SIXTH FRAMEWORK PROGRAMME
PRIORITY [policy-oriented research priority SSP 5A]

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT

FORWAST

Overall mapping of physical flows and stocks of resources to forecast waste quantities in Europe and identify life-cycle environmental stakes of waste prevention and recycling

Contract number: 044409

Deliverable n° 5-1

Title: Review of recent macro-economic scenarios

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Due date of deliverable :31st August 2007
Actual submission date: 16th August 2007
Start date of project: 1st March 2007 Duration: 2 years
Organisation name of lead contractor for this deliverable: University of Technology Vienna – Institute for Water Quality and Waste Management – IWA, Austria
Revision: Final

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Project home page: http://forwast.brgm.fr

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1. Executive Summary

This deliverable reviews existing macro-economic forecasting studies and models and based on this recommends how best to develop the three macro-economic scenarios for WP5 of the FORWAST project.

We recommend that the baseline scenario presented in the *European Energy and Transport: Trends to 2030* be used as the basis from which the FORWAST baseline be generated. This scenario is similar both spatially and temporally, and the data are aggregated to a level of detail such that it can be readily integrated into an input/output table.

The commonly used IPAT equation was used as a starting point for identifying parameters that greatly affect the level of environmental impact associated with anthropogenic activity. From this it was identified that the level of affluence and development of eco-efficient technologies were the most relevant variables to reflect in the variant scenarios.

By comparing a number of global scenario studies, linkages were identified between some of these key indicators. From this, two hypotheses are presented. The first is that there exists a strong coupling between the level of international cooperation and the global GDP growth rate, and the second is that there exists a weak coupling between the level of eco-efficiency technology development and the total amount of global CO_2 emissions. The second hypothesis was categorized as being weak on the basis that strength of a global economy also greatly contributes to global CO_2 emissions.

By varying high and low combinations of the level of affluence and eco-efficient technology development, four future scenarios were suggested, based on the IPAT equation. These scenarios were then compared to the existing global scenarios, in order to develop a better understanding of what realistic macro-economic variations could occur over the time series of the FORWAST projections. Based on this approach, it was determined that the two most plausible variants would be characterized be a low affluent and low eco-efficient society and a high affluent and high eco-efficient society, respectively.

The recommended baseline scenario was 'bench-marked' against the *Low Trust Globalization* scenario produced by Shell International Ltd. The two recommended variant scenarios were also determined to be characteristically similar to the other two scenarios in the same Shell study – *Flags* and *Open Doors*. Based on these results, it was recommended that the *Shell Global Scenarios to 2025* serve as a primary reference for creating realistic scenario variants for the FORWAST project.

2. Introduction

WP5 is the forecasting component of the FORWAST project. It will cross waste management policy options with macro-economic models in order to produce future waste-flow scenarios. Based on this approach, an optimized waste management strategy can be identified in which environmental protection and resource conservation is maximized. This report focuses on the macro-economic model component of WP5.

In the project proposal, it was recommended that three macro-economic scenarios be developed, of which one is to serve as a 'baseline' scenario. In order to determine the best method of doing this, we reviewed available forecasting models that could be applied to the EU-27. We structure the review according to the nature of the studies, with Chapter 3 reviewing the qualitative studies that predominately follow a 'story telling' or narrative approach to developing future scenarios, Chapter 4 on quantitative studies, and Chapter 5 on the models used for developing the quantitative scenarios.

Finally, in Chapter 6, we discuss the commonly used IPAT equation and how its parameters can be used to develop variant scenarios. In conjunction with this, a summary table highlighting some of the key indicators for global scenario studies that are believed to particularly relevant to the FORWAST project is presented. Based on these findings, and with the objectives of the FORWAST project in mind, recommendations for developing three macro-economic scenarios that will encompass a broad range of plausible variations for the EU-27 are presented.

3. Qualitative Studies

Numerous studies and reports have been produced that forecast social-economic trends over short to medium timeframes. These reports differ in scope and approach, but the general intent of most of them is to help policy makers make more informed decisions with regards to the conservation of our natural environment and to help foster stakeholder awareness.

This Chapter describes studies that have incorporated a 'story telling' approach into the development of future scenarios. In most cases, a balance between quantitative modelling and qualitative description was used. This Chapter focuses mainly on the narrative aspects of the scenarios in order to place the more analytical studies and computer models described in the following chapters into a broader context. An overview of the most relevant of the identified studies is presented below.

3.1. Shell Global Scenarios to 2025

Shell global scenarios have been periodically published over the last 30 years. Traditionally, two scenarios were explored (Shell International Limited 2005). One considering a world of globalization, new technology and market liberalization, and another in which emphasis was placed on social and community aspirations. The *Shell Global Scenarios to 2025* has now introduced a third alternative, one that captures the uncertainties associated with lack of trust and security in the market place.

In these scenarios, three forces are considered to drive society towards different objectives. These forces are: market incentives, communities, and coercion or regulation. These forces are considered to display elements of mutual exclusiveness, and it is argued that one cannot be at the same time, freer, more conformant to ones group or faith, and more coerced. To express this concept graphically, a triangle is used in which each force is associated with a vertex. Any future scenario must lie within the area of the triangle and display characteristics of all three driving forces. Instead of assessing the extreme of each force separately, it was believed that a democratic society would most likely blend elements of all three forces together. This was done in a manner in which two forces were assumed to equally prevail over the third (i.e. two wins – one loss).

