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FORASSET

Foresight and ASSessment for Environmental Technologies

SPECIFIC TARGETED RESEARCH OR INNNOVATION PROJECT

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Scientific report

Content

Publishable Executive Summary

The 3% objective by the European Council in Barcelona and the communication "More Research for Europe towards 3% of GDP" does not guarantee the attainment of sustainable development goals, more specifically regarding the environmental dimension. For this reason, an Action Plan for Environmental Technologies has been requested by the Barcelona Council in 2002. Environmental Technologies are defined broadly (reflecting Commission views) to include integrated technologies that prevent pollution as well as materials, energy and resource efficient production processes, new organisation of work, etc… In order to develop the Action Plan, the Commission decided to focus on four environmental issues: climate change, soil protection, sustainable production and consumption, water.

The Commission communication argued that "environmental technologies could contribute to Sustainable Development by protecting our environment and at the same time enhance economic growth". But the trust in this decoupling between environmental pressure and economic growth or "win-win" strategy must be mitigated for several reasons and then it was very important:

- to achieve an analytically sound assessment of the potential impacts of the introduction of environmental technologies in our economies;
- to assess for generic R.T.D. policies and specially these linked to EC 7th Funding Program;
- to seek the most appropriated policies to promote invention, innovation and diffusion of these technologies by carrying out a global assessment of such policies.

An analytically sound and quantified assessment of the potential impacts requires the use of global quantitative methods, i.e. the use of applied economic models in which environmental technologies must be explicitly incorporated. These models must take macro-economic feedbacks of policies into account, that may be important; they must also be detailed enough in order to represent the important sectoral differences from the environment view point. Then the works of the FORASSET project consisted in:

- a characterization and quantification of New Environment Technologies;
- a new module for R.T.D. decisions, innovation and diffusion of N.E.T. implemented in modelling;
- a new assessment for European funding programs for research;
- a new assessment for environmental policies, in particular for EU "Climate Action and Renewable Energy Package", that was agreed the 23 January 2008.

Main results may be summed up as follow:

1- the characterization of New Environmental Technologies determines the technical characteristics, the potential to economic growth, employment, energy consumption, improvement of environment and also the market potentials and the direction and strength of relevant drivers to their introduction. The collect of data is presented on case studies but some data are missing on R&D data available at two aggregate level and need the use of proxy variables such as patents; nevertheless this lack of data did reduce the scope of technologies used for modelling;

2- the modelling progresses of the project are important in several directions:

- the elaboration of a Module for adoption of environment technologies based on stochastic decisions for R&D with behaviour of agents grounded on probability maximization for exceeding a threshold for returns. The other main feature of this module is its diffusion process that incorporates imperfect substitutions between old and new technologies;
- the calibration of this adoption module that implied an important work of data collection for NET, and its introduction in NEEM (NEMESIS Energy Environment bottom-up Module);
- the building of a top down econometric module for energy and environment covering EU-27 countries (NOMEDE, NEMESIS Optional Module for Energy Demand and Environment);
- a dialogue procedure for all the models used in the project: NEMESIS, NOMEDE, NEEM, GEM-E3, PROMETHEUS …

3- An important result of FORASSET concerns notably the assessment for EU Climate Action and Renewable Energy Package, with models, one partial equilibrium model (NEEM, NEMESIS Energy and Environment Module), one general equilibrium (GEM-E3, General Equilibrium Model for Economy, Energy and Environment) and one econometric model (NEMESIS, New Econometric Model for Evaluation by Sectoral Interdependencies and Supply), that have very different mechanisms but show a lot of convergence, and complementarities of results:

- the implementation of EU Climate Action and Renewable Energy Package should have only a limited cost in terms of GDP for EU-27, or even a negative one, depending the way auctioning revenues from EU ETS are recycled by Member States;
- important gains could be obtained for consumers if recycling of auctioning revenue is used to increase households' disposable income;
- employment could also be importantly stimulated if the recycling of revenue, and the stimulation of households' final consumption, passes through a reduction of labor cost and not by an increase in social transfer that could impact negatively on European firms competitiveness;
- lastly the application of the community solidarity principle could EU Climate Action and Renewable 1Energy Package represent an important opportunity for growth and employment in EU countries with GDP below European average like Romania and Poland, that are also very carbon intensive.

FORASSET results complement also usefully previous EU 'Energy and Environment package' evaluation by Commission staff , achieved in February 2008 (SEC(2008) 85 Vol. II), by adding several new scenarios following the way auctioning revenues from ETS allowances are recycled by Member States. FORASSET that focuses on technical change demonstrates in particular that EU climate policy could be used for stimulating importantly technical change in European countries, as illustrated by the design of new policies combining Climate and R&D policies.

Also, the assessment of EU 7th RTD Framework Program with NEMESIS econometric model demonstrated the important gains that EU could get from a doubling of the size of its funding to research, as illustrated by preliminary results of this work that were part of

Commission services ‘Proposal for the Council and European Parliament decisions on the 7th Framework Programme (EC and Euratom)’ (SEC(2005) 430).

These are the more original and important results of FORASSET project.

1. Project Objectives and Major Achievements

The 3% objective defined by the European Council in Barcelona and the communication "*More Research for Europe towards 3% of GDP*" does not guarantee the attainment of sustainable development goals, more specifically regarding the environmental dimension.

For this reason, an Action Plan on Environmental Technologies has been requested by the Barcelona Council in 2002. Environmental Technologies are defined broadly (reflecting Commission views) to include integrated technologies that prevent pollution as well as materials, energy and resource efficient production processes, new organisation of work, etc… In order to develop the Action Plan, the Commission decided to focus on four environmental issues: climate change, soil protection, sustainable production and consumption, water.

The Commission communication argued that "environmental technologies could contribute to sustainable development by protecting our environment and at the same time contributing to economic growth". But the trust in this decoupling of environmental pressure from economic growth or "win-win" strategy must be mitigated for several reasons:

1. the development of environmental technologies may induce a "crowding-out effect" on other technologies with higher potentials for enhancing competitiveness and growth;
2. new technologies, for instance regarding energy, may be less labour intensive, and their adoption could thus lead to an increase in unemployment;
3. many obstacles exist that prevent environmental technologies from realising their full potential (technical barriers, regulatory barriers, etc).

In view of the above remarks, it was very important:

1. to make an analytically sound assessment for the potential impacts of the introduction of environmental technologies in our economies.
2. to assess for generic R.T.D. policies and specially these linked to the 7th Funding Program;
3. to seek the most appropriate policies to promote invention, innovation and diffusion of these technologies by carrying out a global assessment of such policies.

An analytically sound and quantified assessment for the potential impacts requires the use of global quantitative methods, i.e. the use of applied economic models in which environmental technologies must be explicitly incorporated. These models must take macro-economic feedbacks of policies into account, that may be important; they must also be detailed enough in order to represent the important sectoral differences from the environment view point. There exist two types of such models that can provide a detailed analysis incorporating macro-economic feedbacks: Applied General Equilibrium Models and Econometric Models. These models can give fairly robust results on the impact of policies on competitiveness, growth, employment at sectoral level. These two instruments provide complementary insights: the econometric models are more oriented on the medium term consequences of policies while the general equilibrium approach is best suited for longer term analysis. In general existing models in their current state are not suited to describe the complexity of environmental technological change; they are either too aggregated or incorporate only partial mechanisms describing technology dynamics.

Therefore the FORASSET project set the following work-packages:

1. WP1: Identification and characterization of environmental technologies;
2. WP2: Decision module for environmental technologies;
3. WP3: Baseline scenarios;
4. WP4: Assessment of R.T.D. policies;
5. WP5: New assessment for environmental policies.

1.1 WP1. – Identification and Characterization of Environmental Technologies

The objectives of the WP1 are the identification, characterization and implementation in the modeling of New Environmental Technologies (NET). The NET selected are: membrane-based chlorine-alkali electrolysis, short cement kiln with five-stage preheating and precalcination, biopolymers, energy-efficient electric motors, cd free rechargeable batteries, recycling of shredder-light-fraction, membrane based waste water treatment and selective catalytic NOx reduction (SCR).

The collect of data is presented in deliverable 3, but some data are missing and prevent the integration of several NET in the economic models. The main problems come from the R&D expenses which were available from statistical offices sources only on a too high level of aggregation. Then a patent analysis was used to establish R&D expenses. The second step, Market potentials for environmental technologies, underlines the specific base conditioned of diffusion, study of barriers and drivers under more qualitative factors such as regulation and public intervention, economic risk, market structure, social Pressure and technological opportunities.

The last step of work is the introduction of Environmental Technologies in the modelling. The main criterion for the selection was the completeness of the technical economic characterisation of the technologies. Five Environmental technologies are introduced in NEMESIS Environmental module: the membrane-based chlorine-alkali electrolysis, the post shredder technology, the selective catalytic NOx reduction (SRC), the energy-efficient electric motors and the membrane based waste water treatment that are the technologies that addressed a health problem.

1.2 WP2. – Decision Module for Environmental Technologies and other Modelling Issues

The objective of this work-package was to produce new advanced modeling of ET decision mechanisms, with particular emphasis on R&D. The approach is essentially microeconomic. Practically, two main elements compose the model: A stochastic decision module and a diffusion of technologies module. The incorporation of imperfect knowledge and risk is an essential element in a fuller and more realistic representation of investment decisions and especially R&D decisions which are by nature speculative. The option adopted here to characterize the behavior of agents is to maximize probability of exceeding a threshold (of earnings or return of R&D). The advantage of this specification is that it requires no specification of probability levels (since they are maximized) while the thresholds are intuitively acceptable (interest, rates, discount rates, average rate of return…). The diffusion module recognizes three agents representing the equipment manufacturers sectors of the EU, North America and Japan. For the demand side three majors markets are represented: Europe, rest of the OECD and Developing Countries. The nations with the competitive advantage (enhanced by R&D) absorb net additions to demand.

The new technologies compete with the old ones, however the news do not sweep the market. To sum-up the mechanism of the module:

- the diffusion module based on a functioning of markets (of imperfect substitution between old and new technologies) allows calculating with the help of Prometheus model the expected return on R&D;
- the stochastic decision module describes the decision of R&D with behaviour of agents grounded on a maximization of probability of exceeding a threshold on return of R&D.

Other modelling issues as construction of NOMEDE and communication protocols between the different modelling tools are discussed further in deliverable D15 and in section 6.2.3 of this report.

1.3 WP3. – Baseline Scenario

The objective of this Work-Package was to provide baseline scenarios until 2030 for NEMESIS and GEM-E3 models. The set of exogenous variables are the same for the two baselines; they integrate in models the latest available data about economic trends based on expert assumptions. The main set of drivers that determine the baselines is the following: demography, price of raw materials, mainly energy, world demand and R&D efforts.

These drivers show for EU-27 that:

- demography in Europe is declining over the long period. Nevertheless, in the last few years one can observe a rise in the overall growth rate due to migrations. If the growth of population is about 1.8% over 2005-2030 period, inversely the total active population is declining 4.4%;
- world growth outside Europe (divided into ten zones) is fairly high, more than 3.5% per year, during the whole period, with a peak at 3.8% in the 2016-2020 years;
- oil price derived from PROMETHEUS model projections take into account the world demand for oil (based on world growth), reserves and the investment in research (of new fields or substitutes). Baseline evolutions for and gas prices were actualized in mid-2008, to take into account for the most recent trends onto energy prices The high oil prices observed on the past two years are supposed to persist but with a slow decrease from 107 € in 2008 to 68 € 2015, and then progressive re-augmentation with 76 € in 2020 and over 95 € in 2030;

- for R&D expenditures that determine the innovations and then the long term productivity, the assumption for the baseline scenario is based on a simple extrapolation EU trends.

Besides these exogenous assumptions, the results for NEMESIS and GEM-E3 baselines show that European growth, at the beginning of the simulation run, is supported by the finalisation of the transition and integration of the new member states. Nevertheless, for the period 2005-2010, evolutions include also the high prices context for imported energies (oil and gas) and the economic slowdown that is expected to persist until end on 2010.

- For 2010-2015, the better context that progressively takes place, as a consequence of decreasing energy prices and re-start of households' and firms expenditures and world growth, will allow EU-27 GDP growth rate to accelerate over 2.5% on average on the period. After 2015, population trends, with increased ageing, are expected to weight more on growth; hence households' consumption growth slightly decreases from 2015 to 2030. Also, the strength of world growth is foreseen to continue after 2015 but with a slight slowdown. These trends for after-2015 period will then imply a slow-down of European growth, even in eastern countries, but EU-27 economic growth will stay dynamic with GDP annual growth rate n over 2%. European growth will be notably sustained by production sectors as chemical industries and transport equipments, and the development of services as transports and communications.

