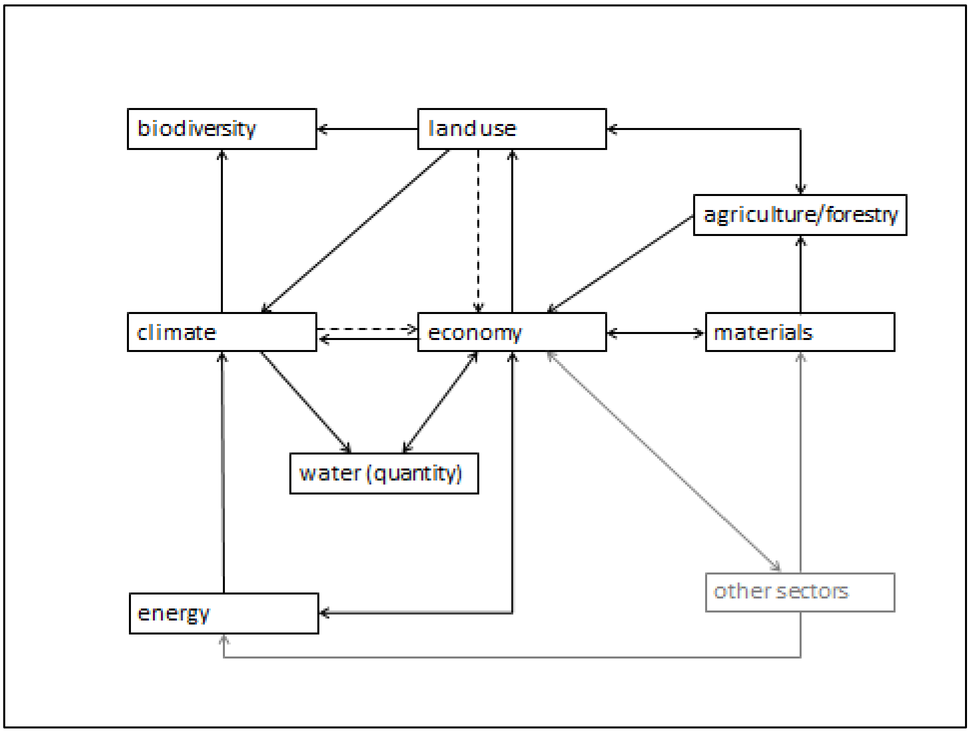
Achieving a common interface for linking models

- There are a number of linkages between resource domains and the economy that do not involve economic transactions and are not well-covered in existing models. It may be possible to link different models to overcome the difficulty but the links are often difficult to define. It may therefore be advisable to develop a common interface for linking models focused on different resource domains via an interface through which model operators and their tools are able to communicate using a common language.

Further understanding of linkages from the environment to economy

- Finally, there are linkages between the resource domains that are not commonly found in existing tools, if found at all. Key omissions are the links from land use changes and climate back to the economy. Their omission reflects the limited understanding of the nature, direction and strength of these linkages. The ultimate aim should be the linking of a key set of environmental pressure indicators to a set of detailed economic sectors. Achieving this will require a research programme focused on developing an understanding of how future changes in the supply of resources will affect economic performance.

Figure 1: A Comprehensive Framework for modelling Resource Efficiency



1 Introduction

This report presents the findings made in the project *Sustainability Scenarios for a Resource Efficient Europe.* The project focuses on one of the priorities of the Europe 2020 Strategy[1], that of achieving sustainable growth by increasing resource efficiency. The project aims to build a vision of an environmentally sustainable Europe in 2050 and to develop appropriate scenarios that describe the pathways to meet this vision.

1.1 Project objectives

The specific objectives of the study are to:

- identify and analyse sustainability scenarios for the global and European economy with a horizon of at least up to 2050, identify how resource efficiency issues have been addressed in these scenarios and compile the basic or common storylines
- identify and provide a comprehensive overview of the baselines used in these scenarios as well as the assumptions prevailing about the key underlying variables used in modelling, and the assumptions made about entering new variables in models
- identify the parameters that could be part of a vision for a resource efficient EU by 2050, put up the elements needed for constructing such a vision within the basic scenarios and identify the models or model suites that would be appropriate to use in a modelling exercise
- assess the scale of cross-cutting policies and how they have been and could be addressed within scenario building and modelling exercises

1.2 Structure of this report

The report is structured as follows:

Chapter 2 presents the results from the first task of the project, which identified and gave an overview of existing sustainability scenarios.

Chapter 3 similarly provides the results of the second task. This identified the key elements of the basic scenarios that will describe the path towards a resource efficient Europe in 2050.

In Chapter 4 details of appropriate models that could be used for a selection of resources are provided. Short introductions and descriptions are given, along with the linkages between the models and the links the models have with the economy. Lengthier descriptions of all the models are given in Appendix B.

Chapter 5 provides some conclusions for the project as a whole.

Appendix A provides details of the discussion that took place at the project workshop, including representatives from the European Commission and external workshops.

Appendices C and D provide further details of the scenarios and the factsheets that were used to assess them[2].

[1] See: http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf

[2] These appendices are provided in a separate document.

2 Identification and Overview of Available Sustainability Scenarios

2.1 Identification of available sustainability scenarios

Overview The first phase of Task 1 of the project aimed to identify scenario-based forward-looking studies prepared by research institutions, international organisations, governments, think tanks, NGOs and business sources that deal with natural resource use and resource efficiency. Together with own web searches, existing catalogues of scenario studies (EEA 2007, EEA 2011a) were parsed for fitting studies. Some studies published in languages other than English were included when they were particularly relevant. The selection criteria were geographical, temporal, and thematic:

- geography: the European Union, or system boundaries including the EU (e.g. global) or included in it (e.g. a Member State)
- time horizon: from 2020, with a preferred horizon of 2050 and beyond
- theme: natural resources

In the context of this project we define natural resources as materials (metals, fossil fuels, minerals, biomass), freshwater, and land, soil and biodiversity. It should be noted that this list does not cover the entire definition of natural resources as presented in the Thematic Strategy on the Sustainable Use of Natural Resources: flow resources such as wind, geothermal, tidal and solar energy, and resources when used as sinks that absorb emissions (soil, air and water) are not considered. In general, energy as a "resource" is not a focus of this project, since it is addressed via material (e.g. fossil fuels or metals for technologies harvesting flow resources), water and land (e.g. land use change associated with biofuel production).

Appendix C (in a separate file) shows the resulting list of 30+ scenario-based studies. Each item of the list is presented as a brief overview of the corresponding study, covering its main characteristics:

- type (e.g. forecasting vs. backcasting[3])
- geographical scale
- temporal scale
- resources covered
- influencing factors—such as drivers and trends (EEA 2011b)
- reference and link to the original publication

A selection of these studies was then reviewed in more detail (see below).

2.2 Detailed review of available sustainability scenarios

The second phase of Task 1 aimed to analyse more thoroughly some of the scenario-based studies identified in Section 2.1 and presented in Appendix C. Some 10+ studies were selected so as to cover all resource themes: materials (metals, fossil fuels, minerals, biomass), freshwater, and land, soil and biodiversity.

[3] In EEA (2011a), forecasting studies are called "exploratory" and backcasting studies are called "normative" studies. Both can be quantitative or qualitative.

The selected studies were reviewed according to a common framework to improve comparability and the results are presented in factsheets that also follow a common template. These factsheets[4] can be found in Appendix D (in a separate file).

Reviewing the studies

The common review framework—and hence the resulting factsheets—is divided in two main components: a 'key assessment' and a 'detailed review'. The former addresses the characteristics of the study that are deemed most relevant[5] for Chapter 3 where visions, targets and political actions for a resource efficient Europe 2050 are proposed. The scenario elements presented under 'key assessment' are as follows:

- visions and targets: the former are rather qualitative and long-term, the latter quantitative and short to long-term
- policies: this item concentrates on policies explicitly tested in the scenarios
- resource efficiency: beyond resource use, is resource efficiency characterized or measured, and how?
- cross-cutting issues: this item considers problems of shifting environmental pressures between categories of resource use
- burden shifting: this item considers problems of shifting environmental pressures between geographical regions

The 'detailed review' complements the 'key assessment'. It analyses the underlying construction of the study and its scenarios from the perspective of the categories of resource use. The following elements are considered:

- geographical scope, temporal scope, resources covered
- environmental impacts considered: in terms of the usual environmental impact categories (climate change, acidification, eutrophication, human and eco-toxicity, resource depletion)
- economic scope: economic sectors or activities included in the scenarios and/or modelling
- influencing factors: drivers and trends of future environmental change in the scenarios and/or modelling
- modelling: here the models used are cited only, Chapter 4 goes into more details to describe available models
- scenarios: business-as-usual or baseline scenarios, as well as the alternative scenarios are described, the assumptions regarding the influencing factors are detailed—if known, scenario outcomes in terms of resource use and resource efficiency are presented

If applicable, any of the items in the 'key assessment' or 'detailed review' presented above can be differentiated by category of resource use. This focus on resources differentiates the factsheets produced within this project from those produced using other templates, although there are of course similarities (e.g. EEA 2011a).

[4] The image at the beginning of each factsheet was produced with the "word cloud generator" Wordle (www.wordle.net) from the 100 words most frequently used in the reference report for the scenario study considered (excluding common English words). It fulfils an illustrative purpose only.

[5] According to the original project specifications and the discussions during the inception meeting.

3 Identification of the Key Elements of the Basic Scenarios

3.1 Introduction

This chapter summarises the key elements of existing sustainability scenarios with regard to resource efficiency. The main goal is to support the European Commission in developing a vision for a resource-efficient Europe. The key elements described can form the basis for deriving comprehensive resource efficiency scenarios and related modelling exercises.

The first part of the assessment (Section 3.2) describes the methodology adopted in reviewing the literature on resource efficiency scenarios and policies. The second part (Section 3.3) describes overarching, headline visions and targets across the different categories of resource use. The third part (Section 3.4) provides information on economy-wide aspects in different categories of resource use, such as materials, energy/climate, water and land use. The fourth part (Section 3.5) informs on specific production and consumption areas with key importance for achieving a resource-efficient Europe:

- construction and housing
- agriculture and food
- industry and manufacturing
- transport and mobility

The chapter closes with an overview of the studies reviewed for the selection of identification of the key elements of the basic scenarios (Section 3.6).

In order to avoid overloading the readers of the report with text, the findings are presented in a "fact-sheet style" that provides the visions, targets and proposed policy actions to achieve the vision in a compact format.

3.2 Methodology for selecting visions, targets and actions on resource efficiency

Scope of the literature review

The report is based on a review of sustainability scenarios at the national, European and global levels and studies analysing resource efficiency as well as recent Communications from the European Commission. The thematic focus of the review was resource efficiency. Toxicity, pollution and similar environmental impacts – while relevant to consider with regard to the impacts of resource use – are not analysed, as they are not directly linked to resource efficiency. The full list of studies considered in this report is found in Appendix C.

Selection of visions

The visions in the different topic areas of resource efficiency include elements of existing visions, which may not always be complementary. Therefore, this report does not present self-contained visions but a selection of key elements which may be part of a vision for a resource efficient Europe at the level of economy-wide resource use and resource efficiency as well as with regard to specific material and resource intensive sectors. Similar vision elements from different scenario studies were aggregated, and complementary elements were integrated, so that there is no exact correspondence between the scenario elements described below and the scenario-based studies presented in Chapter 2. Section 3.3 comprises 'headline visions', which were identified as key elements in different studies and scenarios of resource efficiency. The vision elements are always written from a perspective of 2050, i.e. reporting what has happened in the decades between 2011 and 2050 in backward looking terms.

Selection of targets

Not all the studies reviewed mentioned reduction or efficiency targets. Some of the studies propose visions along the lines of an absolute decoupling of primary material use from economic growth with primary material use decreasing in absolute terms. Some also use CGE or econometric models to test political and economic instruments that could trigger an absolute reduction of primary material use. However, it was not within the scope of all these studies to propose a quantitative reduction in resource use or an efficiency target. Most targets proposed in these studies are more general and illustrative rather than functional, i.e. they are not calculated from what the quantitative evolution of clearly defined indicators should be so that the vision comes true. Therefore, we have also turned to recent scientific literature to cite quantitative targets in relation to the vision. As the quantitative targets may be sensitive and potentially controversial references are included. Finally, it should be noted that the studies used in the review are based on different assumptions. The targets are all rounded, however, and there should be no major discrepancies between them.

The targets include three categories:

- Targets that have been politically accepted and implemented as official EU targets.
- Targets that are currently being discussed by the European Commission as possibilities for the future.
- Targets that go beyond current discussions at the EU level.

As this study focuses on the EU level, the targets refer to the EU. It is important to keep in mind that these targets are in line with (and often go beyond) the few targets that have been proposed at the international level with regard to resource use and resource efficiency, and some of which specifically address developing countries (see overview in Table 3.1: Established targets on resource use at the international level).

Selection of actions

The report highlights the most important levers to improve resource efficiency which

Table 3.1: Established targets on resource use at the international level

Target	Value / range	Political status
Limit global warming	< 2°C	politically accepted(UNFCCC)[1]
MDG 7: providing 1.5 billion people with access to an improved water supply	By 2015	politically accepted(UN Mill Declaration)[1]
Extending protected areas	to 17% for terrestrial biomes and 10% for marine & coastal	politically accepted(CBD – Aichi target 11) [1]
Halting worldwide biodiversity loss	by 2020	
CO_2 emissions reduced worldwide	By 50%, compared to 2005	Discussed at industry level (WBCSD, Vision 2050)[1]
Improvement in the eco-efficiency of resources and materials	Four to tenfold by 2050, compared to 2000	
Reduction in post-harvest losses (mainly in developing countries)	50% by 2050, compared to 2009	beyond current discussions[1]

are repeatedly mentioned in the reviewed studies. Recognising that different countries have different requirements and needs, the actions presented here do not consider specific countries and remain at a more general level. Similarly, the actions do not favour any specific technologies or technical solutions, as many of them are characterised by uncertainties and a lack of consensus regarding their relative strengths and weaknesses, as well as their long-term effects. The actions identified to improve resource efficiency through better materials use, freshwater use and land use, soil and biodiversity were presented, prioritised and discussed with Members of the European Commission and external experts at the project workshop in Brussels on 12 April 2011. They are presented here in their order of preference.

Links between environmental issues

The environmental issues analysed in this report cannot be tackled in isolation. We therefore also identify some of the main direct links between the different environmental issues.

3.3 Headline visions and targets

Key elements of a vision

A vision for a resource efficient Europe should look beyond technological imagination for increasing resource efficiency in the production of goods and services. A vision also needs to address wider issues concerning sustainable consumption and lifestyles as well as a policy framework supporting the realisation of resource efficient solutions. A sensible vision on resource efficiency also draws connections to biodiversity preservation and respect for the carrying capacity of the planet.

At the project workshop, the following headline vision elements were regarded as essential and to be considered together in an integrated manner. Looking back from 2050, the following objectives have been achieved to realise the vision:

- **Strong de-coupling** of economic growth from the use of renewable and non-renewable materials, of water, of land use and of emissions of greenhouse gases has been achieved. The reduction in overall resource use helped to avoid trade-offs between targets in different categories of resources and economic sectors, which used to occur with solutions focused only on increased efficiency.
- **Improvements in areas such as water use and reuse, wastewater treatment, land use, forest management and agriculture** kept humanity on track toward living within the carrying capacity of the planet.
- **Primary material and energy use** have been reduced by 80% in absolute terms (absolute dematerialisation), resulting also in a reduction of the EU’s Carbon Footprint by around 90%.
- As Europeans have changed from **lifestyles** focused on monetary or material wealth to lifestyles aimed at delivering maximum quality of life, there has been a dramatic reduction in resource consumption compared to the year 2010.

To achieve the objectives associated with this vision, a number of headline targets, shown in Table 3.2, are set:

Table 3.2 Possible headline targets for a resource efficient Europe

Target	Value / range	Political status
Absolute reduction of overall material use following "Factor 4 to 10" requirements	80% by 2050	Beyond current discussions at EU level[6]
Significant reduction of the EU's GHG emissions (Carbon Footprint, including emissions embodied in EU trade)	20% by 2020 compared to 1990	Official EU target (Directive 2009/28/EC)[7]
	80-95% by 2050	Beyond current discussions at EU level[8]
Water abstraction per annual available water resource in European water bodies is reduced in order to avoid water scarcities	Abstraction below 20% of available water	Discussed at EU level (EEA target)[9]
Reduction of the EU's direct and indirect global land use	Fair global per capita share	Beyond current discussions at EU level

3.4 Economy-wide resource use and resource efficiency

3.4.1. Materials

Key elements of a vision

One of the most elementary themes that any vision for resource efficiency must address is the use of materials[10]. Commonly found "visionary" terms include "steady stocks society", dematerialisation and minimum waste. In more concrete terms, this encompasses vision elements such as the following, again described in a backward looking perspective from the year 2050:

Steady Stocks Society, Dematerialisation, Minimum Waste

- **Strong de-coupling** of economic growth from the use of renewable and non-renewable materials and a reduction of overall material use in absolute terms has been achieved.
- **The growth of man-made physical stocks** has been stopped.
- **Cascadic use, re-use and recycling** of materials have minimised residual waste (i.e. waste not prevented, reused, or recycled).
- The **efficient use of materials**, including waste and pollution management, is many times greater than at the turn of the century, enabled by collaboration and knowledge sharing.

[6] Giljum et al. (2004), von Weizsäcker et al. (1997), von Weizsäcker et al. (2009), Schmidt-Bleek (2009).

[7] European Parliament, Council of the European Union, 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, in: Union, T.E.P.a.t.C.o.t.E. (Ed.).

[8] Bio IS, IFF/SEC, SERI. 2011. Input to Resource Efficiency Roadmap. Unpublished document of the project.

[9] Target defined by European Environment Agency (EEA). The warning threshold, which distinguishes a non-stressed from a water scarce region, is around 20%, with severe scarcity occurring where the Water Exploitation Index (WEI) exceeds 40%. Note that the WEI does not reflect the diverse situations that occur at regional or large river basin level. Regional analysis is therefore required to get a more specific picture of the situation in terms of water scarcity.

[10] In this study, materials comprise fossil fuels, metal ores, industrial minerals, construction minerals and biomass.

Possible targets Politically, a wide gap still exists at the EU level between intentions and strategies to improve resource efficiency with concrete targets to be achieved[11]. The targets presented here all go beyond current discussions at the EU level but are largely synergistic and complementary.