The scenarios are presented as 'stories' that describe the global socio-economic structure in the year 2025. Each scenario has been coined according to its prevailing characteristic. A brief overview of each scenario is paraphrased below.

> *Low Trust Globalization*. In this scenario, market incentives, coercion and regulation are the dominating objectives. As a result: there is little trust in the market. Transparency is equated with disclosure procedures that are mandatory, complex and costly. The state plays a major role in providing security to the nation and overseeing and upholding regulatory procedures. International politics are far from harmonious, and tend to be formed on an opportunistic basis. The EU political integration process stalls and possibly reverses. Market liberalization continues (e.g. privatization of public services) and state intervention is on the whole market friendly.
>
> *Open Doors.* Market incentives and community forces are dominate in this scenario. The dual crisis of trust and security has been solved (or at least kept at bay) by a web

of security-enhancing and trust-building procedures. Security concerns are high, yet the emphasis is on prevention, and efforts are made to keep checks and controls non-intrusive. A whole industry is at work certifying, assessing and promoting trust-enhancing norms and initiatives – thus smoothing the way to a "global community." Civil society is a source of supervision and screening and assesses contributions by companies and governments towards shared goals. The reputation of a company is determined more by public opinion than by decisions in court. The Precautionary Principle, with a bias towards the status quo, is widely applied to provide people with a stronger feeling of security in a complex open environment. Global free trade encompasses regulatory rules, regional development policies and aid plans similar to those in the EU.

Flags. In this scenario, the forces of community are combined with coercion and regulation. The dual crisis of trust and security is not solved, fostering the development of "gated communities" in society and internationally. Distinct social groups are distrustful of outsiders. A strong home-bias in investment priorities is formed. Governments often promote nationalism in the pursuit of social cohesion. Governments raise economic barriers to reduce the volatility of global economic flows and to limit exposure to external threats. The EU is at pains not to unravel. A key tension exists between nationalism and internationalism. Many different, sometimes incompatible, national regulations make it difficult for companies to become truly international organisations. Differing national rules and standards, as well as protectionist demands, restrict the global mobility of investment and capital, and diminish trade and migrant flows.

In relation to the three scenarios described above, the fundamental trends and critical uncertainties for overall energy usage and the energy mix are explored. Demographic and GDP values are available at both the world and regional level in the report, however very little information on economic activity by sector or global CO_2 emissions is presented.

3.2. Horizons 2020

This report was commissioned by Siemens AG, and presents two alternate views of life in 2020 (Scharioth et al. 2004). These views have characteristics similar to the *Low Trust Globalization* and *Flags* scenarios presented in the *Shell Global Scenarios to 2025*. The views are entirely narrative and describe in detail many aspects of a future society. The main intention of *Horizons 2020* is to develop space for creative thought.

3.3. The Great Transition: Global Scenarios 2002

This report is exceptionally well written and insightful (Raskin et al. 2002), and surmises that humanity is in the midst of a new historical transition with implications equally as profound as settled agriculture and the industrial revolution. Three main classes of scenarios are developed based upon the following story lines: essential continuity ('business as usual'), fundamental but undesirable social change (irreversible ecosystem collapse) and favourable social transformation (strategic sustainable development). These have been respectively coined: *Conventional Worlds, Barbarization* and *Great Transitions.* Two sub-variants of each class were then developed and assessed with respect to their implications on population, economy, environment, equity, technology and conflict.

The scenarios are narrative in form but they also use simple trend-line graphs to illustrate change over time. The time-frame considered approximately spans the 21st century, and strategies for leading society towards the most desirable scenario, referred to as *Great Transitions*, are also discussed. An overview of the three main scenario categories is presented below.

> *Conventional Worlds.* This assumes that the global system in the 21st century evolves without major surprises, sharp discontinuities, or fundamental transformations in the basis of human civilization. The dominant forces and values currently driving globalization still shape the future. Incremental market and policy adjustments are able to cope with social, economic and environmental problems as they arise.
>
> *Barbarization.* This scenario foresees the possibilities that these problems are not managed. Instead, they cascade into self-amplifying crises that overwhelm the coping capacity of conventional institutions. Civilization descends into anarchy or tyranny.
>
> *Great Transitions*. This is the focus of the report, and envisions profound historical transformations in the fundamental values and organizing principles of society. New values and development paradigms ascend that emphasize the quality of life and material sufficiency, human solidarity and global equity, and affinity with nature and environmental sustainability.

3.4. Millennium Ecosystem Assessment

In the report *'Ecosystems and Human Well-being: Scenarios, vol. 2'* (Millennium Ecosystem Assessment 2005), four scenarios are presented. Focal questions, key uncertainties, and crosscutting assumptions behind the scenarios were identified through both interviews with stakeholders and through a literature review of major ecological dilemmas. This information, in turn, was used to shape and develop four plausible alternative futures. The complete report is almost 500 pages and highly comprehensive.