1.4 WP4. – Assessments of European RTD policies: the Case of 7th FP for R&D

Various European RTD policies have been assessed with NEMESIS model endogenous technical change version, from different sub-optional scenarios, that differ from the rate of growth of FP funding under and after FP7 (moderate growth vs. continued rapid growth), the allocation criteria for FP funding between countries and sectors (grand fathering vs. performance), the crowding effects of European funding and the network effects (best practice transfers).

Compared to its modest share of European public R&D funding, the FP can be assumed to achieve large impacts, especially in the long-term, and no matter what economic variable is considered. That is due to two contributing factors unique to the FP. The first one is that it can be assumed that the so-called crowding-in effect of FP funding is higher than that of national research funding. So FP funding generates more additional business R&D expenditure than national research funding. The reason is the higher relative attractiveness to companies all over Europe of participating in high-quality cross-border research projects such as those funded under the FP. And it takes several years between the beginning and the end of the innovation cycle. Carrying out research, generating useful research results, transforming them into product and process innovations, and valorising them through higher turnover takes time. That means that the maximum incremental effect of doubling the FP will take time to be observed. Clear positive effects will start from the years 2010-2015 onwards, however.

Through its impact on product and process innovation and economic valorisation, FP funded research boosts Europe's economic growth. All scenarios assuming that FP7 will be twice the size of FP6 generate substantial extra economic growth over and above the business-as-usual scenario of moderate FP growth. The best results are achieved when FP funding continues to grow rapidly after FP7: up to 0.92 percent extra GDP by the year 2030. Attractive results are also achieved when post-FP7 growth is more moderate. In that case, however, a performance-based funding allocation mechanism appears to work best. An hypothetical discontinuation of the FP would clearly have a negative effect on Europe's economic growth performance. Compared to the business-as usual scenario of moderate FP growth, Europe's GDP would be reduced by 0.84 percent by the year 2030. Correcting GDP for quality – i.e. taking account of the fact that as a result of technical progress the quality and variety of products increase significantly - highlights the differences between the different scenarios. An initial doubling of the FP followed by rapid FP growth thereafter now increases Europe's GDP by up to 1.62 percent by the year 2030 over and above the business-as-usual scenario. On the other hand, discontinuing the FP reduces European GDP by no less than 1.31 percent by the year 2030 compared to the baseline scenario of moderate FP growth.

The direct and indirect employment creation effects of the FP are substantial. If FP7 increases to twice the size of FP6, then at least 428,000 extra (over and above the business-as-usual scenario of moderate FP growth) jobs will be created by the year 2030, regardless of the post-FP7 funding growth path. Should the FP continue to grow rapidly after FP7 too, however, then the number of extra jobs created could reach 904 000. On the other hand, a supposed complete discontinuation of the FP without any form of compensation by the EU member states would result in 838 000 jobs lost compared to the baseline scenario. A substantial part of the FP impact on employment is direct, i.e. research-related. At least 33 000 and up to 213 000 research-related jobs are created under the scenarios that assume a doubling of funding under FP7. An entire discontinuation of the FP would lead to a loss of 87 000 research-related jobs in Europe by the year 2030.

The FP will improve Europe's competitive position in international markets. This is first of all reflected by the fact that, assuming a doubling of funding under FP7 and moderate growth thereafter, exports will increase by an extra 0.64 percent by the year 2030 over and above the business-as-usual scenario of moderate FP growth throughout. Assuming moreover a rapid growth in FP funding after FP7, this percentage could increase to 1.56 percent. On the other hand, a hypothetical complete discontinuation of the FP without national compensation would lead to a loss of 1.92 percent of export growth compared to the baseline scenario. The improvement in Europe's international competitive position would also be reflected in a reduction of imports. All scenarios assuming a doubling of funding under FP7 reduce imports by at least 0.27 percent. In the case of continued rapid growth of FP funding after FP7, this reduction could grow to 0.88 percent. An assumed full discontinuation of the FP would have the completely reverse effect. Imports would increase by no less than 1.43 percent compared to the baseline scenario of moderate FP growth.

Doubling the size of the FP under FP7 would raise Europe's R&D intensity by at least 0.06 percent. That is remarkable given the relatively small share of FP funding in total European public R&D financing. In the case of consistent rapid growth of FP funding also after FP7, Europe's R&D intensity could grow by up to 0.2 percent (note that, assuming a baseline R&D intensity of 2%, this would represent a 10% increase). A presumed discontinuation of the FP, on the other hand, would shave off .09 percent of Europe's R&D intensity. FP funding is at least as effective as national research funding. This is clear from comparing the results for the 'doubling' and 'marginal nationalisation' scenarios. The former assumes that FP funding is doubled under FP7, while the latter assumes that, rather than FP funding doubling under FP7, national research funding increases by an equivalent amount. In other words, a comparison of these two scenarios serves to illustrate the relative efficiency of FP vs. national disbursement of research funding. It is clear that the disbursement of extra research funding through the FP consistently outperforms the disbursement of extra national research funding.

At last, several scenarios show that allocation criteria for European funding based on performance (publication, patents) display the best results on EU competitiveness and employment.

1.5 WP5. – Foresight and Assessments of European Environmental Policies

At the demand of FORASSET Scientific Officer, a special emphasis was put in this work package onto the assessment for European Commission ‘*Package of Implementation measures for the EU’s objectives on climate change and renewable energy for 2020’*, that was agreed the 23 January 2008.

The policy assessment achieved in this work-package uses three different modeling tools:

- First, NEMESIS economic macro-econometric model, for which additional developments were needed to be able to implement strictly the directive proposals includes in EU ‘Energy and Environment’ package. A new module for energy demand and environment was notably developed by ERASME, with the help of NTUA that was included in NEMESIS as an optional module (NOMEDE). This module, extends from EU-15 to EU-27 NEMESIS set of energy and environment indicators, with also an extension for biomass (including biofuels) and all renewable categories;
- NEEM, NEMESIS Energy Environment Module (that includes the new developments for NET) that is run by NTUA team but is limited to EU-15 countries.
- GEM-E3 that was run by KUL.

The three modeling tools used close baseline assumptions for economic and demographic variables. For energy and environmental indicators, NEEM and GEM-E3 use similar assumptions while NEMESIS baseline was recalibrated on PRIMES model latest projections (2007) that were used to re-assess for EU ‘Energy and Environment package’ by Commission staff in February 2008 (SEC(2008) 85 Vol. II), and that take into account for ‘the high energy import price environment of recent years, sustained economic growth and new policies and measures implemented in the Member States’. This harmonization thus rendered possible the comparison of these previous assessments achieved by Commission services, with NEMESIS results for FORASSET, obtained from different modeling tools (PRIMES/GAINS/GEM-E3 on the one hand, NEMESIS/NOMEDE on the other) but that share identical assumptions. The evaluations made with NEMESIS also complement usefully these previous studies, by adding several new scenarios following the way auctioning revenues from ETS allowances are recycled by Member States.

The policy scenarios that were examined in this work-package 5 are the following:

- NEEM, limited to EU-15 countries, examines different cases of efficient implementation of EU ‘Energy and Environment package’, that calculate the carbon balance price for ETS sectors and one unique carbon price for non EU ETS sectors. The results of NEEM were notably used to calibrate some mechanisms of NOMEDE;
- GEM-E3 was similarly used to study efficient implementation of EU ‘Energy and Environment package’ for EU-27, with two types of auctioning revenue recycling: an increase in households’ social benefits, and a combination of R&D subsidy, up to 25% and increase in social benefits. Other policy scenarios were studied with GEM-E3 as R&D subsidy policies, and local pollutants abatement policies. All policies studied with GEM-E3 compare also the case were R&D is endogenous and when it is considered exogenous, and use consequently two different versions of the model;
- with NEMESIS/NOMEDE, the focus was put on the economic consequences in 2020 of the joint implementation of the ‘EU ETS review’, ‘non ETS effort-sharing’ and ‘renewables’ directive and decision proposals. Different scenarios were explored depending on the way auctioning revenues are recycled by States, and compared on the

basis of economic and environmental efficiency criteria defined by the Commission. In Scenario S1, auctioning revenue is kept by states and is used for decreasing national debt. There is no recycling through public investment or revenue redistribution to private agents. In scenario S2, the revenue of auctioning in the EU ETS sector is recycled through an equivalent reduction, in terms of revenue, of employers' social contribution rate. In scenario S3, auctioning revenue is recycled in two ways: A reduction, as in scenario S2, of employers' social contributions rate, and a general subsidy to private R&D expenditures up to 30%. The R&D subsidy in calculated first, and only the difference between auctioning revenue and R&D subsidies is used to reduce employers' social contribution rate.

The main important results of work-package 5 concern consequently the assessment for EU *Climate Action and Renewable Energy Package* , with models, one partial equilibrium model, one general equilibrium and one econometric model, that have very different mechanisms but show a lot of convergence, and complementarities of results:

- the implementation of EU *Climate Action and Renewable 1Energy Package* should have only a limited cost in terms of GDP for EU-27, or even a negative one, depending the way auctioning revenues are recycled by Member States;
- important gains could be obtained for consumers if recycling of auctioning revenue is used to increase households' disposable income;
- employment could also be importantly stimulated if the recycling of revenue, and the stimulation of households' final consumption, passes through a reduction of labor cost and not by an increase in social transfers that could impact negatively on European firms competitiveness;
- lastly the application of the community solidarity principle could EU *Climate Action and Renewable 1Energy Package* represent an important opportunity for growth and employment in EU countries with GDP below European average like Romania and Poland, that are also very carbon intensive.

Other important results concern finally technical change, GEM-E3 and NEMESIS demonstrating that EU climate policy could be used for stimulating importantly technical change in European countries, as it is illustrated by the study of new policy combining Climate and R&D policies. Both models show that recycling part of EU ETS auctioning revenue with subsidies to R&D could lead to important macro-economic gains (GDP, final consumption and employment), and that carbon taxation stimulates technological innovation and for this reason lowers the cost of environmental policies, this even without specific actions for stimulating firms R&D and innovations decisions. These are the more original results of FORASSET project.

2. Identification and Characterization of Environmental Technologies

2.1 Objectives

The objectives are the identification, characterisation and implementation of environmental technologies into the models NEEM, NEMESIS and GEM-E3.

The identification of a suitable set of environmental technologies, representing the Environmental Technology Action Plan and covering a significant proportion of the total economic activity in this field were evaluated in terms of environmental (including human health) performance and cost. Their integration in the modelling tools required then detailed data on:

- total investment cost;
- technical lifetime;
- available capacities and their load;
- variable costs;
- cost digression and floor cost;
- R&D expenditure;
- environmental effect(s).

The collected those data allowed determining technologies that can potentially impact on economic growth, employment and improve environmental conditions. In this respect, the quantification of the market potential and the direction and strength of relevant drivers and barriers were other important aspects of the work. It included a break down of market figures for different countries and regions.

The translation and implementation of data in modelling tools required the translation of the technico-economic characterisation of the technologies into new model variables and new equations. Furthermore, in order to be able to examine R&D policy scenarios, estimation of two factor (R&D and Investment) learning curves was necessary. For this purpose, an extensive analysis was performed in order to identify the most suitable environmental technologies in terms of estimating two factor learning curves and model implementation (Additionally, data found to be lacking in the latter reports for the purposes described are identified and a new search for the missing information is started). Then the main objective was to implement these technologies into the model. For the rest of the technologies, for which problems were identified, the objective was to pinpoint these problems, search for possible solutions and ask for additional information.

2.2. Results

In the selection of environmental technologies we faced the trade-off between:

1. covering a wide array of different technologies which could be grouped in sectors, but, due to the resulting heterogeneity within each sector, would not allow us to draw reasonable conclusions concerning their technical and economic consequences and;
2. characterizing only a limited number of technologies, feeding the resulting data into the model and, subsequently, extrapolate the model output in terms of growth, employment and environmental effects to the economies as a whole.

Choosing the second approach, it was especially important that technologies are selected carefully, making sure that they represent at least the most important aspects of relevant environmental technologies in terms of costs, economic productivity and environmental effects (e.g. emissions). A first hint to the useful selection of environmental technologies was given by ETAP which specifies energy consumption, conservation and use, transport, resources use in industrial production, waste management and information and communication technologies as the most relevant technology fields. Eventually, technologies were selected on the basis of their environmental and economic relevance and, last but not least, the availability of reasonable data. Beside process innovations we also looked for sustainable products and services. However, especially services were hard to specify sufficiently well either with regard to their function or their effects.

Technologies selected according to the above criteria were the following:
1. membrane-based chlorine-alkali electrolysis;
2. short cement kiln with five-stage preheating and precalcination;
3. biopolymers;
4. energy-efficient electric motors;
5. cd-free rechargeable batteries;
6. recycling of shredder-light-fraction;
7. membrane-based waste water treatment;
8. selective catalytic NOx reduction (SCR).