Table 3.3 Possible targets for economy-wide resource use and resource efficiency

Target	Value / range	Political status
Absolute reduction of overall resource use following "Factor 4 to 10" requirements	30% by 2020 80% by 2050	Beyond current discussions at EU level[12]
Increase of total material productivity	5% p.a. or 3% above GDP growth p.a.	Beyond current discussions at EU level[13]
Reduction of per capita abiotic Total Material Consumption (TMC) in the EU	10 t/cap in 2050	Beyond current discussions at EU level[14]
Net addition to material stocks (in particular metals and non-metallic minerals)	zero by 2050	Beyond current discussions at EU level[15]
Increase in the share of secondary metals (recycling/reuse) in total consumption of metals	Target values to be defined	Beyond current discussions at EU level[16]
Net-imports of biomass in Europe reduced	≤ 0 by 2030	Beyond current discussions at EU level[17]

Actions Governments, businesses and civil society have a wide range of possible actions to achieve these visions and targets, ranging from the micro to the macro level and from direct to indirect instruments:

- **Environmental fiscal reforms**: in order to provide incentives for reducing material consumption and investment in material-efficient technologies, introduce material input taxes[18] (in addition to energy taxes) while reducing income taxes,
- **Reform reporting and accounting standards** to integrate positive and negative externalities, include indicators on physical material use, so that policy makers and investors incorporate these new measures into decision-making.
- **Develop a circular economy** with more closed material loops (e.g. by increasing recycling rates of various materials).
- **Improve information** (e.g. through resource efficiency labels) to make consumers aware of the material use of products and thus contribute to changes of consumption patterns.

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[11] Note, however, that some Member States have established targets for resource efficiency. Germany, for example, aims to double raw material productivity by 2020 compared to the reference year 1994.

[12] Giljum et al. (2004), von Weizsäcker et al. (1997), von Weizsäcker et al. (2009), Schmidt-Bleek (2009).

[13] Bio IS et al. (2011). Input to Resource Efficiency Roadmap. Unpublished document of the project "Assessment of resource efficiency indicators and targets". DG Environment, Brussels. For more information, see also Giljum et al. (2004), von Weizsäcker et al. (1997), von Weizsäcker et al. (2009), Schmidt-Bleek (2009).

[14] Bringezu (2011)

[15] Bio IS et al. (2011). See also Bringezu and Bleischwitz 2009.

[16] Bio IS et al. (2011)

[17] Bio IS et al. (2011). See also Bringezu et al. 2009a, Bringezu et al. 2009b.

[18] As suggested by one expert at the project meeting in Brussels, it could be debated whether the EFR should differentiate between virgin and secondary materials.

- **Develop material efficient public procurement** through efficiency standards in order to stimulate demand for material efficient products and services.
- Advance development and implementation of **ecodesign policy and support mechanisms** (guidelines), ensure coherence with the environmental fiscal reforms.
- Support materials science and focus on **research and development** to help the EU specialise in substitution (e.g. for certain rare earths, raw materials).

Links to other domains

Changes in material use can impact the other domains portrayed in this report, in particular the links to land use, biodiversity, and water use.

- **Land use & biodiversity**
  - An absolute reduction of overall resource use diminishes the amount of extraction of metals, minerals, agricultural and forestry products, which reduces land use change and its often negative impacts on biodiversity
  - Transforming fewer non-renewable resources into products (e.g. chemicals, electronics) can help reduce hazardous waste as well as emissions to air and water
- **Water use**
  - Reducing the scale of extraction activities will help to reduce the use and pollution of water and related impacts on water availability and freshwater/marine biodiversity

3.4.2. Energy and climate

Key elements of a vision

The European Commission has recently published a "Roadmap for moving to a competitive low carbon economy in 2050" (European Commission, 2011b). The following vision elements complement this roadmap from a resource efficiency perspective:

Energy-efficient and renewable-based low fossil carbon economy

- A **secure and sufficient supply of low-fossil-carbon energy** has been achieved in Europe.
- Significant increases in **energy efficiency have led to an absolute reduction in energy consumption** and a significant reduction of the EU's Carbon Footprint.
- The risk of supply restrictions of essential energy resources has significantly decreased through a **reduction of imports in total energy supply**.
- A high share of **resource efficient forms of energy supply** has been realised.

Possible targets

As climate change is perhaps the most serious environmental threat facing life on earth, and energy use is one of its most important contributors, a number of targets could be identified which are related to resource efficiency.

Target	Value / range	Political status
Significant reduction of GHG emissions of EU Member States	20% by 2020 compared to 1990	Official EU target (European Parliament Directive)[19]
Significant reduction of Carbon Footprint (including emissions embodied in EU trade) of EU Member States	20% by 2020 compared to 1990	Beyond current discussions at the EU level
	80-95% by 2050	Beyond current discussions at the EU level
Increase of share of Renewables in the EU's energy mix (PwC, 2010; WWF et al., 2011)	20% by 2020	Official EU target[20]
	80-95% by 2050	Beyond current discussions at the EU level[21]
Reduction of share of fossil fuel imports in total energy supply	50% by 2020	Discussed at EU level (EC Roadmap)[22]
Reduce primary energy consumption	20% by 2020 compared to projections (saving 368 Mtoe of primary energy)	Beyond current discussions at EU level[23]

Actions Most actions identified in existing scenario studies are economically orientated. A comprehensive roadmap would gain strength by addressing policies aimed at behavioural change more broadly. The following actions were repeatedly reported:

- Ensure effectiveness of the **ETS** with a sufficient carbon price signal and long-term predictability, e.g. through revisiting the agreed linear reduction of the ETS cap.
- Establish a **global carbon price**.
- Set **incentives for the power sector** to play its full part, e.g. through energy taxation and technological support.
- Implementation of **end-of-pipe measures**.
- **Investments in local networks (smart grids)** to ensure continuity of supply at all times.
- Construct a **European-wide electricity grid,** linking to the local networks described above.
- Change energy supply by using **zero-carbon energy options.**
- Take measures to **increase shares of renewable energy resources** in total energy consumption, e.g. by lowering their cost.
- **Reduce energy consumption** with higher energy taxes and other parafiscal levies.

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[19] European Parliament, Council of the European Union, 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Note that official milestones described in the EU low-carbon roadmap 2050 (COM(2011) 112/4) set the target for GHG reduction at 25% in 2020 if other policies (including 20% renewables, +20% energy efficiency) are fully implemented by that time too.

[20] European Parliament, Council of the European Union (2009), as above.

[21] This target was obtained by extrapolating the official 2020 targets, applying the same ratio as for the GHG reduction target.

[22] European Commission (2011a).

[23] Bio IS et al. (2011).

- Encourage **life-style changes** to increase energy efficiency in energy-intensive areas of consumption (e.g. housing, transport).
- **Improve information** on energy consumption in housing (e.g. through smart meters) and of products and services to consumers (e.g. through expansion of energy labels to all products).

Links to other domains

Energy and climate change both impact each other and are linked to other environmental domains addressed in this report, notably freshwater use, agriculture and food, biodiversity, and land use.

- **Energy → climate**
  - Fewer emissions from the combustion of fossil fuels for energy generation would reduce pressure on climate change
- **Energy → water use**
  - Less electricity generation would reduce negative impacts on freshwater quality and quantity, as many forms of electricity generation (e.g. coal, nuclear energy) are water intensive and produce discharges of water, which have significant impacts on receiving waters
  - Decreased energy demand reduces the demand for hydro-power and related impacts on water quantity and quality
  - Higher energy costs can increase water costs due to energy use in extraction, pumping, processing
- **Energy → Agriculture & food, biodiversity**
  - Energy from biomass might have a role in mitigating climate change but competes for land with food production and biodiversity
  - Climate change affects biodiversity
- **Climate → agriculture, fresh water**
  - Reduced climate change will reduce negative impacts on agricultural productivity and yields (e.g. due to fewer extreme weather events; reduced effects on the hydrological cycle, such as local water scarcity and flooding)
  - Reduced climate change may diminish problems associated with the melting of glaciers
- **Climate → land use & biodiversity**
  - Reduced climate change will reduce the problem of desertification

3.4.3. Freshwater

Key elements of a vision

Given the inefficient and unsustainable use of freshwater resources worldwide, a comprehensive vision is urgently needed. The following elements of a vision for this resource category were found in the reviewed studies:

Circular water use and water engineering in harmony with ecosystems management and protection

- Since 2015 all European water bodies have had **good ecological status or good ecological potential**.
- **Water demand management** is in place to ensure a proper allocation of available resources to water users and the environment.
- An **ecosystems and river basin perspective to water management** is applied; floodplains and groundwater aquifers are used for storing water, making room for rivers, and the environmental impacts of water engineering projects are minimised.

- **Long-term stability of EU freshwater bodies** is ensured and the negative environmental impacts of over-abstraction of water (e.g. low river flows, lowered groundwater levels) have been stopped – particularly in Southern Europe.
- The **energy and material footprint of water consumption is low** as water is being managed in a sustainable way.
- Member States take account of the principle of **recovery of the costs of water services**, including environmental and resource costs.
- **Wastewater** is considered **a valuable resource** and to be **reused**.
- The EU is **not import-dependent** in terms of water supply.

Possible targets The following targets for a more sustainable and efficient use of freshwater resources have been identified:

Target	Value / range	Political status
Achievement of good ecological status or good ecological potential of all European water bodies	By 2015	Official EU target (European Parliament Directive)[24]
Water abstraction per annual available water resource in European river basins is reduced in order to avoid water scarcities	Abstraction below 20% of available renewable water resources	Discussed at EU level (EEA target)[25]
Reduction of EU net imports of embodied (virtual) water	Zero	Beyond current discussions at EU level[26]

Actions A wide range of actions have been identified which can serve to improve the efficiency of freshwater use and thus contribute to a more resource efficient Europe. The following suggestions gained particular attention:

- Pursue the implementation of **(international) institutional arrangements** to cope with the global dimension of water governance (e.g. international protocol on water pricing, water-label for water-intensive products, minimum water rights and maximum allowable levels of water use).
- Bring the principles of **Integrated Water Management** into water governance to improve efficiency of water use.
- Support the diffusion of technology and capacity building for **non-conventional water resources development** (e.g. reclamation of urban sewage waters, desalination) and conservation approaches.
- Implement policies to ensure that **water pricing** acts as an incentive for the long-term sustainable use of water.

[24] European Parliament, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

[25] Target defined by European Environment Agency (EEA). The warning threshold, which distinguishes a non-stressed from a water scarce region, is around 20%, with severe scarcity occurring where the Water Exploitation Index (WEI) exceeds 40%. Note that the WEI does not reflect the diverse situations that occur at regional or large river basin level. Regional analysis is therefore required to get a more specified picture of the situation in terms of water scarcity.

[26] Bio IS et al. (2011).

- Improve **recirculation** and set **incentives to use less water-intensive processes** in all economic sectors to increase productivity per water unit.
- Provide stable and transparent **regulatory frameworks and monitoring systems** for companies.

Links to other domains

Actions for improving the efficiency of freshwater use have direct impacts on other themes discussed in this report, in particular land use and biodiversity as well as energy and climate change.

- **Land use**
  - Improved water management (e.g. design and planning of irrigation) can help sustain land use downstream
- **Biodiversity**
  - Less water abstraction can help protect ecosystems and ecosystem services
  - Less water pollution and increased water treatment decreases the environmental impact of human activities on natural water bodies
- **Energy & climate**
  - Less water abstraction can help prevent groundwater depletion and thus reduce energy use for extracting or desalinising water
  - Improving water efficiency can significantly reduce energy demand
  - Decreased water demand enhances the protection of aquatic ecosystems having a direct influence on micro as well as macro-climates.

3.4.4. Land use, soil and biodiversity

Key elements of a vision

A vision for a more material efficient Europe must also address land use, soil and biodiversity. The following elements have been identified in existing visions and best-case scenarios:

Sustainable human land use, stable soils and flourishing eco-systems

- The **diversity of land management practices** has increased throughout the EU. Ecosystem degradation has been reversed, and ecosystem services are valued, maintained and enhanced.
- **Biodiversity is being better managed**, is flourishing, and continues to enable economies and societies to prosper.
- The **use of agricultural land is limited**. Energy production from biomass is restricted to organic waste and residuals, and to areas not suitable or not in production for annual food crops.
- **Biomass production complies with sustainability criteria and standards, appropriate certification schemes are established/promoted,** while at the same time absolute levels of biomass consumption are kept at sustainable levels.
- The **expansion of built-up land (urban sprawl) has been stopped**.

Possible targets

The following targets have been identified for land use, soil and biodiversity to contribute to a more resource efficient Europe:

Target	Value / range	Political status
Reduction of EU's global land use, in particular cropland, to achieve a fair global per capita share	0.20 ha/cap cropland by 2030	Beyond current discussions at EU level[27]
Net growth of built-up (sealed) land	Zero by 2020	
Net land conversion through mining and from landfills	Zero by 2020	
Nutrient balances for nitrogen and phosphorous in soils	Stable	Beyond current discussions at EU level[28]
Appropriate targets for soil erosion which ensure the protection of soil functions and a sustainable soil use	To be set by each Member State	Discussed at EU level (EC Proposal for Directive)[29]
Halting the loss of biodiversity and the degradation of ecosystem services in the EU, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss	by 2020	Official EU target (EU Biodiversity Strategy)[30]
Protecting, valuing and restoring EU biodiversity and ecosystem services	by 2050	

Actions

Actions to ensure that the above outlined vision and targets are reached span over a range of different policy fields and involve strong regulation. Some of the most widely discussed and feasible tasks include:

- Mainstream the sustainable provision of **biodiversity and ecosystem** services in various policy fields (e.g. transport, energy, fisheries, agriculture, cohesion, aid and trade, REDD).
- Improve **marine biodiversity** (e.g. increasing designated marine sanctuaries; reducing marine fishing efforts to maximum sustainable yield levels).
- Revitalise urban centres, promote resilience of urban systems and provide disincentives for further urban sprawl through **active spatial planning**.

[27] FAO (2006), van Vuuren and Faber (2009), Rockström et al. (2009), Bringezu (2011).

[28] Pau Vall and Vidal (2011).

[29] European Commission, 2006. Proposal for a Directive of the European Parliament and of the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC. COM(2006) 232 final, Brussels. See Montanarella (2011) for a rationale and orientation for potential targets.

[30] European Commission, 2011. Our life insurance, our natural capital: an EU biodiversity strategy to 2020. Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions. COM(2011) 244 final. European Commission, Brussels.

- Revisit policy targets and incentives which lead to over-proportionate **global land use of Europe** (e.g. biofuels debate).
- **Monitor global land use** for domestic consumption of all agricultural and forestry goods with appropriate indicators.
- Expand and strengthen the quality of **protected areas** in the EU and worldwide (increasing the size, improving the conservation status and connectivity of protected areas for healthy ecosystems and increased resilience).
- Reduce deforestation and forest degradation, **improve forest management**, such as Sustainable Forest Management (SFM) or Reduced Impact Logging (RIL) practices.
- Implement measures to increase the **carbon content of soils** and stop its reduction (e.g. avoiding soil compaction and intensive cultivation, reducing the use of chemical fertiliser).
- Prioritising and optimising **food supply** while **restricting non-food biomass consumption** on the basis of the monitored global agricultural and forestry land use of the EU compared with its fair share of globally available land.

Links to other domains

Land use, soil and biodiversity are tightly linked to many other domains discussed in this report, notably freshwater and climate change. Land consumption and soil sealing isolate the soil system and thus affect the water cycle, geochemical cycles, energy transfer and climate (at micro and meso scale). As a result, surface runoff and thus flood risks may increase, and options for biodiversity and nature conservation or restoration are reduced. Biodiversity underpins the supply of a range of ecosystem services, but competes for land with food, feed and fuel

- **Land use→ fresh water**
  - Reduced land sealing can help maintain wetlands, which create resilience to flooding
  - Improved land use management can reduce water demand for agricultural use
- **Land use → climate change**
  - Reducing land use change from urban sprawl (both in and outside the EU) and land conversion through mining and from landfills (largely outside the EU) can help reduce deforestation and forest degradation and related emissions (especially methane emissions from decomposing trees), which are a major cause of climate change
- **Biodiversity → fresh water**
  - Halting worldwide biodiversity loss can help prevent the loss of forests / savannas, which act as rainwater storage
- **Biodiversity → climate change**
  - Halting worldwide biodiversity loss makes an important contribution to climate-change mitigation and adaptation, as biodiversity supports various ecosystem services
  - Halting worldwide biodiversity loss (forests) can help maintain the CO_2 intake of ecosystems as well as support the multi-functional role of forests

3.5 Resource use and resource efficiency in specific economic sectors

3.5.1. Construction and housing

Key elements of a vision

The vision elements presented here focus on construction and housing. They do not address spatial planning questions, such as possible city designs for optimum use of space for housing and other infrastructure.

Resource light, energy-efficient buildings, closed resource use cycles through re-use, renovation and urban mining

- The construction industry shifted its primary activities from new buildings towards **renovation and refurbishment**, and – to a growing extent – deconstruction of old and reconstruction of new buildings at the same location.
- **Resource-efficient construction** where less material resources are needed to build homes and buildings of higher functionality.
- Architects and building planners design and renovate buildings and sites in a way that supports "**urban mining**" of secondary materials and the end-of life recovery process.
- All buildings are designed as **intelligent low- or zero-energy, or even active-energy buildings**.
- The **absorption, transformation, and transport of solar energy** are integrated into the "skin" and "skeleton" of buildings.

Possible targets

So far, no targets have been politically discussed. The following two targets are based on scientific studies but may serve as an input for future discussions.

Target	Value / range	Political status
Reduction of energy consumption of the building stock through improved energy performance	90% by 2050	Beyond current discussions at EU level
Increase recycling rates of construction minerals	80-90% by 2050	Beyond current discussions at EU level

Actions

A number of actions have been highlighted in the literature to improve the efficiency of resource use in construction and housing:

- Favour **refurbishment, renovation and dematerialisation**, e.g. introduce a tax per ton of extracted or imported building material and increase annually (e.g. UK aggregates tax).
- Introduce **standards for new buildings** with a maximum total material requirement per m^2, in line with maximum energy consumption.
- Foster **urban mining**, e.g. set up an information system to keep track of materials in the building stock, develop building materials and techniques to facilitate re-use and recycling.
- Intensify the use of existing buildings with refurbishment and multi-functionality.
- **Substitute central sewage and energy supply systems by decentralised systems** where this will increase resource efficiency, e.g. in areas of low population density.

- Support integrated design of utility buildings with **intelligent energy management**; integrated photovoltaics.
- Support new **resource-extensive solutions** and the development of eco-efficient and renewable building materials.
- **Public procurement** should set a positive example by adopting high standards and latest technologies in its construction-related activities.
- Urban planning instruments should make **sustainability standards for resource-extensive construction and waste minimisation** a condition for construction permits.
- Foster the **transfer of the most advanced construction technologies** from old to new EU Member States.
- Support people with **information** to decrease energy and water consumption in housing, e.g. through smart meters.