Each scenario is presented as a 'story' that is told retrospectively by a person in the year 2050. Simple trend-line graphics and qualitative graphs support these story lines and highlight differences between scenarios in environmental services (e.g. fresh water, health, security, etc.). A brief overview of each scenario is presented below.

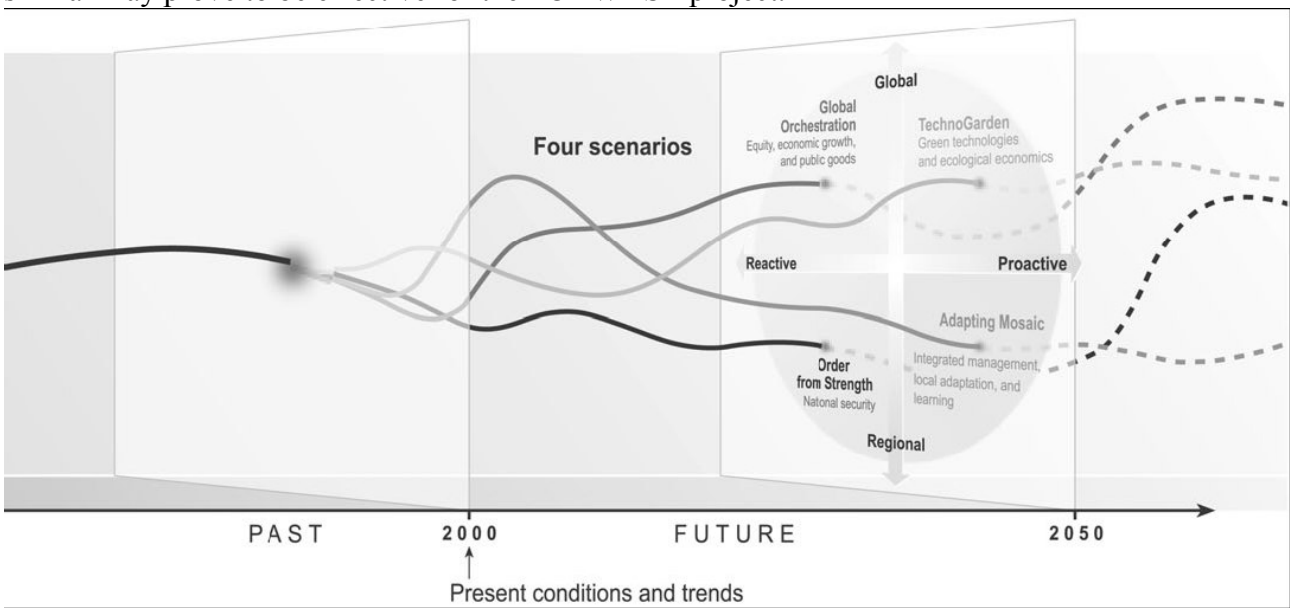
> *Global Orchestration*. In this scenario, global economic policies are the primary approach to sustainability. Trade barriers and subsidies are removed in order to improve the well-being of those in poorer countries. Nations also make progress on global environmental problems, such as greenhouse gas emissions and the depletion of pelagic marine fisheries. Although the wellbeing is improved in many of the poorest countries, it is uncertain as to whether the net impact on ecosystems is positive or negative.
>
> *Order from Strength*. Protection through boundaries in this scenario becomes paramount. Rich nations attempt to confine poverty, conflict, environmental degradation, and deterioration of ecosystem services to areas outside their borders. However, these problems often cross the borders, affecting the well-being of those within. The protection of select natural areas is not sufficient to preserve and maintain

ecosystem services. Global ecosystem services are also degraded due to lack of attention to the global commons.

Adapting Mosaic. In this scenario, a lack of faith in global financial and environmental institutions, combined with increasing understanding of the importance of resilience and local flexibility, leads to a decentralization of power. This creates diverse local practices for ecosystem management in which some regions are much more successful than others. Due to effective communication, regions compare experiences and learn from each other. Global problems are initially ignored, but later addressed with flexible strategies based on successful experiences with locally adaptive management.

TechnoGarden. In this scenario, ecosystems are pushed to their limits of producing the optimum amount of services through the use of technology. These technologies are often more flexible than those currently available, and they allow multiple needs to be met from the same ecosystem. Provision of ecosystem services worldwide is high, but flexibility is low due to high and consistent dependence. Unexpected problems and secondary effects created by technology and erosion can sometimes lead to the interruption or breakdown of ecosystem services.

Of particular note, is a illustrative 3D graphic portraying the four possible future scenario paths (Millennium Ecosystem Assessment 2005, Fig 5.2). This graphic is shown below, and something similar may prove to be effective for the FORWAST project.



4. Quantitative Studies

This Chapter describes studies that predominately use quantitative modelling methods for developing future scenarios. All of the studies selected below include the region of Europe in their analysis.

4.1. European Energy and Transport: Trends to 2030 – Update 2005

A recent report on European energy and transport (Mantzos & Capros 2006) predicts population, GDP and energy use per sector for a number of EU configurations (e.g. EU-25, EU-27 and EU-30) from 1990 to 2030. Individual member country forecasts are also presented.