Table 1: Preliminary characterization of the technologies selected for investigation in this report

Environmental technology	Relevant economic sectors	Type of technology	Process/ product	State of technical development	Environmental relevance	Economic relevance
Membrane-based chlorine-alkali electrolysis	Chemical industry: chlorine production	Integrated	Process	Early diffusion	Of the total chlorine production capacity in Europe only 20% actually use the membrane technology. Use of 100% would avoid emission of 18 t/a Hg and consumption of 8bn kWh/yr electricity.	Conversion of these 80% from actual to membrane technology is equivalent to total investment in the order of EUR 6bn.
Short cement kiln with five-stage preheating and precalcination	Cement industry	Integrated	Process	Early diffusion	The short dry kiln with 5-stage pre-heating and precalcination is not a really new technology, but its global diffusion is still poor. This technology cuts burning energy consumption by	Nearly 50 % of total cement production costs is caused by energy consumption. Application of the technology needs a basic modernization of most of the over 200 cement kiln

					more than 15 %, amounting to an energy conservation potential of 2bn kWh/a and a corresponding CO_2 reduction potential just within the EU.	installation in the EU. The investment volume for this is huge, and has to be quantified by future work.
Biopolymers (polylactic acid)	Chemical industry	Integrated	Product	Demonstration plants	By 2010 (2020) biopolymers could substitute 1m t/yr (up to 3m t/yr) fossil resource-based polymers, save the corresponding resources and avoid CO_2 emissions of 1.7 (5) million t/yr. Biodegradeability	Relevance of substitution in monetary terms is EUR 1-2bn by 2010 and up to EUR 3-6bn by 2020
Energy-efficient electric motor	Many industrial sectors (Cross-sectoral**)**	Integrated	Product& process	Early diffusion	Electric motors consume about 65% of electricity used in industry. About 5% of this (= 30bn kWh) could be saved in the EU-15 by using energy-efficient devices.	Within the EU this avoids electricity costs of about EUR 1.5bn annually. Additionally this may increase competitiveness on the electric motor market worth EUR 1bn/yr in the EU.
Cd-free rechargeable batteries (NiMH or Li-ion)	Households	Integrated	Product	Early diffusion	Avoidance of about 1500 t/yr (i.e. about 75% of total) Cd discharge into the environment.	Market potential for NiCd rechargeable battery substitutes is in the order of EUR 1.5bn per year worldwide.
Recycling of shredder-light-fraction	Automobile industry, manufacturers of white goods	Recycling	Process	Demonstration	2 Mio t/yr shredder residues in Europe from post-consumer waste, mainly cars and large household appliances. Almost all is disposed in landfills, in scare cases incineration is applied.	Need for 20 treatments plants in Europe with a capacity of 100.000 t/a each. This amounts to a total investment of 400 Mio €. Total gate fees for SLF treatment amounts to 200 Mio €/a.

Membrane-based waste water treatment	Sewage treatment	End-of-pipe	Process	Demonstration (large plants) / early diffusion (small plants)	Purification of waste water by means of membrane technology is the only way to ensure compliance with the strong (health) requirements for water discharge into sensitive water bodies	By 2010, the economic potential of membrane-based technology is about EUR 200m for municipal waste water treatment and industrial process water recycling in Europe.
Selective catalytic NOx reduction (SCR)	Many industrial sectors (Cross-sectoral)	End-of-pipe	Process	Early diffusion	SCR brings NO_x in the exhaust down to 100-200 mg/m^3, for glass furnaces from up to 5.000 and for cement kilns from above 1.000 mg/m^3. Also, SCR is a BAT for many other industrial installations. NO_2 emissions matter in particular as a precursor for the formation of ground level ozone in the vicinity of installations.	SCR technology is state of the art for large power plants, but not for industrial installation installations with heavy NO_x emissions. To equip these installations in Europe and world wide with this technique offers a huge economic potential. Alone retrofitting Europe's glass furnaces and cement kilns with SCR bears an investment volume of over 2 billion €.
(Water-soluble varnishes)*	Many industrial sectors & households	Integrated	Product& process	Early diffusion	Varnish application causes about 340000 t/yr (Germany) VOC emissions of which 50% can be avoided.	The potential for substitution of water-based for VOC-based varnishes is above EUR 1bn in Germany and in the order of EUR 5bn in the EU. Europe's car manufacturers are global leaders in the application of highest quality water based varnishes.

*Note: * In the case of water-soluble varnishes, we made use of the option not to investigate one of the technologies, if difficulties in data collection become insurmountable.*

Most of the selected technologies are integrated; one is recycling and two are end-of-pipe technologies. This reflects fairly well the prioritisation of the former owing to the assumption that they are most likely to enable environmental and economic benefits at the same time. One half of the technologies are relevant across sectors. The other half refers to applications in the chemical industry (2 cases), the cement industry (1 case) and the automobile industry (1 case). Energy and related hydrogen technologies were not characterized in this project because data were already available.

For the environmental technologies, all data requirements for integrating the effect of the environmental technologies into the economic models were met to a higher or sometimes lower degree:

1. *investment costs* could always be specified. In some cases, data were available only for one given year, although this turned out to be a shortcoming only in those cases where a cost digression was thought to exist;

2. *the technical lifetime* was also specified in all cases even though with some uncertainty especially in the case of very new technologies (e.g. biopolymers) or when technical lifetime of some components became very long (more than 50 years in the case of chloralkali electrolysis;

3. *existing capacities* could be assessed in all cases but with different degrees of detail. At one extreme, it was possible to identify specific installations (chloralkali, cement, membrane-based municipal waste treatment). At the opposite side only data for Europe and the whole world were available. In between data were found for all EU countries, for only the most important countries or for groups of countries;

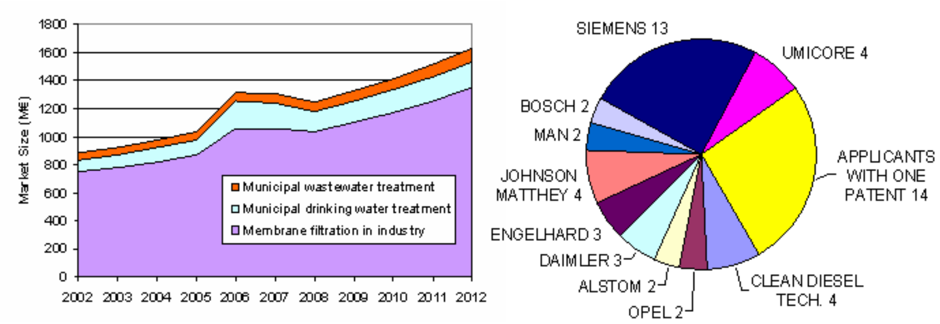
4. the data for the *market potential* are usually less detailed than those for the actual capacities. The target years of the prognoses varied between 2010 and 2020 and the results often depended very much on the strictness of the regulation that is assumed to exist at the end of the period of prospect;

5. all relevant *variable costs* could be assessed, although in the case of cadmium-free batteries they turned out to be irrelevant. For most technologies cost digression could be specified; an exception was post-shredder technologies where this was not possible. In the cases of chloralkali electrolysis and cement production the development already has come to an end such that no further digression is expected;

6. *environmental effects* could be specified and quantified well except for the case of membrane-based wastewater treatment where the effect very much depends on the wastewater that is fed into the plant an on the other components employed for wastewater treatment;

7. most problematic were the R&D expenses which were available from statistical offices or other official sources only on a much too high level of aggregation. Then a patent analysis was used to reconstruct the R&D expenses on the basis of the assumption that R&D effort and results (i.e. the patents) show a proportional relation or take the patents as a direct (relative) measure for R&D effort in various country.

Figure 1: Overview of the main fields of patent applications for SCR-equipment



In order to specify the basic conditions, that are the (exogenous) restrictions under which technology adoption takes place, it was assessed in a first step which research and development (R&D) activities are conducted in Europe and what the potential market capacity for environmental technologies is like. These data are collected for each of the environmental technologies and, where possible, differentiated for major countries or regions within Europe. The latter differentiation is crucial as it is well known that environmental technologies are not equally well developed in all European countries. The same is true for the examination of barriers and drivers undertaken in a second step to identify more qualitative factors that may hamper or support the development, adoption and further diffusion of the latter technologies.

Such factors are:

1. *regulation and public* intervention ranging from command and control to voluntary programs and market-based instruments;

2. *economic risk and uncertainty* related to the central question whether the benefits potentially arising from the adoption of innovative, clean technologies are able to offset the uncertainty about the profitability of the necessary investments. This has direct consequences with regard to the access to financial capital;

3. *markets* are relevant on the *demand* side where consumers with high environmental awareness and a corresponding willingness to pay are generally a driving force and on the supply side where the *market structure* and the organization of companies influence their readiness to engage in new technologies;

4. *social pressure* arises from a community willing to disengage in environmentally harmful technologies as well as from stakeholders supporting clean technologies within and outside the firm or industry. In both cases, the crucial role of public image and social legitimacy has to be acknowledged;

5. *technological opportunities* often arise from the capability of a company to deal with a new technology, which depends on the technology already in place or on forms of organization or infrastructure that are closely related to this, but not to the new technology. Together with the sunk costs of the conventional technology this represents a substantial lock-out for the new technology.

Although it was known beforehand that environmental technologies generally show a substantial market potential, it turned out in the course of the analysis that, despite the limited number of case studies that could be examined, their market potential was indeed quite high – in one case even much higher than expected. More "classical" cases of environmental technologies were the retrofit of large combustion plants (LCP) with selective catalytic NOx reduction (SCR) and the integrated approaches of converting mercury to membrane-based chlor-alkali electrolysis and equipping short cement kilns with five-stage preheating and precalcination.

As the total capacity of existing plants is not expected to increase substantially, these environmental technologies will essentially replace existing capacities in all cases. To which extent this will happen in the future depends on the strength of the corresponding drivers and barriers (e.g. a ban on mercury) and on the extent to which substitution has taken place already. Another case of process improvement is membrane-based wastewater treatment which substitutes for conventional sewage plants. However it differs from the preceding technologies in having additional functionalities like the removal of virus. This basically provides this technology with a market potential that goes clearly beyond the mere substitution.

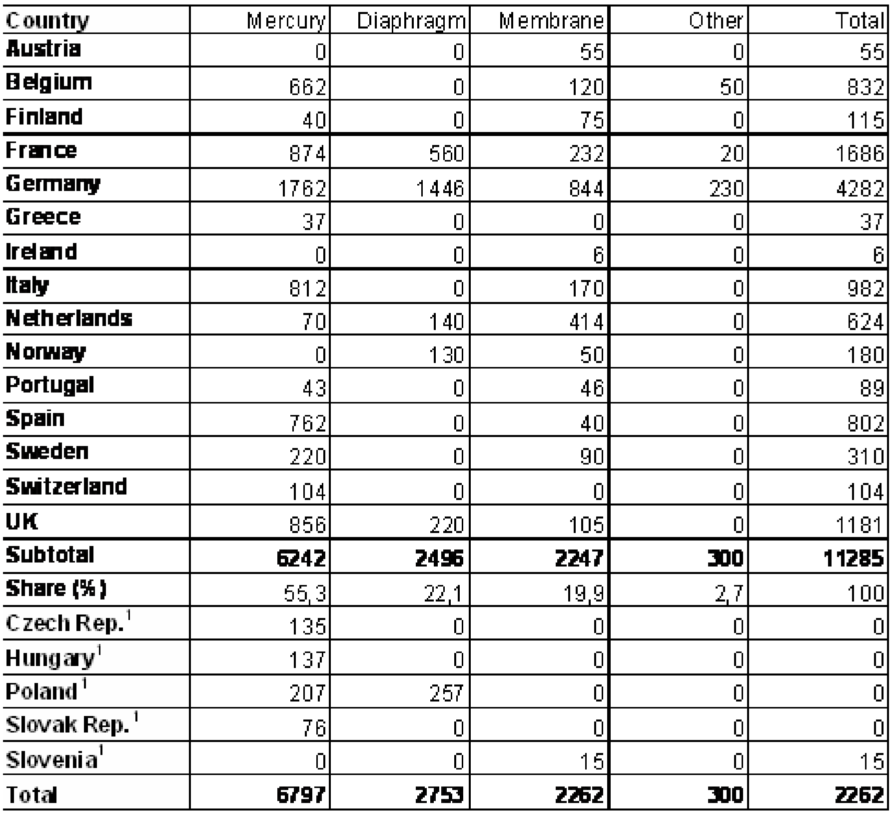
Two environmental technologies, energy-efficient electric motors and cadmium-free rechargeable batteries were product rather than process technologies. Adopting these technologies involves an investment calculus insofar as there is a trade-off between better performance (during operation) and a higher price in the beginning. Although in both cases, this calculus is very much in favour of the environmentally better alternative, it depends a lot on personal and social attitudes whether the technology is adopted or not. In the case of energy-efficient motors, a lack of knowledge and significant transaction costs limit the market potential. By contrast, due to the co-evolution between high-capacity, cadmium-free batteries and electronic appliances that use these batteries the market potential of cadmium-free rechargeable batteries are almost ten times higher.