Links to other domains

Improving the resource efficiency of construction and housing primarily impacts the use of energy, water and land as well as pressures on biodiversity.

- **Energy & water use**
  - Increasing the number of energy-plus houses may contribute positively to the energy sector as decentralized energy producers
  - Reducing the consumption of hot water in buildings reduces the amount of energy used to heat water and the amount of energy used by water utilities to provide water to the buildings
  - Using less energy for air-conditioning of a building reduces the consumption of water
- **Land use and biodiversity**
  - Reducing the expansion of urban (sealed) land lowers pressures on biodiversity

3.5.2. Agriculture and food

Key elements of a vision

The agricultural sector and food consumption contribute significantly to environmental pressures and have a major role to play in building a resource efficient Europe. The following elements could be part of a comprehensive vision:

Low-impact agriculture contributes to healthy diets

- The EU produces high-quality agricultural products in diverse landscapes that host a rich biodiversity.
- Globally, more food is produced more sustainably, on constant extension of cropland, with stable soils, and with less water.
- European diets contain fewer animal products, making them also healthier and leading to smaller feed requirement. This decreases pressure on the agricultural system within Europe and abroad.
- The feed conversion efficiency in animal production is significantly improved and so has animal welfare benefits.
- Fish stocks have regenerated through a strong control system of fish catches and an absolute reduction of fish consumption

Possible targets

The following targets have been identified for agriculture and food to contribute to a more resource efficient Europe:

Target	Value / range	Political status
Significant reduction in the consumption of meat and dairy products in the EU	80% by 2050	Beyond current discussions at EU level
Reduction of non-CO_2 emissions in the agricultural sector	60% compared to 1990	Beyond current discussions at EU level
Reduction in food waste (mainly in the developed world)	50% by 2050, compared to 2009	Beyond current discussions at EU level[31]
Fish capture production	Below Total Allowable Catch (TAC)	Discussed at EU level (European Commission)[32]

Actions Actions must be taken to address both resource use in the agricultural sector and consumer behaviour with regards to food. The following actions were repeatedly stressed:

- Invest in **R&D**: especially in the areas climate adaptation; improvements of energy, nutrient and water-use efficiency; nurture agricultural diversity; create a resilient agricultural system.
- Invest in **environmentally sound practices** such as precision farming, water conservation and measures to protect soils from erosion
- Provide strong support for transformation towards **sustainable forms of agriculture**, including agro-ecological farming and organic agriculture, through
  - Policies / measures that internalise externalities and provide the true costs of production
  - Reforms of the CAP
  - Promotion and information campaigns
  - Ensuring traceability and organic food authenticity
  - Harmonisation of control procedures and accreditation
  - Funding of research in options for large-scale agro-ecological farming
- Make **diversity** of crops and agricultural production systems a strategic aim of the Common Agricultural Policy (CAP) in order to maintain and increase the agricultural productivity in the EU and provide a buffer against shocks (e.g. pests, food shortages).
- Minimise **food waste** in shops and households by information campaigns, improved organisation, etc.
- Reduce the **consumption of animal protein products** by investing in public awareness (stressing the health benefits and reduced pressure on natural resources).

[31] Bakkes et al (2009).

[32] The European Commission proposes TACs on the basis of scientific advice on the state of the stocks, and the Council of Fisheries Ministers decides (for detailed information on current and past TAC quotas, see http://www.eafpa.org/TAC.htm and http://ec.europa.eu/fisheries/cfp/fishing_rules/tacs/index_en.htm) .

Links to other domains

Agriculture and food are mainly linked to energy and climate, biodiversity, land use, and water use.

- **Energy and climate**
  - Reducing animal farming (especially of cattle and sheep farming) and fertiliser production and use would significantly decrease global GHG emissions
  - Improving energy efficiency in agriculture (cultivation, processing, refrigeration, distribution) and food processing can help reduce CO2 emissions
  - Reduced animal protein consumption will reduce livestock farming and related methane emissions
- **Biodiversity & land use**
  - Increasing agricultural productivity may reduce expansion of agricultural land
  - Increasing agricultural productivity may be limited by trade-off to protect biodiversity and to reduce net eutrophication and nutrient loading in freshwater systems (RGBS)
  - Changing diets towards less animal protein consumption may reduce the growth of agricultural land use and GHG emissions and increase biodiversity
  - Reducing demand for agricultural land use can help reduce deforestation
- **Water**
  - Improving agricultural practices can help decrease water use in Europe (and globally). Agriculture is a sector with a large share in water extraction in Europe (up to 80 % in southern countries such as Spain[33]) and worldwide, and by far the largest share (around 80%)[34] in total water consumption (or "consumptive use"; taking into account how much of the water extracted is returned to receiving waters) worldwide.

3.5.3. Industry and manufacturing

Key elements of a vision

The European economy is strongly based on industrial production which still has great potentials for an absolute reduction of resource use as well as improvements in resource efficiency. Achieving a resource efficient Europe will only be possible with efforts from the industrial sector as well as changes in consumer behaviour. The following vision elements reflect both the supply and demand sides:

Resource-efficient and recycling-based industry

- The European industry has become a model for **resource efficient, zero critical waste production** and is based on **closed-loop and networked designs**.
- **Used materials and products are re-engineered** to function again for multiple purposes.
- **Resource-light product designs** are the norm and highly material-intensive products have been phased out.
- The use of certain resources that are associated with a high environmental burden have been prohibited.

[33] EEA (2010).

[34] Chapagain and Hoekstra (2004).

- Consumers have sufficient and **transparent information on the resource consumption** related to the purchases of goods and services.
- Planned obsolescence of technology has been replaced by **planned durability and reuse**.

Possible targets

Currently, targets for industries focus on the reduction of CO2 emissions until 2020, but not on material use. Targets may be a useful tool to motivate and assess changes in resource use. The following targets were found in the literature and selected by the project team on the basis of the headline targets above:

Target	Value / range	Political status
Absolute reduction of overall material use in industry (following the target on resource efficiency)	80% by 2050	Beyond current discussions at EU level
Reduction of GHG emissions in industry (in line with climate change target)	90% by 2050	Beyond current discussions at EU level
High implementation of best practice technologies for material and energy use in different industrial sectors	Target value to be defined	Beyond current discussions at EU level

Actions

Despite the large diversity of different industries in the EU, a number of general regulatory and voluntary instruments have been suggested that can be applied across the board:

- **Regulation by technical standards**, e.g. establish resource-efficiency standards for key products to stimulate product improvements (e.g. through framework product legislation).
- **Economic instruments,** e.g. phase out subsidies for resource-intensive industries and products, value added tax in relation to the material intensity of the product or service groups; implementation of extended producer responsibility (EPR) to include producers' responsibility, physical and/or financial, for a product also at the post-consumer stage of a product's life cycle.
- **Voluntary instruments**, e.g. implementation of a labelling system for life-cycle wide material inputs for all consumer products; extension of eco-audit schemes to include dematerialisation aspects.
- **Information and consultation** instruments, e.g. promotion of best practice technology for material use in the manufacturing sector; develop specific roadmaps in cooperation with the different economic sectors to encourage companies to invest in resource-efficient technologies.

Links to other domains

Industry and manufacturing are most strongly linked to resource use, energy and climate change.

- **Resource use, energy & climate change**
  - A dematerialisation and low-carbon in industry would benefit the climate and resources, as emission-intensive products are also resource-intensive
  - Efficiency improvements alone may lead to rebound effects

3.5.4. Transport and mobility

Key elements of a vision

Transport and mobility are the cornerstones of globalisation and a vital component of all economic activities. There is no lack of visions on how to make transport more resource efficient and sustainable.[35] Here, we summarise important vision elements which illustrate a resource efficient transport system and related mobility patterns.

Safe, material-efficient, low-carbon and low-volume transport,

- An **absolute reduction of passenger and freight transport volumes** has been achieved.
- There is **universal access to reliable and low-carbon mobility, infrastructure and information**.
- Energy and material efficiency are significantly higher than in 2011 due to the **improved design of all the major passenger and freight transportation modes** (scooters, cars, air travel, trucking, rail and shipping).
- The use of **resource-efficient passenger transport modes** has significantly increased (e.g. use of public transport and cycling, high speed trains and videoconferencing instead of air travel) and freight transport modes (rail and coastal shipping transport options instead of trucking).
- There has been a **significant shift in transportation fuels**, so that most energy for transportation comes from renewable electricity sources, second-generation biofuels and hydrogen, instead of fossil fuels.

Possible targets

The following targets have been identified in the literature for transport and mobility to contribute to a more resource efficient Europe:

Target	Value / range	Political status
Reduction of total CO_2 emissions (well-to-wheel) from European transport (Bakkes et al., 2009)	80% by 2050 compared to 1990 levels (factor 12)	Beyond current discussions at EU level
Reduction of total CO_2 emissions by road passenger transport (Bakkes et al., 2009)	95% compared to 1990 levels (factor 20 - 25)	Beyond current discussions at EU level
Road freight transport reduces CO_2 emissions (Bakkes et al., 2009)	by factor 6 by 2050	Beyond current discussions at EU level
Other modes of transport – road freight, aviation and shipping – decrease their GHG intensity (WBCSD, 2010)	by at least 50%	Beyond current discussions at EU level

Actions

The following actions may contribute both to improving resource efficiency and to reducing resource use and its environmental impacts:

- Significantly improve **energy and vehicle efficiency**, e.g. by investing in R&D for improved design of all the major passenger and freight transportation modes.

[35] See for example the White Paper on the Roadmap to a Single European Transport Area (European Commission, 2011b).

- Increase the use of **low-carbon fuels** and **near-zero emission vehicles and fuels** in road passenger transport and public transport, e.g. by introducing tax incentives, speeding up research, development and deployment of alternative fuels, sharing best practices, and harmonising efforts in collecting data and setting standards.
- **Shift the overall structure of the transportation system** towards public transport, railways and inland waterways, and **change logistic organisations** (higher truck utilisation and fewer km) to reduce traffic volumes and improve energy efficiency of the transport sector.
- Use **pricing mechanisms** to fully reflect the costs of transportation activities to society: lower value added tax rate for railroad transportation, raise the value added tax rate for air transport services, introduce comprehensive road pricing and high taxation of fossil fuels, congestion pricing.
- Expand the **trans-European Rail network** and improve interoperability among the continent's rail systems.
- Facilitate **tram-train integration** to allow urban light rail vehicles to operate on European inter-city heavy rail networks.
- Implement **Intelligent Transportation Systems** (ITS) to enhance the efficiency, speed and reliability of public and private transport, and increase the comfort and acceptance of co-modality.
- **Increase comfort and attractiveness of public and shared transport modes**, e.g. by promoting car-sharing, hail & ride, station taxis, park-and-ride facilities.

Links to other domains

Changes in transport and mobility have strong impacts on energy and climate change, agriculture, land use, biodiversity, and material use.

- **Energy & climate change**
  - Reduced road transportation reduces energy consumption and CO_2 emissions
- **Agriculture, land use, biodiversity**
  - Aiming to reduce CO_2 emissions may lead to an increase in the use of alternative fuels, some of which can increase the demand for cultivable land, compete with the production of food crops and reduce biodiversity
  - Reducing the growth of road and air transport infrastructure can help diminish land cover change and related pressures on ecosystems and biodiversity
- **Energy and material use**
- Reducing the overall amount of transport would decrease the use of metals (e.g. in the production of vehicles) and energy (in production and running)

4 Identification of Appropriate Modelling Tools

4.1 Introduction

Identification of models

In this chapter we aim to build a modelling framework that can be applied to assess policies used in implementing the scenarios developed in Chapter 3. The models and methodologies examined in this chapter cover the following resources:

- materials
- land, soils and biodiversity
- energy and climate
- water

Chapter structure

Our focus is primarily on methodologies rather than specific models, although often particular models play some role in defining the methodology. Further details about some of the individual models that are referenced in this chapter are given in Appendix B. Much of the information is taken from a previous report (referenced as Pollitt et al, 2010) submitted to DG Environment[36].

The following section discusses the models that are available to assess the use of each type of resource. Section 4.3 expands on this to consider the linkages between different model types and their possible links through the economy, i.e. what is required to assess a sustainability scenario. In Section 4.4 we construct a top-level conceptual framework that would be required to provide a comprehensive assessment. Section 4.5 concludes.

4.2 Overview of model types

This section considers the four resource types outlined in Section 4.1, in most cases viewed in isolation rather than as part of a sustainable development strategy. Further details for most of the policy areas (except soils) can be found in Pollitt et al (2010). The focus here is on modelling approaches rather than individual models, but further information on the models can be found in Appendix B.

The issue of linking these policy areas in an assessment is described in more detail in Section 4.3.

Materials

Material resources are defined here as fossil fuels, metals ores, industrial and construction minerals and biomass. Analysis of these resources is not generally covered by formal modelling tools (E3ME and GINFORS are the main exceptions, both of which are currently being developed for DG Environment), although more flexible quantitative methods, such as input-output analysis, are often applied and indeed extended.

This situation reflects the nature of material demands; an economic transaction is involved, so the quantitative methods are similar (and linked) to those used in energy-economy analyses. In the past a lack of physical data has been a constraint on the possibilities for formal modelling, but better data are now becoming available; this is discussed in more detail in Pollitt et al (2010). An achievable ambition would be to standardise the modelling of materials in macroeconomic models to match the existing treatment of energy demand.

[36] See http://ec.europa.eu/environment/enveco/studies_modelling/pdf/sustainability_macroeconomic.pdf

Land use, soils and biodiversity

There is quite a wide range of models covering land use, soils and biodiversity issues, reflecting the broad nature of these resources.

Land use There are many models which include some treatment of land use, albeit in different ways. These models can be separated into four broad categories; those that focus on land use or link a land-use model into a family of models (e.g. CLUE, IMAGE), those that are concerned with agricultural land use (e.g. CAPRI, LEITAP), models covering land use in the context of forestry (e.g. EFISCEN, EU-FASOM) and models that focus on other policy issues such as trade or energy (e.g. GTEM, GCAM).

Soils There are a variety of soil erosion models available. The existing models are generally differentiated by both their geographical coverage and also the time horizon that they predict. Additionally, some models predict long-term soil loss, while others are event-based, predicting the soil erosion from a storm for example.

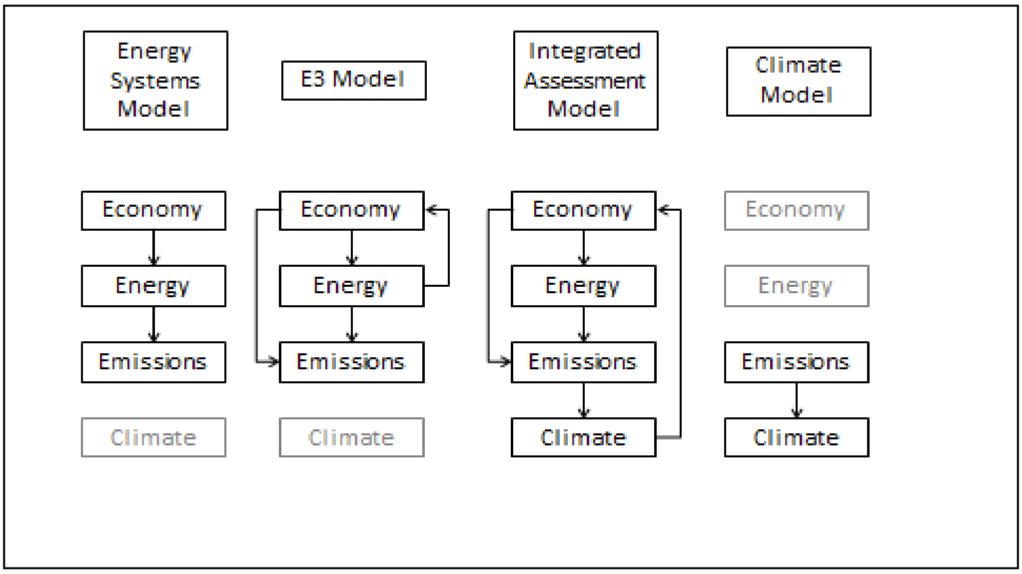
It is noted that, due to data requirements, there is a strong trade-off between the degree of detail and scope of geographical coverage (ranging from an individual farm or field to the whole EU) in this type of model. The Europe-wide models considered here cannot be too demanding in terms of data requirements but still maintain an acceptable level of accuracy. Some examples of models that can be applied at the European level include USLE and PESERA.

Biodiversity The tools available for analysis of biodiversity are limited. This is in part due to the difficulties involved in measuring biodiversity numerically. Two examples of models that do exist are GLOBIO, which is used to specifically look at the impact of environmental change on biodiversity, and the ecosystem component of the IMAGE model.

Energy and climate

There are a relatively large number of models concerned with energy and climate issues, with various different dimensions and degrees of coverage. We have split them into four groups (see Figure 4.1) showing their areas of coverage. However, it should be noted that there is a usually a substantial trade-off between the level of detail (depth of coverage) and the coverage of different areas (breadth of coverage).

Figure 4.1: Energy and Climate Models



Partial, energy systems models Examples of models that focus specifically on energy markets include PRIMES, POLES, TIMES and the IEA's World Energy Model (WEM). These models are currently used for global and EU-level analysis and can have a long timeframe for projections. Their focus on the energy system allows for a highly detailed assessment, including specifically defined technologies and institutional detail.

These models use economic projections as an exogenous input and produce results for energy demand/supply and energy-related emissions.

E3 models E3 models consider the interlinkages between the economy, the environment and energy. Examples include E3ME, GEM-E3, GINFORS and PACE.

The advantage of this model type is the linkages between the energy system and the economy (the economy provides demand for energy, which returns the economic performance of the energy sectors). These linkages can be reversed using price signals so that the costs of reducing emissions may be evaluated.

Integrated Assessment Models Integrated Assessment Models (IAMs) go one step further to include an estimate of the impacts of climate change, with feedback to the economy. They thus incorporate feedbacks that would be desirable to include in an assessment of sustainability scenarios.

The cost of this approach is that the level of detail within each component is usually much less than in a model designed specifically for that purpose. For example, the modelling of the climate system in IAMs is far less detailed than that provided by the climate models discussed below.

Climate change models The earth's climate system is highly complex and this is reflected in the modelling approaches that are used. The models in operation are regularly updated to reflect the most recent scientific findings.

The models can be split into two groups. Atmosphere-Ocean General Circulation Models (AOCGMs) go into the highest level of detail and require large quantities of computer power to perform simulations. The Hadley Centre in the UK operates some of these models. Examples of key features in these models are:

- systems of cloud formation
- solar radiation
- atmospheric and ocean flows and temperatures and salinity of sea water, soil and vegetation
- ice flows
- sea levels

Earth system Models of Intermediate Complexity (EMICs) have been developed mainly on grounds of practicality. Results from these models are less precise but can be obtained much more quickly and easily. MAGICC and Genie are examples of EMICs.

