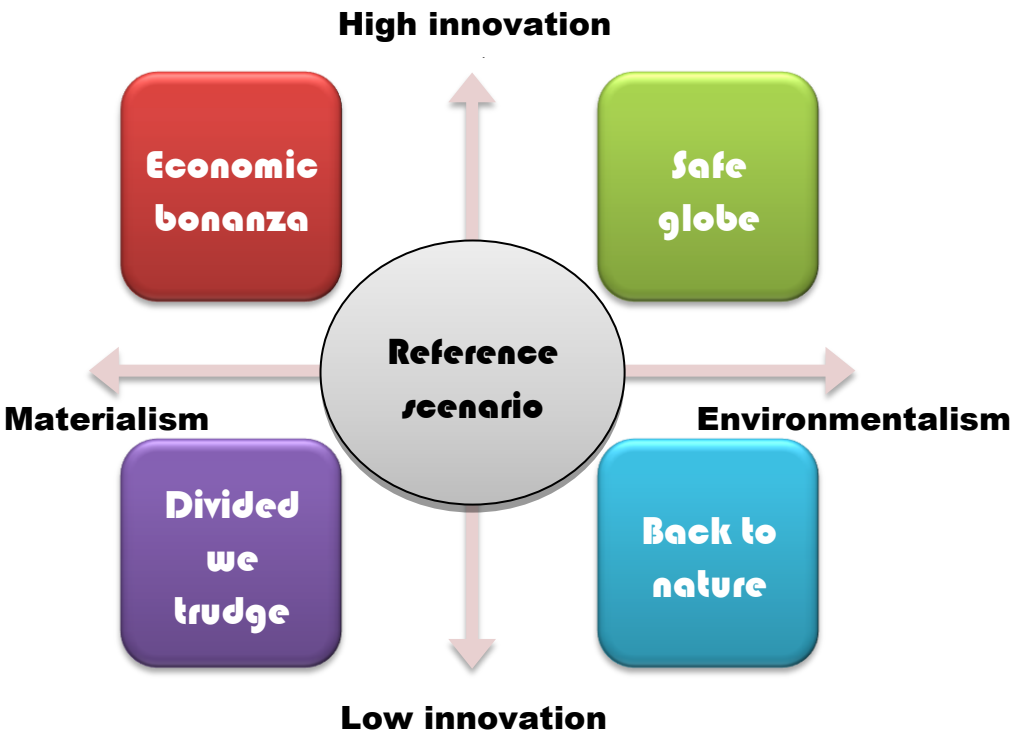
DYNAMIX

Decoupling growth from resource use and environmental impacts

DYNAMIX background scenarios



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DYNAMIX PROJECT PARTNERS

Contents

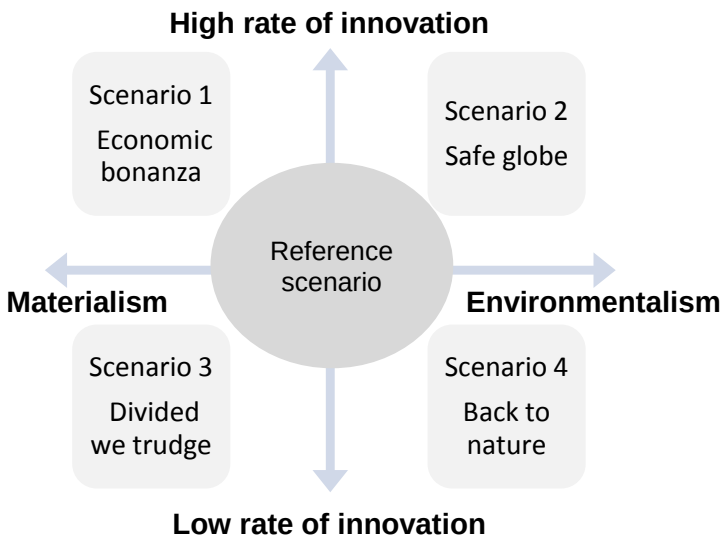
Abbreviations

CGE	Computable General Equilibrium
DYNAMIX	DYNAmic policy MIXes for absolute decoupling of environmental impact of EU resource use from economic growth
EC	European Commission
ECOFIN	Economic and Financial Affairs Council
EPC	Economic Policy Committee
EU	European Union
EU27	The 27 countries in the European Union. As of 1 July the EU consists of 28 member states.
FP6	Sixth framework program (2002-2006)
FP7	Seventh framework program (2007-2013)
GDP	Gross Domestic Production
GHG	Greenhouse gas
GPT	General purpose technologies
IIASA	International Institute for Applied Systems Analysis
IISD	International Institute for Sustainable Development
IPPC	Intergovernmental Panel on Climate Change
MDG	Millennium Development Goal
PIK	Potsdam Institute for Climate Impact Research
PLUREL	Peri-Urban Land Use Relationship
RCP	Representative Concentration Pathways
SRES	Special Report on Emission Scenarios
SSP	Shared Social Economic Pathways
TFP	Total Factor Productivity
TOSUWAMA	Towards Sustainable Waste Management
WEC	World Energy Council
WP	Work Package

Executive summary

The background scenarios presented in this report describe how the economy, technology, and society in the EU might develop until the year 2030 and 2050 without new policy instruments on resource use and environment beyond what is already implemented. The scenarios are intended to provide a background for the assessments of new policy mixes in the DYNAMIX project. Using several background scenarios is a way to assess the robustness of the policy instruments. This is important due to the inherent uncertainty of the future.

The background scenarios are based on different assumptions regarding the future rate of innovation and different sets of dominating values (see figure below). A high rate of innovation means that the scenarios include multiple technological breakthroughs in different areas. They can also include many new business models. The technological efficiency increases even when the rate of innovation is low, but only slowly. Materialistic values focus on maximizing production and consumption, while environmentalist values focus on the well-being of all humanity and future generations. We selected these dimensions because they are heavily influenced by factors beyond the control of policy-makers, they are highly uncertain and important for the assessment of policy mixes, and they are important in the public debate.



The five background scenarios of the DYNAMIX project.

Most of the policy assessments will be made against the background of the reference scenario. This describes a surprise-free future. Improvements in technology continue at a good pace, but the society is not transformed by any major technological break-through. The balance between materialistic and environmental values stays the same as today. Important current trends continue towards, e.g., increased globalisation.

Besides the reference scenario, we present a background scenario for each of the corners in the figure above. These four cornerstone scenarios are important complements to the reference scenario, since the future is actually unlikely to be surprise-free:

- Scenario 1: Economic bonanza. This scenario includes a high rate of innovation and a materialistic focus on production and consumption. It is the scenario with the highest economic efficiency and growth. Global competition over rare metals, phosphorus, etc. becomes fierce.
- Scenario 2: Safe globe. This is a scenario with a high rate of technological and social innovation and an environmentalist focus on the well-being of all humanity, future generations, and nature. The scenario includes global cooperation on environmental protection, workers protection, product safety, etc. It also has the most advanced technology for environmental protection.
- Scenario 3: Divided we trudge. This scenario describes a future with a low rate of innovation combined with a materialistic focus on production and consumption. Lack of cooperation and increased nationalism in Europe lead to diminished knowledge transfer between stakeholders as well as countries, and to a low rate of innovation.
- Scenario 4: Back to nature. This scenario combines a low rate of technological innovation and societal values that focus on the well-being of all humanity, future generations, and nature. In this scenario, repeated failures of experts and advanced technology cause distrust, and society becomes dominated by small-scale solutions, local production and trade. The economy to a large extent becomes informal.

None of the scenarios predicts the future as it must be or is most likely to be with the given combination of innovation rate and value. Many different scenarios might be consistent with each corner in the scenario four-field figure above. However, we argue that our scenarios are all plausible, except that they all include the same resource and environmental policy instruments that are in place today.

The scenarios are intended, in the DYNAMIX project, for assessing the robustness of policy mixes, i.e., to what extent they are effective regardless of the background scenario. We also hope that the scenarios will enable policy-makers and stakeholders to be better prepared to make the best of future challenges and opportunities that are currently unknown.

1 Introduction

1.1 Background

The acronym DYNAMIX stands for “DYNAmic policy MIXes for absolute decoupling of environmental impact of EU resource use from economic growth”. The DYNAMIX project is a collaborative project within the 7th EU Framework Program (FP7). The aim of the project is to identify and assess dynamic and robust policy mixes to shift the European Union (EU) onto a pathway to absolute decoupling of long-term economic growth from resource use and environmental impacts.

DYNAMIX begins with an ex-post analysis of existing inefficiencies in resource use and an assessment of current resource policies. These provide a basis for identifying what paradigm shifts are required in the way production and consumption is organized and regulated, and what policy mixes might be able to achieve absolute decoupling.

The most promising policy mixes will be tested in ex-ante assessments for effectiveness (benchmarked against absolute resource and impact decoupling), efficiency, sustainability and contribution to eco-innovation. The ex-ante assessment will utilize innovative environmental and economic quantitative modelling. These are powerful tools for assessing economic and environmental impacts in the EU and globally; however, models have limitations in representing various social, political and legal aspects, including factors influencing human behaviour. DYNAMIX will thus systematically integrate also qualitative assessments to fully assess the real-world performance of the proposed policy mixes.

The primary target group for the project is policy-makers directly involved in designing and implementing policies addressing resource use levels and related environmental impacts at the EU and national levels. The project strives at strengthening their capacity to select, identify, design and implement effective policies to reduce EU resource use and its related environmental impacts. To this purpose a group of policy-makers, together with other key stakeholders, are involved in a systemic participatory process accompanying the whole project. This process is designed to facilitate mutual learning, which means that the policy-makers are also able to shape the project’s design based on their needs. This increases the likelihood that DYNAMIX provides tangible support to EU policy-making for resource efficiency.

This report presents scenarios describing how the economy, technology, and society in the EU might develop in the future without new policy mixes. These scenarios are intended to provide a background for the ex-ante assessments of policy instruments. This means that scenarios presented here are skeletons that the future work in DYNAMIX will add results to as policy mixes aimed at supporting a decoupling process are modelled and analysed.

The development of these background scenarios is part of Work Package (WP) 4, which is found between the ex-post analysis of current flows and policies and the ex-ante assessment of promising policies. This WP is also where the required paradigm shifts and promising policy mixes are identified. These will be presented in a separate report.

1.2 Scenario typology

Scenarios in a broad sense can be defined as quantitative and/or qualitative descriptions of the future. There are many different kinds of scenarios and also several ways to categorise the various scenario types (see for example Amara 1981; Masini 1993; Marien 2002; van Notten et al. 2003; Dreborg 2004). We here use the distinction developed by Börjeson et al. (2006). This distinction is based on what type of question about the future the scenarios are designed to answer:

- Predictive scenarios respond to questions of the type: What *will* happen in the future?
- Explorative scenarios respond to questions of the type: What *can* happen in the future?
- Normative scenarios respond to questions of the type: What *should* happen in the future?

Börjeson et al. (2006) further distinguish between two scenario types within each scenario category (see Figure 1). Predictive scenarios can be forecasts that present the most likely development. They can also be what-if scenarios that describe what is likely to happen given a specific event that is important for the future development.

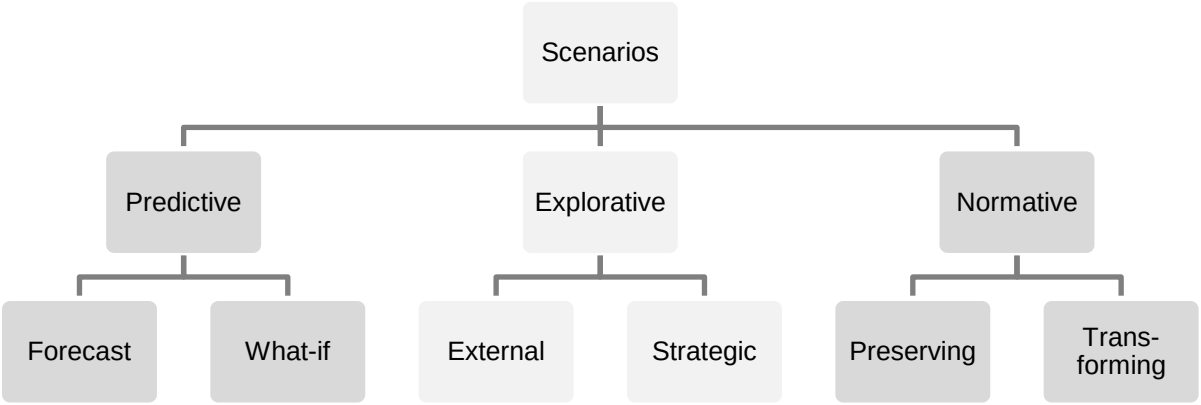


Figure 1: The scenario typology of Börjeson et al. (2006) with three categories and six types.

Explorative scenarios include, according to Börjeson et al. (2006) external scenarios and strategic scenarios. The external scenarios describe possible developments in external factors, i.e., in factors that are *beyond the control of the decision-maker*. Strategic scenarios respond to questions of the type: What can happen if we act in a certain way? They describe how the consequences of policy decisions and other strategic decisions can vary depending on how the future evolves. A strategic scenario can be described as a strategic decision (a set of policies or regulations) implemented in an external scenario.

There are also two types of normative scenarios. Börjeson et al. (2006) call them preserving and transforming, depending on whether the structure of the system is changed or not. Preserving normative scenarios includes adaptations within the current structure only. They can be developed, for example, with optimising systems models. In transforming normative

scenarios, the system structure can be changed to reach a given target. Back-casting is the dominating technique for such studies.

The normative scenarios include a strong subjective element. A development that seems attractive to somebody might look highly unwanted for someone else. To make this explicit, a criterion or target needs to be added to the question about what should happen. A preserving normative scenario developed with an optimising energy-supply model might, for example, respond to the question: what should happen if we want to supply energy at the least total cost? A transforming normative scenario developed through back-casting might respond to the question: what should happen if we want society to become sustainable?

The knowledge can be obtained about the possible future scenarios depends on the time perspective. A prediction is only relevant in the short term. After that, the inherent uncertainties of the future become so great that the prediction is more or less meaningless. A transforming normative scenario, on the other hand, is only relevant in the long-term perspective, because it takes a long time to change fundamental structures such as the transport infrastructure or the infrastructure for electricity generation. Similar long time horizons are needed when looking at changes in industrial sectors requiring large investments.

These facts should be taken into account when scenarios are used for guiding decision-makers. Predictions and preserving normative scenarios can give decision-makers information about what decisions are the most efficient in the short term, but not in the long-term perspective. Explorative scenarios can generate knowledge on what decisions are the most robust in the mid to long term considering a set of variables. When decision-makers have a really long-term perspective, transforming normative scenarios can give insights into what decisions can put the development on a path towards a specific future.

1.3 Typology and purpose of the DYNAMIX scenarios

As stated above, the scenarios presented in this report are intended to provide a background or context for the ex-ante assessments of policy instruments. The project description of DYNAMIX states that the basis for any form of assessment is external scenarios of various alternative future developments, taking into consideration likely trends for exogenous variables that are beyond the influence of the measures under investigation, but will affect their impact.

The scenarios in this report have a two time horizons: 2030 and 2050. The long-term perspective makes the project analysis problematic in two respects. First, as stated in the previous section, questions regarding likely trends are not quite meaningful in the long-term perspective. Long-term scenarios can only consider plausible trends or possible developments. With the terminology of Börjeson et al. (2006), our scenarios are explorative and not predictive.

Second, there will be few aspects of the society that are not affected by the proposed and studied policy mixes in the long run. Even vital scenario variables, such as population, economic growth, trade patterns, etc., are likely to be affected by the policy mixes that we assess. Although they are not controlled by policy-makers, they are also not beyond the influence of policy. Hence, there is hardly any purely external variable in the scenarios. The long-term scenarios, at least, will not and cannot be purely external to the items studied in the project.

To call such scenarios external can cause confusion. Instead, we choose to call them explorative background scenarios. This implies a deviation from the typology of Börjeson et al. (2006), who suggest that explorative scenarios are either external (focussing on factors beyond the control of decision-makers) or strategic (describing what can happen if we make a specific decision). Explorative background scenarios could perhaps be described as a third type of explorative scenario. They can include factors that are influenced by decision-makers but describe what can happen without policy action targeting these factors.

The DYNAMIX project uses two kinds of explorative background scenarios: a reference scenario and four cornerstone scenarios. The reference scenario is essentially a plausible, surprise-free description of the future. It includes no policy instruments other than those that are in place today. In the ex-ante assessment of policy mixes, a plausible impact of each future policy mix is estimated by comparing a policy scenario, i.e., a scenario where the policy mix is implemented, to the reference scenario.

The purpose of the cornerstone scenarios is to assess the robustness of the policy mixes. These scenarios are developed through a four-field approach[1] which is based on combination of two dimensions that each represents a critical uncertainty. To assess the robustness of the policy mixes, the cornerstone scenarios need to be plausible but at the same time sufficiently extreme to cover as much as possible of the plausible future developments of the key uncertainties. Since they are background scenarios, they will only include the policy instruments that are in place today. In other respects, they should ideally span a sufficiently broad range to define the boundaries of what is a plausible future.

Figure 2 illustrates how the background scenarios would be converted into policy scenarios if one of the DYNAMIX policy mixes is inserted into it. The fact that the scenarios are not completely external means that policies can influence the values of the variables that are used to describe the scenarios. When a policy mix is implemented in a background scenario, it is likely to affect, for example, economic growth.