The two remaining environmental technologies assessed in this report are related to new products. One, recycling of shredder-light-fraction, is a process technology that is useful only since the recycling of a certain fraction of end-of-life vehicles (ELV) became mandatory to some extent by the actual legislation. So, there is no other capacity that needs to be replaced and the investment calculus becomes rather easy.

The production of biopolymers on the other hand is very young. To some extent, it replaces existing fossil-based polymers, but it also occupies new niches that sometimes had not been occupied before by polymers. Evidently, the R&D effort going into the environmental technologies differs very much. The main reason for this is, on the one hand, the maturity of the technologies.

Membrane-based chlor-alkali, for instance, has been developed in Japan in the 1970s and 1980s. There are still some R&D investments, but the main part of the development work is done. So, it is little surprising that the total R&D expenditures for a time period of 16 years are as low as € 36 million.

Table 2: Chlor-alkali capacities (in 1000 t) according to process type in the relevant EU-27 countries (June 2000)[1]



Country	Mercury	Diaphragm	Membrane	Other	Total
Austria	0	0	55	0	55
Belgium	662	0	120	50	832
Finland	40	0	75	0	115
France	874	560	232	20	1686
Germany	1762	1446	844	230	4282
Greece	37	0	0	0	37
Ireland	0	0	6	0	6
Italy	812	0	170	0	982
Netherlands	70	140	414	0	624
Norway	0	130	50	0	180
Portugal	43	0	46	0	89
Spain	762	0	40	0	802
Sweden	220	0	90	0	310
Switzerland	104	0	0	0	104
UK	856	220	105	0	1181
Subtotal	**6242**	**2496**	**2247**	**300**	**11285**
Share (%)	55,3	22,1	19,9	2,7	100
Czech Rep.[1]	135	0	0	0	0
Hungary[1]	137	0	0	0	0
Poland[1]	207	257	0	0	0
Slovak Rep.[1]	76	0	0	0	0
Slovenia[1]	0	0	15	0	15
Total	**6797**	**2753**	**2262**	**300**	**2262**

Note: [1] Data for the new EU member states are from 2005
Source: EuroChlor (2006)

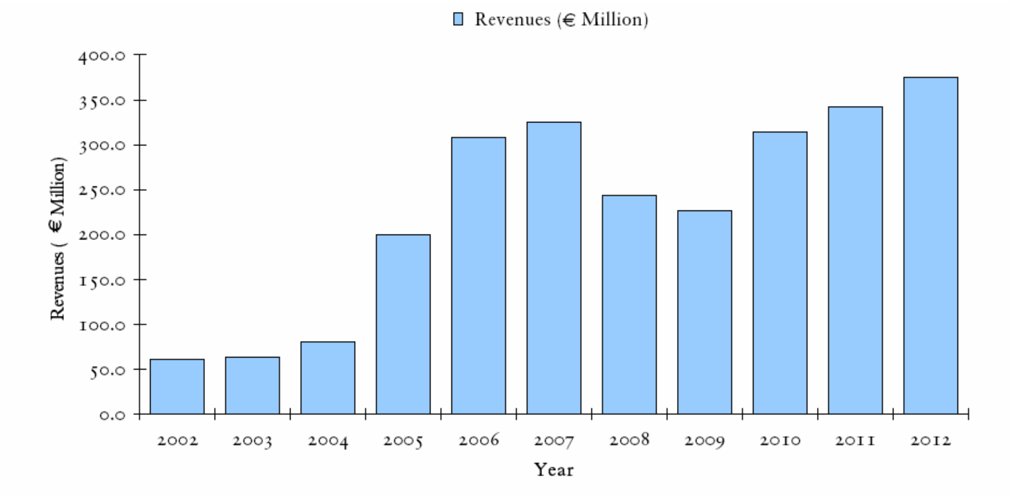
By contrast, biopolymers representing a very young technology show more than ten times this R&D effort although the total market potential is hardly half as big as in the chlor-alkali case. On the other hand, the willingness of companies to invest into R&D depends on the revenue they expect to make with their innovations. Although the complexity of the technologies might differ considerably, the R&D expenditures will usually be in a corridor of between 2 and 10 percent of the actual revenues, mostly closely correlated with the profit that is made.

About one half of the environmental technologies assessed in this report are advantageous not only from the environmental or health perspective but also from the economic perspective. In most applications energy-efficient electric motors show payback times shorter than two years, sometimes even shorter than half a year. Lithium and NiMH batteries show so much better performance that, for most applications, NiCd batteries are even economically worse. With the exception of some minor applications (e.g. production of KOH), membrane-based chlor-alkali plants are chosen for their environmental and economic superiority whenever a new plant is built. And even recycling of the shredder-light-fraction turned out to be economical once initial technical barriers had been overcome by means of regulation. So, this technology can be assumed to persist even if the existing recycling quotas were given up.

It turned out that the eight technologies under consideration give rise to a combined market potential of € 87.5 billion by 2020, which hints to the relevance of the study undertaken. It turned out that in many cases, the available collection of data did not fully meet the requirements of model builders (NTUA). So, data collection was re-entered. In some cases, new data sources could be explored. In other cases, an extended use of known sources was made by making stronger assumptions concerning the relationship between unknown dependent and known independent variables. In the end, we were able to make substantial improvements concerning data availability. The introduction of Environmental Technologies in the new Environmental module of NEMESIS: by performing an extensive analysis of the deliverables D3 and D4, five, out of the eight total environmental technologies considered in D3, were implemented into the model. The main criterion for the selection was the completeness of the technical-economic characterisation of the technologies.

The first technology implemented in the model, was the membrane-based chlor-alkali electrolysis, which is used for the production of chlorine and caustic soda. The main driver of chlorine demand is the production of plastics, since more than 50% of the chlorine produced in Europe is used in this sector. For this purpose, the chemicals sector of the model was divided in plastic and non-plastic chemicals. The main competitors of this technology are the mercury and diaphragm processes. However, since no new capacity is expected to be added in Europe for chlorine production in the forthcoming years, the decision process modelled concerned the retrofitting of existing installations of mercury and diaphragm processes to membrane-based processes. The second technology implemented in the model is the post-shredder technology, used to manage the light-fraction of the shredder residues resulting from the treatment of end-of-life vehicles. First, the model determines the quantity of the shredder residues from the number of the deregistered vehicles per year. The available options to manage these quantities are the post-shredder technologies, the disposal in landfills and the waste incineration. The EC directive 2000/53/EC on end-of-life vehicles, which sets recovery and recycling targets, is also implemented as a constraint in the model. The third technology implemented in the model is the selective NOx catalytic reduction (SCR) used for reducing the emission of NOx from combustion sources. In the model, this technology was introduced in the power generation sector (coal, gas and oil fired power plants). The installations of SCR technologies, is driven by the capacity of the fossil-fired power plants. Not only new plants, but also the existing plants can be equipped with this technology to reduce their NOx emissions, in order to be in compliance with the EU directive 2001/80/EC.

Table 3: Selective Catalytic Reduction Market: Revenue Forecasts for Western Europe, 2002-2012 (Source: Frost and Sullivan 2006c)



This directive has been introduced as a constraint in the model. The SCR technology increases the production cost of fossil fuels fired power plants, affecting in this way the decisions on new investments and plant dispatching. However, this technology is currently the only available option for reducing NOx emissions, since in the deliverable D3 no alternative technology is characterised.

The fourth technology introduced in the model is the efficient electric motors. In the model, a typical configuration of electric motors of a medium factory was used. The requirements of electric motors are determined endogenously in the model, and the decision to meet these requirements is taken among the three classes of electric motors EFF1, EFF2 and EFF3. Also premature replacement for the less efficient, currently existing, electric motors has been introduced in the model. Finally, the fifth technology introduced is Membrane-based waste water treatment which is the only technology that addresses a health problem.

As it was evident above, a temporary regulation may be sufficient in the case of integrated environmental technologies where a threshold has to be overcome before the technology becomes profitable. Sometimes, it is the objective of such a regulatory act to allow for the realisation of learning effects, that is, the technology is protected from conventional competitors until it has become competitive itself. In other cases, the regulation may focus the industrial actors' attention on facts they never though about before. So, the acquisition of economically relevant knowledge becomes an important side-effect. Eventually, a regulation may sometimes just bring about a change of habits that prevented the adoption of a superior technology.

Examples for all these cases are found in Table 4, which at the same time summarises the results of this report.

Table 4: R&D effort, market potentials and drivers and barriers of environmental technologies

Environmental technology	R&D effort (million €)	R&D by origin	Share of ET from total capacity in Europe (in %)		Total capacity increase of ET until 2020		Drivers*	Barriers*
			At present	In 2020	(1000 t/a)	(Million €)		
Membrane-based chlorine-alkali electrolysis	36 (for the period 1980 to 1995)	DE (55%), IT and UK (22% each)	11.6 (in 1997) to 30.2 (in 2004)	80	6090 (435)**	~3700	Social pressure towards phase-out of mercury-based chlorine production (+), IPPC (+), voluntary agreement (++)	High risk perception for major parts of chlorine capacity → short payback time for any further investment (–)
Short cement kiln with five-stage preheating and precalcination	17 (annual average 1995 to 2003)	n/a	29 (in 2001), increasing by 2.1% per year	50–70	55 000–100 000 (2900–5000)**	11 000–20 000 (550–1000)	IPPC (+), high energy price (+), certificate trading scheme (+)	High investment pays only in combination with major maintenance work (– –)
Biopolymers (polylactic acid)	450 (for the period 1989 to 2003)	US (>90%), DE (3%), FI and CH (2% each)	0 (in 2002), <1% (in 2002, worldwide)	~5	500–1000; 1650–3050 worldwide	1100–2200; 3500–6500 worldwide	Good image due to biodegradability (+), strong potential cost digression (+)	Very young technology → high risk (– –), lack of integration in waste management scheme (–)
Energy-efficient electric motor	~150 (in 2003, only a share of this for energy efficiency)	DE (28%), FR (16%), ES (11%), AT (10%)	2 (in 1998) to 8 (in 2005) for EFF1	~25	Does not apply	4200*** (increasing from 160 in 2007 to 500 in 2020)	Investment highly profitable: short payback times (++)	Unwillingness to change a working system (–), lack of information (–), accounting: neglect of operating costs (–)

Cd-free rechargeable batteries (NiMH or Li-ion)	~60 (in 2004)	Mostly Japan	80	100	Does not apply	39500 (in 2011, increasing from 3570 in 2004 to 6300 in 2011)	Very good performance (++), co-evolution with portable electronic appliances (+), reputation of Cd-free batteries (+)	Low budget cordless power tools (–)
Recycling of shredder-light-fraction	20 (in 2004)	AT, BE, FI, NL and DE prominent in EU; CA and AUS outside EU	Does not apply as demand didn't exist before	Does not apply	3300 (until 2015), 11000 (until 2015, worldwide)	420 (until 2015), 1400 (until 2015, worldwide)	ELV and WEEE directives raise the need for this ET (++), meanwhile ET became more economical than incineration or deposition in landfills (+)	Drain-off of end-of-life vehicles to Eastern Europe and Africa (–)
Membrane-based wastewater treatment	Specific assignment to ET not possible	DE, ES, UK, FR; CA and JP very important on global scale	<0.2 (municipal in 2005)	~1 (municipal in 2012)	Does not apply	7200 (until 2012, including industrial) (from 1000 in 2007 to 1400 in 2012)	Various directives (EU) strongly regulate wastewater discharge (+), specific favorable conditions (+)	Lack of experience with the ET (– –), operation and maintenance more expensive (–)
Selective catalytic NOx reduction (SCR)	45 (in 2005)	FR, IT, DE	34 (2005, LCP)	100 (LCP)	150 000 MWel LCP capacity	~12000	LCP directive specific for LCPs (++), other NOx emitters only regulated by IPPC or CAFÉ (+)	End-of-pipe → higher costs (–), retro-fitting an LCP is somewhat risky (–), frequent changes in regulation → risk (–)

Note:
** ++ and – – indicate strong,*
+ and – weak drivers or barriers, respectively.
*** Values in parentheses are annual increases.*
**** In addition to the cost of conventional technology*
Source: Own compilation

3. Decision Modules for Environmental Technologies

3.1. Objectives

The objectives have involved three main steps:

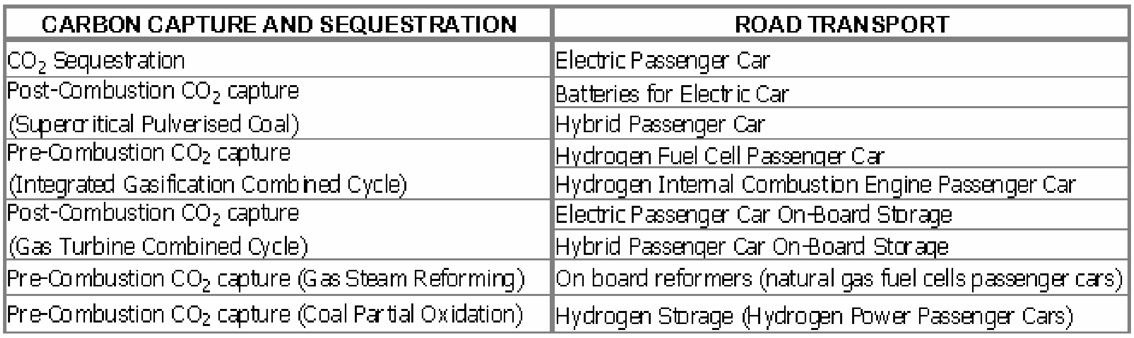
- the First step was to design the theoretical framework from which empirical specifications for New Environmental Technologies R&D and investment decisions were derived;
- the Second step consisted in the estimation or calibration of the R&D and investment decision equations for New Environmental Technologies. The Energy/Environment module of Nemesis, with the integration of these new equations, was re-tested running analytical simulations;
- the Third step was to realize an interface between the new Energy/Environment module and the core economic model of NEMESIS, and then to run the usual analytical testing simulations.