The baseline scenario presented in the report simulates current trends and current policies as implemented in the member states by the end of 2004. This baseline does not assume that indicative targets will necessarily be met - including CO_2 emissions - but rather reflects the effects of implemented policies. Unfortunately, it appears that no variants from this baseline were developed. PRIMES was the main modelling tool used in this study, the details of which are discussed in Chapter 5.

GDP is disaggregated over the time series into a number of activity groups: industry, construction, services, agriculture and the energy sector. The industry and service groups are then further disaggregated into more detailed actives within each group. The unit of measure is given in Euro, and the annual percent change for each activity is calculated. The expected fuel demand by type, and corresponding CO_2 emissions, were calculated based on the projected GDP values.

4.2. Outlook for Waste and Material Flows

This study was produced by the European Topic Centre for Recycling and Waste Management (ETC/RWM 2005), and has a time horizon of 2020. The key assumptions on socio-economic variables stem from *European Energy and Transport: Trends to 2030* (2003 version). Two other variants based on this scenario were also developed; one reflects the implications of reduced economic growth, while the other addresses climate change objectives and explores a reduced fossil fuel consumption scenario. The indicators used in the study include: population, number of households, and GDP. Based on these scenarios, eight waste streams are projected for the EU-27 and Turkey.

Of particular relevance for FORWAST is the approach used in the model, where links between economic activity, population size and the amount of resources/wastes generated are analyzed. These links are then used to derive future resource/waste flows based on forecasted economic and population trends.

4.3. IPCC SRES (Special Report on Emission Scenarios)

Four families of scenarios (A1, A2, B1 and B2) were developed by the IPCC Working Group III in July 2000 (IPCC 2001). Six different computer models were used to develop the scenarios (the specific names and functions of these models are not covered by the present review). The scenarios were used in the *Third Assessment Report* (2001) and the *Fourth Assessment Report* (2007) to forecast global CO_2 emissions up to the year 2100. Collectively they represent a range of future alternatives based on a number of parameters such as: economic growth, material intensity and diffusion of efficient technologies. An overview of the scenario families is presented below.

A1 Scenarios. These are scenarios of a more integrated world, and are characterized by: rapid economic growth, a global population that reaches 9 billion in 2050 and then gradually declines, the quick spread of new and efficient technologies, and a convergent world in which income and the way of life converge between regions (i.e. extensive social and cultural interactions worldwide). There are three subsets to the A1 family which vary based on their technological emphasis: A1F1 – An emphasis on fossil fuels, A1B – A balanced emphasis on all energy sources, and A1T – Emphasis on non-fossil energy sources

A2 Scenarios. These are scenarios of a more divided world, and are characterized by: a world of independently operating, self-reliant nations, continuously increasing population, regionally oriented economic development, slower and more fragmented technological changes and improvements to per capita income.

B1 Scenarios. These scenarios represent a world that is more integrated and ecologically friendly, and are characterized by: rapid economic growth as in A1, but with rapid changes towards a service and information economy, population rising to 9 billion in 2050 and then declining as in A1, reductions in material intensity and the introduction of clean and resource efficient technologies, and an emphasis on global solutions to economic, social and environmental stability.

B2 Scenarios. These scenarios are of a world more divided, but more ecologically friendly, and characterized by continuously increasing population, but at a slower rate than in A2, emphasis on local rather than global solutions to economic, social and environmental stability, intermediate levels of economic development, and less rapid and more fragmented technological change than in B1 and A1.

Datasets for these scenarios are available from the SRES website (http://sres.ciesin.columbia.edu/final_data.html), and are disaggregated into five regions: The World, OECD90, REF, Asia and ALM (REF refers to countries undergoing economic reform and ALM refers to Africa and Latin America). A list of which countries are contained within each region is available in Appendix III of the *Special Report on Emissions Scenarios* (IPCC 2001).

The main indicators used to calculate CO_2 emissions in these datasets are: GDP (USD), final energy (EJ), primary energy (EJ) and land use (million ha). The energy and land use indicators are further disaggregated over the time series.

An IPCC expert meeting on new scenarios will be held in the Netherlands in September 2007. The objective of that meeting will be to identify requirements and plans for the development of new scenarios for a possible *Fifth Assessment Report* of the IPCC. Considering the amount of time required to update and or develop new scenarios, it is unlikely that this work will be finished in time to be incorporated into the FORWAST project.

4.4. A Final Set of Scenarios for the Clean Air For Europe (CAFE) Programme

In this study (Amann et al. 2005) a number of scenarios relating to European air quality, and health and environmental impacts were developed. The scenarios extend to 2020 and outline the consequences of present legislation. A baseline scenario is presented, as well as three scenarios that

collectively address variations in the level of: PM2.5, eutrophication, acidification and ozone. It appears that the PRIMES model (see Chapter 5) was used as a primary source of input data for this study.

4.5. Scenar 2020 – Scenario Study on Agriculture and the Rural World

The scenarios developed in Scenar 2020 (Nowicki et al. 2007) are intended to identify future trends and driving forces for the European agricultural and rural economy. A number of economic models, differing in approach and scope, were used to generate the scenarios in this study. One of these is CAPRI (see Chapter 5). The scenarios extend to 2020, and are affected exclusively by changes in policy. Demographics, macro-economic growth and consumer preferences are exogenous to the model. Three scenarios were generated for the study, an overview of which is presented below.