[1] There are other words for this approach; scenario-axes technique (van't Klooster and van Asselt 2006), two dimensional matrix (van Notten 2006) or two by two matrix (Berkhout and Hertin 2002; Svava Iversen 2005). The approach is the same – two different dimensions or uncertainties forms four scenarios based on variations in the two dimensions considered.

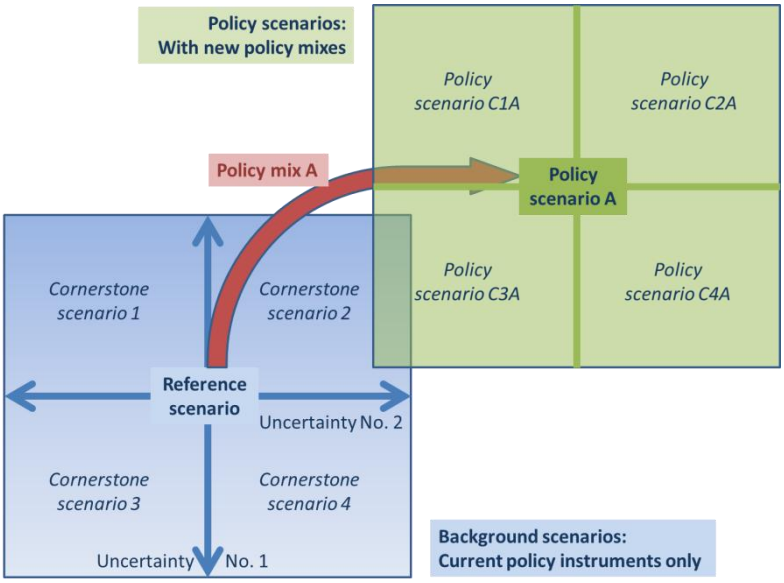


Figure 2: Conceptual model of our four-field approach, which includes a reference scenario. Each of the background scenarios can in principle be converted into a policy scenario when Policy mix A is implemented into it.

1.4 Previous studies with a four-field scenario approach

During the last 15 years the use of scenarios to propose suggestions and form basis for discussion on steps to achieve certain targets have become increasingly common (examples of such scenarios are IPCC 2000a; ECF 2010; IEA 2010; WBCSD 2010; UNEP 2011; Rijnhout and Lorek 2012; Teske 2012). The studies are typically motivated by stakeholders wanting to propose and suggest to decision-makers possible and efficient routes and steps to tackle future challenges such as the rising levels of greenhouse gases in the atmosphere, human development or increased resource depletion. The DYNAMIX project is motivated by a similar objective, that is, to identify, study and propose policy mixes to enable decoupling of economic growth from resource use on an European level.

The four-field approach to formulate scenarios has been utilised in several research and policy development projects. In this section we give some details to five projects/programmes which all link to the approach applied and themes concerned in DYNAMIX project (Table 1). The scenarios produced in the studies presented are typically external explorative but includes components that would belong to more transformative normative scenarios (Figure 1). All of the studies presented have a long time perspective, typically 2050, and all concerns the study of processes for the society to develop in a more sustainable direction. This latter implies a certain degree of normativity and this creates a certain grey zone in the categorisation of the scenarios according to types presented in Börjeson et al. (2006).

Table 1: Summary of dimensions used in projects using a four-field approach with similar theme as the DYNAMIX project.

Project	Dimension 1		Dimension 2	
SRES	**Organisation of society**		**Focus of development**	
	Regional	Global	Development (economy)	Environmental
OPEN:EU	**Technological innovation**		**Development paradigm**	
	Stagnant technology innovation	Dynamic technology innovation	Quantity driven	Quality driven
PLUREL	**Drivers of change**		**Values**	
	Regional/local & bottom up dynamic	Global/macro & top down dynamic	Private enterprise / economic values	Public / social and environmental values
WEC 2007	**Degree of cooperation**		**Degree of control**	
	Low cooperation between government, public and market operators	High cooperation between government, public and market operators	Low government involvement	High government involvement
TOSUWAMA	**Degree of global cooperation**		**Degree of environmental control**	
	Regionalisation	Globalisation	Low level of governmental steering	High level of governmental steering

SRES (IPCC 2000a) has been widely used and been very influential in approach and the results have been used extensively. This work is in the progress of being updated. SRES includes what they refer to as a two dimensional tree where four branches forms the different scenarios (Figure 3). The first dimension links to how the society is organised and tackles challenges/processes and here global is set as opposed to regional. The second dimension makes the distinction economic versus environmental development.

In the OPEN-EU project a set of four scenarios was formulated to support policy makers in thinking about the policy effort needed to transform Europe into an economy that respects all environmental limits and is socially and financially sustainable, enabling people and nature to thrive (Gardner et al. 2011; Roelich et al. 2011). The project provided four scenarios based on a four-field approach applying the dimensions of *development paradigm* (quality driven or quantity driven) and *technological innovation* (dynamic or stagnant). There was no reference scenario utilised in these scenarios.

Another project utilising a four-field approach was the PLUREL project where land use in peri-urban areas was studied (Ravetz et al. 2008). Here the dimension of *Public/social and environmental values* as opposed to *Private enterprise/economic values* is used to define one of the axes, and *Global/macro & top-down dynamic* as opposed to *Regional/local & bottom-up dynamic* defined the other axis. The description of the scenarios is based on the scenario families presented in the IPCC report “Special Report on Emission Scenarios (SRES)” (IPCC 2000b, 2000a). In Ravetz et al. (2008) the SRES storylines provides the reference case onto which the specific storylines of the PLUREL project are added.

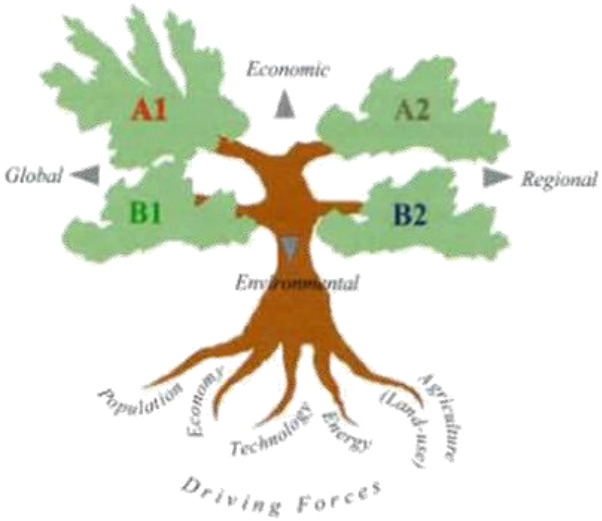


Figure 3: SRES scenario tree (IPCC 2000a)

The World Energy Council (WEC) global energy scenario utilised a two axes approach (WEC 2007). Here the dimension of *High government involvement* as opposed to *Low government involvement* formed one axis. The other axis was formed around *low or high cooperation between governments, public and market operators*. The results are presented as percentage change towards a reference based on IEA (2007) World Energy Outlook 2007. The analysis is done linking the mathematical results to the framework 3 A's; i) Accessibility to modern, affordable energy, ii) Availability in terms of continuity of supply and quality and reliability of service and lastly iii) Acceptability in terms of social and environmental goals. The dimension applied in the global energy scenario analysis are also found in the a later report on global transport scenarios (WEC 2011).

The Swedish research programme "Towards Sustainable Waste Management" (TOSUWAMA) used a four cornerstone scenarios and a reference scenario for the year 2030. The scenarios were used to assess 16 policy instruments for increased materials recycling and waste prevention (Ekvall and Malmheden 2012). In this four-field approach, one of the dimensions was *globalisation* as opposed to *regionalisation* and the other was *the level of political steering of environmental issues from high to low* (Dreborg and Tyskeng 2008). The reference scenario was prominent in this research: some policy instruments were only assessed in the context of the reference scenario. It was based on "The Long-Term Survey of the Swedish Economy 2003/04" (SOU 2004) and the scenario variables were then treated in relation to this reference case. For example commodity price for one of the scenarios could be expressed as 2.5 times the value reported for the reference case. In the TOSUWAMA scenarios with a high degree of political control of environmental issues, the environmental awareness of the public was assumed to be high. In the scenarios with a high degree of globalisation, the rate of innovation was assumed to be high. The degree of environmental awareness and the rate of technological innovation turned out to be the most important scenarios variables in the policy assessment.

2 Method for scenario design

The formation of scenarios based on a two-by-two matrix is well established and considered a good method to come to a mutual understanding of the starting points for the formation of the scenarios (Berkhout and Hertin 2002; van't Klooster and van Asselt 2006). The four-field approach to formulating scenarios is well established. Its strength is the systematic and transparent approach.

A critique of this approach is that a strong focus on two dimensions will lead to a situation where many aspects of change in future will have to be disregarded in favour of keeping the number of scenarios and variables to a graspable amount. The choice of critical uncertainties in a four-field approach is of course subjective but the relevancy of the choice can be more firmly established if stakeholders are involved in the identification of the dimensions that will form the basis for the scenarios. van't Klooster and van Asselt (2006) note that studies applying a four field approach often do not include an analytical presentation of how the dimensions and scenarios were reached, but rather just a presentation of the end-result. In section 3.2.1 a set of criteria to guide the choice of dimensions are presented.

A challenge in all scenario development is to ensure that the scenarios are consistent. The risk for inconsistencies is due to the fact that different aspects in the scenarios depend on each other. As an example, prices depend on, among other things, the economic growth rate, which will have an impact on and is influenced by employment and consumption patterns, which in turn will have an impact on environmental pressures (e.g. GHG emissions), which will have an impact on biodiversity, etc.

Several authors have presented procedures for designing and formulating scenarios (Svava Iversen 2005; van't Klooster and van Asselt 2006; IISD 2007; Wulf et al. 2010). IISD (2007, Module 6) suggests four steps that should be taken in the development of scenarios. These steps, adapted to the Dynamix project, are:

1) Clarifying the purpose and structure of the scenario exercise
   a) Establishing the nature of and scope of the scenario exercise
   b) Identifying stakeholders and scope of the scenario exercise
   c) Identifying themes, targets, indicators and policy options
2) Laying the foundation for the scenario
   a) Identifying critical uncertainties
   b) Selecting critical uncertainties
   c) Creating scenario framework
3) Developing and testing the actual scenario
   a) Elaborating the scenario narratives
   b) Undertaking the qualitative analysis
   c) Exploring policy
4) Communication and outreach

The development of the DYNAMIX background scenarios in the DYNAMIX project includes Stage 1, 2 and 3a above. The analysis and also exploring the policies is done in subsequent WPs of the project. Stage one of the process concerning clarifying the purpose and structure of the scenario exercise is found in Section 1.3 above. Additional information can be found in the project description (DYNAMIX 2012) and the report of our common approach

(Umpfenbach 2013). The DYNAMIX project will include a reference scenario that will form the main basis for the calculations and discussions of the efficiency and effectiveness of the proposed policy mixes. In addition to this reference case a set of four cornerstone scenarios will be prepared that are formed based on a four-field approach. These will add robustness to the results and to the understanding of the results from the modelling exercises as well as the qualitative policy assessments.

Our reference scenario will be a node for the development of the cornerstone scenarios, in the sense that many variables in the cornerstone scenarios can be described in terms of comparisons to the reference scenario.

The critical uncertainties found under 2b above are referred to as dimensions in the terminology of DYNAMIX. The two dimensions in our four-field approach are presented and discussed in Section 3.2.2.

The participatory components in the scenario design have been represented by the discussions at and inputs from the first DYNAMIX policy platform meeting. These meetings are participative events organised for stakeholder contribution involving representatives from EU and national level policy-making institutions, civil society, academics, and industry. The first policy platform meeting was held in March 2013. At that event, WP4 had one working session where the external background scenarios were discussed. The focus in that discussion was on the selection of dimensions and on the overall use of scenarios. In addition, members of the DYNAMIX scenario team took notes of discussions at other sessions to better understand what issues where important to the stakeholders. We also discussed uncertainties in foreseeing the future and how to best reach decoupling with stakeholders during the meeting. This formed the participatory input to the scenario design process.

3 Scenario frameworks

We apply an expanded version of the four-field approach, which also includes a surprise-free reference scenario in the centre of the two-by-two matrix (see Section 1.3). A similar approach was previously used by, e.g., Dreborg and Tyskeng (2008) in the TOSUWAMA research programme.

This chapter discusses the basis for the reference scenario. These are mainly previously published attempts at long-term forecasting.

We also discuss the framework of the cornerstone scenarios. Here the focus lies on identifying and describing the two dimensions in our four-field approach. These have similarities to the dimensions of previous studies (see Table 1). However, based on the experience from TOSUWAMA, we also found it necessary to make some changes.

3.1 Framework of the reference scenario

The policy assessment in the DYNAMIX project will take its point of departure from a reference case that will be based on assumptions and an analysis of the long term development of important variables. As indicated above, this reference scenario will be used as the main basis when modelling the different proposed policy mixes developed in the DYNAMIX project.

The reference scenario will be based on already existing, more or less predictive scenarios. Although predictions far into the future are not very meaningful, they can serve as a basis for the development of a surprise-free scenario. The difference between a prediction and a surprise-free scenario lies in the awareness that there will almost certainly be surprises in the future development. This means that the surprise-free scenario is, in fact, highly unlikely to occur.

A scenario should typically account for the following important drivers of economic growth:

- Population
- Labour supply
- Technological progress
- Supply (change in the stock) of primary inputs other than labour. Traditionally these include capital, land, and exhaustible and renewable natural resources.

Population and labour supply are strongly linked, particularly if it can be assumed that the age structure and education level does not change much and that the employment level is full or constant. These assumptions are not always valid, however, and the population and labour force are often accounted for separately (see, e.g., European Commission 2012b, p.22), because they drive different aspects of the economy. Population is part of the demography. It is a source of labour but also drives consumption. The labour supply, on the other hand, is a driver of production.

Economic activities influence the society and the environment in many respects. In DYNAMIX we will focus on the following three factors:

- GDP: its evolution and potential macro-sectoral composition.

- Resources (including energy sources): changes in stock and patterns of demand and supply.
- Emissions and other pressures on the environment.

The existing literature offers many scenarios building exercises, some produced by long-term international efforts, other elaborated within specific European Commission (EC) Sixth or Seventh Framework Program (FP6, FP7) projects. Scenarios that provide a good mix between data accessibility, richness and coverage, policy acceptance and relevance are the old IPCC SRES scenarios (IPCC 2000b, 2000a), the new Shared Social Economic Pathways (SSPs) (van Vuuren et al. 2012) and, specifically at the EU level, the Ageing Report 2012 (European Commission 2011, 2012b). These sources offer also another non negligible advantage. They define which scenario can be considered "the average" or "central" one among the many produced by each exercise.

The SRES from IPCC (IPCC 2000a) include information and assumptions not only on climate change variables (temperature, precipitation, sea-level rise, etc.), but also on underlying social economic developments. Each SRES scenario is associated to a well-defined development of socio-economic variables, like GDP, population, but also fossil fuel prices. These scenarios have been used in many research projects but are today quite outdated and will soon be replaced by new IPCC scenarios (van Vuuren et al. 2012). van Vuuren et al. (2012) propose a framework for the updated SRES scenario where a set of "4 Representative Concentration Pathways" corresponding to different GHG emissions, concentration and radiative forcing scenarios with a parallel development of social economic pathways (SSPs). The quantitative characterization at the country level for GDP and population of SSPs is available on the International Institute for Applied Systems Analysis (IIASA) website (IIASA 2013b). Of the different scenarios available, the SSP2 can work as a no surprise reference case.

Several other global scenarios can give input to the formulation of the DYNAMIX reference case. Examples are:

- IEA (2010) – World Energy outlook: the reference case is here called the "Current Policies Scenario". This scenario considers no new policy initiatives after mid-2010. This is contrasted to the New Policy Scenario which also accounts for new initiatives to be introduced. In the light of the DYNAMIX project the Current Policy Scenario could feed into the reference case.
- WEC (2007) – World energy policy scenarios 2050 – the reference scenario is based on World Energy Outlook 2007 which would be similar to IEA (2010) Current Policy Scenario[2].
- WEC (2011) – Transport scenario that looks at global transportation.

The focus of these global scenarios is on energy and climate issues, and not on the broader scope of resources that DYNAMIX addresses. However, they could provide useful input data on, for example, global commodity prices.

[2] WEC is soon to publish new energy scenarios.

The reference case formulated should not include any policy or political decisions introduced after present day. These induced changes will be introduced in later WPs through the policy mixes assessed in the project.

3.2 Framework of the cornerstone scenarios

In the surprise-free DYNAMIX reference scenario, there is little room for change beyond the scope and control of the policy mixes that we assess. Since a surprise-free scenario is actually unlikely to come true, it is essential to investigate how robust the assessment and the policy mixes are in the face of plausible external induced changes in society. This is the role of the cornerstone scenarios.

The cornerstone scenarios are developed with a four-field approach. This means the development begins with the selection of two dimensions or axes of critical uncertainties. This section focusses on the discussion and selection of these uncertainties.

3.2.1 Criteria for selection of uncertainties

Inspired by the policy platform discussion, discussion within the group and present literature linked to challenges for the future, we have identified four criteria to guide the selection of the uncertainties to be used to form the external background scenarios.