3.2. Results

For the First step: Theoretical Framework for the Decision Module For Environmental Technologies, work within this Work Package has concentrated on the characterization of a number of technologies and their incorporation into the NEMESIS environmental module.

In the first phase work has concentrated on technologies for which extensive data has already been collected (primarily clean road transport technologies and carbon capture and sequestration technologies). Table 5 gives in detail the technologies that have been incorporated on a country-by-country basis in the module:

Table 5: New Technologies incorporated in the NEMESIS Environmental Module



CARBON CAPTURE AND SEQUESTRATION	ROAD TRANSPORT
CO_2 Sequestration	Electric Passenger Car
Post-Combustion CO_2 capture (Supercritical Pulverised Coal)	Batteries for Electric Car
	Hybrid Passenger Car
Pre-Combustion CO_2 capture (Integrated Gasification Combined Cycle)	Hydrogen Fuel Cell Passenger Car
	Hydrogen Internal Combustion Engine Passenger Car
Post-Combustion CO_2 capture (Gas Turbine Combined Cycle)	Electric Passenger Car On-Board Storage
	Hybrid Passenger Car On-Board Storage
Pre-Combustion CO_2 capture (Gas Steam Reforming)	On board reformers (natural gas fuel cells passenger cars)
Pre-Combustion CO_2 capture (Coal Partial Oxidation)	Hydrogen Storage (Hydrogen Power Passenger Cars)

Modelling has proceeded covering the detail and the general logic that already exists in the power generation sector of the environmental model. This means that the total cost of using the technology (acquisition, fixed operating and maintenance, fuel cost modulated by fuel efficiency, and other non fuel variable operating costs) has been used as a driver for new technology selection in a context where the new technologies are competing with conventional ones. Apart from cost, the penetration of clean technologies also depends on the degree of their maturity, which is either exogenous or endogenous autoregressive and constitutes a measure of possible barriers to their introduction.

The second phase consists in the introduction of technologies for which no information was available within ICCS-NTUA and thus depended on the information gathered and analysed by

Fraunhofer ISI within WP1. ICCS initially produced an extensive list of possible candidates covering cement, waste incineration, refineries, ferrous and non-ferrous metals, and paper and pulp sectors. The final list of the technologies analysed was established by Fraunhofer ISI on the grounds of their environmental importance and the possibility of obtaining suitable data.

Within the FORASSET project considerable effort has been devoted to model elements from the evolutionary paradigm of modern economics. The previous version of the NEMESIS environmental module basically assume a single typical agent for each sector who has simple and clear objectives like profit or utility maximization, cost minimization etc. These agents act in isolation from each other, except in highly reduced models when oligopolistic competition is examined as a variant. They also have full knowledge of the parameters of their decision model (occasionally incorporating risk by adding a fixed premium). In the evolutionary paradigm agents consider the actions of each other through cooperation, competition and social networks. They generally operate under uncertainty and this uncertainty is explicitly reflected in their decisions. On the other hand they do tend to learn from experience. The incorporation of imperfect knowledge and risk is an essential element in a fuller and more realistic representation of investment decisions and especially R&D decisions which are by nature speculative.

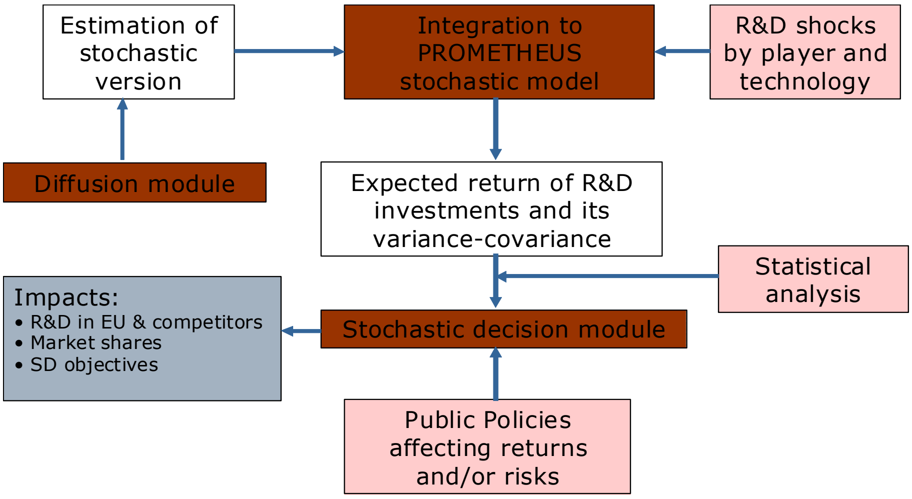
Two basic options for the incorporation of risk are generally considered. The first involves the maximization of expectation subject to a risk constraint and conforms closer to more traditional risk analysis practice. The second involves the maximization of the probability of exceeding a particular threshold. The first approach still essentially places the emphasis on expectations. At the same time, it presents a number of intuitive difficulties in setting the constraints, i.e. it is not a priori evident what probabilities and what thresholds could be used for the constraints. On the other hand, the second approach (maximizing probability of exceeding a threshold) places the emphasis on risk minimization which is in general underestimated as a force in economic behavior. It requires no specification of probability levels (since they are maximized) while the thresholds are intuitively acceptable (interest rates, discount rates, average rate of return etc.). For the above reasons this method has been adopted.

The approach adopted represents a departure from the classical deterministic model which is equivalent to expectation maximization. This departure may on the other hand be less important than it is often assumed because along the efficient pay-off curve between risk and expectation there are regions of perfect synergy: a decision that increases expectation also tends to increase the probability of exceeding a given threshold. On the other hand, the area that presents specific interest in decisions is precisely where risk minimization will involve some sacrifice in terms of expectation. The relative synergies or conflicts of risk and expectation notwithstanding, the approach definitely introduces an additional dimension to the model specification with the introduction of joint probability distributions as key elements in decision behavior.

In view of the above ICCS-NTUA has developed and incorporated within the Environmental module of NEMESIS a *multi-agent model for R&D decisions*. The main elements of this model are: *a stochastic decision module* developed according to the principles introduced above and a diffusion module and its stochastic version integrated into the PROMETHEUS stochastic model, which is used to provide the essential input to the stochastic decision module and at first the stochastic rate of return on R&D. The decision module is specified as a Nash equilibrium situation. The main players (the equipment manufacturers in different regions) are differentiated by existing R&D commitments, market shares for different technologies in different parts of the world and potentially different risk tolerance. Each player operates under risk and knows how other players behave faced with their risks. The probability distributions of R&D impact of a given player are affected by the R&D actions of other players. The specification allows for both competition and cooperation. Typically, the problem produces a sub-optimal situation for every player, a deviation from which results in a deterioration given the reaction of the other players.

In order to ensure that analytical solutions can be obtained it is assumed that the impacts of R&D actions are distributed normally. This assumption is made while recognizing that many of the impacts as they emerge from the stochastic version of the diffusion module are skewed. However, the distribution of linear combination of non normal variates is generally unknown, though it can be approximated numerically, but such approximations will result in non analytic and often non convex set of characteristic equations.

Figure 2: The micro endogenous R&D model: Overview of construction and use



The construction of the decision module involves the simulation of R&D shocks for each player on each technology category using the integrated stochastic model in order to obtain the expectations, standard deviations and correlations of the returns to R&D. This raw data is statistically analyzed in order to obtain linear transformations linking the expectations and variance co-variances of each player given the actions of the others, which constitute the parameters in the constraints of the decision module.

The diffusion module recognizes three agents representing the equipment manufacturers' sectors of the EU, the United States and Japan. Each sector is treated as a single firm. A given region constitutes a captive market for its own equipment manufacturing sector. The enhanced competitive advantage produced by R&D actions is translated into increased market share in third countries. The actor with the competitive advantage absorbs net additions to demand to the extent that this player retains this advantage. The new, improved version of this technology is assumed to compete with the old version. However, the new version does not sweep the market especially if the advantage is small. Technological spillover occurs at a constant rate, starting as soon as the improvement takes place. This implies a rapid erosion of advantage in early years but also the maintenance of some advantage in the longer term. The way the module has been formulated, it does not consider cases where part of the gain is invested back on R&D: this would necessitate more assumptions thus sacrificing transparency. On the other hand, the omission of this feedback results in a possible underestimation of the long term benefits of R&D to the companies undertaking.

In order to integrate this diffusion module into the PROMETHEUS stochastic model, a stochastic version is estimated including stochastic estimates for the rates of spillover, market penetration parameters and error terms. The estimates of all the above have been obtained by using econometric methods. The integration of the stochastic version of the diffusion module into PROMETHEUS allows for the consideration simultaneously of other technological, economic, energy and environmental risks.

The Second step, estimation, calibration and test results of the Technology Dynamics Model, consisted of providing technology dynamics mechanisms for the NET described in WP1. This consisted in building Two Factor Learning Curve relations (learning by research and learning by doing) for all their techniques and economic characteristics. The specification follows the general framework developed in ICCS-NTUA for power generation technologies in earlier projects. Since many of the technologies covered are completely or virtually new, it has not been possible to establish learning by doing mechanisms for them econometrically using historical series. However, it was deemed necessary to include such mechanisms since it is expected that some of these technologies will benefit considerably from learning by experience. It was therefore necessary to revert to the use of parameters obtained from pooled samples concerning other technologies that have reached a degree of maturity within the historical period. Such parameters have been modified in the light of perspective analysis concerning the new technologies combined with testing using provisional versions of the technology market sub model within the environment module of NEMESIS. This hybrid method ensures at the same time some grounding on econometric analysis, respect for constraints and possibilities identified in technology perspective analysis and a smoother behavior once the model is fully implemented.

For each environmental technology an extensive analysis was done in order to identify problems related to the integration of the technology in the model and to examine the potential of the technology in the context of the sustainable development. The latter is necessary for the design of meaningful policy scenarios.

The analysis of the *membrane-based chlor-alkali electrolysis* showed that the retrofitting of all existing installations of mercury and diaphragm processes for chlorine production could save around 0.3% of electricity consumption and about 7.5% of Hg releases per year. However, current EU-wide polices, have already locked-in the penetration of this technology in the market, so the main question is when the retrofitting of the existing mercury processes will take place. On the other hand, the estimation of two factor learning curves for this technology was not possible since according to its characterisation, the retrofitting costs were increased over time as result of the increased retrofitting efforts.

In the *cement production*, the analysis showed that if all existing technologies turned into the more efficient short-cement kiln technologies then about 0.6% of the annual CO2 emissions in EU could be saved. However, the retrofitting is a very expensive process which can be justified only in conditions of high carbon values. Thus, scenarios of strong climate policies can be examined in order to assess the penetration of this option. On the other hand, in the deliverable D3 there was not sufficient information to introduce this technology in the model and estimate two factor learning curves, since there were not available: a) the installations per cement production technology in Europe, b) a complete technical-economic analysis and c) R&D data.

In *biopolymers production*, and especially PLA production, the analysis showed that PLA is a costly alternative to PE (about two times higher than PE). The potential environmental impact is about 0.1% annual reduction in CO2 emissions, resulting from the adoption of what is essentially a high cost option. This technology was also not introduced in the model, because the key element for its successful penetration is the production cost of lactic acid.

Energy efficient electric motors are already implemented in the model.

The same holds for the *cadmium free rechargeable batteries* where about 83% of the sales are today batteries of this type. In addition, directive 2006/66/EC requires the phase out of cadmium batteries until 2010, making further policies promoting cadmium free batteries, superfluous.

Post-shredder technologies are new technologies for which further policies for its penetration can be examined despite the directive 2000/53/EC which aids the promotion of these technologies. However, their potential environmental impact is small (around 2% of the total municipal waste can be recycled through this technology). The post-shredder option is already integrated in the model but the lack of R&D and the absence of a perspective analysis in deliverable D3 prevented the estimation of two factor learning curves for this technology.