> *Reference Scenario*. This scenario establishes a possible and reasonable perspective of what might happen until 2020 from today's perspective. The main agricultural policy assumptions are the conclusion of the WTO negotiations based on the EU proposal and the strengthening of the second pillar by obligatory modulation. For the market side, a balanced market approach has been chosen, leaving public stocks at a level of 1% to 2% of domestic consumption and adjusting support prices where necessary. The enlargement process would continue with the Western Balkan countries and Turkey.
>
> *Regionalization Scenario*. This scenario assumes that the WTO negotiations would not conclude and bilateral trade agreements would become more important. Agricultural policies would remain largely as they stand and rural development funding would be significantly increased. Consequently, total spending for the CAP would increase. For the market side, again, a balanced market approach has been chosen.
>
> *Liberalization Scenario*. This scenario assumes a complete dismantling of the first pillar policies, i.e. agricultural markets would be completely liberalised and rural development funding substantially reduced. Environmental legislation would be partially withdrawn in order to assure competitiveness with agriculture in developing countries and other sectors of the economy.

The main indicators for the study relate to land use and food production, however a projected sectoral structure of the economy (as a percentage) is provided for the EU-25.

4.6. EuroCARE 2004

This study, reported as *'Outlooks on Selected Agriculture Variables for the 2005 State of the Environment and the Outlook Report'* (EuroCARE 2004) primarily uses the CAPSIM model (see Chapter 5) to generate a forecast. The area analysed is the EU, although the number of member countries that this includes fluctuates between 8 and 23. The time series is from 1994 to 2025, and the main indicators examined in the study are nutrient balances (N,P and K) and gaseous emissions (NH_3, N_2O, CH_4). Two other scenarios are also generated: a stronger euro, and a liberalization of animal product markets.

4.7. Interaction Between Economic and Physical Growth

This report (Netherlands Environment Assessment Agency 2006) considers the relationship between physical and monetary growth of OECD countries. Three economic sectors are assessed: industry, transport, and households and services. Of particular interest is the information relating to the consumption of various bulk materials.

The report identified a general trend towards declining intensity of consumption with increasing per capita GDP, but still an overall general trend towards increasing absolute per capita materials consumption. These results show that a shift towards the service economy can lead to weak decoupling between physical and monetary growth but not to absolute dematerialization.

The empirical findings are combined with three scenarios for Western Europe over the time series from 1997 to 2020. The *IPCC A1* scenario is used to represent a high growth scenario, and it appears that the two other scenarios, representing medium growth and low growth, were derived from it. Physical growth rates for the bulk materials, metal, transport, and service industries are presented, although it is acknowledged that there is great uncertainty in the results.

The report concludes that in the high and medium growth scenarios, the physical flow of bulk material is likely to increase by a factor of 2 to 2.5. The report states that this value seems implausibly high, and suggests that the economic projections for the industry are consequently too high. The report also concludes that only a weak decoupling between physical and monetary growth seems possible in the near future, while the physical flows in absolute terms are expected to increase substantially.

Some of the content in the report appears quite relevant to the FORWAST project. This is especially true if it is deemed that alternate scenarios, reflecting variations in material consumption, are to be derived from an already existing 'baseline' scenario. On the whole, the report is not very concise, and much time would be required to extract and validate the information presented.

4.8. VLEEM 2 Final Report

Chapter 3 of the *VLEEM 2 Final Report* (EC 2002a) presents results similar to those intended to be generated by the FORWAST project. Production and consumption values for ten bulk material categories are forecasted for a number of World regions, including parts of Europe, up to the year 2100. The results were calculated based on historical production and consumption statistics, and represent a 'business as usual' scenario.

The two major drivers for energy use related to the production of bulk materials are the production volume and the specific energy needed to produce one tonne of a given material. The materials contributing most to global energy use were taken into account for the bulk material categories; these are (in decreasing order of primary energy use): polymers, iron and steel, paper, cement, aluminium, ammonia, wood, bricks and tiles, and glass. The primary, and in some cases secondary, energy requirements to produce these materials are calculated, and energy reductions that might occur in the future based on envisioned technological improvements has also been taken into consideration. Detailed results for the bulk material consumption categories are in annex 2 of the final report (EC 2002b).

5. Forecasting Models

A number of macro-economic models have been developed over the last decade. These models are typically quite versatile and can be used as the 'engine' for generating data for a variety of studies. Input parameters such as demographics, region and time series are most often exogenous to the model and can be adjusted to suit the specific study being produced. Most of the models are specific to energy sector applications, however there are some that focus on agriculture and more general economics as well. This Chapter provides summaries of the models that may be applicable to the FORWAST project.

5.1. CAPRI

Common Agricultural Policy Regional Impact Analysis (CAPRI) is a global agricultural sector model with a focus on the EU-27 and Norway. The objective of the model is to evaluate regional and aggregate impacts of the 'CAP and Trade' polices on production, income, markets, trade and the environment. There is a supply module covering about 250 regions, and a market module representing a global multi-commodity market with 40 products, 40 countries and 18 trade blocks. The model is a comparative static equilibrium model, solved by iterating supply and market modules. It was developed by the Institute for Food and Resources Economics at Bonn University (http://www.ilr1.uni-bonn.de/agpo/rsrch/capri/capri_e.htm). A new model, CAPRI-dynaspat, is currently being developed (2004-2007).