Fresh water There are a limited number of models available that cover fresh water, and often these models are specific to geographical regions (i.e. river basins) rather than on a European or a country level.

In the context of assessing scenarios of global sustainability the WaterGap model is perhaps best suited for considering fresh water. The model was developed to analyse water availability, use and quality on a global level.

4.3 Model linkages between policy areas

The overarching scenario presented in Chapter 3 stressed the integrated nature of the targets and policy areas. Ideally an assessment framework should have the same properties. However, the quantitative tools described in Section 4.2 tend to focus on a specific policy area. This raises the question of whether it is possible and desirable to link these tools to form a single model that can cover a range of policy areas.

This section discusses the linkages that already exist and where there is scope for future development.

The present situation

Figure 4.2, taken from the presentation at the project workshop, summarises the linkages between the difference policy areas. In most cases the model linkages are one-way from the economy to the particular resource (e.g. energy and climate change models use economic development as an input). There are also some linkages between the different resources, represented by the dotted lines (and including diagonally), and some feedbacks to the economy (e.g. from IAMs) but these are not usually included as standard.

Figure 4.2: Model Linkages

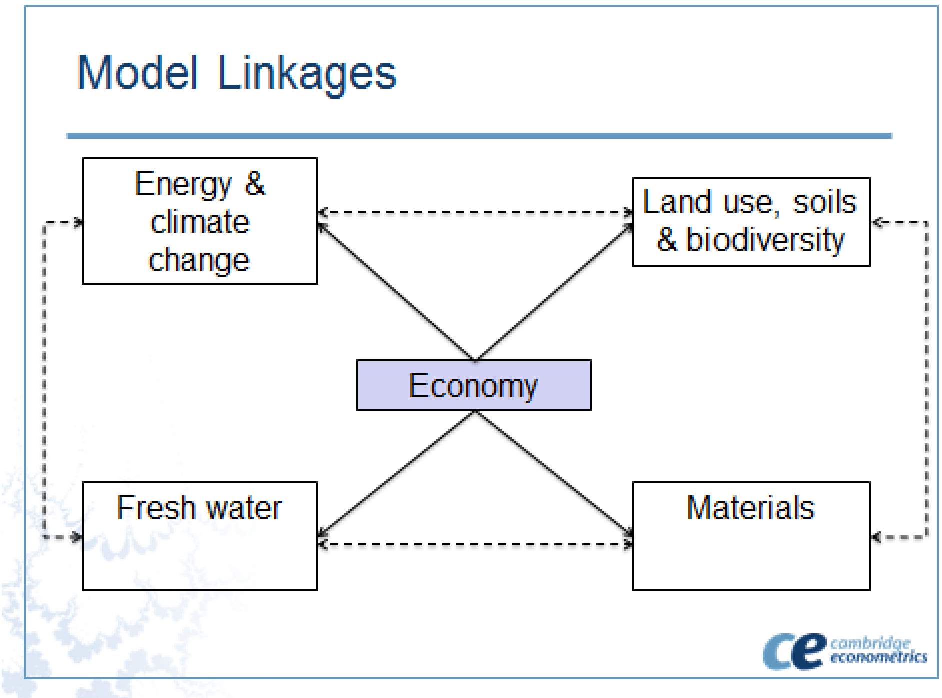


Figure 4.2 essentially represents a modified version of a similar chart in Pollitt et al (2010), which was based on the Eurostat Sustainable Development Indicators[37]. The

[37]See http://epp.eurostat.ec.europa.eu/portal/page/portal/sdi/indicators for an explanation of the Sustainable Development Indicators. This also includes social and governance indicators, plus policy areas such as transport.

conclusion is similar, that the available policy areas link to the economy (although the linkage tends to be only in one direction) with relatively few linkages between the different areas.

This suggests that there are two ways that the different policy areas could be linked in a modelling framework:

- a more comprehensive coverage of direct linkages between policy areas
- better feedback to the economy

It should be noted that the first of these linkages would likely be based in physical units, and the latter more dependent on monetary units.

Examples of existing and desired physical links

One of the best examples of a physical link between these policy areas is between land use and climate change. Modelling frameworks can include two-way linkages, for example deforestation is a source of greenhouse gas emissions, but a changing climate also leads to changes in forestry coverage.

More generally, however, these linkages tend to be neglected. There are several possible reasons for this, for example:

- the linkages are not always well understood
- the effects are indirect, through the economy (in which case approaches below are more relevant)
- there has not been a demand from policy makers to link the policy areas
- there is a lack of understanding or communication between disciplines

The broadest coverage at present generally comes from the framework that has been built around the IMAGE model, which includes linkages to the energy system (TIMER) and the ecosystem, as well as economic linkages to the WorldScan model.

Examples of existing and desired economic feedbacks

The description above perhaps suggests that a more promising approach may be to link the policy areas through the economy, with two-way feedbacks to each policy area.

There are some examples where feedbacks are provided:

- E3 and IAM models (as discussed in previous sections)
- incorporation of economic damage costs, e.g. from ExternE[38]

Again, these are typically the exception rather than the rule. The first example could (and is being) generalised to cover other policy areas where an economic transaction is involved, including purchases of raw materials and water, but not any further. The second example is the result of a series of large studies to estimate the costs to society of certain environmental actions.

Sometimes the links are too complex or are not well enough understood to provide detailed economic feedbacks. For example the effects of the degradation of a local environment on tourism will depend on factors such as the initial state of the environment, the type of tourism and the type of tourist involved. Even if a damage coefficient could be estimated, it would likely only provide a single linear value for the marginal economic costs of a (not-yet defined) unit of degradation. However, in reality it is possible that this reduction in visitors would reduce the level of environmental degradation in future periods, representing an important feedback.

[38] See http://www.externe.info/

The recovery in fish stocks in the Gulf of Mexico following the oil spill in 2010 (and subsequent loss of economic production) is another example of feedback that would be missing in most modelling approaches.

Links within a model or links between models?

This discussion raises the issue of whether it is preferable to build a model that incorporates these desirable linkages or whether these linkages are best represented by linking a group of specialised tools.

There are obvious attractions to creating a single 'super-model' that covers all the areas of sustainability with linkages between each component part. However, in practice such a tool is likely to suffer from the one of these two sets of shortcomings:

- It has a very broad scope but does not have a detailed coverage of any particular policy area.
- It is extremely large and complex, meaning:
    - it is difficult and time-consuming to operate
    - results are difficult to interpret
    - uncertainty in one part of the model could affect results elsewhere.

In both cases there is also the issue that the model operator will not have expertise specific to each part of the model.

The prototype model that was developed as part of the FORESCENE project (Bringezu et al, 2009) is a good example of a model that addresses several different policy areas. The modular approach used in this model could form the basis for future developments of large-scale multi-purpose models.

Pros and cons of linking models

Participants in the project workshop also reflected this view, preferring an approach of linking specialised existing modelling tools. It is noted that there are some ongoing or recently completed projects that have aimed to improve model linkages, including within the European Union's research framework programmes[39].

Model linkages can be described as 'hard' (linking computer code, which is half way to the position described above) or 'soft', which means linkages through data. Both of these are highly resource intensive but it is important to note that the costs are in upfront investment for hard linkages, but are operating costs though transferring data for soft linkages. These costs could possibly be reduced by the use of a common software platform[40].

There are also more fundamental issues that must be considered. Differences in model dimensions can be very difficult to reconcile, as they often reflect the data that are available to use in each policy area:

- geographical dimensions, e.g. by country or using a 100m^2 grid approach
- sectoral definitions, e.g. national accounts and trade data
- time dimensions, e.g. monthly or five-year solutions

There may also be differences in underlying assumptions (e.g. some models assume optimising behaviour, others do not), definitions used in the data and baseline forecasts.

[39] SENSOR, SEAMLESS, iTREN are some examples.

[40] CIAS is an example of a platform that creates an IAM from specialised component parts. See http://www.tyndall.ac.uk/research/cias

Finally it can be difficult to understand the properties and key sensitivities of the combined models, particularly those connected through soft linkages, as the size/complexity of the tools increase and practicalities limit the number of runs that can be carried out.

4.4 Designing a model structure

An integrated assessment framework

Building on the policy areas defined in previous chapters and the assessment in the previous section, Figure 4.3 presents an overview of the structure for a possible comprehensive modelling framework. Each box (module) represents a policy area that could have a distinct modelling tool attached to it. The linkages are our interpretation of how these models and policy areas could interact (in physical terms, price relationships will often move in the opposite direction). Clearly the design requires a certain amount of judgement, but we have tried to take into account both what is desirable and what could be achievable. It is not dissimilar to the model designed in the FORESCENE project. However, it is aimed to enhance discussion rather than state a definitive structure.

Our suggested framework comprises around eight different modelling tools, depending on how the different parts are separated. Even though our aim is to suggest a framework that is both theoretically coherent and practical to use, it is recognised that this would be a major undertaking given the difficulties outlined in the previous section.

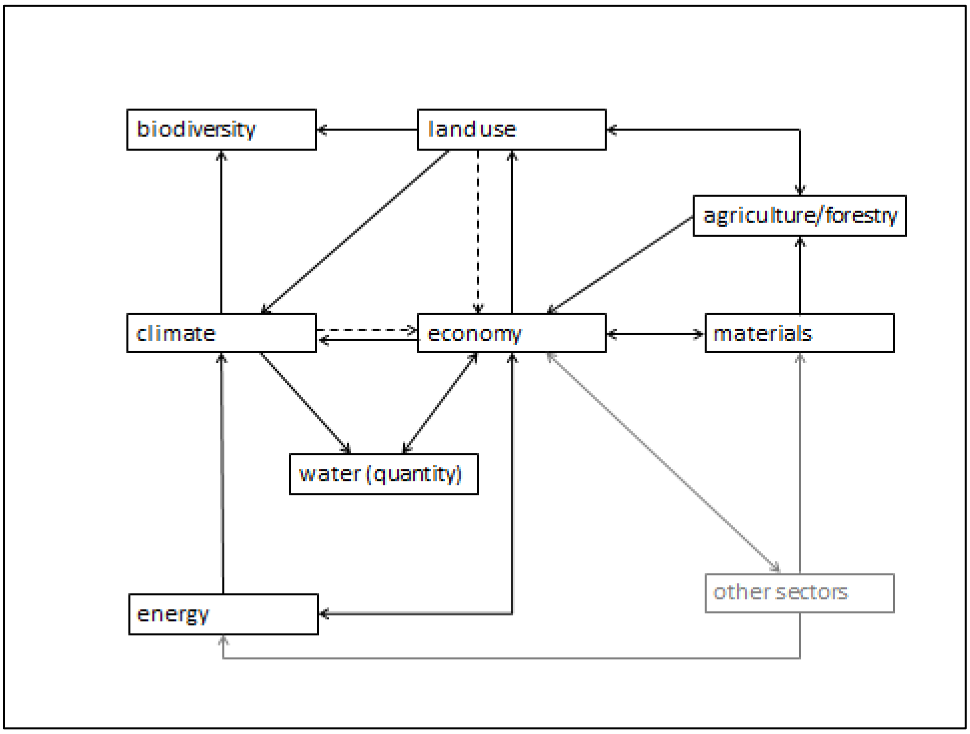
The economy (including the labour market) sits in the middle of the chart as it represents the interaction between the users and suppliers of different resources. There are several direct two-way linkages from the economy module (to water, materials and energy), where the economy module provides a measure of demand and the other module returns the impacts on supplies, such as turnover at water companies. The other main loops are through materials, agriculture and land use, and through energy and climate.

There are some additional linkages that could or should be added to the figure, depending on the specification of the models used. For example agriculture is the largest user of water[41], and biological land use is also dependent on climate. Under the current specification, biodiversity is the one module that does not feed back to any of the other modules.

The dotted lines in Figure 4.3 refer to linkages that would be preferable to have but cannot be quantified (except possibly through the use of damage coefficients). These would therefore need to be addressed in a more qualitative manner.

[41] In Figure 4.3 agriculture is indirectly connected to water consumption via the economy. This means that an increase in agricultural production would lead to an increase in water consumption but it would not take into account the requirements of different crops or the differences between crops and livestock.

Figure 4.3: Suggested Model Structure



Possible further additions

The grey section in the bottom right suggests where further partial models, based on physical relationships, could be added to enhance the analysis. These would have two-way linkages with the economy and could create demands for material and energy, improving the basic linkages.

Transport, which was identified as a key sector in previous chapters, is an obvious example of a sector that could be covered in this way, but other possibilities include single-sector models of the steel or cement sectors. Construction, which is more heterogeneous in nature, would be another example (and a key user of mineral resources), although we are not aware of any models that cover this sector in great detail.

Physical relationships and input-output coefficients

The reason for including physical relationships is not just that it is better to use a physical representation for an assessment of sustainability, but that the physical data are typically available in time series rather than the single years for which we get input-output data. This allows the relationship to respond to changes in price or economies of scale.

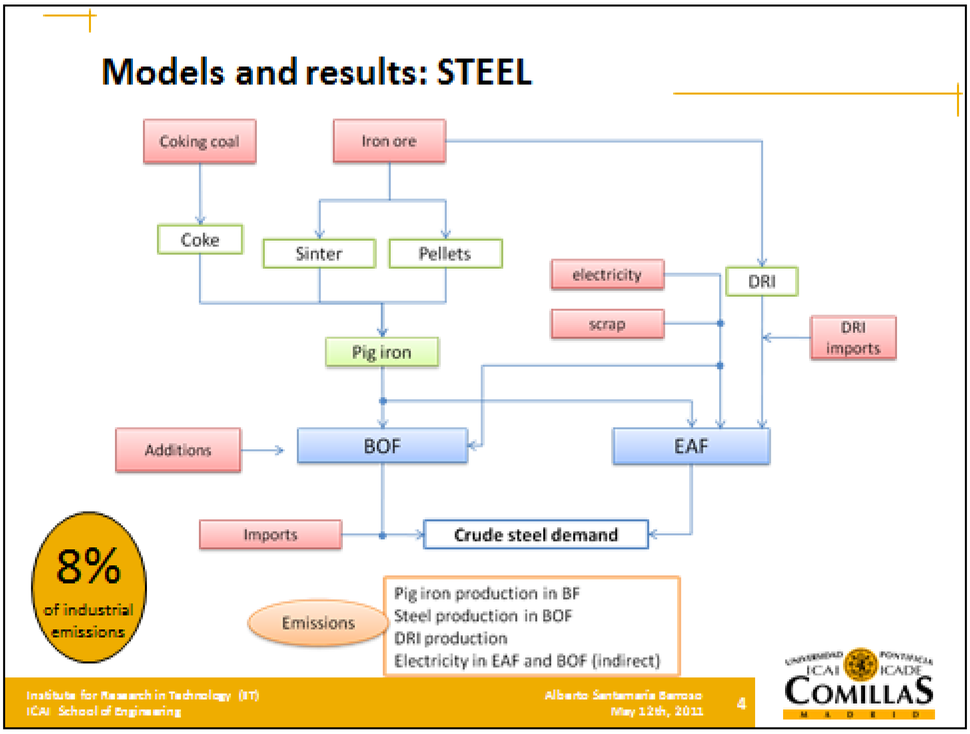
Consider an example in which transport costs increase by 10%. In an economic model based on fixed input-output coefficients this would not influence the demand for transport (i.e. the direct price elasticity = 0). In a transport model, however, using physical data (e.g. freight tonne-kilometres) it would be possible to use the empirical data to estimate a price elasticity and a demand response[42]. The type of change that would be required to bring about a sustainability scenario is thus represented.

Our estimate is that 20-25% of the coefficients in an input-output table could be allowed to vary if the economic model included all the possible physical relationships[43]. This includes coverage of many of the most resource-intensive sectors (many of the others relate to business services).

The ultimate aim is to replace many of the fixed top-down relationships within the economic model, which are measured in monetary units, with ones instead measured in physical units (see discussion of disaggregation below), essentially meaning that the economic model itself becomes a structure for holding together a series of bottom-up tools that cover all the main resource-intensive sectors and their key technologies in detail. A more modular approach (as in FORESCENE) that allowed for a 'plug-and-play' type interaction, with the ability to test different modules, would facilitate this.

An example of what such a module for the steel sector, taken from Santamaría and Linares (2011, forthcoming), might look like is provided in Figure 4.4. The material, energy and technological choices are explicitly defined. Although the data requirements are quite extensive, it is not difficult to imagine how this could be linked to a wider economic context.

Figure 4.4: Example of a Bottom-Up Model for Steel Production



[42] In economic terms, this is relaxing the assumptions of fixed factors of production in a Leontief production function and replacing with a CES function (or one that is more complex still, depending on parameterisation).

[43] This is based on the 60 sectors used in the current Eurostat National Accounts Breakdowns, based on Nace rev 1.1.

Model dimensions

A consistent set of dimensions is required to carry out the analysis. We discuss three of the most important below, the sectoral aspect, spatial disaggregation and time steps used.

Sectors

The most important sectoral dimension is the one in the economic model, as this plays a key role in integrating the other models. Under the suggested framework it would be necessary to include the sectors that supply resources:

- Agriculture
- Forestry
- Energy extraction (preferably split into coal plus oil and gas)
- Non-energy mining
- Energy supply
- Water supply

This is not a major constraint, however, as all of these sectors are defined at the NACE 2-digit level in revisions 1.1 and 2.0. It would also not be too problematic to explicitly include the main purchasing sectors, such as food, metals, non-metallic minerals, construction, etc, as these are also mostly defined at the same level of aggregation. The transport sectors can also be defined without too much difficulty.

More generally, however, one of the key advantages of using a framework of distinct modelling tools is that each one is able to offer a high level of detail. There should therefore be a high level of detail within each component part, as well as the economic model.

Spatial dimension

From a policy perspective it is necessary to define model outputs at the Member State level, and the available data are unlikely to support a degree of accuracy beyond this. There are two additional issues:

- how to reconcile grid-based data and national boundaries
- the global context

The first of these requires a translation exercise but not one that should be particularly problematic. The models can still operate and produce results using their own highest level of disaggregation, and it is only the information that is passed between tools that must be transformed.

The approach to the global context largely depends on the policies and scenarios that are being evaluated. A truly sustainable scenario can only be considered in a global context but for an evaluation of European policy a European coverage may be sufficient. The constraints here are largely driven by data and software rather than imposed on theoretical grounds.

Time

It is noted that the modelling framework contains policy areas with different timespans of interest, ranging from months or quarters (e.g. economic development, water supply) to decades or centuries (e.g. climate). In addition, there is a combination of stocks and flows involved.