Membrane waste water treatment is the only technology that addresses a health problem. It is an expensive option (to turn all current installations of municipal waste water into membrane would cost 0.2% of the EU GDP). Moreover, the environmental impact of this technology is unrelated to the remainder of the model. Finally, the lack of R&D for this technology made the estimation of a two factor learning curve impossible in the current reporting period. However, these data have been provided after request and the estimation.

The *selective catalytic NOx reduction* is an expensive option (adding SCR to all fossil fuel based power plants would require the 0.2% of the European GDP) but it can save about 80% of the NOx emissions annually. SCR is a new function that did not exist before and currently its diffusion depends on relevant legislation. However, alternative methods to reduce NOx emissions do exist such as reburn (or fuel staging) and overfire air, which in case of data availability could be introduced in the model as “competitors” of SCR.

Work performed by E3Mlab of the ICCS/NTUA in the second period from concentrated on the numerical implementation of the decision module, a prototype of which together with the diffusion module were tested at the mid-term of the project. And, in order to ensure that analytical solutions can be obtained it is assumed that the impacts of R&D actions are distributed normally. This assumption is made while recognizing that many of the impacts as they emerge from the stochastic version of the diffusion module are skewed. However, the distribution of linear combination of non normal varieties is generally unknown, though it can be approximated numerically, but such approximations will result in non analytic and often non convex set of characteristic equations. The module has been constructed incorporating linear cross-impacts and formulated as a mixed complementarily problem and implemented in GAMS using the PATH solver. Work on the use of the decision module is continuing in particular in terms of refinements of the correlations and the design of simulations involving policy measures that reduce variability of returns to R&D investments.

For the Third Step, there is a realisation of an interface between the New Energy/Environment Module and the core economic model of NEMESIS. The objectives are now to improve the coherency between the New Energy/Environment Module (NEEM) and NEMESIS model. The following Environmental Technologies were implemented in NEEM (as described above the problems with identification and characterization of Environmental Technologies are taken into account for their integration in NEEM).

The results are the following:

1. *membrane based chlorine-alkali electrolysis*: Around 20% of the current Chlorine plants are using the membrane-based technology. Conversion of the remainder of the existing plants would require 0.06% of the EU GDP, while the benefits are estimated to be 0.3% savings on electricity consumed and 7.5% savings on Hg releases. This small environmental impact is considered to be already locked in by current policies. Furthermore, diaphragm-based processes already appear to be converted to membrane-based processes, due to the lower energy costs;

2. *short cement kiln*: Around 30% of the currently installed cement production capacity has incorporated this technology, as it is considered a BAT technique. The benefits from the conversion of the existing plants are estimated to be 0.1% of electricity savings and 0.6% of CO2 emissions reduction. However, retrofitting is very expensive and it becomes cost effective only at high carbon values (150€/tn of CO2). Consequently, the benefits appear to be small compared to the high costs involved;

3. *biopolymers-PLA production*: There are currently only demonstration plants for this environmental technology. The benefits from the implementation of this technology are trivial, since it results to 3-6 million tn/yr or 0.1% of CO2 emissions reduction and the PLA is not biodegradable in landfills. It is estimated that this change over to PLA production would double the PE production cost, as lactic acid production is a key element. Consequently, the benefits appear to be doubtful compared to the high costs involved;

4. *energy efficient electric motors*: In order to introduce the energy efficient electric motors in the NEMESIS Energy/Environment Model, a typical configuration of electric motors of a medium size factory was used: The characteristics of this typical installation are as follows: The total power capacity is 510 kW, operating 4500 hours p.a. and consisting of three types of motors, in terms of electrical output: 1.5kW, 15kW and 75kW. Specifically, there are 40 x 1.5kW motors, 10 x 15kW and 4 x 75kW, i.e. a total of 510kW. The number of these typical installations in each industrial sector was estimated using information on the structure of the sector and its electricity consumption. This way, the installations of the electric motors can be determined for the base year. The model also projects the number of typical installations and determines the requirements in electric motors in each year. The model also includes competition between EFF1, EFF2 and EFF3 motors and pre-mature replacement of EFF2 and EFF3 motors. EFF2 and EFF1 currently represent 92% of the sales, with EFF1 accounting only for 7% of the sales. The difference in annual costs between EFF2 and EFF1 are 6-7% for the smallest motors (1.5kW), dropping to only 1-2% for the higher output motors (75kW), while the benefit of a change from EFF2 to EFF1 for higher output motors is about 1% of electricity savings. Nevertheless, electric motors are an important electricity market and there is considerable potential for efficiency improvements other than introduction of EFF1;

5. *cadmium free rechargeable batteries*: In conclusion, this Environmental Technology has not been incorporated in the model for a number of reasons. Firstly, the impact on the environment from future production of small cell NiCd batteries is deemed to be small, taking into account the fact that there is small potential for new sales of NiCd batteries. The issue that needs to be addressed should focus more on the recycling of the currently sold batteries, but cannot be incorporated in the NEMESIS-EEM, without specific additional information on the technical and economic aspects of recycling. Secondly, the cadmium free rechargeable batteries currently hold 83% of total sales in the small cell sector, hence indicating that the transition is virtually affected and the outcome of additional policies would be insignificant;

6. *post shredder technologies*: The impact on the environment seems relatively small, considering that post-shredder waste represents only 2% of total municipal waste. Nonetheless, recycling of shredder residues makes a contribution to the improvement of overall resource efficiency of the EU economy, which is a priority policy according to the EU Environment strategy. In addition, post shredder technologies appear to compete directly with other alternatives in terms of cost;

7. *membrane based wastewater treatment*: There is a main cost disadvantage of membrane-based wastewater treatment amounting to € 0.91 per cubic meter, representing 0.2% of the EU GDP, if all plants were to be converted to membrane technologies. So, substantial subsidization (up to 50 percent of the investment cost) is the reason why membrane-based plants have been built until now. In the future, the cost gap can be assumed to close for several reasons, the most important of which is technical progress. This technology is the main one addressing health problems and therefore the positive environmental impacts are unrelated to remainder of model. It is worth mentioning that the additional energy costs, the high investment cost and the small area required for the installation may render this technique applicable only in big cities, where wastewater purification is more challenging. The membrane-based plants currently represent less than 1% of the total waste water treated and heavy subsidization is the economic reason for

their existence. Nevertheless, a strict policy on water quality could make this technology a more attractive option;

8. *selective catalytic NOx reduction*: The selective catalytic NOx is a new option and currently its diffusion depends on relevant legislation. The SCR is an expensive option. Specifically, SCR installation to all fossil fuel based power plants and assuming 54€/kW would require 0.2% of the European GDP. However the environmental impact is significant, as it can save about 80% of the NOx emissions annually. The only current driver to SCR installation is the 2001/80 EC directive to reduce emitted NOx to 200mg/m3 of waste gas from 2016. A forecast for the future of SCR technology shows a decrease of revenues for the years 2008/2009 followed by an increase in the following years due to new plants in new member states and retrofits of existing plants. New projects, both coal and gas will make contributions from 2009 onwards and there will also be some retrofit projects in certain markets. If stringent limits were introduced in the short or medium term, the impact would simply be to stimulate growth of SCR earlier, rather than create a new market.

4. Baseline Scenario for NEMESIS and GEM-E3

4.1. Objectives

The objectives were composed of two separate steps:

1. provide a baseline scenario until 2030 for NEMESIS core economic model and Energy/Environment Module;
2. provide a baseline scenario until 2030 for GEM-E3 model.

The baseline scenarios aim integrating in NEMESIS and GEM-E3 the most Up-to-date information about major economic trends (sectoral production, population Growth, Technical Progress, R&D Investment, rate of technical progress, interest rates) for the national economies and world regions they represent, and for their different production sectors. From these exogenous trends, NEMESIS and GEM-E3 project all relevant economic variables to the 2030 horizon: sectoral employment, energy and material use, investment and R&D expenditures; public receipts and expenditures; households' revenues and consumption (aggregate and by product); exports and imports price and volumes by product.

The baseline scenarios incorporate independent expert's assumptions concerning technological trends. *Inter alia* they provide reference projections on key variables of interest in the project such as the "Business as Usual" effort of National economies in the area of Research and Development, the development of environmental technologies and eco-industries, the consequences in terms of energy consumption, greenhouse gas emissions and other environmental damage indicators, sectoral employment and skills. These baseline assumptions and results play a crucial role for policy cases analysis, as, actually, the need for co-ordinated European policies will depend on how far "business as usual" evolution differs from European Actions Plans in the areas of RTD, Environmental Technologies and, more generally, Sustainable Development.

4.2. Results

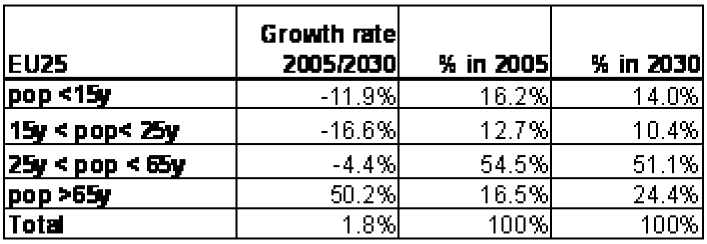
4.2.1. The BAU drivers

The main drivers of the two models are the following: demography, world demand growth, oil prices, research and development expenditures.

- **Demography**

The projections used are the latest published by Eurostat DG ECFIN (by age group, covering the current EU-27). The reference scenario corresponds to the 'Medium projection' computed by Eurostat where fertility remains below the level of inter-generational replacement in the long term, but a small upturn in some countries is expected. The combined result of these assumptions is that, in the reference scenario, Europe's total population remains more or less constant up to 2025, thanks to net migration flows, and decreases slowly afterwards.

Table 6: Major Demographic trends for EU-27



EU25	Growth rate 2005/2030	% in 2005	% in 2030
pop <15y	-11.9%	16.2%	14.0%
15y < pop< 25y	-16.6%	12.7%	10.4%
25y < pop < 65y	-4.4%	54.5%	51.1%
pop >65y	50.2%	16.5%	24.4%
Total	1.8%	100%	100%

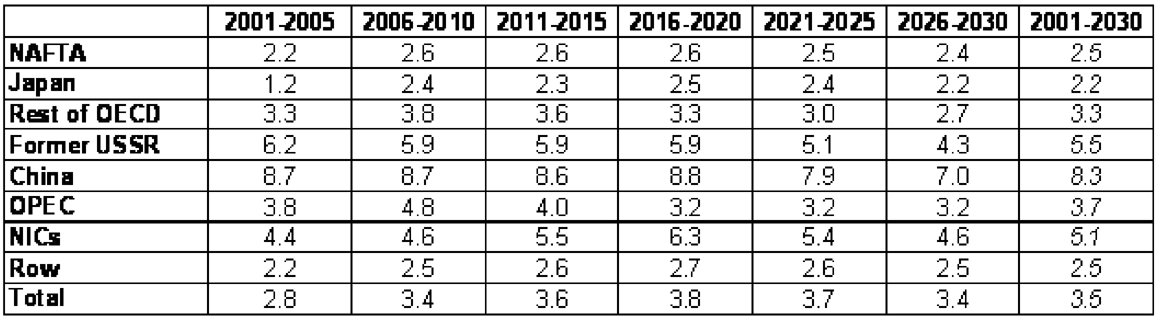
Source: Eurostat

The difference between the total population of the EU today and in 2030 is quite small: around 1.8% or nearly 8.5 million persons in absolute figures (out of a total of about 500 million people). The most important figure of the future European demography is the strong modification in the population's structure: compared to the present situation, the number of children, young people and in the working age group (15-65) will decline in 2030 while in the same time the number of aged people (more than 65) will increase rapidly: the pyramid becomes increasingly top-heavy.

• World demand

The growth of the rest of the world will partially determine external trade in goods and services between European countries represented in NEMESIS and GEM-E3, and with countries outside Europe. In GEM-E3 the Rest of the World is aggregated into one region while in NEMESIS it is split into 8 regions, but the same projections are used for both models. Assumptions used for the baselines are based on OECD projections and trend extrapolations.

Table 7: Annual growth projection for world zones



	2001-2005	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2001-2030
NAFTA	2.2	2.6	2.6	2.6	2.5	2.4	2.5
Japan	1.2	2.4	2.3	2.5	2.4	2.2	2.2
Rest of OECD	3.3	3.8	3.6	3.3	3.0	2.7	3.3
Former USSR	6.2	5.9	5.9	5.9	5.1	4.3	5.5
China	8.7	8.7	8.6	8.8	7.9	7.0	8.3
OPEC	3.8	4.8	4.0	3.2	3.2	3.2	3.7
NICs	4.4	4.6	5.5	6.3	5.4	4.6	5.1
Row	2.2	2.5	2.6	2.7	2.6	2.5	2.5
Total	2.8	3.4	3.6	3.8	3.7	3.4	3.5

The projections underline the prevalence of China which keeps a high rhythm of GDP growth (but lower than in the past). From more than 9% in 2005, its growth rate would be reduced to 6% in 2030. On the opposite side, we find Japan, which will be characterized by a growing old population, weighing on its potential growth (the Japanese GDP growth would only attain 1.5% in 2030). We can see in Table 7 that the annual growth rate between 2000 and 2030 for the world including EU 27 will be 3.5% in the OECD projections, the best performance being obtained during the period 2016-2020, with 3.8% on average.