1. External to the decision-maker. When external scenarios are developed one aspect to consider is that the selected uncertainties are external to the decision-maker. For a company, a sector, or a small country with an open economy, the future of the rest of the world can be described by external scenarios, because it is beyond the control of the decision-makers. However, the policy mixes that are going to be assessed in the DYNAMIX project will affect a broad range of aspects and there are few variables that are completely external to the policy mixes that are going to be assessed. This criterion should help choose uncertainties that are as external as possible.

2. High degree of uncertainty in the reference case. Some aspects are more uncertain than others in the reference case. For example, the possibility to model and also forecast demographic variables is relatively good. Other aspects, such as future consumer preferences, are much more uncertain. If the cornerstone scenarios focus on variables with a high degree of uncertainty, they will cover a larger share of the plausible futures and produce more useful insights into the significance of the uncertainties in the reference case.

3. *Significant for the policy assessment.* If the uncertainty is important for the effectiveness and consequences of the policy instruments, the cornerstone scenarios are likely to bring more additional explanatory value to the reference case. The uncertainties are likely to be important for the policy assessment if they are strongly related to resource use and the economy. Hence, the uncertainties considered should be assessed regarding the level of relation they have with resource use, management and economy.

4. High priority in the public debate. If the uncertainty is considered important in the public debate, the information generated by the cornerstone scenarios is more likely to be considered relevant by the stakeholders and policy-makers. It also increases the likelihood that the findings give a significant contribution to the debate and subsequent policy decisions.

3.2.2 Proposed dimensions of the cornerstone scenarios

The paradigm for development, the dominating values, the rate of government involvement, and the rate of cooperation within and between world regions are examples of dimensions that have formed the basis in previous four-field approaches to formulate scenarios (see Section 1.4). These possible dimensions are all linked to policy and politics included in the resource use/economy discourse.

As stated in Section 1.4, the environmental awareness and the rate of innovation were the most important scenario parameters for the policy assessment in the TOSUWAMA research programme. Based on this experience, we choose to form the background scenarios based on a dimension related to *innovation* in technology and business and a dimension related to the focus of the *values*, ranging from materialism to environmentalism, that affect the lifestyle and the direction of the consumption and economy (see Figure 4).

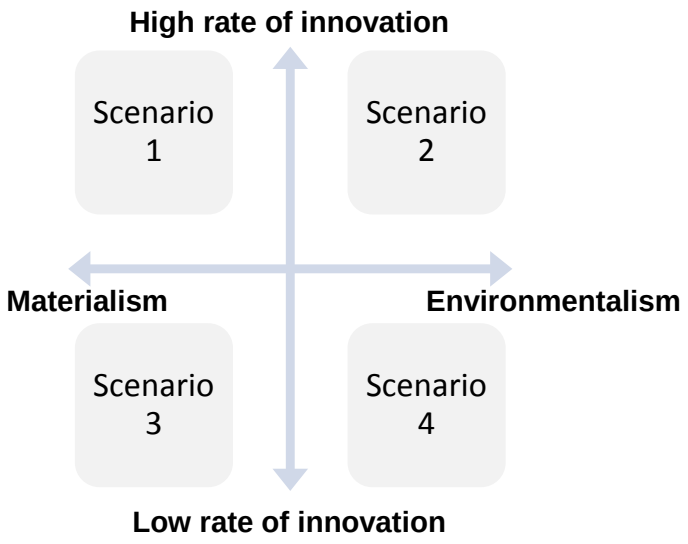


Figure 4: Proposed four-field model for the cornerstone scenarios of DYNAMIX.

Our dimensions are not identical to the dimensions of previous four-field approaches (see Table 1), but there are clear similarities with most of them. Innovation corresponds roughly to Dimension 1 in Table 1. The link is evident with the OPEN:EU project. The rate of innovation was in TOSUWAMA connected to the degree of globalisation. The SRES scenarios make the same connection. The materialism/environmentalism dimension corresponds roughly to Dimension 2 in Table 1: to the quantity/quality focus of the OPEN:EU project, to the economic/social distinction of SRES and PLUREL, and to the level of governmental steering in at least TOSUWAMA.

Table 2 presents a summary of the dimensions Innovation and Values in relation to the criteria above. The dimensions are further presented and discussed below.

Table 2: Summary of the assessment of our selected scenario dimensions

Criterion	Innovation	Values
External to the policy mixes proposed	Stimulated by policy but the breakthroughs are mainly external.	Affected by policy but also governed by many external factors.
Level of uncertainty in the reference case	Highly uncertain, mainly because scientific and technological breakthroughs cannot be predicted.	Variable and, hence, highly uncertain in the long term.
Significance for policy-making	New innovations can create the need for new policy. They also create new possibilities to adapt to policy and increase resource efficiency.	Individual and social norms are important for the need for policy, the acceptance of policy and, probably, the type of policy that will be affected.
Level of priority in the public debate	Innovation is given a high priority in the political debate. In the European context innovation policies and framework is seen as pivotal to progress into a more resource efficient economy.	Norms and life styles are important factors behind the consumption, which is understood to be a key driver for sustainability.

Technological and business innovation

One of the dimensions in the DYNAMIX scenarios is the rate of innovation in technology and business. In line with the definition of eco-innovation given in the common approach (Umpfenbach 2013), we define innovation as the introduction of any new or significantly improved product (good or service), process, organizational change or marketing solution.

Technological development/progression is typically seen as increased efficiency of existing production systems, but technological innovations can also bring about shifts and jumps in terms of how resources are managed. The innovation dimension includes both the refining and broader application of existing technology, and the introduction and integration of new technologies in society. Technology is here understood in its wide definition i.e. “the application of scientific knowledge to the practical aims of human life” (Encyclopædia Britannica Online 2013). Technology thus encompasses specific products but also general-purpose technologies (GPTs) that facilitate the development of a wide range of new products (Jovanovic and Rousseau 2005). Historic GPTs include the steam engine, internal combustion, electricity and, most recent, the information and communication technology (ICT). Potential new GPTs include, for example nano-technology and graphene.

The dimension of innovation also includes organisational changes in business. These can follow from technological innovations such as ICT, but they can also occur independently of a specific technology. Innovations in business include new business models such as, for example, leasing, renting or selling services instead of products. They also include innovations in management and decision-making processes in business. The latter can include procedures to, for example, account for scientific uncertainty more comprehensively in strategic decision. They can also include organisational changes, such as having a director-level person responsible for environment/sustainability.

The innovation dimension in our background scenarios does not include other social innovations[3] since these are more closely connected to the value dimension.

The innovation dimension meets the criteria in Section 3.2.1 rather well. The rate of innovation is to a large extent external. Policies can stimulate the development of new technologies and business models through, for example, requirements on the environmental performance of technology, R&D spending, and the education system. However, innovation processes can also be stimulated and supported by civil society, industry and financial sector. Innovation in business is affected by the full framework within which companies operate. For technological innovation, at least, luck can also be an important factor: the outcome of such processes strongly depends on whether technological breakthroughs lay waiting around the corner.

The rate of innovation is highly uncertain. The breakthrough and significance of a GPT, in particular, is difficult, if not to say impossible, to foresee beforehand. This is important since GPTs are able to boost innovation. Moreover, they shape evolution of productivity and resource use, and influence social inequalities, performance of stock market and patterns of consumption.

The dimension of innovation is important for the impacts of and need for policies on resource efficiency. A low rate of technological innovation will include slow technical development in efficiency, etc. A high rate of innovation in technology as well as business is likely to open new opportunities for increased resource efficiency and for responding to policy instruments. On the other hand, a high rate of technological innovation is also likely to generate new products that typically consume resources. Additional policy instruments might be needed to regulate the efficiency and resource use of such new products.

Finally, innovation is a key variable in discussions on future societies and economic development (see for example European Commission 2010c, 2010b; OECD 2011; European Commission 2012a).

Scenarios with a high rate of innovation include causes and consequences of such innovation. As indicated above, policy instruments can be part of the causes for a high rate of innovation. To make the DYNAMIX background scenarios more exogenous, we focus on the causes of innovation that are not directly related to policy instruments.

A high degree of globalisation is likely to be a driver for innovation for two reasons. One is that globalisation can increase the exchange of knowledge and technological findings between different parts of the world. The other reason is that globalisation increases competition, and the need for increased competitiveness can stimulate innovation. Hence globalisation can provide both the need for and means of a high rate of innovation.

Crises of different kinds are potentially strong drivers for innovation, because they force people to find new solutions to the challenges posed by the crisis. Several other factors could also stimulate innovation:

- a good education system,
- collaboration between universities, business and authorities,

[3] Social innovation is defined by Mulgan et al. (2007) as “innovative activities and services that are motivated by the goal of meeting a social need and that are predominantly developed and diffused through organisations whose primary purposes are social.”

- an open atmosphere that allows for free exchange of ideas within companies and other organisations,
- relevant incentives for innovators; what incentives are relevant can depend on if the scenario is dominated by materialistic or environmentalist values (see below),
- etc.

A scenario with a high rate of innovation is likely to see many new business models and management methods. It is also likely to include technological breakthroughs. In the shorter time perspective, until the year 2030, such breakthroughs can occur in areas such as nanotechnology, graphene, quantum computers, and/or fusion energy. In the longer time perspective, 2030-2050, a high rate of innovation is likely to include breakthroughs in GPTs that are not yet considered.

In the surprise-free reference case we have a significant increase in the efficiency of existing technologies but no major breakthroughs. This is because each individual breakthrough is almost by definition a surprise. This is despite that few would argue that technological breakthroughs are unlikely in the future.

In scenarios with a low rate of innovation we have only a little increase in the efficiency of existing technologies and no breakthroughs.

The rate and type of future innovations will affect and shape the society on many different levels. A high rate of innovations is likely to result in rapid increases in the efficiency of currently existing products and processes. It will also result in rapid development and deployment of new products and services. These might be wasteful or efficient depending on the consumer preferences.

If the rate of technological innovation is high, new products and models are frequently introduced and each product model is likely to be on the market for a shorter time. Infrastructure, buildings and capital goods will be retrofitted and/or replaced not because they are worn out but mainly because they are outdated.

Innovations can also affect the industrial structure. A high rate of innovation is likely to cause frequent changes in the industrial structure. This will cause temporary unemployment for many people and a high demand for both retraining staff and reinvestment in capital goods.

When the rate of innovation is high, different generations will grow up under very different conditions. This means that the differences in knowledge, consumption patterns, habits, and world views are likely to be great between the generations.

The rapid changes in society can cause tensions and create counter-cultures with a strong interest in old things and old ways. A high rate of innovation in technology and business models can also create room for and stimulate the rise of many other, parallel sub-cultures.

The above indicates that the culture in any given country is likely to be diverse in a future with a high rate of innovation with a large difference between generations and many parallel sub-cultures. At the same time, rapid development in technology and business models is likely to further increase globalisation, reducing the cultural and technological variation between countries and continents. Although the culture within each country becomes more heterogeneous, the world as a whole can become more homogeneous.

Technological innovations can, in addition, cause changes in societal functions and democratic structures. Continued innovation in information technology might, for example,

allow for an increased use of referendums through internet and even affect the format of elections to national and European parliaments.

Values and lifestyle

The dimension of values includes both individual and collective norms and values. These form the basis for habits and lifestyle. They also affect what we do to meet needs such as self-fulfilment and societal rank. In the DYNAMIX scenarios, we distinguish between environmentalism and economic materialism. Environmentalism is here defined by a widespread environmental concern based on the view that the well-being of all humanity and future generations is vital, and that other species and nature have an intrinsic inviolable value. Materialistic scenarios, on the other hand, are dominated by the general idea that increased consumption (and hence production) is the main marker of success.

Just like innovation, the value dimension meets the criteria in Section 3.2.1 rather well. Policy instruments can reinforce existing values by, for example, prohibiting certain behaviour. There are also cases when values seem to be changed by policy instruments. However, such changes imply a moral role for policy-makers, which can be difficult to accept or deliver. Values are also affected by many other factors than policy: for example, advertisements, news, technological and scientific progress, cultural achievements, pioneers, natural disasters, economic crises, and underlying long-term societal trends. For this reason, values are to a great extent external to policy-making.

The uncertainty in future values is large. The basic human needs are relatively fundamental and constant and, therefore, predictable. However, what is required to meet these needs depends on values and norms, and these shift over time. Examples of such shifts include the hippie culture in the mid-1960s, the Swedish ruralisation in the 1970s, and the US shift from isolationism to interventionism following 9/11. These shifts are sometimes slow and gradual but sometimes rapid and radical, and typically difficult to predict.

It was found, in TOSUWAMA, that the level of environmental awareness was very important for the assessment of policy instruments aiming at waste prevention and recycling (Ekvall and Malmheden 2012). This was partly because the need for policy instruments would be less and the implementation of many policy instruments would be more easily accepted; however, the anthropologists and psychologists involved in the assessment also argued that different instruments would be effective depending on the level of environmental awareness. Economic instruments such as a weight-based waste-collection fee were seen as potentially counterproductive in a scenario with a high level of environmental awareness, because the sense of individual responsibility is reduced when households are given the opportunity to pay instead of striving towards waste prevention and increased source separation (Andersson et al. 2011).

Based on the experience from TOSUWAMA, we have the hypothesis that the effectiveness and side-effects of some policy instruments vary between the scenarios. A materialistic society aims to economic growth, which has traditionally been obtained through increased efficiency. Efficient use of resources can be a natural part of this. Shifting taxes from labour to emissions and other negative external costs are policy instruments that might fit well in this context, because they increase the efficiency of the economy. Cap-and-trade and certificate systems can also be effective because they allow production systems to find the most efficient way to meet a political target.

In an environmentalist society, the core values are not so much about doing things efficiently; they are more about doing the things that are right according to the social norms. Since each individual is regarded as a responsible citizen in these scenarios, policies that allow for local solutions might be particularly effective. They allow for individuals, small companies and local politicians to tap into their dedication and take active part in the development towards sustainability. Policies that ban wasteful and harmful technologies and actions can also be effective because the risks of obstructions will be relatively small. Cap-and-trade and certificate systems might not fit well in this context, however, because they fix the political target at a national or European level, which reduce the effect of individual and local initiatives. Even environmental taxes could be considered morally wrong: the value of nature is limitless and inviolable in these scenarios, and it could be perceived to be morally wrong to let someone buy the right to destroy or pollute it by paying the environmental tax. These tentative links between values and effective policy instruments can be regarded as hypotheses to be evaluated in the further development of scenarios and through the use of scenarios in the subsequent assessment of policies.

Finally, individual and collective values affect consumption patterns, which is a key variable in discussions on future societies and economic development. During the first policy platform of the DYNAMIX project, stakeholders emphasised the importance of changing consumption patterns in order to be able to achieve decoupling between economic growth and the resource use and its environmental impacts. The idea that we should strive for sustainable consumption is well founded in the policy debate and articulated by, for example, the European Commission (2008). Consumption here does not only include private consumption but consumption in society as a whole.

The sustainability of future consumption patterns could in principle have been a dimension in the DYNAMIX scenarios; however, they are not very external to policy-makers since consumption patterns can be strongly affected by policy instruments such as taxes and product bans. We choose to base the scenarios on the individual and collective values instead, because they are more difficult to affect through policy instruments.

Scenarios with environmentalist or materialistic values and lifestyle include causes and consequences of such values. As indicated above, policy instruments can affect the values. To make the DYNAMIX background scenarios more exogenous, we focus on the causes that are not policy instruments. As stated above, such causes can include natural and environmental disasters, economic progress and crises, technological and scientific progress, cultural achievements and pioneers, news that emphasises any of the above, and advertisements that encourage consumption.

Values can also change as a result of long-term societal trends. For example, history can be interpreted as including a trend over many centuries towards the recognition of the intrinsic human value and human rights of an ever wider range of people: men from other regions and continents, women, and babies. More recently, the development of legislation protecting endangered species and regulating the living conditions of livestock, as well as the growing animal-rights movement, can be interpreted as a logical continuation of the trend towards an ever wider interpretation of the concept “us”. If this trend continues, environmentalist values are likely to become stronger in society.

Many aspects of the future society will be affected, if it is dominated by environmentalist thinking. An environmentalist concern for future generations, other species, and nature would be reflected in an interest in the protection of the rights and well-being of these. Because

ecosystems and other species are assigned an inviolable value, preservation and restoration of habitats and ecosystems is likely to be an important part of the environmental regulation. Environmentalist norms will also be a threshold that prohibits companies as well as individuals from at least some actions that significantly harm ecosystems and the nature in general.

Environmentalist values are consistent with a general shift towards reduced focus on material wealth in favour of prosperity in a broader sense, of well-being, and of other, non-material forms of wealth is consistent with the. In the environmentalist scenarios, the success of an individual might be measured in close social bonds and cultural achievements rather than in economic wealth. Active participation in political processes is likely to be common in such a future. The individual can be regarded as a morally responsible citizen rather than merely a worker and consumer (see below).

The increased focus on animal rights in an environmentalist future is likely to be reflected in a reduced consumption of meat. The significance given to the environment over material wealth is likely to result in a general shift away from wasteful consumption towards long-lasting and environmentally adapted products and services. The markets are likely to be dominated by companies that produce and sell more sustainable products and services, both because customers demand such products and services and because many employees and owners of companies share the environmental concern.