A minimum time horizon of 2050 is required and a longer time frame should be available from each of the component parts, albeit with a much larger degree of uncertainty attached. The question of time steps up to 2050 is more subjective. It is important to consider the transition and immediate short-term effects, suggesting annual results (which is probably the highest frequency supported by the data) would be preferable. However, beyond the short term, five or ten-year intervals would probably suffice.

Other modelling characteristics

At the project workshop, much of the modelling discussion focused on the linkages described above. However, the discussion also included some topics of modelling characteristics that are either desirable or should be acknowledged more openly. These are briefly discussed below.

Empirical basis

It was stressed at the workshop that an empirical basis should be used whenever possible (there are cases, for example in climate modelling, where it may not be). This discussion was not aimed to discount the use of theoretical models, but that their behavioural relationships should be formed from actual data rather than pre-selected (see Mitra-Khan (2008) for a discussion).

This is perhaps of particular relevance when combining modelling approaches, as it helps to ensure that the models involved have a common starting point based on the latest available data.

Limitations of modelling

Pollitt et al (2010) discusses some of the more technical constraints of existing modelling approaches. Several of these are highly relevant to sustainability scenarios that are considering large-scale changes over a relatively long time period. Some examples include:

- the unknown state of technology in 2050
- using linear approximations of non-linear relationships

It is thus important to acknowledge the considerable range of uncertainty surrounding long-term model outcomes. This applies to any modelling approach that may be used.

Applying such a model

All of the models that sit within this framework can be applied to assess the outcomes of scenarios and, to our knowledge, there is no reason that these models cannot be run over a time horizon up to 2050. The key questions are whether it is possible to start the models at a consistent baseline position and then to use a consistent scenario definition.

The resources required to construct a single baseline should not be underestimated. The starting point for this could be a set of economic projections (consistent with the dimensions described above) that could be used to inform the other models[44]. Even so it could be difficult to ensure consistency with so many feedbacks between modelling tools (e.g. if the economic projections suggest a physical capacity is breached).

The modelling framework would then be in a position to assess policy scenarios and, ultimately, a set of policies aimed at achieving the vision outlined in Chapter 3. These policy inputs must also be defined on a consistent basis so that the modelling framework remains coherent as a whole.

How would this work in practice?

Assuming that there are soft linkages between each of the individual tools, an iterative process would be required to solve the complete package with data moving between each component part. Most of the feedbacks to the economic model are to different sectors, but in some cases the sectors that supply one good will also provide the demands for another.

[44] This is the procedure used for the projections of energy demand in *EU Energy Trends to 2030* (European Commission, 2010).

The first stage would be to determine an order in which to solve the models. To be most efficient this would broadly follow the lines of causality (i.e. the arrows in Figure 4.3), taking each of the loops in turn. For example the following two steps could be repeated:

- economy, materials, agriculture, land use
- then economy, energy, climate, water

The module for biodiversity can be run at the end as it does not feed back to other modules.

Clearly this approach would be much more efficient if the model inputs and outputs were automatically passed on between each step. A common software platform would be a major step to achieving this. It should also be noted from a practical perspective that the types of models involved take different lengths of time to run, ranging from seconds to hours. The focus should be on limiting the number of runs required from the most complex models.

Assessing the degree of uncertainty

As described in previous sections, it would be difficult to test the key sensitivities of the complete modelling system due to the practicalities of carrying out a large number of simulations. By adopting a modular approach it would, however, be possible to compare individual tools by substituting in and out different models, or setting parts of the system as exogenous (i.e. breaking the links).

It would be easier to design a methodology for addressing this issue if a modelling framework was already established.

4.5 Conclusions and suggested developments

The tools are available to assess the key elements…

In Section 4.3 we found that it is largely possible to model all of the individual elements of a sustainability scenario using existing tools. The different resource types have different levels of coverage, for example there are many different energy models, but relatively few models of material use. The quantitative assessment of biodiversity suffers from measurement issues, but there are tools available that address the topic.

… but linking these tools is much more difficult

However, existing modelling tools are much more limited when it comes to assessing these key elements within a single framework. There are relatively few linkages between resource types (excepting energy and climate) and, although economic linkages exist, these tend to be with limited feedback as it can be difficult to estimate the effects of environmental degradation on economic indicators.

A comprehensive framework therefore requires either direct linkages between resource types or a more complete set of economic feedbacks. This can be achieved either by creating a new model that encompasses all the resources or policy areas, or by linking existing models through data transfers or code amalgamation. For several (mainly practical) reasons the latter option was found to be preferred.

On this basis a modelling framework was suggested

In Figure 4.3 we propose a modelling framework that can be used to assess a complete range of policies aimed at achieving a sustainable Europe. This includes the linking of around eight different tools, with possible further extensions to improve the treatment of key sectors such as transport. It is similar in scope to the framework developed in the FORESCENE project (Bringezu et al, 2009).

Several other features of this framework, which should (and in some cases would be required to) apply to all the models involved were proposed:

- detailed sectoral disaggregation
- Member State coverage, or a specification that can be accumulated to match this
- a time horizon of at least 2050, preferably further
- an empirical basis
- common data definitions
- a single set of baseline projections

Even if all of these conditions were met, it must be acknowledged that linking models for scenarios analysis is a difficult and highly resource-intensive exercise, especially so when so many models are involved and when there are two-way linkages and circular causalities involved. The proposed framework may thus be technically feasible but it is highly ambitious in nature.

Recommendations

These findings suggest that there are two possible ways forward:

- We could continue to use a suite of separate and distinct modelling tools to assess individual policies and parts of the vision described in Chapter 3, addressing issues of interlinkages manually (e.g. changing assumptions) as they arise. This is adequate for many existing policy assessments but is less suitable for assessing the overarching scenarios described in Chapter 3.
- We could move towards one or more standard (possibly web-based) software platforms for linking modelling tools and the users of these tools. This would create a common interface for models but could also allow discussion by model operators starting from a common understanding. The application of this software need not be limited to sustainability analysis but it should probably be part of a wider forum for discussion among users.

Before undertaking an ambitious plan of software development (that has been tried before) it would be worth reviewing any previous exercises (e.g. FORESCENE) and whether they were part of a wider effort at interdisciplinary cooperation. This includes developments by researchers within these policy fields, but also those in other disciplines, such as engineering or computer science. Both successful and unsuccessful attempts should be considered, with the key factors in each case summarised. It would be beneficial to draw up a list of key questions in advance.

The outcomes from this would be a list of key features and requirements that would be of benefit to the research community and thereby ensure adaption of the system. This, and other possible developments in assessment methodologies, is discussed in more detail in the following chapter.

5 Implications for the Resource-Efficiency Initiative

5.1 Introduction

Overview

This report has taken a direct approach to identifying environmentally sustainability scenarios for a resource-efficient Europe. In particular we addressed the following two questions:

- What are the key elements of a sustainability scenario?
- How can such a scenario be assessed quantitatively?

In Chapter 2 we presented a broad literature review of scenarios that had been carried out previously, covering various aspects of factors that we would expect to see in a comprehensive scenario. Chapter 3 built on this and outlined the key elements of this scenario. It is similar in coverage and priority to the European Commission's Resource-Efficiency Initiative (European Commission, 2011c) but suggests fixed targets for each policy area. This approach was further discussed at the project workshop.

In Chapter 4, the focus shifted to quantitative assessment methodologies and practical steps to scenario evaluation. This is expanded on in the sections below in an attempt to bring together the theoretical design of a sustainability scenario with the practical options for providing assessment.

Outline of this chapter

The remainder of this chapter is split into three parts. In the first part we summarise the modelling framework that was described in Chapter 4. In Section 5.3 we provide some examples of some models that could be fitted into this framework. The final section outlines in practical terms the main steps that are required to develop and apply such a framework.

5.2 Identification of a modelling framework

Overview of the framework

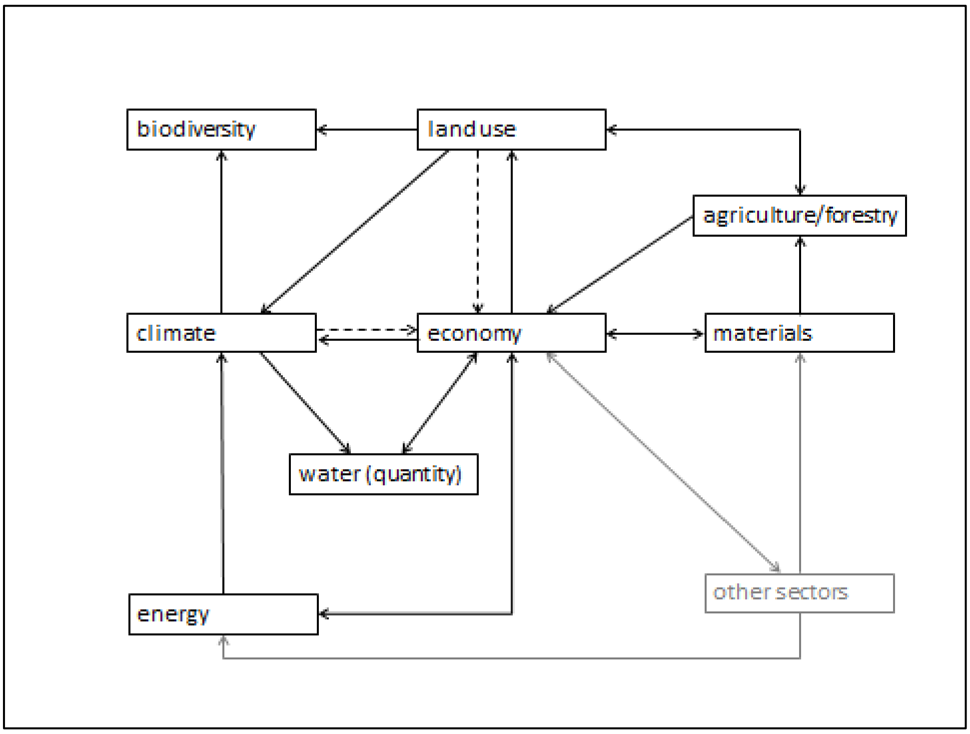
A suggested modelling framework was presented in Chapter 4 (reproduced here as Figure 5.1). It includes the key elements of sustainability scenarios that were identified in Chapter 3, as modules within the overall framework. They are:

- materials
- energy and climate
- fresh water
- land use, soils and biodiversity

Figure 5.1 also highlights some of the key linkages between these aspects.

However, central to this modelling framework is a representation of the economy. This provides the key linkages between the different resource types and links together the suppliers and users of the resources. The common currency units used in economic models provide the basis for these linkages, although it should be noted that within each module it is preferable to use physical rather than economic units.

Figure 5.1: Overview of Modelling Framework



Energy and materials

In Chapter 4 we showed that the linkages between the economy and energy demand (and resulting CO2 emissions) are well understood and are common in economic models. More recently a similar treatment of material demands has been developed, although this is to some extent recognised as work in progress.

Our first recommendation is thus that a state of the art in incorporating material demands is established and that these linkages become as common and well understood as existing economy-energy linkages.

Sectoral disaggregation

In economic terms the modules in Figure 5.1 cover the supply of resources to the economy. The figure does not explicitly show all the users that provide demands for materials (they are mainly implicitly tied up within the economy module) but at the workshop there was a clear preference expressed for these sectors to be defined in as much detail as possible. In practical terms this broadly means the NACE 2-digit level, as supplied by Eurostat, because this is the highest level offered by the input-output tables that link the sectors (and therefore resources) together.

Input-output relationships

However, there are also grounds for including some sectors explicitly using the physical data that are available. This is shown in the grey module in Figure 5.1, where a sector receives its demand from the wider economy and uses materials and energy to meet this demand. This can be used whenever there are physical data to match the economic relationship that is represented in the input-output table.

Transport is an obvious example; the demand for transport depends on macroeconomic factors and these demands are met by different modes (that go beyond the level of detail in the economic data) that use differing amounts of fuel. However, increasingly there is the prospect of linking macroeconomic tools to bottom-up engineering-based models of particular sectors that incorporate a rich representation of the production methods used in a single sector, such as steel production.

Moving towards a comprehensive economic representation

Eventually the economic model would incorporate a series of modules that can be brought in and out, covering the main suppliers of resources and the main consuming sectors. These key relationships between sectors would be allowed to vary according to parameters based on physical time-series data, while the fixed input-output coefficients would provide the remaining sectoral linkages.

Examples of where such bottom-up models already exist and are well established are:

- agriculture
- energy demand (especially power generation)
- transport
- water

There are also attempts to build models of other sectors that have specifically defined (and costed) technologies, each with its own energy and material demands (usually for fairly homogenous products like steel). Similarly to the models listed above, these take measures of demand and price from the economic model and estimate the energy and materials required to meet this demand, based on the available capacities and technologies. The advantages are considerable; what an economic model would consider with a single log-linear parameter, the bottom-up model can include threshold effects, economies of scale and specific production technologies.

Our second recommendation is therefore that economic models move towards a modular position, where specific and detailed treatments of key sectors can be brought in and out according to the user's requirements.

Non-economic linkages

There are, however, some linkages that cannot be defined in terms of economic transactions. Examples include the links to climate, land use or biodiversity.

These linkages are much more difficult to define in the models (and some are difficult to measure, see below). It is also likely to be the case that the model operators come from different backgrounds. Although it is possible to link models across this divide (see Figure 4.1 for an example), there is a loss of detail when the models are linked.

The recommendation is thus that an interface is created so that model operators and their tools are able to communicate using a common language. Although there is an obvious software development required, this needs to be part of a broader platform so that it is adopted as the standard methodology for linking tools. A review of existing software tools, including outputs from the FORESCENE project (Bringezu et al, 2009) could establish a best practice.

Undefined linkages

The final recommendation relates to the dotted connections in Figure 5.1. The two that are included in the figure are only examples; more generally this feedback from environment to economy is not well understood. It is not quantified beyond the use of estimated static damage coefficients.

It is noted that attempts have been made to estimate the current value of local environments to the economy, but this exercise has rarely been carried out in the context of future scenarios. This is partly due to a lack of empirical basis.

Clearly this would be a major task that is only just starting. It must be carried out at a sufficiently high level of detail (both geographical and sectoral) in order to capture the impacts of changes to the local environment. It must avoid being sidetracked by imprecise definitions of what constitutes resources and the 'environment'.

In the near term it should not involve modelling, as there is little that current tools can offer; initially a more qualitative framework should be developed. However, the ultimate aim should be the linking of a key set of environmental pressure indicators to a set of detailed economic sectors.

The final recommendation is thus a programme to develop an understanding of how future changes in the supply of resources will affect economic performance.

5.3 Examples of models

In Chapter 4 we found that there are examples of models that could contribute to all of the modules shown in Figure 5.1, although some areas are much better developed than others.

Rather than reproduce a long list of examples of models here, the reader is referred to Appendix B, or the discussion in Pollitt et al (2010), which discusses some of the key characteristics of these models.

5.4 Practical steps to development of an overarching framework

In Section 5.2, four key recommendations were presented:

- economic models include materials as standard
- economic models develop a modular framework to provide better detail of key sectors
- a common interface is developed for linking models
- further research is conducted to deepen the understanding of the linkages from environment to economy

These are discussed briefly in turn below.

Including materials in economic models

Two macroeconomic models, E3ME and GINFORS, already include a treatment of material demands. This is being enhanced further under work being carried out for DG Environment. Although both these models are econometric in structure, there is no reason that this development could not also be brought into CGE models.

The requirement is thus to produce a methodology that is clearly documented and is generally accepted by model developers, so that widespread adoption becomes a possibility. The challenge is partially one of dissemination, but is not one that is insurmountable.

Developing a modular framework for economic models

Previous examples of model linkages have been based on a modular approach, but this has not usually been generalised to a position where modules can easily be added or removed for a particular assessment.

The academic literature has increasingly been moving in this direction although putting the recommendations into practice has in general been less successful.

This could be the subject of a research project, but the focus of the work and the research outputs must be on the methodology used rather than the results for particular scenarios. If these outputs defined a standard modular framework, other models could be adapted on this basis.

This could be achieved within three years, for example as the output of a medium to large European research project.

Design a common interface for linking models

We are less well placed to provide recommendations on software development, as this requires particular expertise. However, there are some general principles that must be adhered to if the interface is to be widely accepted and used. For example:

- A system must be flexible so that different types of models can use it.
- The requirements of model operators from different backgrounds must be taken into account.
- Issues of differences between models in spatial and sectoral disaggregation and time steps should be addressed.

Before carrying out any development work, it is recommended to carry out a scoping study to provide a complete list of specifications.

If this was to go ahead, the estimated timescale for completion probably lies in the range of five to ten years.

Understanding linkages from environment to economy

The final recommendation is fairly open-ended in nature. At least in the initial stages it does not have a large direct relation to quantitative modelling.

It is recognised that there is work in this area going on; in terms of forming useful modelling inputs this needs to form a pattern of:

- identifying key linkages
- determining the key sectors / regions where these occur
- quantifying

5.5 Conclusions

The aim of this chapter was to develop a quantitative modelling framework that could be used to provide a comprehensive assessment of a sustainability scenario and the policies that might be implemented to achieve this scenario. This is closely tied into the European Commission's ambition to:

… develop a set of tools to allow policy makers to drive forward and monitor progress. This will help build the clear support and involvement of national, regional and local authorities, stakeholders and citizens.

(European Commission, 2011c, p. 4).

We found that there are some aspects of the scenarios that cannot be quantified under the current knowledge base. However, in the main the modelling capabilities to carry out the assessment exist and are reasonably well established.

The focus of future development is thus to improve the linkages between resources within a single modelling framework. The preference was for this to be through a consistent method for linking distinct tools, rather than building a new 'model of everything', that would be too unwieldy to use. The four recommendations outlined in the previous section thus aim to address this issue, with the ultimate aim of providing an assessment framework for looking at sustainability scenarios.

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Appendices

Appendix A: Details of Workshop

A.1 Introduction

This appendix presents an overview of the discussion from the workshop that constituted Task 4 of the project. As described in the next section, the main focus of the workshop was on the final two objectives of the project:

- identify the parameters that could be part of a vision for a resource-efficient EU by 2050, put up the elements needed for constructing such a vision within the basic scenarios and identify the models or model suites that would be appropriate to use in a modelling exercise
- assess the scale of cross-cutting policies and how they have been and could be addressed within scenario building and modelling exercises

A.2 Overview

A one-day workshop was held at the European Commission in Brussels in April 2011, and was attended by around ten EC staff. Two experts, Bernd Meyer from GWS and Doreen Fedrigo-Fazio from the IEEP, were also invited to the workshop to provide their thoughts on the issues presented, and to stimulate discussion among all participants.

The project team are grateful to all who attended the workshop and participated in the discussion.