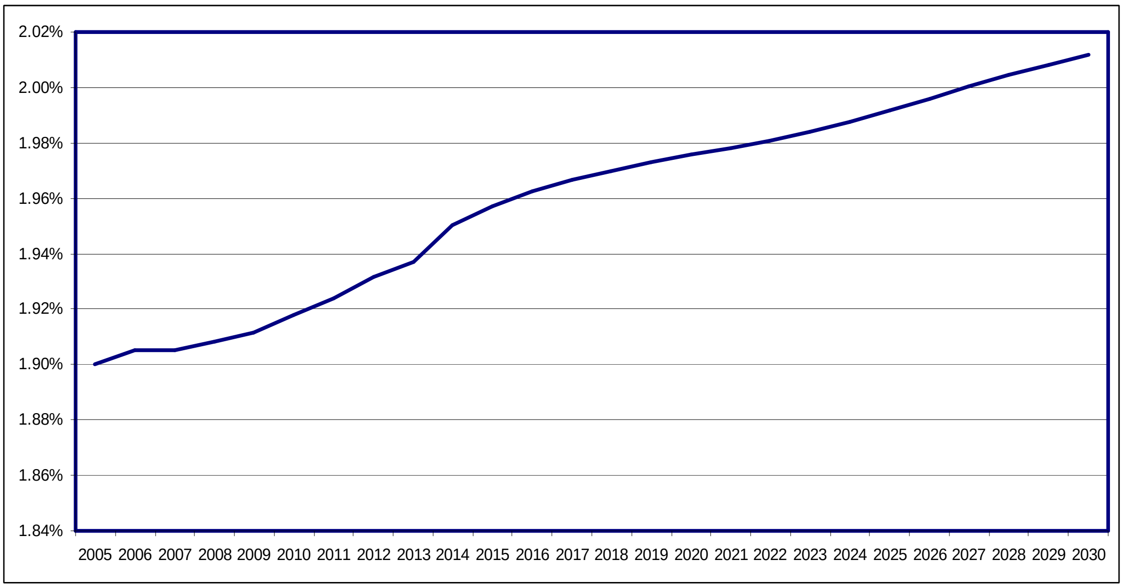
• Energy prices on the world market

In NEMESIS, we have taken into account the oil price projections made with PROMETHEUS, a stochastic model of the world energy system developed at the NTUA (Uyterlinde *et al.* 2004:20, 82, 87). This model provides different scenarios on the price of oil, associated to the probability of being confronted to a price of the barrel higher than the profile of price given. The trend of the oil price integrated in NEMESIS corresponds to the situation where there is 50% chance that the barrel becomes more expensive. Baseline evolutions for and gas prices were actualized in mid-2008, to take into account for the most recent trends onto energy prices (see figure 18, section 6.2.3). The high oil prices observed on the past two years are supposed to persist but with a slow decrease from 107 € in 2008 to 68 € 2015, and then progressive re-augmentation with 76 € in 2020 and over 95 € in 2030.

• Research and Development

In NEMESIS, sectoral R&D intensities (as % of value-added) and public R&D expenditures as % of GDP remain constant over time. EU-27 GDP R&D intensity increases nevertheless slightly over 2005-2030 period, from 1.9 to 2%, due to the increasing importance taken by R&D intensive sectors such as equipment goods and chemical industries. Technological development is in GEM-E3 reflected by an exogenous technical progress factor associated with production factors and by R&D expenditures. These elements are crucial in determining the economic growth. For the reference scenario, the past trends have been prolonged without real breakthrough: labour and capital efficiency is improving gradually around 1% a year. For the new member states these improvement were assumed to be slightly higher, at least at the beginning of the horizon. There is a certain dematerialisation of the production; the service content of the goods is relatively increasing compared to the good content. It is important to mention that in a CGE model such as GEM-E3, these exogenous factors reflect the relative position of the EU compared to the Rest of the World and not an absolute position as the model only generates relative price evolution. No country specific assumptions have been made.

Figure 3: GDP R&D intensity over 2005-2030 period, EU-27



Source: Nemesis model

• Public expenditures, exchange rates and interest rate

In *NEMESIS,* policies are kept constant for the baseline scenarios. By ‘constant’, we mean that policies, which are already implemented, are included in the baseline. To the extent that national policies are relevant, no change in them is assumed to happen. This assumption implies that exchange rates and interest rate are supposed to stay constant over all the period (base year is 2002); it is the same for the long term interest rate, which establish to 5% for the Euro zone until 2030. The public expenditures rates in the European area are supposed to stay constant as a percentage of GDP, despite the ageing of population and its consequence, in particular on retirement and health. In this context, health expenditures will grow faster than education expenditures and other general expenditures as Defence.

In *GEM-E3,* the public sector consumption and investment are a component of GDP and are exogenous in the model. They are assumed to grow with GDP. Other policy variables such as taxation or redistribution were kept at their base-year level. No climate policy was assumed in the reference, though there are already some elements into place at country or EU level. This is to allow getting a clearer picture of the cost of policies when running policy scenarios.

4.2.2. NEMESIS

European growth, in the beginning of the simulation run, is supported by two main pillars, the first one is the finalisation of the transition and integration of the new member states, and second one follows the labour force scarcity that arises from European population ageing and as a consequence, in the long run, the decline of its population.

For the period 2005-2010, evolutions include also the high prices context for imported energies (oil and gas) and the economic slowdown that is expected to persist until end on 2010. The period that will follow 2005-2010 will then show a recovery and re-enforced economic growth.

- **Macro-economic results for EU-27**

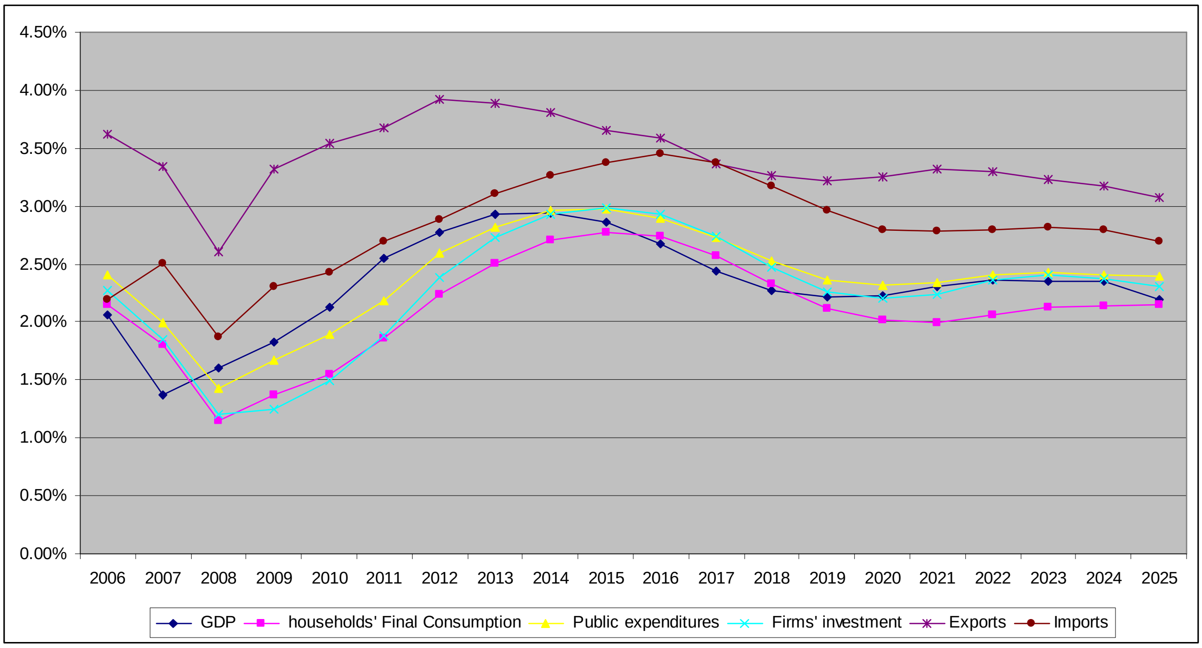
At the beginning of the 2005-2020 period demographic scarcity is less important and eastern countries growth and world demand potential are important, but they are hampered by the high prices for oil and gas, together with the economic slowdown resulting from excessive investments and consumptions patterns over the 2002-2007 period. European GDP growth is then expected to stay limited to 1.86% in average over the 2005-2010 period. For 2010-2015, the better context that progressively takes place, as a consequence of decreasing energy prices and re-start of housholds' and firms expenditures and world growth, will allow EU-27 GDP growth rate to accelerate to 2.66% on average on the period. After 2015, population trends, with increased ageing, are expected to weight more on growth and these trends are foreseen to continue after 2020 implying a net decrease of labour force at the end of the period. This labour force scarcity will increases wage pressure, but wage increase is not important enough for sustaining private consumption that slows down progressively due to population decrease, hence households' consumption growth slightly decreases from 2015 to 2025. In the same time wage pressure increases inflation, even if prices increase is partially limited by the labour productivity growth. Also, the strength of world growth is foreseen to continue after 2015 but with a slight slowdown. These trends for after-2015 period will then imply a slow-down of European growth, even in eastern countries, but economic growth will stay dynamic with for EU-27 GDP respectively 2.49% and 2.32% annual growth in average over 2015-2020 and 2020-2025 periods.

Table 8: Macroeconomics Results: EU27 (growth rates)

	2005/2010	2010/2015	2015/2020	2020/2025	2005/2025
GDP	1.86%	2.66%	2.49%	2.32%	**2.33%**
Households' Final Cons.	1.60%	2.41%	2.36%	2.09%	**2.12%**
Public expenditures	1.88%	2.71%	2.57%	2.39%	**2.39%**
Firms' investment	1.61%	2.58%	2.52%	2.34%	**2.26%**
Exports	3.29%	3.79%	3.34%	3.22%	**3.41%**
Imports	2.26%	3.06%	3.15%	2.78%	**2.81%**
Employment	0.09%	0.38%	0.30%	0.07%	**0.21%**
Labour Productivity	1.71%	1.99%	2.12%	2.18%	**2.00%**
Total Population	0.22%	0.12%	0.06%	0.01%	**0.10%**

Source: NEMESIS Model, baseline projection

Figure 4: Macroeconomics Results in Baseline (year on year growth rate)



Source: NEMESIS model, baseline projection

The productivity gains will limit the increase of production costs and thus will prevent a deep loss of competitiveness on external trade which should be the traditional effect of wage pressure. Hence, European exports will be sustained, on the one hand by the strong world demand (mainly during the first part of the projection) and on the other hand by the maintained competitiveness. European imports, on the other hand, which largely depend on the evolution of European internal demand, that will also be limited by the maintained European competitiveness. Finally, net European exports (exports less imports) should bring a positive contribution to the development of European GDP during the whole projection period.
Note that sustained exports after 2020 will support investment and the progressive slowing down of imports in the same period testify of our capacity to be competitive on the foreign market because of our labour productivity gains growth.

• Sectoral results for EU-27

For industrial sectors, the most dynamic sectors of the European economy are transport equipment and chemicals with an average growth rate of around 3% (table 5). These sectors reflect a dynamic growth, especially in the middle of period and benefit above all from the European and world demand. The increase in labour productivity enables firms hold down their production costs and to maintain their market shares with respect to their trade partners, while their market position on non Europe trade, compared to the other sectors, was not initially the best. Moreover the activity of the transport equipment sector benefits from the strong growth of transport demand. At the opposite side, sectors ‘Agriculture and industrial machines’, and ‘Other Manufacturing’, with a really weak EU 27 demand, display a low growth of 1.8%,. This performance is explained by the weakness of internal demand and by their disadvantageous positions on the foreign market dominated by more competitive countries. In this case the sectors just benefit of labour productivity. The employment growth rate is 0.6% for “Agriculture” and “industrial machines” and 0.7% for ‘lodging and catering’ in spite of the weakness of sector growth.

Some sectors suffer a lot of international competition, this is the case ‘textile and clothes’ of which production growth stays around 1.9% and for ‘food drink and tobacco’ with the lowest production growth over all the period (inferior to 1%), after agriculture sector.

Regarding the service sectors, communications and transport are among the most dynamic EU-27 sectors, with growth rates of respectively 2.4% and 2.6%. The services know an acceleration of their activity until 2015; afterwards, services’ growth would be stabilized at a favourable level (more sustained than globally for industrial sectors). Services will benefit from the maintenance of the households’ expenses and of the dynamism of the rest of the world growth. They are not limited by the oil price rise contrary to the majority of the industrial sectors.