The mind-set of all individuals will never be identical. An environmentalist future will almost certainly include groups of people that object to the prevailing environmentalist norms. Tension is likely to grow from time to time between such groups and the rest of the society. As a result, the degree to which environmental awareness and environmentalist values dominate the society would probably vary over time. In the environmentalist scenarios, we assume that the general trend is towards more and stronger environmentalist values, but that the society will fluctuate somewhat around this trend.

Materialistic scenarios, on the other hand, are dominated by the desire to maximise consumption (and hence production). This means, for the individual, that a high salary or personal income and visible consumption provide the basis for self-esteem and a good life. For society, the characteristics of a strong country are a high gross domestic production (GDP). Society regards the individual mainly as a consumer and as part of the work-force.

In a materialistic scenario, different stakeholders are likely to have different views on the environment. The environmental concern of households might be limited to impacts that directly affect the individual and the family. Authorities have a more diverse view:

- Since society regards the individuals as consumers and labour, consumer protection and work environment can be relevant issues also in a materialistic scenario.
- Authorities are likely to recognise that nature is important because it contributes to the economy: it has a value as a source of production, recreation and other ecosystem services. Although this value, in contrast to environmentalist scenarios, is limited and quantifiable in the materialistic scenarios, it makes the protection of ecosystem services relevant.
- Authorities also recognise that resource depletion and environmental impacts such as climate change can entail large economic costs. This can make resource efficiency, climate adaptation, and climate mitigation relevant issues for purely economic reasons.

Since environmental awareness and interest are low among the broad population, environmental regulation needs to make allowances for economic growth and competitiveness of the industry. In materialistic scenarios, economic growth is regarded as a prerequisite also for improved environmental performance and protection. The concept of a growing economy as an integrated part of sustainable development was proposed during the 1990s, and often referred to as ecological modernisation (Gouldson and Murphy 1996; Buttel 2000; Mol 2002). Simply put, ecological modernisation proposes that economic growth can go hand in hand with environmental protection and environmental concern (Gouldson and Murphy 1996). Car catalysts and increased application of solar and wind energy in the energy system can be considered examples that support and illustrate this view. If this school of thought is correct, a green materialistic future is possible.

The description of materialistic and environmentalist scenarios above includes both scenario assumptions and hypotheses. It is important to clearly distinguish between these. The hypotheses can, at least in principle, be tested. The assumptions are subjective and cannot be tested. Table 3 summarises the scenario assumptions we have made, and the hypotheses presented, for the value dimension.

Table 3: Summary of assumptions for scenarios dominated by materialism or environmentalism; summary of hypotheses on policy implications.

	Materialism	**Environmentalism**	**Comment**
Perspective	Anthropocentric	Biocentric	Scenario assumption
The concept "us"	Narrow: mainly family and friends	Broad: including the whole world, future generations and other species	Scenario assumption
Value of nature	Limited and quantifiable	Limitless and inviolable	Scenario assumption
Goal	Wealth	Well-being	Scenario assumption
Markers of success	Material: visible production and consumption	Non-material: social bonds, cultural achievements, etc.	Scenario assumption
Role of individual	Employee and consumer	Morally responsible citizen	Scenario assumption
Environmental focus	Efficiency	Protect, preserve, restore	Scenario assumption
Easily accepted types of policy instruments	Market-Based Instruments	Bans and obligations, voluntary approaches.	Hypothesis
Important features	Allow companies and individuals the freedom to find the most efficient solutions	Allow individual municipalities, companies and citizens to make a difference	Hypothesis

4 Scenario narratives and variables

This chapter presents a qualitative description of the five background scenarios: the reference scenario and the four cornerstone scenarios. All background scenarios are based on different combinations of the rate of innovation and the values that dominate the society (see Section 3.2.2). Many future scenarios are consistent and possible with each combination. We do not aspire to describe what must happen in each corner of the scenario four-field model. Instead, our aim is to make a brief but coherent description of a plausible future for each combination of innovation rate and values.

The chapter also presents and discusses some of the key variables in the scenarios. The variables on which this section focuses are a small subset of those that can be possibly considered in a scenario building exercise: GDP, population, total factor productivity (TFP), fossil fuel (in fact oil) prices and GHG emissions.

The inclusion of population and total factor productivity is motivated by their recognized role in the macro-economic literature (Solow 1957; Romer 1986, 1990; Grossman and Helpman 1994; Aghion and Howitt 1998) as determinants of social economic growth. Total factor productivity, in particular, measures how much GDP a given quantity of primary inputs (a bundle of land, labour and capital) can produce. As such, its changes are usually considered a proxy for technical progress.

GDP and GHG emissions are included as indicators respectively of growth and its quality. Fossil fuel prices are included as indicators of natural (fossil) resources use.

A different approach would have been to provide the richest data set possible covering all the potential requirements useful to develop quantitative (but also supporting qualitative) analyses. What follows here is exactly the opposite. A minimal set of key variables, common to all modelling exercises is defined. Then different research groups within DYNAMIX are supposed to define autonomously the development trends for those variables which are relevant for their analyses, but not covered here. This is based on the assumption that different experts are in a better position than the authors to know what is reasonable/possible to embark in their assessments. What is required, nonetheless, is a reasonable consistency in the trends of these additional variables with the macro economic trends hereby proposed and some coordination effort, should different groups work with the same variables.

In this spirit, it may be also the case that not all the trends described, albeit concerning few variables, could be embodied into the different exercises. What is feasible will be naturally determined by the specific research questions examined and by the features of the investigation tools and methodologies used, specifically by the list of the respective endogenous and exogenous variables. Just to make an example: population is likely to be an exogenous driving force in nearly all the models and as such easy to incorporate. GDP however is usually endogenous especially in economic models like computable general equilibrium (CGE) models. Therefore replicating a given future GDP growth path implies to leave as “free” or “residual” some other variables. In CGE models for instance this is usually TFP. This means that GDP and TFP cannot be set together.

This is also the reason why, differently from what was mentioned in section 3.1, the changes in capital and land stock available to the production side of the economic systems (i.e. the

primary inputs different from labour and fossil resources)[4] even though important to determine the growth path of an economy, are not defined. Changes in land and capital stock are closely linked to GDP. Indeed they are determinants of GDP. Therefore, when GDP is fixed as a scenario variable, land and capital stocks need to vary freely to get the desired GDP. Moreover they will also differ across the different assessment exercises depending on the different model used.

All this said, if needed, more quantitative social and economic information is available as, for instance, the sources used to define the reference are richer in data. The full data set can be retrieved directly from the quoted documents or databases which are all free access or made available by the author of this section.

4.1 Reference scenario

This section introduces the main features of the DYNAMIX reference scenario. We define the reference scenario as a plausible, surprise-free scenario. This means that the balance between environmental and materialistic values remains essentially the same as today. It also means that society is not transformed by any major technological break-through. However, the efficiency and reliability of current technology continues to be improved at a steady pace based on historical progression.

The tendency towards increased globalisation continues in the reference scenario. China becomes the leading economy and main driver of the global economic growth. The continued growth in China is spurred in part by cheap labour in western China, but also by increased investments in research and technological development in eastern China.

As a consequence of global economic growth, the natural resources are depleted at an increasing rate in the reference background scenario, which leads to increased prices of natural resources. Prices of manufactured materials and consumer prices on energy also increase. As a consequence, more efficient technology is developed and used in order to reduce input need and the associated costs. This results in a continuing trend of relative decoupling of economy and resource use (see for example Krausmann et al. 2009). Environmental technology is also developed, in part driven by severe environmental problems in countries like China and India.

The increased competition over natural resources leads to tension. This tension does not result in outright war in the reference scenario. The EU sometimes mediates between the great powers of the world and sometimes takes side with the US.

The high prices on natural resources have strong effects on countries with rich resources, for example in Africa. Some of them enter a period of strong economic growth with large foreign and eventually domestic investments in infrastructure, education, etc. Others remain or become ridden by conflicts over the resources.

Within the EU, the balance of power between Brussels and the national governments remains. So does the European currency. The EU slowly overcomes the current financial

[4] The availability of these last is implicitly determined by the evolution of their prices.

crisis, partly through an increase flow of labour between the member states. The EU also slowly expands to include and integrate more countries.

In the reference background scenario, consumption preferences and consumption patterns in Europe and the rest of OECD remains essentially the same as today. Consumption patterns and lifestyle in non-OECD countries slowly grow more similar to the consumption in OECD.

No single source exists for input data on all key scenario parameters. Instead, the scenario here proposed is a consistent mix based on different documents.

Specifically:

- EU27 GDP, population and total factor productivity trends derive from the Ageing Report 2012 (European Commission 2011, 2012b). This is the latest and up to date document on social-economic and demographic evolution for the EU27 until 2060.
- Non EU GDP and population is derived from the Shared Social Economic Pathway (SSP) 2 (van Vuuren et al. 2012). This specific “average or business as usual” scenario is in fact reasonably similar to the Ageing Report when the EU27 performances are compared. Therefore this supports the idea that mixing the two can be not unreasonable.
- Fossil fuel prices derive from central estimates available from established international institutions (for example EIA 2011; IEA 2011, 2012; EIA 2013).
- Fossil fuel emissions derive from a reasonable coupling of SSP2 with the Representative Concentration Pathway 4.5 (van Vuuren et al. 2012) and finally with emissions from the old IPCC SRES scenarios (IPCC 2000a, 2000b).

The above mentioned macroeconomic variables have to be related to a “business as usual” or “average” or “no surprise” future situation, which is the characterization of the DYNAMIX reference scenario. We use the already defined no-surprise scenarios of the mentioned sources as a basis for developing our reference scenario. An extended dedicated appendix to this document provides details on the data sources used, the rationales for their choice and the specific figures provided.

Below Tables 4 and 5 give data on GDP growth and population. The data are from the “Ageing Report” (European Commission 2012b) that also contains detailed information on for example employment and demography.

Table 4: EU27 + Norway GDP in the reference scenario (annual average growth rates in %) (European Commission 2012b)

	2010-20	2021-30	2031-40	2041-50	2051-60	2010-60
BELGIUM	1.5	1.5	1.7	1.7	1.7	1.6
BULGARIA	1.9	1.3	1.4	0.9	0.9	1.3
CZECH. REP.	2.0	1.7	1.6	1.3	1.1	1.5
DENMARK	1.0	1.5	1.5	1.7	1.6	1.4
GERMANY	1.2	0.7	0.6	0.8	0.8	0.8
ESTONIA	1.4	2.2	1.8	1.1	0.9	1.5
IRELAND	1.2	3.2	2.2	1.7	2.2	2.1
GREECE	0.2	1.2	1.2	1.1	1.3	1.0
SPAIN	1.3	2.6	1.5	1.1	1.4	1.6
FRANCE	1.7	1.8	1.6	1.6	1.6	1.7
ITALY	0.8	1.4	1.2	1.3	1.4	1.2
CYPRUS	1.6	2.0	2.3	1.8	1.5	1.8
LATVIA	0.8	2.3	1.5	0.7	0.5	1.1
LITHUANIA	1.1	1.8	1.7	1.2	0.7	1.3
LUXEMBOURG	2.6	1.8	1.8	1.7	1.7	1.9
HUNGARY	0.8	1.8	1.4	1.0	0.9	1.2
MALTA	1.8	1.9	1.7	1.1	0.8	1.4
NETHERLANDS	1.4	1.1	1.2	1.4	1.3	1.3
AUSTRIA	1.6	1.3	1.4	1.4	1.3	1.4
POLAND	3.1	1.7	1.4	0.8	0.6	1.5
PORTUGAL	0.4	1.9	1.5	1.2	1.1	1.2
ROMANIA	1.7	1.3	1.2	0.7	0.5	1.1
SLOVENIA	1.8	1.5	1.2	0.9	1.1	1.3
SLOVAKIA	3.1	2.3	1.2	0.7	0.8	1.6
FINLAND	1.7	1.4	1.6	1.5	1.4	1.5
SWEDEN	1.9	1.8	1.8	1.7	1.6	1.8
UK	1.8	1.9	1.9	1.9	1.7	1.9
NORWAY	2.4	1.9	1.8	1.8	1.7	1.9
EU27	1.5	1.6	1.4	1.3	1.3	1.4

Table 5: EU27 + Norway population in the reference scenario (million) (European Commission 2012b)

	2010	2020	2030	2040	2050	2060
BELGIUM	10.9	11.6	12.2	12.7	13.1	13.5
BULGARIA	7.5	7.1	6.6	6.2	5.9	5.5
CZECH. REP.	10.5	10.8	10.8	10.7	10.7	10.5
DENMARK	5.5	5.7	5.9	6	6	6.1
GERMANY	81.7	80	77.7	74.6	70.6	66.2
ESTONIA	1.3	1.3	1.3	1.2	1.2	1.2
IRELAND	4.5	4.8	5.3	5.8	6.2	6.6
GREECE	11.3	11.5	11.6	11.6	11.6	11.3
SPAIN	46.1	48.1	50.1	51.8	52.7	52.2
FRANCE	64.9	68	70.4	72.3	73.2	73.7
ITALY	60.5	63	64.6	65.7	65.9	64.9
CYPRUS	0.8	0.9	1.0	1.0	1.1	1.1
LATVIA	2.2	2.1	2.0	1.9	1.8	1.7
LITHUANIA	3.3	3.2	3.0	2.9	2.8	2.7
LUXEMBOURG	0.5	0.6	0.6	0.7	0.7	0.7
HUNGARY	10.0	9.9	9.7	9.4	9.2	8.8
MALTA	0.4	0.4	0.4	0.4	0.4	0.4
NETHERLANDS	16.6	17.2	17.6	17.6	17.3	17.1
AUSTRIA	8.4	8.6	8.9	9.0	9.0	8.9
POLAND	38.2	38.4	37.5	36	34.5	32.6
PORTUGAL	10.6	10.7	10.8	10.8	10.6	10.2
ROMANIA	21.4	21.0	20.2	19.4	18.4	17.2
SLOVENIA	2.1	2.1	2.2	2.1	2.1	2.1
SLOVAKIA	5.4	5.6	5.6	5.5	5.3	5.1
FINLAND	5.4	5.6	5.7	5.7	5.7	5.7
SWEDEN	9.4	10.1	10.6	10.9	11.2	11.5
UK	62.2	66.5	70.4	73.6	76.5	79
NORWAY	4.9	5.4	5.8	6.1	6.4	6.6
EU27	501.8	514.9	522.6	525.7	523.8	516.5

To operationalize the aspect of technology progression and innovation one option is to utilise the variable Total Factor Productivity. This variable is found in the Ageing Report (European Commission 2012b) and a summary of the variables for EU27 plus Norway is given in Table 6.

Table 6. EU27 + Norway total factor productivity (TFP) in the reference scenario (annual average % growth rates) (European Commission 2012b)

	2010-20	2021-30	2031-40	2041-50	2051-60	2010-60
BELGIUM	0.7	1.0	1.0	1.0	1.0	0.9
BULGARIA	1.3	1.5	1.5	1.4	1.1	1.4
CZECH REP	1.3	1.2	1.2	1.1	1.0	1.2
DENMARK	0.6	1.0	1.0	1.0	1.0	0.9
GERMANY	0.7	1.0	1.0	1.0	1.0	0.9
ESTONIA	1.1	1.4	1.4	1.3	1.1	1.2
IRELAND	1.1	1.0	1.0	1.0	1.0	1.0
GREECCE	0.1	0.8	1.1	1.0	1.0	0.8
SPAIN	0.2	0.8	1.0	1.0	1.0	0.8
FRANCE	0.8	1.0	1.0	1.0	1.0	0.9
ITALY	0.2	0.9	1.0	1.0	1.0	0.8
CYPRUS	0.2	0.8	1.1	1.1	1.0	0.8
LATVIA	1.0	1.4	1.5	1.3	1.1	1.2
LITHUANIA	0.7	1.2	1.4	1.3	1.1	1.1
LUXEMBOURG	0.7	1.0	1.0	1.0	1.0	0.9
HUNGARY	0.2	1.0	1.4	1.3	1.1	1.0
MALTA	1.0	1.1	1.2	1.1	1.0	1.1
NETHERLANDS	0.9	1.0	1.0	1.0	1.0	1.0
AUSTRIA	0.9	1.0	1.0	1.0	1.0	1.0
POLAND	1.5	1.4	1.4	1.3	1.1	1.3
PORTUGAL	0.2	1.0	1.3	1.2	1.1	0.9
ROMANIA	1.0	1.4	1.5	1.4	1.1	1.3
SLOVENIA	0.8	1.0	1.1	1.1	1.0	1.0
SLOVAKIA	2.0	1.5	1.3	1.2	1.1	1.4
FINLAND	1.4	1.1	1.0	1.0	1.0	1.1
SWEDEN	0.9	1.0	1.0	1.0	1.0	1.0
UK	1.1	1.0	1.0	1.0	1.0	1.0
NORWAY	1.2	1.0	1.0	1.0	1.0	1.1
EU27	0.7	1.0	1.1	1.0	1.0	1.0

As can be noted in Table 6, TFP is assumed to increase smoothly in the reference scenario, as it should be in a “no surprise” context. In the cornerstone scenarios different paths for TFP can be devised. However it is generally difficult to devise “jumps” or abrupt changes due to technological breakthrough, therefore it is suggested to keep continuous transitions also in the cornerstones.

Non-EU GDP and population growth rates in the reference scenario can be retrieved from the SSP2 (van Vuuren et al. 2012; the database is found at IIASA 2013b).