5.2. CAPSIM

Common Agriculture Policy Simulation Model (CAPSIM) is a partial equilibrium modelling tool designed for policy relevant analysis of the EU-15 agricultural sector (Eurostat 2003). Demographics, economic growth and technical change are all exogenous to the model, which was developed on behalf of Eurostat for policy relevant analysis of the 'CAP'.

5.3. GEM-E3

GEM-E3 is a general equilibrium model, simultaneously representing World regions or European countries, linked through endogenous bilateral trade and environmental flows. The European version covers 15 EU countries. The model uses 18 production and consumption activities, the data of which is derived from the Eurostat database (IO tables, national accounts data and energy balances). Most of the projects involving this model occurred between 2002-2004, and there is no indication of any ongoing work or development with this model. Further information is available from the website (http://www.gem-e3.net/index.htm).

5.4. NEMESIS

This is a macro-sectorial econometric model aimed at developing tools for decision-making in the fields of energy, environment and economic policies. The model currently covers Europe and Norway. From the website (http://www.nemesis-model.net/) it appears that little development or work with this model has occurred since 2002.

5.5. POLES

POLES is a partial equilibrium world model designed for addressing long-term energy, technology and climate change issues. The model simulates the energy demand and supply for 32 countries and 18 world regions. Population and economic growth are the main exogenous drivers for the model.

Additional information can be found at the website (http://www.enerdata.fr/enerdatauk/services/models/Model_POLES.html)

5.6. PRIMES

This model simulates a market equilibrium solution for energy supply and demand in the EU member states (Capros s.a.). It is a general-purpose model developed for forecasting, scenario construction and policy impact analysis. It covers a medium to long-term horizon. The model was developed by the Energy-Economics-Environment Modeling Laboratory (E3M Lab) in Athens, Greece, and was successfully peer reviewed by the European Commission in 1997-1998. More information is available from the website (http://www.e3mlab.ntua.gr/DEFAULT.HTM).

5.7. MARKAL (ETSAP)

MARKAL is a generic model that simulates the evolution of a specific energy system over a period of typically 40 to 50 years. The modal can be spatially adjusted for national, regional, state or province, and community level analysis. MARKAL was cooperatively developed over a period of almost two decades under the umbrella of the International Energy Agency.

Specific types of energy and emission control technologies are the fundamental components within the model. Each one is represented quantitatively by a set of performance and cost characteristics, and a menu of both existing and future technologies can be used to customize those available for each analysis. Both the supply and demand sides are integrated such that one side responds automatically to changes in the other, and the model selects the combination of technologies that minimises total energy system costs. More information about the model method and publications can be found at the website (http://www.etsap.org/markal/main.html#back).

6. Recommendations for FORWAST Scenarios

Due to the complexity of macro-economic model scenario building, it is recommended that the FORWAST project use results from previous studies instead. This can be done in two stages. The first would be to identify an existing scenario that is similar both spatially and temporally to the requirements of the FORWAST project that can serve as a baseline scenario. This scenario must also have a sufficient amount of relevant data such that it could be integrated into the FORWAST input/output model. Once this has been established, the second stage would be to derive two scenario variants from the baseline that encompass plausible macro-economic variations for the EU-27.

Following this methodology, a scenario that could serve as the FORWAST baseline is first recommended, followed by the rationales and considerations required for developing two appropriate variant scenarios.

6.1. Baseline Scenario

The *European Energy and Transport. Trends to 2030 – Update 2005* stands out as a good choice for the FORWAST macro-economic baseline scenario. The main reasons for this are:

- This study is specific to the European region and contains macro-economic forecasts for the EU-27 as well as other configurations of the EU (e.g. EU-25, EU-30, etc.). These forecasts are also disaggregated, providing data for the individual member countries.

- The parameters presented in the study are highly relevant. Population, GDP and energy use per sector can readily be integrated into input/output tables. Furthermore, GDP is disaggregated into, industry, construction, services, agriculture, etc., which will allow for a higher level of integration with the FORWAST model.

- The PRIMES model is the 'engine' used for generating the forecasts. This model was developed in Europe and successfully peer reviewed by the European Commission.

- The study was recently published (2006), and the time series considered extends from 1990 to 2030; only five years short of the FORWAST project time horizon.

- Fuel demand by type and corresponding CO_2 emissions are calculated in the study, and may prove to be useful for verifying the waste flow results developed by the FORWAST model.

6.2. The IPAT Equation

Once a baseline scenario has been established, variant scenarios can be developed by adjusting some of the main parameters. In order to help determine which macro-economic parameters greatly affect the waste-flows generated by a certain population, the widely accepted IPAT equation (Ehrlich & Holdren 1971) was considered. This equation is commonly written as follows:

$$I = P \times A \times T$$

Where:

I = Environmental Impact
P = Population
A = Affluence
T = Technology

It is apparent from the formula that a variation in either Population, Affluence or Technology will directly effect the level of Environmental Impact.