Structure of this appendix

The structure of this appendix is as follows. In Section A.3 the objectives of the workshop are given. Section A.4 details the first of the two sessions of the workshop, providing commentary on the team presentation, the panel discussion from the two experts and the open discussion.

Section A.5 presents the results of the poll carried out, that was designed to feed into the second session. This is discussed further in Section A.6, following the same format as Section A.4.

The discussion document

Prior to the workshop, the project team had completed the first two tasks of the project and provided the results to the workshop participants in a discussion document.

A.3 Objectives of workshop

The main objectives of the workshop were to:

- validate the vision developed by the team and the key elements designed to reach it
- discuss policy options to achieve the vision
- discuss the modelling approaches currently available to assess the scenarios
- identify the gaps in modelling capabilities and how they could be addressed

A.4 Session 1: Visions and targets for a resource-efficient Europe by 2050

Team presentation

The team presented the results from Tasks 1 and 2 of the project. The purpose of Task 1 was to identify existing sustainability scenarios from the available literature. Around 30 scenarios were identified, of which eleven underwent a detailed review.

The scenarios were assessed using several criteria, including the type of study, narrative visions and quantitative targets, and explicitly tested policies.

Task 2 summarised the main visions, targets, and proposed or modelled actions from sustainability scenarios at the European and global level. This included studies on resource efficiency as well as recent Communications from the European Commission. The four overarching headline visions were then explained and linked to possible headline targets to achieve a resource-efficient Europe (taken from the literature and existing policy strategies). The visions and possible targets for three resource categories (materials; fresh water; and land use, soil and biodiversity) were also presented. Table A.1 and Table A.2 summarise the visions and targets respectively.

Table A.1: Summary of Visions for a Resource-Efficient Europe by 2050

SUMMARY OF VISIONS FOR A RESOURCE-EFFICIENT EUROPE BY 2050

Headline visions	Visions for materials	Visions for fresh water	Visions for land use, soil & biodiversity
Strong de-coupling of economic growth from the use of renewable and non-renewable materials, water, land use and GHG emissions → absolute dematerialisation.	Strong de-coupling of economic growth from the use of renewable and non-renewable materials, water, land use and GHG emissions.	From 2015 all European water bodies have good ecological status or good ecological potential.	Expansion of built-up land has been stopped.
One Planet Living: Better resource management and changes in lifestyles and consumption patterns ensures we live within the carrying capacity of the planet.	Steady man-made physical stocks.	Long-term stability of EU freshwater bodies.	Stable soils: further degradation of soils has been prevented, functions preserved, degraded soil has been restored to a level that enables at least its current or intended use.
Energy-efficient, renewable-based, low-fossil-carbon economy → significant reduction of EU Carbon Footprint.	Minimum residual waste through cascadic use, re-use and recycling of materials.	Negative impacts of over-abstraction of water have been stopped.	Flourishing eco-systems: Ecosystem degradation has been reversed, ecosystem services are valued, maintained and enhanced.
Reversal of ecosystem degradation, valuation of ecosystem services → rich & flourishing biodiversity.	Improved efficiency of material use (including waste and pollution management).	Sustainable water management → low energy and material footprint of water consumption.	Biodiversity is flourishing, enabling economies and societies to prosper.

Table A.2: Summary of Targets

SUMMARY OF TARGETS							
Headline		**Materials**		**Fresh water**		**Land use, soil and biodiversity**	
Target	**Value or range**	**Target**	**Value or range**	**Target**	**Value or range**	**Target**	**Value or range**
Absolute reduction of primary material use following 'Factor 4 to 10' requirements.	80% by 2050	Absolute reduction of primary material use following 'Factor 4 to 10' requirements.	30% by 2020 80% by 2050	Reduction of EU net-imports of embodied (virtual) water.	Zero	Reduction of EU's global land use, in particular cropland.	Fair global per capita share, i.e. 0.20 ha/cap cropland by 2030
Significant reduction of EU's GHG emissions (Carbon Footprint, including emissions embodied in EU trade).	20% by 2020 compared to 1990 80-95% by 2050	Increase in total material productivity.	5% pa or 3% above GDP growth	Water abstraction per annual available water resource in European river basins is reduced in order to avoid water scarcities.	Abstraction below 20% of available renewable water resources	Net-growth of built-up (sealed) land stopped.	Zero
Water abstraction per annual available water resource in European water bodies is reduced in order to avoid water scarcities.	Abstraction below 20% of available water	Reduction of per capita abiotic Total Material Consumption (TMC) in the EU.	10 t/cap in 2050	Achievement of good ecological status or good ecological potential of all European water bodies.	By 2015	Net land conversion through mining and from landfills.	Zero
Reduction of the EU's direct and indirect global land use.	Fair global per capita share	Net addition to material stocks (in particular metals and non-metallic minerals).	zero by 2050			Nutrient balances for nitrogen and phosphorous in soils.	Stable
		Increase the share of secondary metals	Target values to be			Minimum share of unused land /	Target share to be

SUMMARY OF TARGETS

Headline		Materials		Fresh water		Land use, soil and biodiversity	
Target	**Value or range**	**Target**	**Value or range**	**Target**	**Value or range**	**Target**	**Value or range**
		(recycling/reuse) in total consumption of metals.	defined			protected land area under Natura 2000 and Habitat Directive.	defined
		Net-imports of biomass in Europe.	≤ 0 by 2030				
		Reuse and recycling of metal in Municipal Solid Waste.	≥ 50 % by 2020				

Panel discussion

The two guest speakers, Bernd Meyer (GWS) and Doreen Fedrigo-Fazio (IEEP) presented their views following the team's presentations. Their comments on the first session are summarised below.

Comments from Bernd Meyer

Bernd Meyer had several general remarks to make about the visions for a resource-efficient Europe:

- The vision presents a 'green growth' concept based on decoupling resource consumption from economic growth; the concept demands absolute decoupling to prevent the criticisms of 'zero growth' and 'de-growth' advocates.
- The holistic approach used avoids the problems of the present environmental policies that often induce partial and inconsistent solutions, but the vision must also consider aspects that cannot be measured.
- The concept addresses the interrelatedness of targets for 'pressure variables' and 'state of the environment' variables and insofar overcomes a conflict between the two policy approaches.
- Setting targets for 2050 will not be enough on its own; annual targets, target paths and a monitoring system are required.
- It is important to create more public awareness for resource efficiency so that environmental targets gain more priority.

Bernd also made several comments specific to the visions and targets related to the resources:

- With respect to the 80% ('factor 5') reduction in materials consumption, does the European scenario also represent a realistic global target, considering the large increases in world population expected by 2050?
- Are the materials targets concerned with total material consumption (TMC) or total material requirement (TMR)? For the 2050 targets TMC is the right indicator to consider. However, we also need TMR targets in order to observe import substitution of materials.
- One of the identified targets for energy was a significant reduction in greenhouse gas (GHG) emissions, including emissions embodied in EU trade. Bernd considered the fact that trade emissions were included in this as very important since many instruments for avoiding GHG emissions simply lead to import substitution.
- Bernd questioned whether the above-mentioned target for GHG emissions would already be achieved by another of the energy targets, to reduce the share of fossil fuel imports in total energy supply. He suggested a differentiation between 'burned' and 'not burned' uses should be made, so that process emissions are properly accounted.

Comments from Doreen Fedrigo-Fazio

The following bullet points summarise Doreen's thoughts about the proposed visions and targets:

- In general, Doreen supported the overarching perspective of the visions and targets proposed by the team and agreed with the resource categories chosen to consider. In particular, she agreed with the 'three-pronged approach' used – meaning the visions include materials (including biomass), key resources (energy, water, land use, soil and biodiversity) and the key consumption areas. This helps to build a more layered natural resources policy framework with measures having different orientation levels (overarching objectives, resources, sectors and products).

- Doreen appreciated that targets were included in the workshop note, in particular it was good to have the explicit mention of reduction in overall resource use, trade-offs (since there has been little policy development addressing these), carrying capacity (implying equitable access and use globally) and stocks (as much of the current focus is on flows).
- When putting this into practice it will be important to formally define certain broad terms, if we decide to use them, such as ‘green growth’. In this context it is important to think about absolute decoupling of economic growth from resource use instead of relative decoupling, if Europe is to achieve an actual reduction in resource use.
- It is important that research goes further than the existing studies identified and that an agenda is set to achieve a resource-efficient Europe within the expected timeframe.
- Doreen questioned why energy consumption reduction was reached only through targets related to efficiency measures. Work on roadmaps in other relevant policy areas (e.g. transport, low-carbon economy and energy) offer opportunities to reduce consumption levels absolutely and address changes in behaviour (beyond labelling and other information-related initiatives).
- Other questions were raised about the energy targets included, such as why there was no mention of the extensions to the 20% reduction in GHG emissions by 2020 to 30% if international cooperation is achieved.
- It was questioned why there was no mention of toxicity or water pollution targets for the fresh water resource. This is an important issue that should be addressed.
- Within the targets for land use, soil and biodiversity one target focuses on the restriction of biofuel production. Doreen questioned why the focus was on biofuels, as the biomass market is not only concerned with the energy sector but also other sectors such as those developing bio-based products. Doreen suggested including biomass itself in the vision and targets, and that it should be addressed directly through policy actions.
- With respect to the targets identified for specific economic sectors, three of the four targets for the transport sector are concerned with CO2 emission reductions. However, other targets should be considered in order to reach the visions for this sector, such as targets related to land use and material intensity.
- Doreen stressed the importance of going beyond the scope of current studies, to allow more progressive visions and scenarios to be developed.

Open discussion

The key questions the project team asked the workshop participants to discuss were:

- Which of the headline visions and targets are essential?
- Which of the visions and targets for the different categories of resource use are essential?

The following paragraphs summarise the comments made.

The **methodology** for selecting the headline visions and visions and targets for resources was questioned. This methodology was briefly described during the workshop, emphasising that selections were made on the basis of existing studies and previous analysis. This methodology will be clarified in the final report.

Several **criteria** were suggested **for the appropriate selection of targets**, including whether they are politically feasible, or whether the targets are realistic and mutually compatible (see below), can they be phased in, in time to meet the visions for 2050 and are they flexible. The political status of the targets (e.g. already fixed, legally binding, or under discussion) is clearly important in this discussion. Where there are currently no politically agreed targets it was suggested that they could be derived from existing targets. The timing of the targets, and the political context of the timing, is also important; short-term targets can be more easily achievable with existing technology while there is much more certainty about longer-term targets. It was noted that the transition path is important as well as the end point, particularly with regards to stocks such as greenhouse gas emissions.

The mutual **compatibility of the visions and targets and the ability of the targets to support the visions** were also questioned. It was agreed that the targets and the vision itself are closely tied, and participants enquired whether these had been tested by the project team using modelling techniques. The project team explained that the task was to summarise existing studies, some of which are incompatible, and some of which included formal modelling. However, modelling of the possible visions is not included in this particular project, although it would be a further step to take (discussed more in the second session).

Due to the interdependence of the resources analysed, it was discussed whether the related **targets overshoot/overlap each other** and whether there could be some **trickle-down effects**. An equilibrium situation could therefore be considered.

It was recognised that the vision presented may be idealistic but in practice it may be necessary to make **trade-offs between the policy areas**. Further discussion of the nature (and flexibility) of the targets is clearly important to this issue.

Part of the discussion also focused on the **global element of the targets**. First, can the targets be realistically achieved given the development of the global setting? For example, can the EU achieve 80% material reduction given the predicted growth in global population by 2050? Does it make sense to define targets on a European basis? Second, have the targets been agreed internationally? Targets that require possible international cooperation also need to address issues of fairness. Western countries developed without the constraints created by environmental and resource legislation. Developing countries can argue that it is only fair they are allowed to do the same.

It was noted that there is substantial **uncertainty** surrounding a long-term vision. For example, we cannot predict rates of economic or technological development up to 2050. All the studies that were assessed are implicitly making these assumptions when they define/assess the targets; unfortunately they may not be consistent with each other. The team will aim to address this to the extent possible.

The issue of **measuring** targets and the resource efficiency achieved was also talked about during the open discussion, particularly for biodiversity. Measuring the impact/success of biodiversity targets would be difficult since biodiversity is not easily quantified. In order to quantify these effects proxies such as land use may need to be considered.

Some further suggestions for policy areas and targets were made. These included air pollution and marine resources.

A.5 Ranking the relative importance of elements of the vision

Following the first session of the workshop, all participants were asked to vote on their preferred policy options for achieving the vision for each resource.

Each workshop participant received twelve stickers for voting. These were allocated to:

- six headline actions (three stickers/votes per person)
- six actions for materials (three stickers)
- six actions for fresh water (three stickers)
- six actions for land use, soils and biodiversity (three stickers)

Workshop participants were also invited to suggest any vision or action that they felt was missing from those provided.

Headline visions

In total, 32 votes and one white (unused) vote were cast for the preferred headline visions. The results of this vote are presented in Table A.3. No additional visions were suggested; however, two modifications were proposed, as shown in Table A.4.

Table A.3: Votes for Headline Visions

VOTES FOR HEADLINE VISIONS	
Visions	**Votes**
Strong de-coupling of economic growth from the use of renewable and non-renewable materials, of water, of land use and of emissions of greenhouse gases has been achieved.	31%
All the headline visions are equally essential and should be considered together in an integrated manner.	22%
Improvements in areas such as water use and reuse, wastewater treatment, land use, forest management and agriculture keep humanity on track toward living within the carrying capacity of the planet.	19%
Primary material and energy use have been reduced by 80% in absolute terms (absolute dematerialisation), resulting also in a reduction of EU's Carbon Footprint by around 90%.	13%
Biodiversity is being well managed, is flourishing, and continues to enable economies and societies to prosper.	13%
This reduction in overall resource use helped to avoid trade-offs between targets in different categories of resources and economic sectors, which used to occur with solutions focused only on increased efficiency.	3%

Table A.4: Modifications of Proposed Visions

MODIFICATIONS OF PROPOSED VISIONS	
1	All the headline visions are (equally) essential and should be considered together in an integrated manner, in a life cycle approach.
2	This reduction in overall resource use helped to avoid trade-offs between targets in different categories of resources and economic sectors which used to occur with solutions focused only on increased efficiency.

Actions for materials

33 votes and one white vote were cast for the policy actions for materials proposed by the project team. A further two votes were cast for additional suggestions 3 and 4

(shown in Table A.6 below) made by the participants. No modifications to the original policy actions were suggested.

Table A.5: Votes for Actions for Materials

VOTES FOR ACTIONS FOR MATERIALS	
Actions	**Votes**
Environmental fiscal reforms: introduce material input taxes (in addition to energy taxes) while reducing income taxes, in order to provide incentives for reducing material consumption and investment in material-efficiency technologies.	28%
Reform accounting standards to integrate positive and negative externalities, include indicators on physical material use, so that policy makers and investors incorporate these new measures into decision-making.	22%
Implement policies to increase recycling rates of various materials in order to develop a circular economy with more closed material loops.	19%
Make consumers aware of the material use of products through better information (e.g. resource-efficiency labels) and thus contribute to changes of consumption patterns.	16%
Reformulate valuation, investment and accounting criteria to create incentives for businesses and markets to couple traditional profitability with the creation of long-term value.	9%
Develop material-efficient public procurement through efficiency standards in order to stimulate demand for material efficient products and services.	9%

Table A.6: Additions to Proposed Actions

ADDITIONS TO PROPOSED ACTIONS	
1	EFR includes differentiation in prices between virgin and secondary materials?
2	More developed eco-design policy + support mechanisms (guidelines) + coherence between these and EFR.
3	Materials science focus in R&D + EU specialisation in substitution (e.g. for certain rare earths, raw materials).
4	Develop markets for recycled materials? EU policy focuses very much on supply of recyclates (recycling targets) only.

Actions for fresh water

Altogether 34 votes and one white vote were cast for the policy actions for fresh water. The results of this vote are given in Table A.7. The participants made no further modifications to the actions nor did they suggest additional policies.

Table A.7: Votes for Actions for Fresh Water

VOTES FOR ACTIONS FOR FRESH WATER	
Actions	**Votes**
Pursue the implementation of (international) institutional arrangements to cope with the global dimension of water governance (e.g. international protocol on water pricing, water-label for water-intensive products, minimum water rights and maximum allowable levels of water use).	25%
Improve efficiency of water use through integrating the principles of Integrated Water Management into water governance.	22%
Support the diffusion of technology and capacity building for non-conventional water resources development (e.g. reclamation of urban sewage waters, desalination) and conservation approaches.	22%
Implement policies to ensure that water pricing acts as an incentive for the long-term sustainable use of water.	19%
Increase productivity per water unit by improving recirculation and setting incentives to use less water-intensive processes in all economic sectors.	16%
Provide stable and transparent regulatory frameworks and monitoring systems for companies.	3%

Actions for land use, soils and biodiversity

Again, 34 participants voted for the policy actions for land use, soils and biodiversity (with one additional white vote). Again, no additional actions or modifications were suggested.

Table A.8: Votes for Actions for Land Use, Soils and Biodiversity

VOTES FOR ACTIONS FOR LAND USE, SOILS AND BIODIVERSITY	
Actions	**Votes**
Mainstream the preservation of biodiversity and ecosystem goods and services in various policy fields (e.g. aid and trade policies, REDD).	28%
Improve marine biodiversity (e.g. increasing designated marine sanctuaries; reducing marine fishing efforts to maximum sustainable yield levels).	22%
Revitalise urban centres and provide disincentives for further urban sprawl through active spatial planning.	19%
Revisit policy targets and incentives which lead to over-proportionate global land use of Europe (e.g. biofuels debate).	16%
Monitor global land use for domestic consumption of all agricultural and forestry goods with appropriate indicators.	16%
Expand and strengthen resilience of protected areas (increasing the size and connectivity of protected areas).	6%

A.6 Session 2: Actions for a resource-efficient Europe and appropriate models

Preferred policy options

The first part of the presentation made use of the results of the poll on preferred policy options to achieve a resource-efficient Europe (the poll was carried out during the coffee break, allowing time for the results to be collected). As well as discussing each of the resource policy options in order of preference (this order can be seen in the tables in the previous section), some exemplary sector-specific actions were also provided for each of the resources. The sectors for which specific actions were provided were construction and housing, industry and manufacturing, agriculture and food and transport and mobility. Table A.9 presents an overview of these additional policies.