As motivated in the introduction of the section, the evolution of primary factors different from labour and natural resources will be developed as parts of the reference scenario in conjunction to later stage in the project as more details are known on what variables are needed to operationalize the assessments of policy mixes.

Table 7: World oil price trend in the reference scenario (annual average growth rates)

	2010-15	2016-20	2021–25	2026-30	2031-35	2036-40	2041-45	2046-50
Low prices (*)	0.2	4.4	3.0	0.8	1.0	0.9	0.7	1.1 127 US$$_{2008}$$
High prices (**)	9.0	2.2	1.6	1.1	0.8	1.1	0.7	0.6 153 US$$_{2008}$$

Sources our elaboration from:
(*) Eurelectric (2010)
(**) IEA (2011)

GHG emissions for the reference scenario can be retrieved from the B1, B2 or A1B IPCC SRES and are those consistent with roughly a CO2 concentration of 650 ppm by the end of the century at the global level.

4.2 Cornerstone scenario 1: Economic bonanza

Cornerstone scenario 1, called Economic bonanza, has a high rate of innovation and a materialistic focus on production and consumption. These combine to a scenario with higher economic efficiency and economic growth than in any of the other scenarios.

In this scenario, the financial crisis in the EU is overcome through reduced governmental spending in countries with a large budget deficit and an increased flow of labour between the member states. As a result, the difference between rich and poor countries in the EU grows large. The gap between rich and poor within each country also becomes wider, because few countries focus on social and economic equality. The economic and social system in the EU becomes more similar to the current US system. The economic gaps result in high crime rates, to which society responds with severe punishment.

Innovation is in this scenario driven by successful education systems, collaboration between universities, business and authorities, increased global competition, a strong economic incentive for innovators, and a high level of military spending. Multinational companies and spies ensure that technology developed in one part of the world is transferred to other parts. As a result, the rate of innovation is high not only in Europe but all over the world.

Technological breakthroughs occur until 2030 in areas such as nanotechnology, graphene, quantum computers, and/or fusion energy. In the longer time perspective, 2030-2050, breakthroughs are seen in technologies that are not yet even considered. The technological breakthroughs allow for a much more efficient use of resources in currently existing products and processes. Such new, efficient technology is in this scenario employed for economic reasons and creates an economic boom. The resulting increase in efficiency is off-set by many new, wasteful products that are developed and sold to materialistic consumers.

The resource prices are higher in this scenario than in any other of our scenarios. This is because the stakeholders in the booming economy demand more resources than in other background scenarios and also because the strong economy makes it possible to afford the high prices. New energy sources are made available through increasing prices and technological innovation. The high energy demand is met through, for example, liquefaction and gasification of coal, an increase in nuclear energy and, eventually, the introduction of fusion energy. The high demand for meat, paper and wood is met through a more intensified

forestry and agriculture that increases the production per unit land area. The high demand for bulk metals like iron and aluminium is met through an increasing number of mines. The high demand for rare metals, phosphorus and water is more difficult to meet. Conflicts and local wars frequently arise over these resources, for example in Africa. The conflicts over water are inherently regional, but conflicts over metals and phosphorus have global implications. The great powers of the world are at least indirectly involved in the local wars over resources. Global military spending increases partly as a result of these conflicts.

The EU becomes politically more closed towards the rest of the world. Waves of refugees enter Europe from the war-torn regions, but these are often illegal. Within the EU, the balance of power between Brussels and the national governments remains. So does the European currency.

The high rate of innovations causes frequent changes in the industrial structure. This will cause a high demand for reinvestment in the industry and temporary unemployment for many people. As economic growth gains speed, both unemployed from outdated industries, immigrants within the EU, and refugees from other parts of the world soon find employment, although with low wages and uncertain conditions.

Because of the rapid changes in technology etc., future generations are born into a very different society. There are large differences in knowledge, consumption patterns, habits, and world view between the generations. The large number of innovations also creates room for sub-cultures based on new technological gadgets etc.

The tensions caused by the harsh social climate and rapid changes in the society create other sub-cultures. Some of these are counter-cultures with a strong interest in old things and old ways. They succeed in making antiquities fashionable. They also strive for the protection of old cultural buildings.

The level of consumption is unevenly distributed but on average very high in this scenario. Visible consumption is the marker for success for the individual. International tourism, housing, cars and other technological products dominates the consumption in OECD countries, with antiquities as an important niche product. Meat consumption is high all over the world. Some of the very rich spend large amounts of money on visible charity, for example through initiating charity foundations.

New consumer products and new models of existing consumer products are frequently introduced on the market, and old products are discarded long before they are worn out. Also infrastructure, buildings and capital goods are retrofitted and/or replaced not because they are worn but mainly because they are outdated.

The environmental awareness and interest of the population is low in this background scenario. As a result, households, industry and society do little to prevent the environmental impacts of the economy – beyond the current environmental policies that are common to all background scenarios. As a result, the environmental impacts of the economy soon become severe. The local and regional environmental impacts are often dramatic and the impacts of climate change eventually become severe. Instead of preventing these impacts, society is forced to remediate them. In OECD countries, society spends more and more money on rebuilding infrastructure after floods and hurricanes caused by climate change, on cleaning up after environmental disasters, and on restoring polluted soil, water and air to a quality where it can once again be used in the economy. In the long-term, after 2030, the remediation costs

and the costs of natural resources become so large that they significantly affect the economy and reduce the economic growth.

Consumption patterns and lifestyle in non-OECD countries slowly grow more similar to the consumption in OECD, with exception for countries torn by war. The wars as well as the economic growth come at a high environmental cost. In the mid-term perspective, the pollution and environmental impacts increase dramatically in these countries. In the long-term remediation is initiated also in the non-OECD countries.

4.3 Cornerstone scenario 2: Safe globe

Cornerstone scenario 2, Safe globe, combines a high rate of innovation with an environmentalist focus on the well-being of all humanity and future generations. It is the scenario with the highest degree of global cooperation and the most advanced technology for environmental protection.

In this scenario, several unforeseen and unrelated but dramatic industrial disasters happen in different parts of the world (cf. the Union Carbide disaster in Bhopal 1984). The stories of these disasters affect the mind-set of the European population through bestselling books, role-models stating that this must never happen again, etc. A sense of solidarity and a focus on safety grow strong. This change in values is reinforced by a sudden increase in storms and flooding, associated with climate change. Global cooperation on issues such as environmental protection, workers protection, and product safety grows strong. The cooperation also stimulates increased global trade. The world in this scenario is highly integrated and the UN, the World Bank, the World Trade Organization and other global organisations are strong.

The financial crisis in the EU is overcome through increased cooperation and an integration of the economies to create a more efficient, European economy. This means that power is shifted to Brussels and EU develops towards a political federation. With an active interest in global issues and a strong common representation, EU takes the lead in global negotiations aiming at a peaceful and stable world.

Innovation is in this scenario driven by the need to increase safety in global industrial systems, but also by global cooperation; collaboration between universities, business and authorities; successful international education and research systems; and strong immaterial incentives (fame and titles) for innovators. The global cooperation ensures that the rate of innovation is high not only in Europe but all over the world.

Technological breakthroughs occur until 2030 in areas such as nanotechnology, graphene, quantum computers, and/or photovoltaics. The development of fusion energy is avoided due to the risks involved. These include some issues of radioactivity and also a greater vulnerability of the electricity supply. Generation of electricity from fusion would be highly centralised with a few giant power plants in Europe. This would make the electricity supply sensitive to both accidents and sabotage.

In the longer time perspective, 2030-2050, breakthroughs are seen in technologies that are not yet even considered. The technological breakthroughs allow for increased production and improved storage of renewable energy and a safer and cleaner use of resources in most products and processes.

This scenario also includes many new business models. These allow customers to buy services such as a warm home and transportation, instead of goods like fuel and cars. Renting and co-ownership also become possible for new types of products. Technological innovations, such as 3D printing, contribute to making more business models possible.

The overall economic growth is similar to the reference scenario. The innovations increase the productivity of the industry, but increased protection of the environment and animal welfare reduces the productivity, particularly in farming, forestry and fishery. In addition, people spend less time earning wages since their values focus less on production and consumption, compared to the reference scenario. Instead, more time is spent on voluntary work and hobbies.

Social norms are strong in this scenario. On a general level this is because social ties are a marker of success and belonging to the group is important. In particular, there are environmentalist norms that prohibit companies and individuals from some actions that harm ecosystems, etc. The strong social norms make the society relatively homogenous both within each country and in EU as a whole. However, the strong norms also create counter-movements, particularly among rebellious young people. These counter-movements are sometimes destructive but sometimes find cultural expressions that enrich the cultural life of the society as a whole.

The rate of new products is slower than the rate of innovations in this scenario. Each new technology or product is carefully tested and often abandoned before it is introduced on the market. The change in industrial structure is even slower. Obsolete industries are maintained and protected because of concern over unemployment etc. This also contributes to making the economy less efficient than in the scenario “Economic bonanza”.

The level of consumption in Europe is, in economic terms, similar to the reference scenario, but the balance of the consumption pattern is shifted from products towards more services and cultural experiences. Shopping in second-hand stores increases. Meat consumption decreases in the EU, and is dominated by meat from free-ranging animals.

As a result of changes in the production pattern and a high rate of source separation of recyclable waste in households and business, a significant relative decoupling between economy and resource use in Europe is achieved in this background scenario, i.e., without additional policy instruments.

The environmental impacts of the European economy are much less severe, compared to the reference scenario, because most stakeholders protect the local, regional and global environment. The impacts that occur, for example due to environmental accidents and mistakes, are remediated to a large extent.

Thanks to global cooperation, the level of consumption in non-OECD countries rapidly approaches the OECD level. Here the meat consumption increases. Global resource prices resemble the prices in the reference scenario because the demand for resources is lower in Europe but higher in non-OECD countries.

4.4 Cornerstone scenario 3: Divided we trudge

Cornerstone scenario 3, Divided we trudge, combines a low rate of innovation with a materialistic focus on production and consumption. It is dominated by European nationalism and lack of cooperation.

In this scenario, the current financial crisis in Europe leads to division amongst and within countries. Nationalists and separatists grow strong and take power in parts of Europe. A few countries with big budget deficits and debts cancel payments on the public debt. The European currency is abandoned and power is shifted from Brussels to national and regional governments with often conflicting interests. The European Commission focusses on resolving issues within Europe and shows little interest in global issues. As a result, EU is weak and politically closed towards the rest of the world.

The economic transfer between EU member states is reduced in this scenario, and the differences between rich and poor countries in the EU increases. The gap between rich and poor within each country also becomes wider, because few countries focus on social and economic equality. The economic gaps result in high crime rates, to which society responds with severe punishment.

The low rate of innovation in this scenario is to a large degree caused by lack of cooperation between countries, stakeholders, and individual researchers and innovators. Each stakeholder looks strictly to her own interests. There are no major technological breakthroughs and only a small increase in the efficiency of current technology. Despite the focus on production and consumption, the lack of cooperation and innovation makes the European economy grow more slowly than in the reference case. The development is stronger in other parts of the world and the economic, scientific, political and military significance of Europe decline.

Because of the slow improvements in technology and the low environmental awareness in the scenario, the use and price of resources are similar to the reference scenario despite slower economic growth. The resource demand is lower than in the scenario “Economic bonanza”. On the other hand a low rate of innovation and a weak economy makes few new energy sources commercially available (cf. Section 4.2). As a result, the global competition over resources focus on oil and natural gas, which makes the Middle East, northern Africa and Russia key areas for geopolitical conflicts.

Households, industry and society do little to prevent the environmental impacts of the economy – beyond the current environmental policies that are common to all background scenarios. As a result, local and regional environmental impacts are sometimes dramatic and the climate change eventually results in frequent flooding and storms. Since society lacks the means to rebuild all flooded infrastructure, areas that are often flooded are abandoned. This includes fields as well as part of cities near the sea. Houses in abandoned areas become occupied by squatters. These areas are sometimes organised into alternative societies, like Christiania in Copenhagen.

The level of consumption is only slightly higher than today and more unevenly distributed. Visible consumption is the marker for success for most individuals. International tourism, housing, cars and other technological products dominates the consumption in OECD countries. Consumption patterns and lifestyle in non-OECD countries slowly grow more similar to the consumption in OECD. Meat consumption is high all over the world.

4.5 Cornerstone scenario 4: Back to nature

Cornerstone scenario 4, Back to nature, combines a low rate of innovation with an environmentalist focus on the well-being of all humanity and future generations. It is dominated by local trade and an economy that to a large extent is informal.

In this scenario, repeated failures of advanced and large-scale technological systems in Europe occur with catastrophic human and environmental consequences. These turn the population against the experts that create and manage such systems. The partly anti-intellectual distrust towards experts in general and technological research in particular contributes to a low rate of technological innovation. The belief in technological development as the solution to both economic and environmental problems also wanes. Instead, the population turns to local, low-tech systems for increased safety to themselves, other people, and the environment.

Global trade steeply declines in this scenario. Instead, the consumption is dominated by locally produced goods and second-hand goods. These are often traded for other goods or services. It also becomes fashionable to grow your own food, and to circulate nutrients through home composting. The meat consumption is low in the EU, and dominated by locally produced meat.

As a result of changes in the patterns of consumption and trade, the total economy is less efficient than in the reference scenario and the formal part of the economy contracts. Tax revenues decline and governments have less money to spend. The responsibility for social welfare is to a great extent taken over by the local community, relatives and friends. Social norms are strong in this society, but national governments and the EU become weaker as they grow less important for the general population.

The resource use is lower than in the reference scenario. However, water and arable land within EU become scarce resources that need careful management.

The environmental impacts of the European economy are much less severe, compared to the reference scenario, because the sum of the formal and informal economy grows more slowly and because households and industry protects the local environment. However, the impacts that occur are not always remediated due to lack of technology and resources. For this reason, environmental accidents and mistakes leave lasting traces in the environment.

In this scenario the rest of the world evolves fairly independently of the EU, which becomes less important from a global economic, scientific, political and military perspective. On the other hand, EU also becomes less dependent on the rest of the world. The strong social norms and the relative poverty in the EU create counter-cultures that strive for freedom and/or material wealth. Many people in these counter-cultures move to other parts of the world to realise their dreams.

5 Scenario parameters

This chapter summarizes the background scenarios in a single table with quantitative and qualitative parameters.

Table 8: Parameters of the DYNAMIX background scenarios. Note that the trends in the four cornerstone scenarios are in comparison to the trend in the reference scenario and not to the current state.

Factor	**Reference scenario**	**Scenario 1: Economic bonanza** Materialism/ High innovation rate	**Scenario 2: Safe globe** Environmentalism/ High innovation rate	**Scenario 3: Divided we trudge** Materialism/ Low innovation rate	**Scenario 4: Back to nature** Environmentalism/ Low innovation rate
Global					
GDP	5.2% annual average growth rate 2010-2060	↗	↗ Higher outside EU, particularly in non-OECD countries	↘	↘
Total Factor Productivity (TFP)	na	↗	↗	↘	↘
Population	39.3% change 2010-2060	→	→	→	→
Oil Prices	1.9-2.8% annual average growth rate 2010-2050	↗	→	→	↘
Emissions	Any consistent with ~650 ppm at the end of the century	↗	↘	↗	↘
International commitments to tackle development challenges	Challenges lies in finding appropriate conclusions and ways forward – many different views on responsibilities and sharing of costs.	↘	↗	↘	→
Global trade of recycled materials		↗	↗	↘	↘
International transports	For example “Global land transport infrastructure requirements” (Dulac 2013) – ref case is 6DS.	↗	↗	→	↘

Factor	Reference scenario	Scenario 1: **Economic bonanza** Materialism/ High innovation rate	Scenario 2: **Safe globe** Environmentalism/ High innovation rate	Scenario 3: **Divided we trudge** Materialism/ Low innovation rate	Scenario 4: **Back to nature** Environmentalism/ Low innovation rate
EU27					
GDP	1.4% annual average growth rate 2010-2060 (see Table 4)	↗ Higher	→ Similar	↘ Lower	↘ Recession: formal economy declines
TFP	1% annual average growth rate 2010-2060 (see Table 6)	↗ Much higher	↗ Higher	↘ Lower	↘ Much lower
Rate of technological change	See TFP above	↗	↗	↘	↘
Rate of non-technological innovation, including business practices		↗	↗	↘	↘
Population	2.9% change 2010-2060 (see Table 5)	↗ Mainly illegal refugees	→	↘ Population declines due to emigration from Europe and low nativity	↗ Mainly higher nativity
Emissions	Any consistent with ~650 ppm at the end of the century	↗ The thriving economy increases emissions, although the high rate of innovation gives some decoupling of emissions	↘ High rate of innovation and environmentalism values gives room for reduced emissions	→ Smaller economy bur less efficient technology	↘ Environmentalist values create incentives for reduced emissions.
Work time	Based on the Ageing Report (European Commission 2012b)	↗ Extra hours for the well-paid. Double employment for low wages.	↘	↗ Extra hours for the well-paid. Double employment for low wages.	↘ Much less time in formal economy; more time in informal economy