Population. Population projections are not expected to deviate significantly for the EU-27 over the time series of the analysis, and variations in this parameter are therefore irrelevant.

Affluence. This parameter is usually associated with the level of GDP/capita, which could vary significantly over the duration of the times series, and will have a great affect on the accumulated stocks and waste flows for the EU-27. Populations that are more affluent will consume more materials. This relationship is generally true, although a weak decoupling between physical and monetary flows has been observed in countries shifting towards more service-based economies (Netherlands Environment Assessment Agency 2006). Nevertheless, it is assumed that affluence is an important variable of material consumption.

Technology. The technology factor is used to represent the environmental impact intensity of the applied technology, i.e. the Environmental Impact per GDP. It is anticipated that future technological advancements could significantly *reduce* environmental impacts per GDP in the EU-27 (compared to the technologies used today). For this reason, it is important that the modelled scenarios capture variations in the level of technology development and whether the environmental impact intensity of the new technologies is reduced or increased. The term 'Eco-efficient Technology Development' will be used to define new technologies that have reduced environmental impact intensity.

Assuming that Population is constant, high and low values for affluence and technology can be used to generate four scenarios. This is show in Table 1.

Table 1. IPAT Scenarios with Constant Population

Scenario	Affluence (consumption)	Eco-efficient Technology Development
IPAT 1	High	Low
IPAT 2	Low	Low
IPAT 3	High	High
IPAT 4	Low	High

Of the four scenarios in Table 1, *IPAT 1* represents the maximum human impact on the natural environment and *IPAT 4* represents the minimum.

6.3. Global Scenario Studies with Variants

The *Shell Global Scenarios to 2025, Ecosystems and Human Well-being: Scenarios, Vol 2.* and *IPCC SRES* studies all present and contrast multiple scenarios. These studies in particular may serve as useful guidelines for deriving variant scenarios from the FORWAST baseline scenario. , Table 2 summarises key indicators that are common to each study and that relate to the IPAT equation discussed in the previous section.

Table 2. Global Scenario Indicators.

	International Cooperation	**Global GDP Growth Rate (%)**	**Eco-efficient Technology Development**	**Global CO_2 Emissions (GtC-equivalent)**
Shell Global Scenarios				
Low Trust Globalization	Med	2005-2025: 3.1%	Med	-
Open Doors	High	2005-2025: 3.8%	High	*Above 550 ppm
Flags	Low	2005-2025: 2.6%	Low	*Below 550 ppm.
Eco-Systems and Human Wellbeing Scenarios				
Global Orchestration	High	1995-2020: 2.5% 2020-2050: 3.0%	Low	2050: 20.1
Order from Strength	Low	1995-2020: 1.4% 2020-2050: 1.0%	Low	2050: 15.4
Adapting Mosaic	Low	1995-2020: 1.5% 2020-2050: 1.9%	Low/Med	2050: 13.3
Technogarden	High	1995-2020: 1.9% 2020-2050: 2.5%	High	2050: 4.7
IPCC Scenarios				
A1F	High	1990-2020: 3.1% 2020-2050: 3.8%	Low	2050: 23.9
A1B	High	1990-2020: 3.3% 2020-2050: 4.0%	Med	2050: 16.4
A1T	High	1990-2020: 3.4% 2020-2050: 4.0%	High	2050: 12.3
A2	Low	1990-2020: 2.3% 2020-2050: 2.3%	Low	2050: 17.4
B1	High	1990-2020: 3.1% 2020-2050: 3.2%	High	2050: 11.3
B2	Low	1990-2020: 3.0% 2020-2050: 2.6%	Med/High	2050: 11.0

* Only cumulative atmospheric CO_2 concentrations for the second decade of the scenarios period were available.

The intention behind presenting these scenarios together in one summary table is to allow easy identification of similarities and linkages between indicators. Once these linkages become apparent, it should be possible to use them to help develop variant scenarios for the FORWAST project.

The Global GDP Growth Rate and Global CO_2 Emissions values can be compared both within and between the various studies, and provide a good qualitative 'snap shot' of the main characteristics of each scenario. The International Cooperation and Eco-efficient Technology Development indicators were in most cases inferred from the narrative description of each scenario. These indicators were then ranked comparatively between scenarios within a particular study. Although these indicators may prove to be useful for broadly comparing between studies, it should be kept in mind, that no common 'benchmark' was used to establish them.

A strong correlation between the level of International Cooperation and the Global GDP Growth Rate is apparent from Table 2. This relationship is consistent across all three studies.

A weaker coupling can be observed between the level of Eco-efficient Technology Development and Global CO_2 Emissions in both the *Eco-systems and Human Wellbeing* and *IPCC* scenarios. Although comparable emissions data was not available for the Shell scenarios, approximate atmospheric CO_2 concentrations were provided for two of the three scenarios. From this information it can be seen that the highly integrated and eco-efficient world of *Open Doors* actually generated more CO_2 emissions than the divided less eco-efficient world of *Flags*. This is attributed to the fact that world economy is much stronger and active in *Open Doors*, and is consequently consuming more energy and resources – all be it in a more efficient and environmentally conscious manner.