Table A.9: Exemplary Sector-Specific Actions

EXEMPLARY SECTOR-SPECIFIC ACTIONS			
	Resources		
Sector	**Materials**	**Fresh water**	**Land use, soil and biodiversity**
Construction and housing	Actions to encourage refurbishment, renovation and dematerialisation, e.g. introduce a tax per ton of extracted or imported building material and increase it annually (e.g. UK aggregates tax).	Adopt a directive on water savings in buildings (similar to that already adopted on the energy performance of buildings) e.g. foster water-saving standards in national building regulations.	
Industry and manufacturing	New regulation by technical standards (e.g. establish resource-efficiency standards for key products).	Foster the development of targets for water efficiency at industry level.	
Agriculture and food	Actions to minimise food waste in shops and homes.	Actions to ensure that water saving potential is realised and abstraction is reduced.	Set incentives to reduce consumption of animal products and invest in public awareness (stressing health benefits and reduced pressure on natural resources).
Transport and mobility			Less traffic in urban areas, e.g. through better demand management and land-use planning / infrastructure design, facilitate walking and cycling.

Modelling techniques

The second part of the presentation provided an introduction to Task 3 of the project, which aims to prepare an inventory of the most appropriate models available for analysing policies related to the selected resources (plus energy). A brief overview of the current coverage of the models was explained:

- there are many models that look at energy and climate change
- there are very few models that look at material resources, although quantitative analysis is carried out, for example using input-output tables
- models of water extraction and consumption exist but tend to be specific to a particular river basin
- there are various models that look at elements of the land use and soils categories

The current linkages between models were also discussed, as well as the linkages between resources in the real-world which are missing in standard modelling techniques. The main theme of this part of the presentation was that, while there are links between each resource and the economy, there is no single model that addresses all the selected resources. Furthermore, there is a lack of modelling linkages between resources as well as feedbacks to the economy.

Panel discussion

Comments from Bernd Meyer

Bernd had various comments on the policy options for achieving a resource-efficient Europe. These were as follows:

- With respect to environmental tax reform (ETR), Bernd had the following points to make about the introduction of a material input tax (MIT):
  - A consistent system could include the taxation of fossil fuels and eliminate energy taxes.
  - Revenue neutrality should not only be reached by reduction of income taxes, but also by reduction of value added taxes. In many countries only half of households pay income taxes, but all pay value added taxes.
- He also noted that tradable permit systems are not a substitute for a MIT:
  - If there is another economic crisis the European Trading System (ETS) will be destabilized with other financial markets.
  - Permit systems are expensive to operate and a system based on material consumption would include many small installations.
- With regards to policy measures that focus on information provision and consultation:
  - There is potential for the reduction of material consumption in manufacturing at relatively low cost.
  - Materials are a physical part of the product, material inputs can be reduced by only by changes of the product design.
  - Material inputs are not in the focus of control systems so negative-cost savings could be possible with better information.
  - Strong rebound effects are possible; the use of economic instruments could prevent this.
- Policy measures that focus on regulation (technical standards) will be necessary if the MIT does not succeed. Top runner design would be appropriate.
- Bernd noted that other policy instruments, such as labelling consumer goods or extended producer responsibility over the whole life cycle of a product, would help but should not be central to policy.

Bernd also made various comments specific to the modelling approaches related to the resources:

- The main model features required:
  - A framework that includes the long-run interdependence of the EU economy and the environment (two-way linkages).
  - Empirically based: Model assumptions should be tested by statistical methods, for example with econometric parameterization.
  - General analysis: Macroeconomic closure depicting the activity of agents in the circular flow of income on product and factor markets.
  - Development of the economy and the environment:
  - Deep sectoral disaggregation consistent with the macroeconomic accounting framework that allows for the link with environmental issues.
  - Integration of international trade and global development.
  - Allocation of resource inputs in physical terms to sectoral economic activity.
  - Modelling the link between material consumption and the environment.
- Following these points, the following remarks relate to what the existing models can actually do, and their limitations:
  - There is no model available that fulfils all the mentioned requirements.
  - There is no model that fulfils in an acceptable way the requirement of interdependency of the economy and the environment. There are severe data problems and a lack of theory for modelling the feedback from the state of nature to the economy. However, to some extent interdependency can be captured by scenario assumptions (e.g. manually adjusting otherwise exogenous oil prices in response to changes in demand).
  - It is even difficult to model the link between resource consumption and the state of the environment.
  - However, there are models that fulfil the remaining requirements: E3ME and GINFORS are two examples.

Comments from Doreen Fedrigo-Fazio

The following bullet points summarise Doreen's thoughts about the proposed visions and targets:

- She expressed support for the proposed policy developments as they reflect the **integrated nature of the environmental targets** and therefore avoid being developed and carried out in isolation. However, other policy areas should be considered, such as innovation, sustainable industrial policy, cohesion policy, trade, development and taxation policy. Land use should also be covered.
- The study represents a coherent and coordinated approach that addresses various policy issues. Doreen was particularly pleased to see land use addressed since this is a resource that is largely overlooked. However, policy related to land use would require careful political treatment due to the conflicts that may occur between the EU level and the national level.
- Although the EU has made some steps towards a natural resources policy on the sustainable use of natural resources, it has made little progress in identifying that path and the different steps along the way. Furthermore, awareness and understanding needs to be raised in the other important policy areas previously mentioned (such as innovation and industrial policy).
- Policy should focus on **short-term** achievable targets as well as **longer-term** goals. However, we also need to address what is needed by 2050, not just what is needed now. Gaps that exist between the targets and visions can be addressed by new policy and legislation.

- 'Factor 5' author, Ernst von Weiszacker identified that resource efficiency can be stimulated through market-based instruments, but that sufficiency (absolute decoupling) requires legislation. Europe will need legislation in new areas, including in controversial areas, such as CAP reform or consumption policy (e.g. meat consumption is already addressed in the project document, but sustainable consumption policy will need to be developed in future which goes beyond historical consumer protection or safety).
- Policy measures to address **toxicity** and **chemical pollution** are missing. This can be linked to industrial or innovation policies since less pollution can be achieved through better technologies and techniques and through ecodesign. In addition to toxicity issues, chemicals and other emerging technologies (such as nanomaterials) are known to be material- and energy-intensive, but these issues are not addressed in existing chemicals policy. REACH focuses on sustainable chemicals management, not use.
- **Measures should also go beyond just information provision**, for example more design-related measures should be introduced to improve the energy consumption performance of products and not just focusing on the potential expansion of the existing Ecodesign Directive. We need to consider the development of framework product legislation that is not as cumbersome as the Ecodesign Directive which takes anywhere between two and five years to take decisions.
- There are no policies currently included focusing on biomass in a wider sense, and not just on biofuels.
- The distinction between virgin and secondary materials should also be recognised.

Open discussion

Policy discussion

Some additional points about the suggested policies were raised:

- **Innovation and research** is a cross-cutting issue that affects all the policy areas. Creating the right framework for innovation to take place is therefore a key goal.
- For **market-based instruments** a means of identifying quantities (e.g. tax rates, caps) is required. The revenues generated by MBIs should also be considered in any policy proposal. However, it must be noted that there are limitations to the effects of price signals alone.

Modelling discussion

The second open discussion focused mainly on the modelling side of the session, as opposed to the policy options. This in part reflected the fact that participants had already had the chance to state their views on preferred policies through the poll, and through the additional suggestions and modifications they submitted.

Part of the discussion concentrated on whether it would be better to have one **single model** that addresses all resources and policy areas, or whether **linkages between individual models** should be developed. Some agreement was reached that linking partial models that are specific to one particular area would be the ideal choice, as opposed to developing one 'super-model' and work (including land use) is going on within the EC and elsewhere. However, it was noted that this is not an easy task.

The **appropriate application of various modelling techniques** was also debated, for example the distinction between theoretical and empirical approaches, and relevance of the Lucas Critique (which states that macroeconomic policy decisions should not be made on the projections of econometric models, since the impacts of policy cannot be accurately predicted by empirical data) to the assessment of long-term policy scenarios using modern tools.

It was also noted that **economic costs** could be estimated using damage coefficients rather than a full economic modelling approach (i.e. by attaching to a partial model). This is an easier way to estimate costs and in some cases this may be more practical.

It is important to note the **limitations** of what modelling can and cannot achieve. Assumptions need to be made clear. It is recognised that modelling will work better with price-based mechanisms than regulation, and that there are some issues (e.g. ones that cannot be quantified) where models will not help.

A.7 Conclusions from the workshop

The conclusions from the workshop can be split into four main groups. These are discussed in turn below.

Project methodology

There was useful feedback to the team regarding the methodology that was used. These comments will be incorporated as much as possible into the final report:

- The methodology for selecting the targets needs to be made clear.
- The individual targets have been drawn from scenarios that use different baseline assumptions; this needs to be taken into account as much as possible.
- The political status of the targets should be made clear in the final report.

Constructing a vision

Several issues were highlighted as being of key importance:

- The overarching nature of the constructed vision is important as the policy areas cannot be viewed in isolation.
- Absolute decoupling must be achieved if economic growth is to continue while resource use declines. This aspect will be more prominently addressed in the vision.
- Transition pathways are important as well as end points.
- The vision for the EU must fit into a wider global vision, which raises further issues of international treaties and the concept of fairness.
- Uncertainty, particularly over future technologies, must be recognised.
- Although the targets are central to the vision, aspects of sustainability that cannot be measured must not be ignored.

Policy priorities

The main conclusions are:

- The results from the poll suggested that absolute decoupling should be a focus in policy development.
- Market-based instruments have an important role to play within a wider policy framework.

Modelling conclusions

The following points were noted:

- It is recognised that modelling can contribute to overall assessment, although limitations must also be recognised; modelling for some policy areas is presently in a more advanced state than for others.
- A priority for model development is improving feedbacks from the environment to the economy.
- Where possible, an empirical basis should be provided.

Appendix B: Model Overviews

B.1 Introduction

This expands on the modelling approaches that were discussed in Section 4.2. The following sections relate to the four types of resources that are considered in the report.

Further details on all of the modelling approaches, except those relating to soils, may be found in Pollitt et al (2010). The discussion of models used for assessing soil erosion is covered in more detail below.

B.2 Materials

Material resources are defined in this report as fossil fuels, metals ores, industrial and construction minerals and biomass. Analysis of these resources is not generally covered by formal modelling tools (E3ME and GINFORS are the main exceptions, both of which are currently being developed for DG Environment), although more flexible quantitative methods, such as input-output analysis, are often applied and indeed extended.

This situation reflects the nature of material demands; an economic transaction is involved, so the quantitative methods are similar (and linked) to those used in economic analyses. In the past a lack of physical data has been a constraint on the formal modelling that can be done, but better data are now becoming available; this is discussed in more detail in the report linked in Pollitt et al (2009).

B.3 Land use, soils and biodiversity

There is quite a wide range of models covering land use, soils and biodiversity issues, reflecting the broad nature of these resources. Often the main attention of the relevant models is on land use, but with some linkages to soils and/or biodiversity. Other models may also include some treatment of these resources, but have a primary focus on other key policy areas.

Land use There are many models which include some treatment of land use, albeit in different ways. These models can be separated into four broad categories;

- those that focus on land use or link a land-use model into a family of models
- those that are concerned with climate change and land use
- models covering land use in the context of agriculture and forestry
- models that focus on other policy issues such as trade or energy

CLUE The CLUE model is a tool that is used in analysis of general land use. The model can be used to track past changes in land use and to explore possible land-use changes in the future, driven by geophysical changes such as climate and soil types and human drivers such as agriculture. The model is mainly used for analysing land-use dynamics for different land types and agricultural trends, simulating the effects of different land-use and protection policies and estimating the effects of macro-level changes, such as demographics and economic development, on land use. Its main characteristics are that it is:

- GIS oriented, with the spatial resolution varying across case studies

- designed to be applied at a regional level, with data representation and other features differing from case study to case study
- taking into account both bottom-up and top-down land-use changes, through a multi-scale approach
- based on historical relationships (similar to the methodology for econometric economic models)

The CLUE model is also included in the EU-Clue Scanner family of models, meaning that land use can be addressed alongside a variety of other policy issues.

Further information: http://www.cluemodel.nl/

Agriculture and forestry

Land use in agriculture and forestry is an area where models are well represented, especially in the EU. Some examples of models that cover these areas are provided below.

CAPRI

Models primarily focused on agricultural land use include CAPRI. This model is mainly used for simulating the impacts of the Common Agricultural Policy (CAP) on production, income, markets, and the environment in the EU27, Norway and the Western Balkans. It is split into a supply and market module. The supply module ensures that simulation results are consistent with general resource constraints, including availability of land.

Further information: http://www.capri-model.org/dokuwiki/doku.php?id=start

EFISCEN

The EFISCEN model is a forestry model used to analyse changes in wood demand and forest area. To date, the model has been applied to 30 different European countries and various regions of Russia. The model also has the capability to split forest types by administrative unit, ownership, tree species and site class.

Further information: http://www.efi.int/portal/completed_projects/efiscen/

EU-FASOM

EU-FASOM is another forestry model that can be used for analysis of policies specifically related to this kind of land use, as well as to agriculture. In particular, the model can be used for forecasting production quantities, including agriculture and forest harvests and land-use transfers. The model is disaggregated by 25 EU counties and a further 11 non-EU world regions and includes land-use change between agriculture, forestry, nature reserves and energy crop plantations.

Further information: http://www.fnu.zmaw.de/fileadmin/fnu-files/publication/working-papers/wp156_eufasom.pdf

LEITAP

Another model focused on land use within the agricultural sector is LEITAP. This model is an extension of GTAP (a well-known global trade model) to include land use, making the GTAP model more appropriate for the analyses of the agricultural sector.

Further information:
https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=3009

The IMAGE modelling framework

The IMAGE (Integrated Model to Assess the Global Environment) model has been designed to simulate the global society-biosphere-atmosphere system and is mainly used for assessing linkages between these three dimensions, as well as the consequences of global policies. It includes a detailed treatment of crops and land use, alongside modelling of the ecosystem, economic and energy systems. Out of all the tools covered in the model review, it has the widest scope across policy areas, making it of particular interest when considering ways in which sustainability scenarios can be assessed. IMAGE was developed and linked with ENV-Linkages, the model operated by the OECD Environment Directorate, in order to provide a detailed environmental baseline for the *OECD Environmental Outlook to 2030*[45]. Results from the IMAGE model are also presented in the *Global Environment Outlook*, produced by the United Nations Environment Programme.

Further information: http://themasites.pbl.nl/en/themasites/image/index.html

Other models that include measures of land use

There are some other models that incorporate some land-use effects, although this is not their primary objective. For example, ASF is an integrated assessment model (see section on energy and climate change) that provides links between biofuels, land use, technological development and greenhouse gas emissions policy.

The EcoSense model analyses the impacts resulting from emissions of pollutants into the atmosphere, part of which includes looking at the impacts on materials and crops. The main features of the model include detailed geographical/spatial information on European countries and the evaluation of physical impacts of air pollution (such as crop losses) expressed in monetary terms using damage coefficients from the ExternE projects.

Further information: http://www.externe.info/tools.html

Other relevant tools include the GTEM model (which focuses on commodities and resource constraints, including land) and the GCAM model (which includes a land-use module alongside several other areas).

Further information (GTEM): http://www.daff.gov.au/abares/models

Further information (GCAM): http://www.globalchange.umd.edu/models/gcam/

Modelling of soil erosion

Soil erosion models can be classified in a number of ways. Models are generally differentiated by both their geographical coverage and also the time horizon that they predict. For example, some models are designed to predict erosion at a single point (or at a field level), while others are spatially distributed models which can capture erosion at a regional level. Additionally, some models predict long-term soil loss, while others are event-based, predicting the soil erosion from a storm for example.

Clearly the data that is required to estimate soil erosion at a field level is generally not available or is much less accurate when at a greater regional level, so European-wide models considered here must compromise in not being too demanding in terms of data requirements while maintaining an acceptable level of accuracy. Another key challenge regarding soil erosion models within the context of sustainability scenarios is in linking them to macroeconomic models. With models that have been built up from micro-level analysis of how soil erosion occurs, it is not immediately clear how the effects of macroeconomic policy can fit into such a framework.

The following paragraphs provide information on modelling approaches to soil erosion that have been applied before at a European level, having been well summarised in a paper by Grimm et al (2002).

EUROSEM

The EUROSEM model was developed with the objective of creating a new model for use in EC countries for erosion risk evaluation and the design of erosion control measures. It was also intended to address some of the suggested weaknesses of the

[45] See http://www.oecd.org/document/20/0,3746,en_2649_37465_39676628_1_1_1_37465,00.html

USLE approach to soil erosion modelling; whereas the USLE predicts mean annual soil loss, the design of strategies to control pollution associated with runoff and erosion requires knowledge of what happens in individual rainstorms.

EUROSEM is a dynamic simulation model and has a modular structure, with each module reflecting the most advanced available research on that area. It is intended that this will enable the model to continuously adapt to incorporate new research. The model incorporates (Morgan et al, 1998):

- the interception of rainfall by plant cover
- the volume of kinetic energy of the rainfall reaching the ground surface as direct throughfall and leaf drainage
- the volume of stemflow
- the volume of surface depression storage
- the detachment of soil particles by raindrop impact and by runoff
- sediment decomposition
- the transport capacity of the runoff

Further information: http://www.eurosem-soil-erosion.org/

LISEM The LISEM model was originally made to test the effects of grass strips and other small-scale conservation measures on soil loss. The processes that are captured by the model include:

- rainfall
- interception
- surface storage in micro-depressions
- infiltration
- vertical movement of water in the soil
- overland flow
- channel flow
- detachment by rainfall and throughfall
- transport capacity
- detachment by overland flow

One of the key characteristics of the LISEM model is that it makes no prior assumptions, such that the user must set all appropriate variables. Whilst this allows the user greater levels of freedom in using the model, it also requires a greater level of knowledge.

Further information: http://www.itc.nl/lisem/

MESALES The approach developed by INRA (Institut National de la Recherche Agronomique, France), called the MESALES model, is now considered as an intermediate step in modelling soil erosion at the European level, preceding the more recent development of the PESERA model. Initially developed to model erosion in France, it employs a modelling approach known as hierarchical multifactorial classification. This is where the model is based on a decision tree which ranks the importance of the different factors that are included. The MESALES model includes the following factors in the model (in descending order of importance):

- land use
- crusting
- slope
- soil erodibility

Priority was given to factors which could be modified by human activity. The output for a Europe-wide map of soil erosion is given at a resolution of 1km x 1km.

The model is very simple in structure and as such can be applied to a wide range of scenarios. It can also accommodate heterogeneous data resolution and quality and does not require the use of parameters that are not available at national scale. However, one particular disadvantage of this approach compared to the USLE model is that the final information is provided on a 5 class scale of risk and it is not possible to link these classes to quantitative values of erosion.

Further information: http://erosion.orleans.inra.fr/alea_france_version2000/index.html

PESERA The most advanced model to date that has attempted to assess soil erosion at a European scale is called the Pan-European Soil Erosion Risk Assessment (PESERA). This uses a process-based and spatially-distributed model to quantify soil erosion by water and assess its risk across Europe. The model considers four parameters of soil erosion:

- land use
- topography
- soil
- climate

It is able to provide output for soil erosion risk at a resolution level of 250m – 1km.