Factor	Reference scenario	Scenario 1: **Economic bonanza** Materialism/ High innovation rate	Scenario 2: **Safe globe** Environmentalism/ High innovation rate	Scenario 3: **Divided we trudge** Materialism/ Low innovation rate	Scenario 4: **Back to nature** Environmentalism/ Low innovation rate
Price on emissions	For example EU Energy trends to 2030 (European Commission 2010a)	↗ With the current ETS system, emission prices will go up.	↘ With the current ETS system, emission prices will go down with lower emissions.	→	↘
Resource demand EU* *This includes virgin material, recycled etc. – the shares are results of the model		↗ Critical resources: rare metals, water	↘ Critical resources: water, metals for photovoltaics	→ Critical resources: oil, natural gas	↘ Critical resources: land and water within EU
Citizen community involvement		↘	↗	↘	↗
Private sector – CSR focus		→	↗	↘	↗
Politically expressed environmental concern		? Will be linked to the politics proposed.	↗ General increase in environmental awareness	? Will be linked to the politics proposed.	↗ General increase in environmental awareness
Private and corporate consumption preference - expressed environmental concern		? Will be linked to the politics implemented.	↗	? Will be linked to the politics implemented	↗
Other attitudes related to increased public interest in environmental issues (e.g., waste, travel)		↘	↗	↘	↗
Social innovation		→ Mainly due to new technology	↗	↘	↗ Mainly in the local community

Factor	Reference scenario	Scenario 1: **Economic bonanza** Materialism/ High innovation rate	Scenario 2: **Safe globe** Environmentalism/ High innovation rate	Scenario 3: **Divided we trudge** Materialism/ Low innovation rate	Scenario 4: **Back to nature** Environmentalism/ Low innovation rate
Time scales in production side decisions, repay periods, and reporting	Current trend on quarterly reports and relatively short repay periods continues	→	↗ Decisions tend to become more long-term, repay periods extended.	→	↗ Decisions tend to become more long-term, repay periods extended.
Employment	Based on the Ageing Report (European Commission 2012b)	↗ Mainly creation of new jobs	↗ Partly protection of old jobs	↘ Slow economy and unsecure employ-ment conditions	↘ Other priorities of the employees
Transports of goods	For example EU Energy trends to 2030 (European Commission 2010a) – appendix 2A	↗ Higher	↗ Slightly higher	↘ Lower	↘ Much lower
Transports of people	For example EU Energy trends to 2030 (European Commission 2010a) – appendix 2A	↗	↘	→	↘
Consumption patterns		International tourism, housing, cars, consumer electronics, antiquities, etc.	More services, cultural experiences, and second-hand goods.	International tourism, housing, cars, consumer electronics, etc. Lots of meat.	More services and cultural experiences. Even more second-hand goods.
Recycling		↗ High resource prices	↗ High rate of source separation	↘	↗ Particularly local recycling of nutrients
Energy efficiency	For example EU Energy trends to 2030 (European Commission 2010a) – appendix 2A	↗	↗	↘ Marginal improvements compared to today	↘ Local, low-tech systems: less efficient than today

Factor	**Reference scenario**	**Scenario 1: Economic bonanza** Materialism/ High innovation rate	**Scenario 2: Safe globe** Environmentalism/ High innovation rate	**Scenario 3: Divided we trudge** Materialism/ Low innovation rate	**Scenario 4: Back to nature** Environmentalism/ Low innovation rate
Meat consumption	For example "World Agriculture Towards 2030/2050" (Alexandratos and Bruinsma 2012)	↗	↘ Mainly from free-ranging animals	→	↘ Mainly locally bred animals
Use of renewable resources	Depends on sector – energy see for example EU Energy trends to 2030 (European Commission 2010a)	↗	↗	→	↗

6 The use of the scenarios

The background scenarios are intended for a multidisciplinary assessment of the effectiveness, robustness and sustainability of new policy mixes aiming at decoupling of resource use and environmental impacts from economic growth. For this purpose, all of the background scenarios include the policy instruments that are in place today, but no other resource or environmental policies.

The effectiveness and sustainability of each investigated policy mix can be calculated, estimated or discussed by comparing a scenario where the policy is implemented to the reference scenario (see Figure 2). This is likely to require further scenario assumptions and/or parameters to be defined for the reference scenario, because different aspects and parameters of the scenario will be important depending on the scientific discipline. The descriptions and parameters presented in Chapters 4 and 5 provide a common basis for the development of the scenarios, a starting point for the scenario development that will continue during the policy assessment.

The robustness of each policy mix can be analysed by discussing how effective and sustainable the same policies would be against the background of any of the cornerstone scenarios. It might also be possible to calculate the effectiveness of a policy mix in the cornerstone scenarios (see Umpfenbach 2013), but this requires that qualitative parameters in Chapter 5 are quantified.

Chapter 3 proposes that the effectiveness and side-effects of some policy instruments can vary depending on the predominant values in the scenario. Economic instruments like emission-trading and certificate systems might fit well with materialistic values; in an environmentalist scenario, however, they might reduce the effect of individual and local initiatives. They might also be regarded as a way to buy free from responsibilities given by the strong social norms in the environmentalist scenario.

From the descriptions of the scenarios such side-effects seem plausible in Scenario 4: Back to nature, because of its focus on local solutions, but not really in Scenario 2: Safe globe. However, these observations should still be regarded merely as hypotheses to be evaluated in the assessment of the policy mixes.

A related hypothesis is that there might be two paths from the materialistic scenarios to an absolute decoupling (see Figure 5). One is to build on the values present in the society and focus on economic policy instruments that allow stakeholders to find the most cost-effective solution to increased resource-efficiency and reduced environmental impacts. The other is a two-step path: to first use policy instruments like environmental and resource taxes in combination with information in an attempt to shift the predominant values towards environmentalism, and then to implement a mix of stronger economic and legal instruments that fits with the new values.

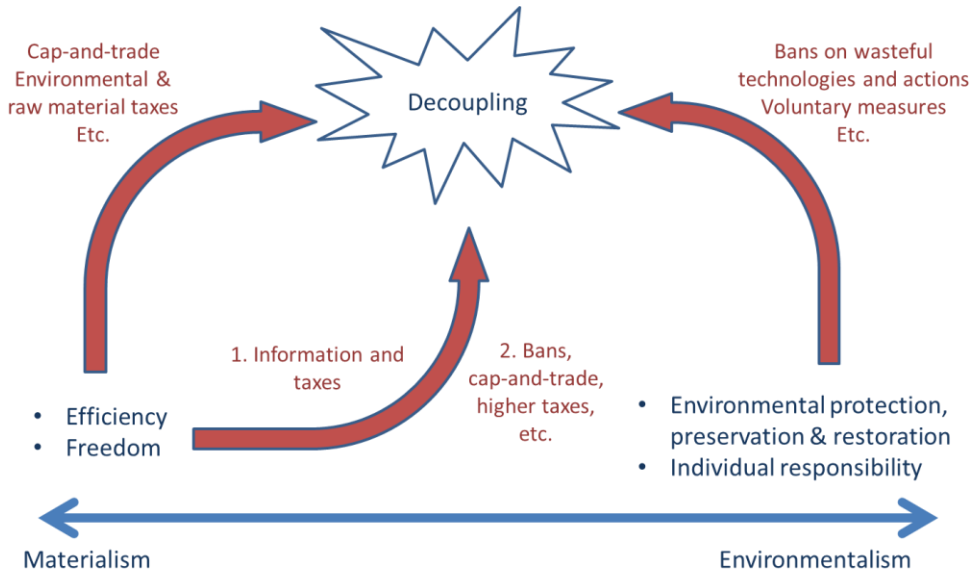


Figure 5: Paths towards decoupling. The blue arrow and text represents the assumptions on background scenarios dominated by materialism or environmentalism. The red arrows and text represents hypotheses of how decoupling can be obtained from different background positions.

The background scenarios can also have a function beyond the scientific policy assessment. They hold a message directly to policy-makers and stakeholders, emphasising that the future is uncertain. Future technology might bring both possibilities and challenges on the path towards decoupling. Europe might become easier or much more difficult to govern. The acceptability of different types of policy instruments might shift. The future is unlikely to be surprise-free.

In this context, it is important to be prepared to use new developments and events for policy purposes. Environmental accidents could, for example, be used to help build stronger values and change norms to reduce the risk that new accidents happen. It is also important to safeguard and nurture the environmental awareness and interest among the public and other stakeholders. When values and norms change, this might require that policies be adapted to ensure their acceptability.

7 References

Aghion, P. and P. Howitt. 1998. *Endogenous Growth Theory*. Cambridge, Massachusetts: MIT Press.

Alexandratos, N. and J. Bruinsma. 2012. *World Agriculture Towards 2030/2050. The 2012 Revision*. 12-03. Rome, Italy: Agricultural Development Economics Division, Food and Agriculture Organization of the United Nations (FAO).

Amara, R. C. 1981. The Futures Field: Searching for Definitions and Boundaries. *The Futurist* 15(1): 25-29.

Andersson, M., C. von Borgstede, O. Eriksson, M. Guath, G. Henriksson, J.-O. Sundqvist, and L. Åkesson. 2011. *Hållbar avfallshantering – utvärdering av styrmedel från ett psykologiskt och etnologiskt perspektiv*. TRITA-INFRA-FMS: 2011:5. Stockholm, Sweden: Royal Institute of Technology.

Berkhout, F. and J. Hertin. 2002. Foresight Futures Scenarios. Developing and Applying a Participative Strategic Planning Tool. *Greener Management International (GMI)*(37): 37-52.

Buttel, F. H. 2000. Ecological Modernization as Social Theory. *Geoforum* 31: 57-65.

Börjeson, L., M. Höjer, K. Dreborg, T. Ekvall, and G. Finnveden. 2006. Scenario types and techniques: Towards a user's guide. *Futures* 38(7): 723-739.

Castles, I. 2004. Climate Work Based on Unsound Economics. *Australian Financial Review*(Feb 7th).

Castles, I. and D. Henderson. 2003a. The IPCC Emission Scenarios: An Economic-Statistical Critique. *Energy and Environment* 14(2-3): 159-185.

Castles, I. and D. Henderson. 2003b. Economics, Emission Scenarios and the Work of the IPCC. *Energy and Environment* 14(4): 415-435.

Dreborg, K.-H. 2004. Scenarios and Structural Uncertainty. Explorations in the Field of Sustainable Transportthesis, Royal Institute of Technology (KTH) and Swedish Defence Research Agency, Stockholm.

Dreborg, K.-H. and S. Tyskeng. 2008. *Framtida förutsättningar för en hållbar avfallshantering - Övergripande omvärldsscenarier samt referensscenario*. 2008:6. Stockholm: Miljöstrategisk analys (fms), Royal Institute of Technology (KTH).

Dulac, J. 2013. *Global land transport infrastructure requirements. Estimating road and railway infrastructure capacity and costs to 2050*. Paris, France: International Energy Agency (IEA).

DYNAMIX. 2012. *Description of Work*. Brussels: DYNAMIX - project.

ECF. 2010. *Roadmap 2050. A Proctical Guide to a Prosperous, Low-carbon Europe. Policy Recommendations*. Den Haag, The Netherlands: E3G, The Energy Research Centre of the Netherlands, The Regulatory Assistance Project and the European Climate Foundation (ECF).

EIA. 2011. *International Energy Outlook 2011*. Washington, USA: Energy Information Administration (EIA).

EIA. 2013. *International Energy Outlook 2013*. Washington, USA: Energy Information Administration (EIA).

Ekvall, T. and S. Malmheden. 2012. *Hållbar Avfallshantering. Populärvetenskaplig sammanfattning av Naturvårdsverkets forskningsprogram*. 6523. Stockholm: Naturvårdsverket.

Encyclopædia Britannica Online. 2013. Technology. http://www.britannica.com.ezproxy.ub.gu.se/EBchecked/topic/585418/technology. Accessed June 2013.

Eurelectric. 2010. *Power Choices. Pathways to Carbon-Neutral Electricity in Europe by 2050*. Brussels: Euroelectric.

European Commission. 2008. *Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan*. COM(2008) 397 final. Brussels: European Commission.

European Commission. 2010a. *EU energy trends to 2030*. Brussels: Directorate-General for Energy in collaboration with Climate Action DG and Mobility and Transport DG, European Commission.

European Commission. 2010b. *Europe 2020 A Strategy for smart, sustainable and inclusive growth*. COM(2010)2020. Brussels, Belgium: European Commission.

European Commission. 2010c. *Europe 2020 Flagship Initiative Innovation Union*. COM(2010)546. Brussels: European Commission.

European Commission. 2011. *The 2012 Ageing Report. Underlying Assumptions and Projection Methodologies*. 4/2011. Brussels, Belgium: European Commission (DG ECFIN) and the Economic Policy Committee (AWG).

European Commission. 2012a. *Innovating for Sustainable Growth: A Bioeconomy for Europe*. COM(2012) 60 final. Brussels, Belgium: European Commission.

European Commission. 2012b. *The 2012 Ageing Report. Economic and budgetary projections for the 27 EU Member States (2010-2060)*. 2/2012. Brussels: European Commission (DG ECFIN) and the Economic Policy Committee (AWG).

Gardner, L., I. Omann, C. Polzin, S. Stoessel, and K. Wentrup. 2011. *OPEN:EU Scenario Storylines Report: Scenarios for a One Planet Economy in Europe*. WP6. Berlin: OPEN:EU - FP7 project.

Gouldson, A. and J. Murphy. 1996. Ecological Modernization and the European Union. *Geoforum* 27(1): 11-21.

Grossman, G. M. and E. Helpman. 1994. Endogenous Innovation in the Theory of Growth. *Journal of Economic Perspectives* 8(1): 23-44.

Henderson, D. 2005. The Treatment of Economic Issues by the Intergovernmental Panel on Climate Change. *Energy and Environment* 16(2): 321-326.

IEA. 2007. *World Energy Outlook 2007*. Paris, france: International Energy Agency (IEA).

IEA. 2009. *World Energy Outlook 2009*. Paris, france: International Energy Agency (IEA).

IEA. 2010. *World Energy Outlook 2010*. Paris, france: International Energy Agency (IEA).

IEA. 2011. *World Energy Outlook 2011*. Paris, France: International Energy Agency (IEA).

IEA. 2012. *World Energy Outlook 2012*. Paris, France: International Energy Agency (IEA).

IIASA. 2013a. The GGI [Greenhouse Gas Initiative] Scenario Database (Version 2.0). http://www.iiasa.ac.at/web-apps/ggi/GgiDb/dsd?Action=htmlpage&page=about. Accessed 20 August 2013.

IIASA. 2013b. SSP Database. https://secure.iiasa.ac.at/web-apps/ene/SspDb/dsd?Action=htmlpage&page=about#intro. Accessed 18 June 2013.

IISD. 2007. *GEO Resource Book. A training manual on integrated environmental assessment and reporting*. Canada: International Institute for Sutainable Development (IISD) and United Nations Environment Programme (UNEP).

IPCC. 2000a. *Special report on Emissions Scenarios*. Intergovernmental Panel on Climate Change (IPCC).

IPCC. 2000b. *Summary for policymakers. Emissions Scenarios*. Intergovernmental Panel on Climate Change (IPCC).

Jovanovic, B. and P. L. Rousseau. 2005. General Purpose technologies. In *Handbook of Economic Growth*, edited by P. Aghion and S. N. Durlauf: Elsevier.

JRC. 2013. EDGAR - Emission Database for Glabal Atmospheric Research. http://edgar.jrc.ec.europa.eu/. Accessed 20 Aug 2013.

Kaya, Y. 1990. *Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios*. Paris, France:

Krausmann, F., S. Gingrich, N. Eisenmenger, K.-H. Erb, H. Haberl, and M. Fischer-Kowalski. 2009. Growth in global materials use, GDP and population during the 20th century. *Ecological Economics* 68(10): 2696-2705.

Marien, M. 2002. Futures Studies in the 21st Century: a Reality-Based View. *Futures* 34: 261-281.

Masini, E. B. 1993. *Why Futures Studies?* London: Grey Seal Books.

Mol, A. P. J. 2002. Ecological Modernisation and the Global Economy. *Global Environmental Politics* 2(2): 92-115.

Mulgan, G., S. Tucker, R. Ali, and B. Sanders. 2007. *social innovation. What it is, why it matters and how it can be accelerated*. London, England: The Young Foundation.

van Notten, P. 2006. Scenario development: a typology of approaches. In *Think Scenarios, Rethink Education*, edited by OECD. Paris, France: Organisation for Economic Co-operation and Development (OECD).

van Notten, P. W. F., J. Rotmans, M. B. A. van Asselt, and D. S. Rothman. 2003. An updated scenario typology. *Futures* 35(5): 423-443.

O'Neill, B., T. Carter, K. Ebi, J. Edmonds, S. Hallegatte, E. Kemp-Benedict, E. Kriegler, L. Mearns, R. Moss, K. Riahi, B. van Ruijven, and D. van Vuuren. 2012. Meeting Report of the Workshop on The Nature and Use of New Socioeconomic Pathways for Climate Change Research. Paper presented at Workshop on The Nature and Use of New Socioeconomic Pathways for Climate Change Research, November 2-4, 2011, Boulder, CO.

OECD. 2011. *Fostering Innovation for Green Growth, OECD Green Growth Studies*. Organisation for Economic C-operation and Development (OECD) Publishing.

Ravetz, J., J. Carter, N. Green, M. Rounsevell, A. Piorr, V. Skirbekk, and B. Boitier. 2008. *Scenario Framework – a guide for exploring the future of the peri-urban*. PLUREL D1-3-2. Manchester: Peri-Urban Land Use Relationships (PLUREL).