Based on the observed relationships between indicators, the following hypothesis are proposed:

Hypothesis 1: There exists a strong coupling between the level of International Cooperation and the Global GDP Growth Rate such that a more integrated World will exhibit a higher global GDP.

Hypothesis 2: There exists a weaker coupling between the level of Eco-efficient Technology Development and the amount of Global CO_2 Emissions such that a society exhibiting a greater level of eco-efficiency – either through technological advances, or more regionalized economies – will have lower CO_2 emissions.

6.4. Bench-marking the Baseline Scenario

It would be extremely informative to be able to compare the GDP growth rate and CO_2 emissions of the recommended baseline scenario to the values shown in Table 2. This would provide an excellent indication of where the baseline scenario sits in relation to other scenarios. Unfortunately, this is easily done since the baseline scenario results are specific to Europe and not comparable at the global scale. One comparison can be made, however, to the Shell scenarios as GDP growth values from this study are provided at the European level (Shell International Limited 2005b).

Table 3. European Forecasted GDP Growth Rate

	GDP Growth Rate (%)
European Energy and Transport: Trends to 2030	
Baseline	2000-2010: 2.1% 2010-2020: 2.3% 2020-2030: 1.7%
Shell Global Scenarios	
Low Trust Globalization	2005-2025: 2.1%
Open Doors	2005-2025: 2.8%
Flags	2005-2025: 1.8%

It can be seen that the GDP Growth Rate for the *Baseline* scenario is most similar to that of the *Low Trust Globalization* scenario. This is in accordance with the fact that the *Baseline* scenario was generated from economic trends and policies that have already been implemented and that the *Low Trust Globalization* represents a more or less 'business as usual' type of scenario. The *Baseline* scenario can therefore be 'benchmarked' as being similar in characteristics to the *Low Trust Globalization* scenario, and then compared indirectly to the other scenarios presented in Table 2.

6.5. Variant Scenarios from the Baseline

As mentioned in the Introduction, one of the requirements for the FORWAST project is to develop three macro-economic scenarios for the EU-27. These scenarios should encompass realistic variations in both affluence and eco-efficient technology development, since it was shown using the IPAT equation that these two factors are the most relevant in affecting the level of environmental impact. In order to develop a 'feel' for what these realistic variations might be, the global scenarios presented in Table 2 are compared to the four IPAT scenarios from in Table 1.

IPAT 1. This variant would be characterized by a high level of affluence with little emphasis on the development of new eco-efficient technologies. Based on the hypotheses presented in the previous section, this translates into a world that is highly integrated and cooperative, but one that also experiences high global CO_2 emissions, and consequently a high level of environmental impact. This represents one extreme of the all the scenarios considered, and would be similar in character to the *Global Orchestration* and *IPCC A1F* scenarios.

IPAT 2. This variant would be characterized by a low level of affluence with little emphasis on the development of new eco-efficient technologies. This would equate to a divided world with moderate global CO_2 emissions and environmental impact, and would be similar in character to the *Flags, Order from Strength, Adapting Mosaic* and *IPCC A2* scenarios.

IPAT 3. This variant would exhibit the exact opposite characteristics of *IPAT 2* and would be characterized by a high level of affluence with great emphasis on the development of new eco-efficient technologies. This would translate into a world that is highly integrated and cooperative, and that develops and diffuses new eco-efficient technologies on the global scale. Despite these positive efforts, this world would still experience moderate global CO_2 emissions and

environmental impacts - primarily because of the high level of GDP growth. *Open Doors, Technogarden*, and *IPCC A1T* and *B1* scenarios are representative of this future world.

IPAT 4. This variant would exhibit the opposite characteristics of the *IPAT 1* variant, and would be characterized by a low level of affluence with great emphasis on the development of new eco-efficient technologies. This scenario represents the minimum extreme of environmental impact of the scenarios considered, and would have similar attributes to the *Adapting Mosaic* and *IPCC B2* scenarios.

Based on these comparisons, we believe that it is unlikely that the two extreme variants, represented by *IPAT 1* and *IPAT 4*, will develop within the time series of the FORWAST project. Large fundamental changes to the current world economic and political paradigm would need to occur in order for either of these two scenarios to be realized. Consequently, we believe that the two more moderate, yet directly opposed variants, represented by the *IPAT 2* and *IPAT 3* scenarios, are more plausible in their variation from the *Baseline* scenario.

In terms of GDP growth, the *IPAT 2* scenario would be less than that of the *Baseline* scenario, while the *IPAT 3* scenario would be higher, thus spanning a realistic range of macro-economic variation for the EU-27. Similarly, the level of eco-efficient technology development for the two variant scenarios would also be both above and below that of the baseline scenario. This would then define a realistic range of possible levels of technology development.

As identified in the previous section, the *Low Trust Globalization* scenario developed by Shell is closely aligned to the intended *Baseline* scenario of the FORWAST project. It was also shown that the *IPAT 2* and *IPAT 3* variants are similar to the *Flags* and *Open Doors* also developed by Shell. With this mind, it could be suggested to use the *Shell Global Scenarios to 2025* as primary reference for when developing scenarios and variants for the FORWAST project.

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