One advantage of the PESERA approach is that it lends itself to scenario analysis for changes in land use and climate, which may be useful for policy making (agricultural policy in particular). However, the model has demonstrated certain problems during validation exercises[46]. Focussing on Central Belgium, the Czech Republic, Spain and Italy, the model is relatively successful in predicting soil loss from agricultural areas in Central Belgium and Czech Republic, but the results do not correctly predict erosion patterns in Spain and Italy. This reflects the on going challenges to large-scale modelling of soil erosion.

Further information:
http://eusoils.jrc.ec.europa.eu/esdb_archive/pesera/pesera_cd/sect_2_2.htm

USLE The Universal Soil Loss Equation (USLE) was initially developed by Wishchmeier and Smith (1978) and since has been used for many research studies of soil erosion. The USLE is a simple empirical model, based on regression analyses of rates of soil loss from erosion plots in the USA, with the technique having more recently been applied in Europe (see for example, Rompaey et al (2003). Soil erosion is explained as a function of the following variables:

- rainfall erosivity
- soil erodibility
- slope
- slope length
- cover management

The model produces an output in terms of actual soil loss (tonnes per hectare per year, for example), which may be seen as an advantage over the risk-grading output given by the MESALES model described below.

[46] see http://eusoils.jrc.ec.europa.eu/esdb_archive/pesera/pesera_cd/sect_5_1_1.htm

Another key advantage of the USLE lies in the fact that the estimates of erosion are based on standardised data sets for the whole of Europe, enabling a more objective comparison of erosion risk across Europe than expert-based approaches may give. The USLE is one of the least data-demanding erosion models that have been developed, which reflects its attractiveness in terms of applicability to a wide range of scenarios. Despite this, the data requirements that it does make bring into question the reliability of some input data. Particular areas of concern include vegetation cover, rainfall erosivity, soil erodibility and the effect of management practice (Renard *et al.*, 1997). Given that management practice in particular may be one of the most important factors affecting erosion, uncertainties over such data should cause some concern.

Further information: http://www.omafra.gov.on.ca/english/engineer/facts/00-001.htm

WATEM

The WATEM model provides another approach to modelling soil erosion, by focusing more on the spatial variation of relief parameters than temporal variation such as EUROSEM. WATEM is a topography driven model, enabling it to avoid major problems over the special variability of parameter values and uncertainty of parameter estimates. It can be used to estimate:

- water erosion/deposition rates and patterns
- tillage erosion/deposition rates and patterns
- the combined effect of water and tillage erosion
- the effect of changes in landscape structure on water and tillage erosion

The water component of the model uses an adapted version of the Revised Universal Soil Loss Equation, whereas the tillage component of the model uses a diffusion-type equation where the intensity of the tillage process is captured within one parameter.

Further information:
http://www.kuleuven.be/geography/frg/modelling/erosion/watemsedemhome/index.htm

Modelling of biodiversity

The tools available for analysis of biodiversity are limited. This is partly due to the difficulties involved in measuring biodiversity numerically. One model which can be used is GLOBIO. This model is used to specifically look at the impact of environmental change on biodiversity. Features of the model include:

- detailed analysis of biodiversity trends (looking both forward into the future and backwards over history)
- links to socio-economic and environment (e.g. climate change) models
- clear aggregation and presentation of the results; policy-focused presentation
- aquatic, marine and terrestrial and agricultural ecosystems, which can be aggregated into habitats
- solutions up to 2050
- results for seven world regions (including Europe) and at the global level

Further information: http://www.globio.info/

The IMAGE system of models (see land-use section) includes an ecosystem component, enabling it to analyse issues concerned with biodiversity.

Both models are applied in providing results for the *Global Environment Outlook*, produced by the United Nations Environment Programme.

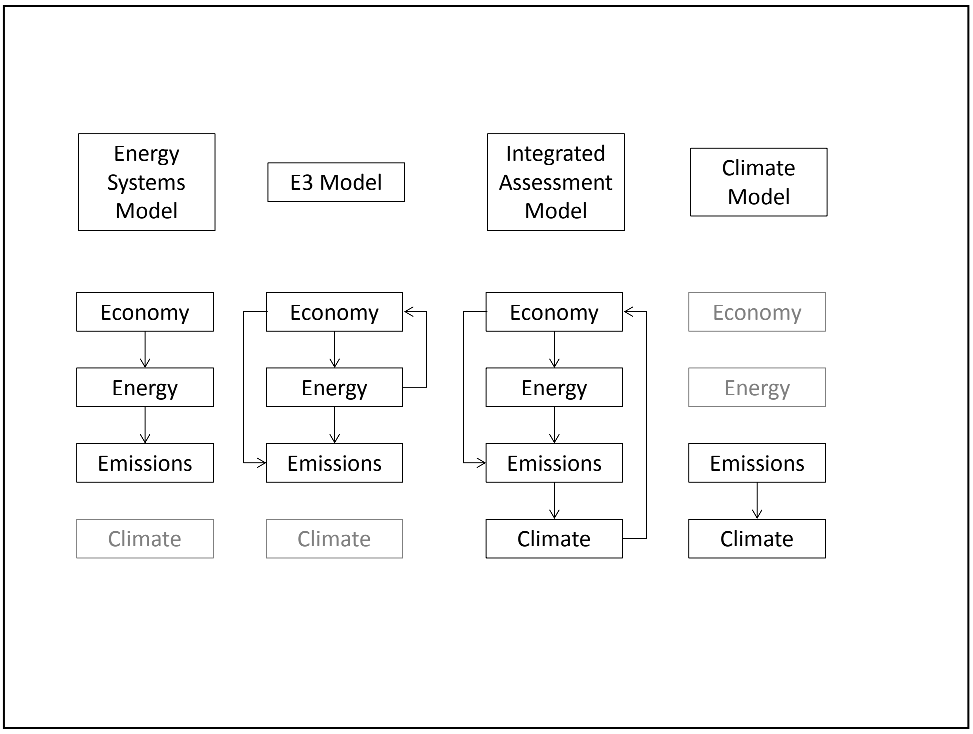
B.4 Energy and climate

There are a relatively large number of models concerned with energy issues, with various different dimensions and degrees of coverage. We have split the models into four groups:

- energy systems models
- E3 models
- integrated assessment models
- climate models

Figure B.1 shows the coverage of the models in each of these four groups, based on four areas: economy, energy, emissions and climate.

Figure B.1: Energy and Climate Models



Integrated assessment models have the widest coverage, as they include links between all four of the key policy areas. In contrast, climate models are only concerned with one link, between emissions and climate change. However, it should be noted that there is usually a substantial trade-off between the level of detail (depth of coverage) and the coverage of different areas (breadth of coverage).

In the following sections we will describe some of the available models in each category.

Partial, energy systems models

Examples of models that focus specifically on energy markets include PRIMES, POLES, MARKAL-TIMES and the IEA's World Energy Model (WEM). These models are currently used for global and EU-level analysis of energy systems and have a long timeframe for projections. Their focus on the energy system allows for a highly detailed assessment, including specifically defined technologies and institutional detail.

These models use economic projections as an exogenous input and produce results for energy demand/supply and energy-related emissions. The following paragraphs describe some of the main features of each model.

MARKAL-TIMES The MARKAL-TIMES family of models is able to generate sustainable energy production scenarios for a given spatial background (i.e. national, regional, province, community) in Europe and the rest of the world over a period of 40 to 50 years. MARKAL relies on a consistent energy technology database and projections for energy demand and resource costs to create scenarios that minimise energy system costs depending on abatement policies. The models choose the abatement technologies on the basis of future required reductions of emissions.

Further information: http://www.climateplanning.org/tools/markaltimes

POLES The POLES model is similarly designed for detailed modelling of the energy sector and is mainly used for running scenarios to project energy demand, supply prices and trade volumes up to 2030. The model features 40 world regions, including the EU (north and south) and the G7. Within these regions the model has four main modules dealing with final energy demand by twelve sectors, new and renewable energy technologies, the energy and electricity transformation system and fossil fuel supply. The characteristics of POLES are such that the model is able to focus on technological change since twelve renewable energy technologies and twelve electricity generation technologies are included.

Further information: http://www.ec4macs.eu/home/poles.html

PRIMES The PRIMES model simulates energy markets in Europe and calculates equilibrium prices for each energy source. The model is highly disaggregated and includes 24 energy forms, five demand sectors (with up to 30 sub-sectors each) and three supply sectors. Electricity is modelled in particular detail, including 148 different plant types per country for existing thermal plants and 678 different types per country for new thermal plants. The impact of new technologies and renewable resources are also considered. The model has good geographical coverage and a lengthy timeframe since it produces results for the EU27, up to 2030. PRIMES is mainly used for projections and the analysis of energy policy issues such as security of supply, energy efficiency, generation and distribution. It also covers environmental issues due to its ability to produce results for seven types of emissions.

Further information: http://ec.europa.eu/environment/air/pollutants/models/primes.htm

World Energy Model The World Energy Model (WEM), developed by the International Energy Agency, is a large-scale model designed to replicate world energy markets. Within the model there are six main modules including final energy demand, power generation, refinery and other transformation, fossil fuel supply, CO_2 emissions and investment. The model is mainly used for analysing global energy prospects, estimating the environmental impact of energy use, analysing the effects of policy actions and technological change and estimating investment in the energy sector.

Further information: http://www.iea.org/weo/model.asp

E3 models There are several models that can be classified as E3 models as they consider the interlinkages between the economy, the environment and energy. Examples include E3ME, GEM-E3, GINFORS and PACE (described below).

The advantage to this model type is the linkages between the energy system and the economy (the economy provides demand for energy, which returns the economic performance of the energy sectors). These linkages can be reversed using price signals so that the costs of reducing emissions may be evaluated. However, their treatment of the energy system is usually not as advanced as the models described above.

E3ME E3ME and E3MG (energy-environment-economy model for Europe and the world, respectively) both produce projections for energy demand up to 2050 at least. Energy demand is disaggregated by 19 fuel users including power generation, manufacturing industries, transport and households. Twelve fuel types are also included in the models, including solids, liquids and gases as well as electricity, heat and biofuels. The models are econometric in design and link energy consumption to a representation of the economy. This means they are suitable for short as well as long-term policy analysis.

Further information: http://www.e3me.com

Ecomod Ecomod is a dynamic general equilibrium model with a high disaggregation of sectors, commodities, countries and regions. The model is based on the latest GTAP database and is mainly used for general macro and sectoral economic analysis and forecasting. The Greenmod model is an extension of Ecomod that can be used for the analysis of interactions between energy and the environment, pollution abatement and investment in low-carbon technologies.

Further information: http://ecomod.net/

GEM-E3 There are two versions of the GEM-E3 model, a European model and a global version. The European model includes 24 countries (the EU27 excluding Cyprus, Malta and Luxembourg), while the global version is split into 20 regions, including the USA, China, India and Japan. Various other disaggregations exist in the models, including 18 products and sectors (in both models) and 6 emissions types (in the European model, the global model includes 2 emission types). These equations are linked to the economy through a general equilibrium structure.

Further information: http://ipts.jrc.ec.europa.eu/activities/energy-and-transport/gem-e3/model.cfm

GINFORS The GINFORS model includes all EU and OECD countries and their major trading partners, covering energy demand and the economy. The bilateral trade model is at the heart of the system, providing consistent linkage of trade volumes and prices for the 25 commodities included in the model, plus a service sector. Material inputs have also been integrated into the GINFORS modelling system. For each country resource extraction is explained for six categories and is driven by economic activity or energy demand for fossil fuels. The model is econometric in nature.

Further information: http://www.gws-os.com/de/index.php?option=com_content&task=view&id=173&Itemid=109

NEMESIS NEMESIS is a macro-sectoral econometric model covering all the EU27 countries plus the USA and Japan. The model includes 32 sectors and 27 consumption categories and provides yearly solutions over a 30-year forecast period. The model is mainly used for the assessment of short and medium term consequences of energy and environment and R&D policies.

Further information: http://www.erasme-team.eu/index.php/erasme-nemesis/41-overview/53-presentation-of-the-nemesis-model.html

PACE PACE is a flexible system of general equilibrium models, integrating the economy, energy, and environment dimensions. The model has a standard multi-sector, multi-region core made up of global trade and energy use, which was designed to assess major policy initiatives in a world that is increasingly integrated through trade. Around the core module, other various PACE modules allow for the problem-specific analysis of policy interference at different regional and sectoral levels as well as time treatments. One of the model's main uses is for economic analysis of energy and environmental policy initiatives.

Further information: http://unfccc.int/adaptation/adverse_effects_and_response_measures_art_48/items/5187.php

Second Generation Model The Second Generation Model (SGM) is a computable general equilibrium model used by the US government to analyse issues related to energy, the economy and greenhouse gas emissions. The model is disaggregated by 14 global regions (including Western Europe, Eastern Europe and the Former Soviet Union), and various sectors and emissions. It includes linkages between technology and the economy and the explicit treatment of energy and land stocks. The model is used to project energy consumption and greenhouse gas emissions but its main relevance is its use in evaluating the economic impacts of climate change policies and the use of technologies for emissions mitigation.

Further information: http://www.epa.gov/oar/sgm-sab.html

WorldScan WorldScan is a dynamic general equilibrium model developed to analyse long-term issues in the global economy. There are several extensions to the WorldScan model including a climate change module and an energy module, and versions of the model which include R&D spillovers and imperfect competition. This enables WorldScan to address various policy issues. The model is mainly used for analysis in the fields of climate change, trade, European integration and R&D.

Further information: http://www.ecmodels.eu/index_files/WorldScan_model.pdf

Integrated Assessment Models Integrated Assessment Models (IAMs) go one step further to include an estimate of the impacts of climate change, with feedback to the economy. They thus incorporate feedbacks that would be desirable to include in an assessment of sustainability scenarios.

The cost of this is that the level of detail within each component is usually a lot less than in a model designed specifically for the purpose. For example, the modelling of the climate system in IAMs is much less detailed than that provided by the climate models.

AIM The AIM model is a good example of an IAM. It comprises three main models, a greenhouse gas emission model, a global climate change model and a climate change impact model. Its main focus is on the analysis of climate change and environmental issues, but it contains a detailed technology module which enables the evaluation of the effects of introducing new, advanced technologies in the energy sector. Although focused on the Asian-Pacific region, the model is worth noting since it includes specialised techniques which could be applied at the European level, with the right data.

Further information: http://www-iam.nies.go.jp/aim/infomation.htm

ASF The ASF is another IAM, which provides a framework for developing scenarios of future emissions based on consistent demographic, economic, and technological assumptions. The current version of ASF includes various models covering energy, agriculture, GHG emissions and atmospheric conditions. In the energy model balancing the supply and demand for energy is achieved by adjusting energy prices, which are disaggregated by region and type of energy.

Further information: http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=151

MERGE The MERGE model is mainly used for estimating the regional and global effects of GHG reductions. It contains several sub-models, one of which covers energy-related emissions of greenhouse gases, which are projected through a bottom-up perspective. Fuel demands are projected in this model through ‘process analysis’.

Further information: http://www.stanford.edu/group/MERGE/GERAD1.pdf

Climate change models

The earth’s climate system is highly complex and this is reflected in the modelling approaches that are used. The models in operation are regularly updated to reflect the most recent scientific findings.

The models available can be split into two groups. Atmosphere-Ocean General Circulation Models (AOCGMs) go into the highest level of detail and require large quantities of computer power to perform simulations. The Hadley Centre in the UK operates some of these models. Examples of key features in these models are:

- systems of cloud formation
- solar radiation
- atmospheric and ocean flows and temperatures and salinity of sea water, soil and vegetation
- ice flows
- sea levels

Earth system Models of Intermediate Complexity (EMICs) have therefore been developed on grounds of practicality. Results from these models will be less precise but can be obtained more quickly and more easily. MAGICC and Genie are examples of EMICs.

The following paragraphs describe the main features of some of the existing climate change models.

FAMOUS FAMOUS is an atmosphere-ocean general circulation model (AOGCM) based on the Met Office Hadley Centre HadCM3 model. It is a global model which can be used to create long-term (centuries) climate change simulations. The model is made up of and atmosphere component and an ocean component and is mainly used for analysing long-term scenarios of climate change impacts on issues such as air temperature, precipitation and sea levels.

Further information: http://www.geosci-model-dev.net/1/53/2008/gmd-1-53-2008.pdf

GENIE The GENIE model is focused on long-term paleo-climate change, and the future long-term response of the Earth system to human activities. It includes modules of the atmosphere, ocean, sea-ice, marine sediments, land surface, vegetation and soil, ice sheets and energy. The model is mainly used for climate variation simulations, investigating carbon cycles and producing long-term projections of climate change and carbon cycling.

Further information: http://www.genie.ac.uk/about/modelling.htm

MAGICC MAGICC is an interactive model that allows users to investigate future climate change and its uncertainties at both the global and regional levels. MAGICC is coupled with SCENGEN (a Regional Climate Scenario Generator). MAGICC calculates the estimates at the global-mean level, using upwelling-diffusion, a phenomenon that involves the movement of cooler water towards the ocean surface, replacing the warmer, usually nutrient-depleted surface water, and energy-balances techniques similar to those employed by the IPCC (Intergovernmental Panel on Climate Change). SCENGEN uses the calculations to produce spatially detailed information on future changes in temperature, precipitation, mean sea level pressure, changes in their variability, as well as a range of other statistics.

Further information: http://www.cgd.ucar.edu/cas/wigley/magicc/UserMan5.3.v2.pdf

B.5 Water

There are a limited number of models available that cover fresh water, and often these models are specific to geographical regions. Some models also focus on other policy issues, but include some treatment of water resources, for example the GTEM model primarily concentrates on trade and the environment, but includes water as a resource constraint. Furthermore, many climate models include an ocean component, but not necessarily a fresh water module, such as the GLOBIO model, which has a specific focus on marine ecosystems.

The WaterGap model is best suited for looking at fresh water overall. The model was developed to analyse water availability, use and quality on a global level. WaterGap comprises of hydrological module, used in determining global water resources and water availability, and a water-use module, which looks at consumption from different economic sectors, including a sub-model for an assessment of global irrigation requirements. Results from the WaterGap model feature in the *Global Environment Outlook*, produced by the United Nations Environment Programme.

Features of the model include:

- results for water flow and storage for six main categories
- consumption and withdrawals of water in five main sectors
- annual results for household and industry water consumption
- daily results for irrigation and livestock water consumption
- estimation of structural and technological changes that affect water consumption
- estimations of both natural and actual water discharge
- world coverage (except Antarctica), at a spatial resolution of five degrees (55 x 55 km at the equator), giving a relatively detailed regional coverage

Further information: http://www.usf.uni-kassel.de/watclim/pdf/watergap_model.pdf