Rijnhout, L. and S. Lorek. 2012. *EU Sustainable Lifestyles Roadmap and Action Plan 2050 - "Pathways for enabling social innovation and behaviour change"*. Brussels: SPREAD Sustainable Lifestyles 2050.

Roelich, K., A. Owen, C. West, and D. Moore. 2011. *OPEN:EU Scenario Quantification Report:Scenarios for a One Planet Economy*. WP7. Berlin: OPEN:EU - FP7 project.

Rogelj, J., M. Meinshausen, and R. Knutti. 2012. Global warming under old and new scenarios using IPCC climate sensitivity range estimates. *Nature Climate Change*.

Romer, P. 1986. Increasing returns and long-run growth. *Journal of Political Economy* 94(5): 1002-1037.

Romer, P. 1990. Endogenous technological change. *Journal of Political Economy* 98(5): 71-102.

Solow, R. 1957. Technical Change and the Aggregate Production Function. *Review of Economics and Statistics* 39(3): 312-320.

SOU. 2004. *The Long-Term Survey of the Swedish Economy 2003/04*. 2004:19. Stockholm, Sweden: Ministry of Finance, Government offices of Sweden.

Svava Iversen, J. 2005. *Futures Thinking Methodologies - Options Relevant for Schooling for Tomorrow*. Paris, France: Organisation for Econnomic Co-operation and Development (OECD).

van't Klooster, S. A. and M. B. A. van Asselt. 2006. Practising the scenario-axes technique. *Futures* 38(1): 15-30.

Teske, S. 2012. *A Sustainable EU27 Energy Outlook*. Brussels: Greenpeace and European Renewable Energy Council (EREC).

Umpfenbach, K. 2013. *Common Approach for DYNAMIX. How will we know if absolute decoupling has been achieved?* Berlin, Germany: DYNAMIX project.

UNEP. 2011. *Decoupling natural resource use and environmental impacts from economic growth*. Paris, France: United Nations Environment Programme (UNEP).

WBCSD. 2010. *Vision 2050*. Geneva, Switzerland: World Business Council for Sustainable Development (WBCSD).

WEC. 2007. *Deciding the Future: Energy Policy Scenarios to 2050*. London: World Energy Council (WEC).

WEC. 2011. *Global Transport Scenarios 2050*. London: World Energy Council (WEC).

Wulf, T., P. Meissner, and S. Stubner. 2010. *A Scenario-based Approach to Strategic Planning – Integrating Planning and Process Perspective of Strategy*. 1/2010. Leipzig, Germany: Center for Scenario Planning, Leipzig Graduate Shcool of Management.

van Vuuren, D. P., K. Riahi, R. Moss, J. Edmonds, A. Thomson, N. Nakicenovic, T. Kram, F. Berkhout, R. Swart, A. Janetos, S. K. Rose, and N. Arnell. 2012. A proposal for a new scenario framework to support research and assessment in different climate research communities. *Global Environmental Change* 22(1): 21-35.

van Vuuren, D. P., J. Edmonds, M. Kainuma, K. Riahi, A. Thomson, K. Hibbard, G. C. Hurtt, T. Kram, V. Krey, J.-F. Lamarque, T. Masui, M. Meinshausen, N. Nakicenovic, S. J. Smith, and S. K. Rose. 2011. The representative concentration pathways: an overview. *Climatic Change* 109(1-2): 5-31.

8 APPENDIX: Basis for the reference scenario

As anticipated, the DYNAMIX reference scenario derives its data information set from a consistent integration of different sources. GDP, population and emissions come from the old IPCC SRES scenarios (IPCC 2000b, 2000a), the new Shared Social Economic Pathways (SSPs) (van Vuuren et al. 2012) and, specifically at the EU level, the Ageing Report 2012 (European Commission 2012b). Their short description, strengths and weaknesses are reported in the next section.

8.1 The IPCC SRES scenario exercise

As well known, the 1996 Plenary of the IPCC requested a Special Report on Emissions Scenarios (SRES). This was motivated by the long-term nature and uncertainty of climate change and its driving forces which required as a basis for scientific and policy discussion, scenarios that extend to the end of the 21st century. The report was accepted by the Working Group III (WGIII) plenary session in March 2000.

The IPCC SRES proposes 4 main scenario families.

The **A1 storyline** and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B)

The **A2 storyline** and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and the per capita economic growth and technological change are more fragmented and slower than in other storylines.

The **B1 storyline** and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

The **B2 storyline** and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

By a quick inspection of the qualitative description, emerges that the B2 scenario could be considered an “average” or “reference” among the different families.

A strength of the 2000 SRES scenarios is the high detail of information available not only on GDP and population evolution, but also on emissions and energy use.[5] One major shortcoming of the IPCC SRES scenarios in relation to the DYNAMIX project[6] is that these are considered outdated and are currently being replaced by the new IPCC scenario building process involving the production of Shared Social Economic Pathways (SSPs) and Representative Concentration Pathways (RCPs).

8.2 The Shared Social Economic Pathways (SSPs)[7]

The SSPs (O'Neill et al. 2012; van Vuuren et al. 2012) are part of a new framework that the climate change research community has adopted to facilitate the integrated analysis of future climate impacts, vulnerabilities, adaptation, and mitigation.

The SSPs framework is built around a matrix that combines climate forcing on one axis (as represented by the so called Representative Concentration Pathways (RCPs)) and socio-economic conditions on the other. Together, these two axes describe situations in which mitigation, adaptation and residual climate damage can be evaluated. The process started in 2005.

The associated narratives are briefly summarized below (O'Neill et al. 2012):

SSP1 - Sustainability: This is a world making relatively good progress towards sustainability, with sustained efforts to achieve development goals, while reducing resource intensity and fossil fuel dependency. Elements that contribute to this are a rapid development of low-income countries, a reduction of inequality (globally and within economies), rapid technology development, and a high level of awareness regarding environmental degradation. Rapid economic growth in low-income countries reduces the number of people below the poverty line. The world is characterized by an open, globalized economy, with relatively rapid technological change directed toward environmentally friendly processes, including clean energy technologies and yield-enhancing technologies for land. Consumption is oriented towards low material growth and energy intensity, with a relatively low level of consumption of animal products. Investments in high levels of education coincide with low population growth. Concurrently, governance and institutions facilitate achieving development goals and problem solving. The Millennium Development Goals (MDG) are achieved within the next decade or two, resulting in educated populations with access to safe water, improved sanitation and medical care. Other factors that reduce vulnerability to climate and other global changes include, for example, the successful implementation of stringent policies to control air pollutants and rapid shifts toward universal access to clean and modern energy in the developing world.

SSP 2 - Middle of the Road (or Dynamics as Usual, or Current Trends Continue, or Continuation, or Muddling Through): In this world, trends typical of recent decades

[5] These are accessible with a country detail at: http://www.iiasa.ac.at/web-apps/ggi/GgiDb/dsd?Action=htmlpage&page=about (IIASA 2013a)

[6] The IPCC SRES have been subjected to many criticisms, beyond the scope of this note. The interested reader is addressed for instance to Castles and Henderson (2003b, 2003a), Castles (2004) and Henderson (2005).

[7] Unless stated otherwise, this section is an extract from IIASA (2013b)

continue, with some progress towards achieving development goals, reductions in resource and energy intensity at historic rates, and slowly decreasing fossil fuel dependency. Development of low-income countries proceeds unevenly, with some countries making relatively good progress while others are left behind. Most economies are politically stable with partially functioning and globally connected markets. A limited number of comparatively weak global institutions exist. Per-capita income levels grow at a medium pace on the global average, with slowly converging income levels between developing and industrialized countries. Intra-regional income distributions improve slightly with increasing national income, but disparities remain high in some regions. Educational investments are not high enough to rapidly slow population growth, particularly in low-income countries. Achievement of the Millennium Development Goals is delayed by several decades, leaving populations without access to safe water, improved sanitation, medical care. Similarly, there is only intermediate success in addressing air pollution or improving energy access for the poor as well as other factors that reduce vulnerability to climate and other global changes.

SSP 3 - Fragmentation (or Fragmented World): The world is separated into regions characterized by extreme poverty, pockets of moderate wealth and a bulk of countries that struggle to maintain living standards for a strongly growing population. Regional blocks of countries have re-emerged with little coordination between them. This is a world failing to achieve global development goals, and with little progress in reducing resource intensity, fossil fuel dependency, or addressing local environmental concerns such as air pollution. Countries focus on achieving energy and food security goals within their own region. The world has de-globalized, and international trade, including energy resource and agricultural markets, is severely restricted. Little international cooperation and low investments in technology development and education slow down economic growth in high-, middle-, and low-income regions. Population growth in this scenario is high as a result of the education and economic trends. Growth in urban areas in low-income countries is often in unplanned settlements. Unmitigated emissions are relatively high, driven by high population growth, use of local energy resources and slow technological change in the energy sector. Governance and institutions show weakness and a lack of cooperation and consensus; effective leadership and capacities for problem solving are lacking. Investments in human capital are low and inequality is high. A regionalized world leads to reduced trade flows, and institutional development is unfavourable, leaving large numbers of people vulnerable to climate change and many parts of the world with low adaptive capacity. Policies are oriented towards security, including barriers to trade.

SSP 4 - Inequality (or Unequal World, or Divided World): This pathway envisions a highly unequal world both within and across countries. A relatively small, rich global elite is responsible for much of the emissions, while a larger, poorer group contributes little to emissions and is vulnerable to impacts of climate change, in industrialized as well as in developing countries. In this world, global energy corporations use investments in R&D as hedging strategy against potential resource scarcity or climate policy, developing (and applying) low-cost alternative technologies. Mitigation challenges are therefore low due to some combination of low reference emissions and/or high latent capacity to mitigate. Governance and globalization are effective for and controlled by the elite, but are ineffective for most of the population. Challenges to adaptation are high due to relatively low income and low human capital among the poorer population, and ineffective institutions.

SSP 5: Conventional Development (or Conventional Development First): This world stresses conventional development oriented toward economic growth as the solution to social and economic problems through the pursuit of enlightened self-interest. The preference for rapid conventional development leads to an energy system dominated by fossil fuels, resulting in high GHG emissions and challenges to mitigation. Lower socio-environmental challenges to adaptation result from attainment of human development goals, robust economic growth, highly engineered infrastructure with redundancy to minimize disruptions from extreme events, and highly managed ecosystems.

Currently the database (IIASA 2013b), includes projections (up to 2100) with country detail for:

- population by age, sex, and education;
- urbanization;
- economic development (GDP)

For each SSP a single population and urbanization scenarios is provided, developed by IIASA and NCAR respectively. For GDP, three alternative interpretations of the SSPs have been developed by the OECD, IIASA, and Potsdam Institute for Climate Impact Research (PIK).

Among the SSPs, SSP 2 is explicitly defined “middle of the road” and therefore a good candidate to be a “reference” for DYNAMIX. The SSPs however are not yet associated to emissions or more generally to resource use/availability.

8.3 The Ageing Report

The Ageing Report (European Commission 2011, 2012b), has been prepared as part of the mandate the Economic and Financial Affairs Council (ECOFIN) gave to the Economic Policy Committee (EPC) in 2009 to update and further deepen its common exercise of age-related expenditure projections by 2012, on the basis of a new population projection by Eurostat.

It contains projections, of the budgetary impact of the ageing population in the 27 EU Member States over the period 2010–2060 and has been presented to the ECOFIN Council in May 2012. Thus, it can be considered the more up to date, well established and shared reference for the EU policy debate.

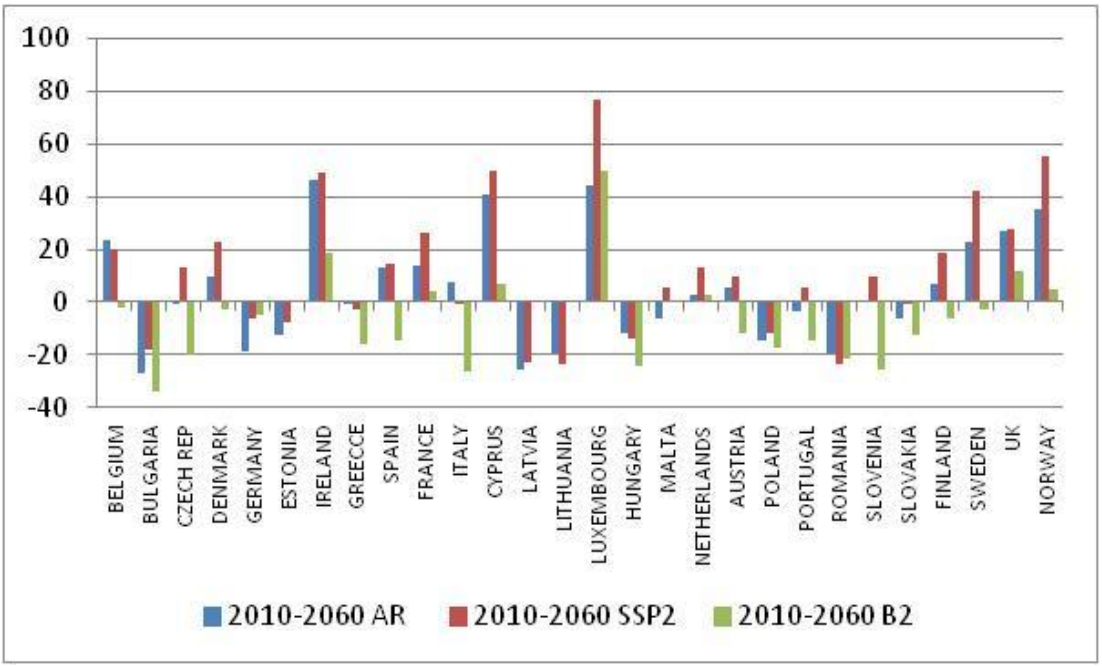
The report is extremely rich in describing population dynamics in the EU27 and related social economic trends namely: labour force and employment projections, age-related expenditure items like those of health care, pensions, education. In addition, it projects up to 2060 consistent scenarios for total GDP and total factor productivity growth trends.

More interestingly, the report does include the impact of the 2008-2009 economic recession on short-term and long-term employment rate. Accordingly, also potential GDP growth has been revised downwards in 2010 and the surrounding years, compared with the baseline projection of previous reports

The Ageing Report focuses on the EU, therefore dynamics outside the region are not captured. Moreover it is limited to EU population driven dynamics neglecting aspects like resource use including energy supply/consumption patterns and potential feedback on prices and environmental impacts like pollution including GHG emissions.

8.4 A scenario comparison

This section compares population and GDP growth trends across the different scenarios that can be candidates to provide information to the DYNAMIX reference. These variables are those common to all the three scenarios and as such offer the opportunity for a consistent comparison. In addition they summarize major macroeconomic trends and as such particularly relevant.

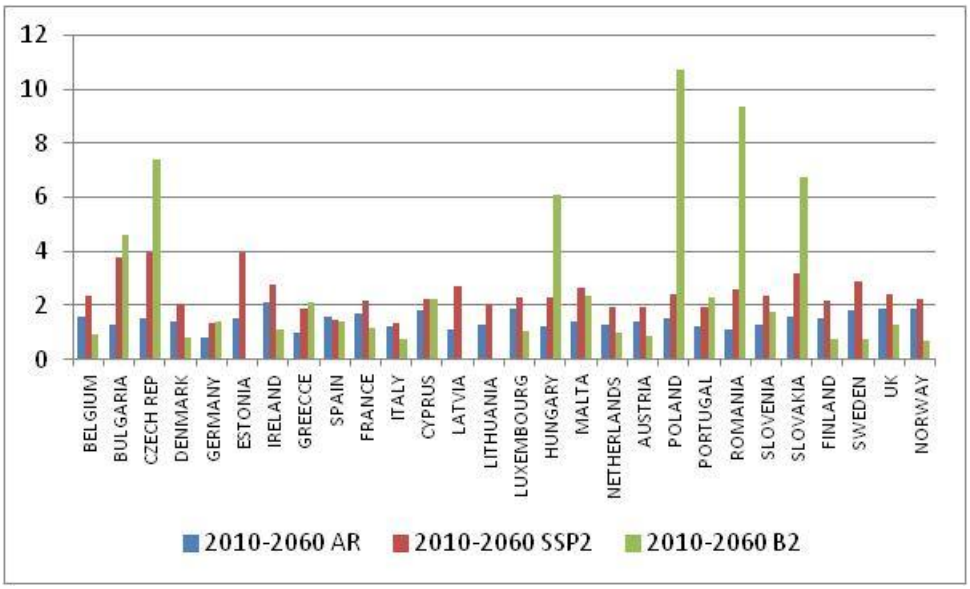


Note: AR – Ageing Report, SSP2 – updated IPCC scenario, B2 – SRES

Source: our elaboration based on European Commission (2012b), SSPs database (IIASA 2013b) and SRES database (IIASA 2013a)

Figure 6: EU27 (+ Norway) population growth rates 2010-2060 (%)

Figure 6 shows a rather consistent qualitative development across all the chosen scenarios for population in the EU27 until the middle of the century. There is however a broader quantitative gap between the couple SSP2 - Ageing Report and the B2 IPCC SRES scenario. B2 presents lower population growth (or higher decreases) than the other two with the Ageing Report somehow in between.



Note: AR – Ageing Report, SSP2 – updated IPCC scenario, B2 – SRES

Source: our elaboration based on European Commission (2012b), SSPs database (IIASA 2013b) and SRES database (IIASA 2013a)

Figure 7: EU27 (+ Norway) average yearly growth rates of GDP 2010-2060 (%)

A roughly comparable GDP growth is detectable between the SSP2 and the Ageing Report, while a more marked difference is shown by the B2 IPCC SRES scenario. This scenario, as all those characterizing the IPCC SRES exercise, assumes absolute convergence of GDP. Thus, it consistently projects higher growth rates for relatively less developed countries. In practice, this translates into higher growth rates in Eastern European countries (note particularly the case of Poland) and lower growth in Western European countries. Some convergence in GDP is shown also by the SSP2, but much blurred. The Ageing Report finally incorporates the latest revision of economic development for the EU27 including the effects of the 2008-2009 economic downturns. Its average yearly GDP growth rates are lower than that of the SSP2, but interestingly, with the exception of Greece and Portugal, tend to remain higher than that of B2 as long as EU15 is concerned.

In summary, regarding GDP growth in the EU27, the Ageing Report is more conservative than the SSP2, but less (and less convergent) than B2 in the case of Eastern EU.

In the light of what said, considering the data richness and recent update, we propose to use the Ageing Report assumptions on population and GDP growth trends (together with the associated information of total factor productivity and employment when necessary) to characterize the future EU27 in the DYNAMIX reference. Should population and GDP be needed also for the non EU countries we suggest to use as complementary source the SSP2 (OECD version).

8.5 Fossil fuel prices

Associating energy (especially fossil fuel and oil) price trends to GDP, TFP and population dynamics can be important. On the one hand they are an indicator, albeit indirect, of the

pressure on (fossil) resources, on the other hand, in many models, they are key driver of energy use influencing the energy mix and the carbon and energy efficiency of the economic systems. The problem is that neither the Ageing Report nor SSPs provide this information. Therefore the issue is firstly to find alternative sources of information on the evolution of fossil fuel prices, and then associate them consistently to the chosen reference.

This section thus offers some indication on how to identify fossil fuel trends in DYNAMIX reference scenario. The following discussion focuses on oil, but the approach presented can be easily extended to coal and gas, if needed.

Projecting energy and especially oil prices is a challenging task. Many factors influence their trends:

- New discoveries, easier accessibility to already ascertained sources (e.g. easier drilling in the Arctic due to thinning of the ice sheet)
- Energy saving technological progress and technological improvement in renewable energy production
- Development/penetration of unconventional fossil fuel sources, e.g. shale gas
- Evolution of climate/energy policies
- Last, but not least energy demand is a powerful determinant of oil prices. It is driven by population and GDP growth and by all the complex and intertwined factors (like technology, habits etc.) determining the “quality” of its development.

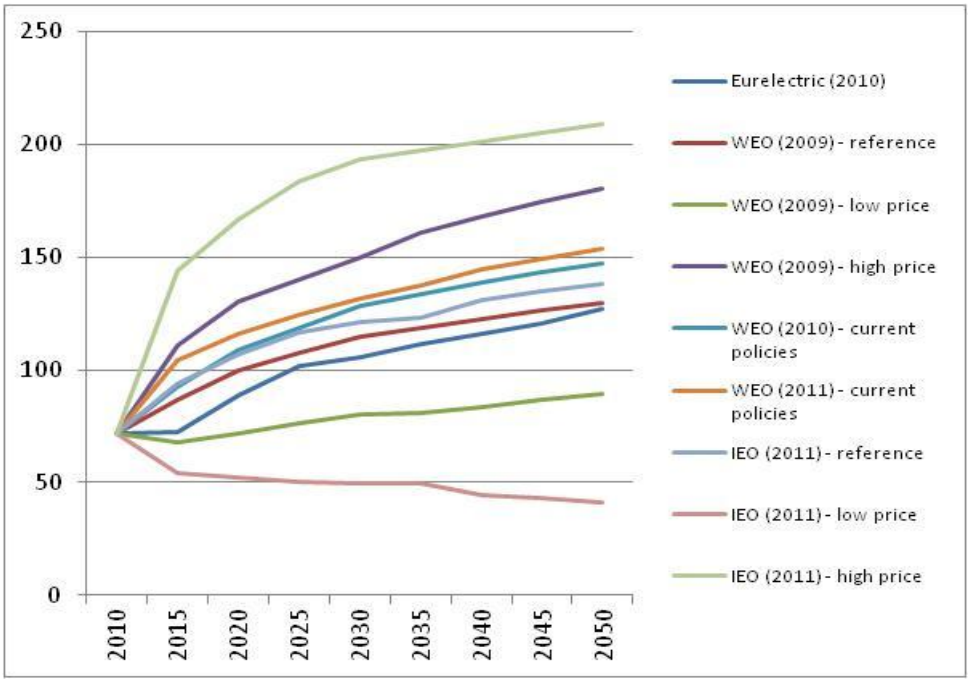
Accordingly, the available information sources present a huge range of variability (see Table 9 with some elaboration to fill missing future values).

Table 9: Oil prices in US$$_{2008}$$ per barrel

	2010	*2015*	*2020*	*2025*	*2030*	*2035*	*2040*	*2045*	*2050*
Eurelectric (2010)	71.9	72.6	88.4	101.6	105.9	111.2	116.2	120.4	126.8
IEA (2009) - reference (1)	71.9	86.7	100.0	107.5	115.0	**118.6**	**122.8**	**126.4**	**129.5**
IEA (2009) - low price (2)	71.9	67.6	72.0	76.0	80.0	**81.0**	**83.8**	**86.6**	**89.5**
IEA (2009) - high price (3)	71.9	110.6	130.0	140.0	150.0	**160.6**	**168.1**	**174.5**	**180.2**
IEA (2010) - current policies (4)	71.9	92.8	108.6	118.4	128.3	133.2	**138.6**	**143.2**	**147.3**
IEA (2010) - current policies (5)	71.9	104.2	115.7	124.8	131.8	137.2	**144.7**	**149.4**	**153.6**
EIA (2011) - reference (6)	71.9	93.8	106.6	116.5	121.4	123.4	**130.9**	**134.8**	**138.3**
EIA (2011) - low price (7)	71.9	54.3	52.3	50.3	49.4	49.4	**44.4**	**42.8**	**41.4**
EIA (2011) - high price (8)	71.9	144.1	166.8	183.6	193.5	197.4	**201.3**	**205.3**	**209.2**

Notes: in red our extrapolations.(1), (3), (4), (5), (6), (7) logarithmic; (2) exponential; (8) linear, using last 2 observations

Only Eurelectric (2010) reports information up to 2050. The other sources stop in 2030 or 2035. When missing, data up to 2050 have been derived with trend extrapolations. Both IEA (2009) and EIA (2011) report high and low price estimates embedding “extreme” assumptions on the major driving forces influencing oil prices. Figure 8 visualizes the range of variability. Table 10 transforms data from Table 9 in yearly growth rates



Sources: IEA (2009); Eurelectric (2010); IEA (2010); EIA (2011)

Figure 8: Oil prices in $\$_{2008}$ per barrel

Table 10: Oil Prices: Average yearly growth rates over the indicated periods

	2010 - 2015	*2015 - 2020*	*2020 – 2025*	*2025 - 2030*	*2030 - 2035*	*2035 - 2040*	*2040 - 2045*	*2045 - 2050*	*2010 - 2025*	*2025 – 2050*	*2010 - 2050*
Eurelectric (2010)	0.2	4.4	3.0	0.8	1.0	0.9	0.7	1.1	2.8	1.0	1.9
IEA (2009) - reference	4.1	3.1	1.5	1.4	0.6	0.7	0.6	0.5	3.3	0.8	2.0
IEA (2009) - low price	-1.2	1.3	1.1	1.1	0.3	0.7	0.7	0.7	0.4	0.7	0.6
IEA (2009) - high price	10.8	3.5	1.5	1.4	1.4	0.9	0.8	0.7	6.3	1.1	3.8
IEA (2010) - current policies	5.8	3.4	1.8	1.7	0.8	0.8	0.7	0.6	4.3	1.0	2.6
IEA (2010) - current policies	9.0	2.2	1.6	1.1	0.8	1.1	0.7	0.6	4.9	0.9	2.8
EIA (2011) - reference	6.1	2.7	1.9	0.8	0.3	1.2	0.6	0.5	4.1	0.8	2.3
EIA (2011) - low price	-4.9	-0.7	-0.8	-0.4	0.0	-2.0	-0.7	-0.7	-2.0	-0.7	-1.1
EIA (2011) - high price	20.1	3.2	2.0	1.1	0.4	0.4	0.4	0.4	10.4	0.6	4.8

The proposal is then:

- To discard from the current observation set those referring to extreme scenarios.
- To leave anyway a range of variability in oil prices in the DYNAMIX reference.
- To use as high end oil price estimate that associated to the highest value reported by the bundle of "moderate" price scenarios, and to use as low end price estimate that associated to the lowest value reported by the bundle of "moderate" scenarios.

The results of this procedure are shown in Table 11.

Table 11: Oil Prices: Average yearly growth rates over the indicated periods for the reference scenario.

	2010-2025	2025-2050	2010-2050
Low prices - Eurelectric (2010)	2.8	1.0	1.9 127 US$$_{2008}$
High prices - IEA (2011) current policies	4.9	0.9	2.8 153 US$$_{2008}$

8.6 GHG emissions

Projecting GHG emission is challenging.

To understand why, it is sufficient to decompose country per capita emissions according to (equation 1)[8] :

$$\frac{GHGr}{Pop_r}\frac{GHG_r}{Pop_r} = \frac{GDP_r}{Pop_r} \cdot \frac{EN_r}{GDP_r} \cdot \frac{GHG_r}{EN_r} \qquad (1)$$

It is immediately evident that per capita emissions depend on multiple factors. They are positively correlated to increases in per capita GDP, energy intensity of GDP and carbon intensity of the energy mix (respectively first, second and third factor in (1)). All, and especially the last two components, are linked to technological progress. The evolution of this is very difficult to anticipate. It depends on a mix of "market signals", that is ultimately changes in relative prices signalling profit/cost saving opportunities and thus the convenience on where when to invest in (energy/emission) R&D, totally unexpected discontinuous factors, and obviously climate and energy policies. For all the above mentioned, emissions trajectories (of GHGs, but also other potential pollutants), should also be left to the endogenous generating process of the different models.

If however some quantitative indications are needed the following procedure can be can used.

[8] This is a slight re-elaboration of the Kaya identity (Kaya 1990). The Kaya identity is applied in for example the SRES (IPCC 2000a)

As mentioned, neither the Ageing Report nor the SSPs are associated to emission growth paths. However the new scenario building exercise currently being developed at the IPCC, devises, together with SSPs, a parallel construction of Representative Concentration Pathways (RCPs). Table 12: RCP description describes the different CO_2 equivalent concentrations that the four RCPs set for the end of the century. They range from a minimum of the RCP 2.6 which is more or less consistent with a global effort to keep temperature increase below the 2°C within the century, to the very high concentration of RCP 8.5. There are then many studies that are associating RCPs to temperature increases. Figure 9 reports for instance the results by Rogelj et al. (2012). As can be seen, in terms of temperature signal, RCP 6 and 8.5 would be consistent with a warming of 2.6-3.7 and 4.0-6.1 °C by the end of the century respectively, while RCP4.5 with a warming between 1 and 3 °C. Figure 9 also highlights the temperature increase correspondence of the new RCPs with the old IPCC SRES scenarios. Focussing on RCP4.5 for instance, it can be noted that it almost overlaps with the old B1 IPCC SRES scenario, but considering the respective uncertainty ranges of -40% + 60% around the mean, it constitutes a reasonable match also for the A1T and B2 IPCC SRES scenarios. Not to mention that some future temperature records of RCP 4.5 are not at odd with some realizations of particularly "optimistic" developments of A1B and A2 SRES. This emphasizes the ample flexibility in associating RCPs to temperature increases and accordingly to the related emission trajectories.

Having associated RCPs to old IPCC SRES scenarios through temperature increase, the last step consists to associate RCPS to SSPs and especially to SSP2 which is the proposed reference for non EU GDP and population in DYNAMIX.[9]

Table 12: RCP description (van Vuuren et al. 2011)

	Description[a]	Publication—IA Model
RCP8.5	Rising radiative forcing pathway leading to 8.5 W/m^2 (~1370 ppm CO_2 eq) by 2100.	(Riahi et al. 2007)—MESSAGE
RCP6	Stabilization without overshoot pathway to 6 W/m^2 (~850 ppm CO_2 eq) at stabilization after 2100	(Fujino et al. 2006; Hijioka et al. 2008)—AIM
RCP4.5	Stabilization without overshoot pathway to 4.5 W/m^2 (~650 ppm CO_2 eq) at stabilization after 2100	(Clarke et al. 2007; Smith and Wigley 2006; Wise et al. 2009)—GCAM
RCP2.6	Peak in radiative forcing at ~3 W/m^2 (~490 ppm CO_2 eq) before 2100 and then decline (the selected pathway declines to 2.6 W/m^2 by 2100).	(Van Vuuren et al., 2007a; van Vuuren et al. 2006)—IMAGE

[a] Approximate radiative forcing levels were defined as ±5% of the stated level in W/m^2 relative to pre-industrial levels. Radiative forcing values include the net effect of all anthropogenic GHGs and other forcing agents

[9] Given that the EU27 currently contributes around 11% of world total GHG emissions (JRC 2013), and the uncertainty range associated to RCPs, the approximation introduced by the different growth rates of the Ageing Report for the EU27 compared to that of SSP2, is scarcely relevant.

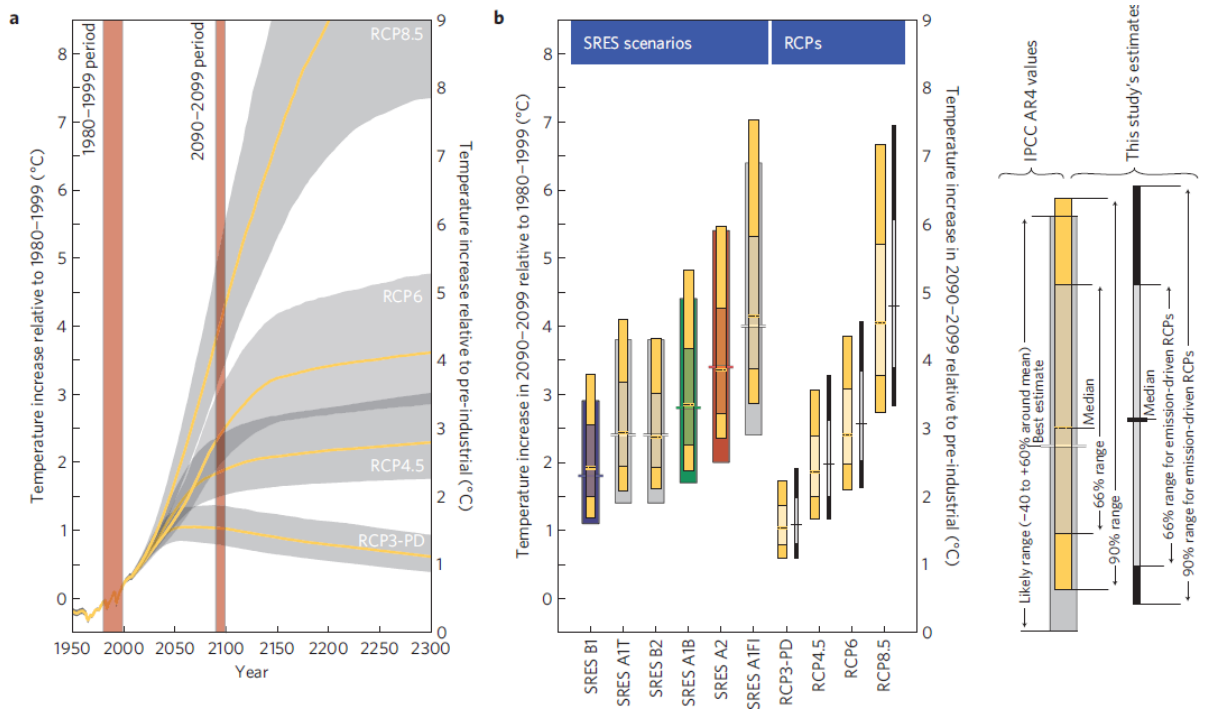


Figure 9: RCPs and temperature increases (Rogelj et al. 2012)

The process of linking SSPs to RCPs is also under way. However, even considering the great flexibility and also, to a certain extent, the subjectivity in this exercise, some general indications on possible correspondences can be derived.

For instance, a scenario like SSP1 with its sustainability concerns and technological progress towards the decarbonisation of energy system is hard to reconcile with a 6°C increase by the end of the century characterizing the RCP8.5. Following the same train of thoughts, SSP2 (the “middle of the road scenario”) is broadly consistent with RCP 4.5.

Therefore, if emission trends need to be associated to the DYNAMIX reference, we note that using the emission range determined by the old B1 and B2 (or even A1B) can be justified.

To conclude, note that the SSP2 (as the old IPCC SRES scenarios) does not assume strong climate (and environmental) policy in place. This is another advantage for DYNAMIX that could then test how thing can change respect to this reference when active resource efficiency action is implemented.