The communications display a quite constant activity growth rate of about 2.4% on average, answering to an increasing final consumption, as well to world demand due to R&D productivity gains. It is one of the best exporting sectors. However, this sector knocks against labour force availability in a context of labour scarcity and of marked wage inflation. Confronted to large wage increases, this sector reduces its labour force by 0.4% per year. At the opposite side, in some sectors activities are totally depending on foreign trade, like the energetic sector. The gas and electricity sectors development may be due to the important increase of the crude oil price.

Table 9: Some Sectoral Results (Average Production Growth Rates)

	2005/2010	2010/2015	2015/2020	2025/2020	2025/2005
Agriculture	-0.12%	0.26%	0.47%	0.27%	0.22%
Coal and Coke	0.00%	0.00%	0.00%	0.00%	0.00%
Oil and Gas Extraction	-0.73%	2.26%	1.78%	1.46%	1.19%
Gas Distribution	0.76%	2.64%	3.12%	1.84%	2.09%
Refined Oil	-0.91%	1.77%	2.09%	1.17%	1.02%
Electricity	0.80%	1.66%	2.06%	1.76%	1.57%
Water supply	1.18%	1.67%	2.01%	1.81%	1.67%
Ferr & Non Ferrous Metals	1.34%	1.81%	2.18%	1.74%	1.77%
Non Metallic Min. Prod.	1.55%	1.97%	2.48%	2.03%	2.01%
Chemicals	2.50%	3.15%	3.25%	2.87%	2.94%
Metal Products	1.50%	1.95%	2.39%	1.96%	1.95%
Agri & Industr. Mach.	1.23%	1.73%	2.00%	1.65%	1.65%
Office Machines	2.23%	2.73%	2.98%	2.65%	2.64%
Electrical Goods	2.49%	2.83%	2.96%	2.68%	2.74%
Transport Equipment	2.58%	3.06%	3.30%	2.91%	2.96%
Food, Drink & Tobacco	0.80%	0.86%	0.99%	0.85%	0.88%
Tex., Cloth & Footw.	1.37%	1.87%	2.19%	1.74%	1.79%
Paper & Printing Prod.	1.74%	2.11%	2.48%	2.07%	2.10%
Rubber and Plastic	1.69%	2.07%	2.42%	2.04%	2.05%
Other manufactures	1.49%	1.88%	2.10%	1.69%	1.79%
Construction	1.66%	2.27%	2.72%	2.30%	2.24%
Distribution	1.58%	2.02%	2.32%	2.04%	1.99%
Lodging and Catering	1.27%	1.88%	2.35%	1.91%	1.85%
Inland Transports	1.80%	2.35%	2.72%	2.33%	2.30%
Sea and Air Transport	2.64%	3.22%	3.21%	3.10%	3.04%
Other Transport	2.00%	2.47%	2.79%	2.50%	2.44%
Communication	2.01%	2.48%	2.80%	2.44%	2.43%
Bank, Finance and Insurance	1.56%	2.08%	2.53%	2.11%	2.07%
Other Market Services	1.47%	2.13%	2.55%	2.14%	2.07%
Non market Services	1.61%	2.36%	2.53%	2.22%	2.18%

Source: NEMESIS model. baseline projection

• Results for EU-27 Member States

Table 10 gives the GDP growth by country. New member states observe a higher growth, contributing to a certain convergence within the EU for levels of GDP per capita. This can be mainly explained by higher efficiency improvements in those countries with their integration in the EU market

Table 10: GDP growth rate by countries (mean growth rate

	2005/2010	2010/2015	2015/2020	2020/2025	2005/2025
Austria	1.56%	2.04%	2.05%	1.84%	**1.87%**
Belgium	1.12%	2.28%	2.26%	2.07%	**1.93%**
Czech republic	3.99%	3.36%	3.69%	2.98%	**3.50%**
Denmark	0.94%	3.30%	0.84%	2.76%	**1.96%**
Estonia	7.98%	6.65%	5.40%	4.64%	**6.16%**
Finland	2.77%	2.90%	2.78%	2.50%	**2.74%**
France	1.45%	2.29%	2.42%	2.04%	**2.05%**
Germany	1.07%	1.91%	1.90%	1.71%	**1.64%**
Greece	2.38%	3.30%	3.02%	2.93%	**2.91%**
Hungary	1.75%	3.32%	3.23%	2.91%	**2.80%**
Ireland	3.64%	3.60%	3.42%	3.03%	**3.42%**
Italy	0.38%	2.03%	1.97%	1.73%	**1.52%**
Latvia	6.85%	5.65%	4.86%	4.55%	**5.47%**
Lithuania	5.23%	4.76%	4.20%	3.56%	**4.44%**
Luxembourg	3.84%	3.28%	3.50%	3.49%	**3.53%**
Malta	2.15%	2.79%	3.31%	3.39%	**2.91%**
Netherlands	2.00%	2.68%	2.45%	2.36%	**2.37%**
Poland	3.35%	3.55%	3.70%	3.75%	**3.59%**
Portugal	0.15%	2.19%	2.65%	2.32%	**1.82%**
Romania	3.49%	4.73%	3.96%	2.72%	**3.72%**
Slovakia	4.46%	3.84%	4.12%	3.50%	**3.98%**
Slovenia	3.82%	3.69%	3.65%	3.02%	**3.54%**
Spain	2.16%	3.10%	2.86%	2.00%	**2.53%**
Sweden	2.73%	3.32%	3.06%	2.84%	**2.99%**
United Kingdom	2.15%	2.61%	2.36%	2.46%	**2.39%**

Source: NEMESIS model. baseline projection. In annual growth rate

4.2.3. GEM-E3 Europe

• The EU results

The endogenous variables of the GEM-E3 model include (in volume for each sector and each country) the supply (production and imports) and demand (use in production, private and public consumption, investments and exports) of goods and services, the sources and uses of material, energy, labour and capital inputs. The model also computes, for each sector and each country, the changes in relative prices of domestic production, exports, imports and changes in primary factor incomes (average wage rate and return on capital).

In Table 11 the macroeconomic growth for the EU as a whole is given. The projected average growth rate is around 2.3%. It is associated with an increased labour productivity induced by the increased wage rate due to the declining labour supply. The increased wage rate has positive impact on private consumption which follows the GDP growth. Investment and foreign trade remain important contributors to the growth especially at the beginning of the horizon. There is a decoupling of the GDP growth and the energy demand over the entire projection horizon and thus a moderate growth in CO2 emissions.

Table 11: EU Macroeconomic growth

	2005/2010	2010/2015	2015/2020	2020/2025	2025/2030	2005/2030
Macroeconomic Aggregates						
Gross Domestic Product	2.4%	2.5%	2.3%	2.2%	2.1%	2.3%
Employment	0.4%	0.3%	0.2%	0.1%	0.0%	0.2%
Private Consumption	2.0%	2.7%	1.5%	2.0%	2.0%	2.1%
Investment	3.3%	3.4%	2.6%	2.6%	2.6%	2.9%
Final Energy Consumption	1.6%	1.8%	1.3%	1.5%	1.6%	1.6%
Share Coal*	-0.1%	0.2%	-0.1%	0.1%	0.0%	
Share Oil*	0.0%	0.0%	-0.4%	0.2%	-0.2%	
Share Gas*	-0.3%	-0.4%	-0.2%	-0.4%	0.2%	
Share Electricity*	0.4%	0.1%	0.7%	0.1%	0.0%	
Exports to RW	4.9%	2.8%	4.7%	3.4%	3.0%	3.8%
Imports from RW	3.0%	3.5%	2.0%	3.0%	3.2%	2.9%
Real Wage Rate	1.7%	2.7%	1.6%	2.3%	2.4%	2.1%
Terms of Trade	-0.9%	0.5%	-1.0%	0.0%	0.3%	-0.2%
Current Account (% of GDP)*	2.0%	0.1%	2.3%	1.0%	0.8%	
Total Atmospheric Emissions						
CO2 Emissions	1.1%	1.4%	0.8%	1.3%	1.4%	1.2%
NOX Emissions	-2.0%	-2.2%	-2.2%	1.6%	1.6%	-0.6%
SO2 Emissions	-3.8%	-0.9%	-0.2%	1.8%	1.6%	-0.3%
VOC Emissions	-2.0%	0.0%	-0.2%	1.8%	1.8%	0.3%
PM Emissions	-0.9%	0.5%	0.3%	1.9%	1.9%	0.7%
NH3 Emissions	1.5%	1.9%	2.4%	2.2%	2.1%	2.0%

*Source: GEM-E3 model. baseline projection. In annual growth rate except for * where difference*

Table 12: EU sectoral evolution

Domestic Production in Volume	2005/2010	2010/2015	2015/2020	2020/2025	2025/2030	2005/2030
Agriculture	2.0%	1.9%	2.4%	2.1%	2.0%	2.1%
Energy Production	1.3%	1.6%	1.3%	1.6%	1.6%	1.5%
Ferrous and non ferrous metals	2.7%	2.2%	2.6%	2.3%	2.0%	2.4%
Chemical Products	2.6%	1.9%	2.8%	2.2%	2.0%	2.3%
Other energy intensive	2.5%	2.2%	2.7%	2.3%	2.2%	2.4%
Electric Goods	3.2%	2.3%	2.9%	2.4%	2.1%	2.6%
Transport equipment	3.3%	3.0%	1.6%	2.7%	2.0%	2.5%
Other Equipment Goods	3.0%	2.4%	2.8%	2.3%	2.0%	2.5%
Consumer Goods Industries	2.2%	2.0%	2.3%	2.0%	1.9%	2.1%
Construction	3.0%	3.1%	2.6%	2.6%	2.5%	2.8%
Telecommunication Services	2.7%	3.0%	2.8%	2.8%	2.7%	2.8%
Transport	2.4%	2.1%	2.4%	2.2%	2.0%	2.2%
Services of credit and insurances	2.8%	3.0%	2.8%	2.7%	2.7%	2.8%
Other Market Services	2.6%	2.9%	2.6%	2.6%	2.6%	2.6%
Non Market Services	1.4%	1.8%	1.7%	1.7%	1.7%	1.7%
Investments in Volume						
Agriculture	2.9%	2.6%	2.6%	2.3%	2.2%	2.5%
Ferrous and non ferrous metals	3.3%	2.6%	3.0%	2.6%	2.3%	2.7%
Chemical Products	2.6%	2.0%	3.1%	2.4%	2.2%	2.4%
Other energy intensive	3.1%	2.7%	3.1%	2.7%	2.5%	2.8%
Electric Goods	3.0%	2.4%	3.3%	2.7%	2.4%	2.8%
Transport equipment	1.9%	2.3%	1.9%	3.0%	2.3%	2.3%
Other Equipment Goods	3.3%	2.7%	3.1%	2.6%	2.3%	2.8%
Consumer Goods Industries	2.9%	2.5%	2.6%	2.2%	2.1%	2.5%
Construction	4.1%	4.0%	2.9%	2.9%	2.9%	3.4%
Telecommunication Services	3.8%	3.7%	3.1%	3.0%	3.0%	3.3%
Transport	2.1%	2.0%	2.7%	2.4%	2.2%	2.3%
Services of credit and insurances	4.1%	4.0%	3.2%	3.1%	3.1%	3.5%
Other Market Services	4.0%	3.8%	2.7%	2.7%	2.7%	3.2%

Non Market Services	1.5%	3.0%	1.9%	1.9%	2.0%	2.1%

Source: GEM-E3 model. baseline projection. In annual growth rate

The sectoral evolutions for the domestic production are given in Table 12. They imply a slow shift towards a more service oriented economy though still limited. It is rather more pronounced in the exports in the period 2005/2010. This shift towards less energy intensive sectors contributes to the slower growth of CO_2 emissions.

• Country Results

Table 13 gives the GDP growth by country. New member states observe a higher growth at least till 2020, contributing to a certain convergence within the EU. This can be mainly explained by higher efficiency improvements in those countries with their integration in the EU market.

Table 13: GDP annual growth rates per country

	2005/2010	2010/2015	2015/2020	2020/2025	2025/2030	2005/2030
Austria	2.3%	2.5%	2.4%	2.3%	2.1%	2.3%
Belgium	2.3%	2.6%	2.4%	2.3%	2.2%	2.4%
Germany	1.9%	2.0%	1.9%	1.7%	1.6%	1.8%
Denmark	2.1%	2.3%	2.1%	2.1%	2.0%	2.1%
Finland	2.7%	2.8%	2.6%	2.4%	2.2%	2.5%
France	2.6%	2.7%	2.6%	2.4%	2.3%	2.5%
Greece	2.9%	2.9%	2.8%	2.7%	2.6%	2.8%
Ireland	3.4%	3.2%	3.1%	3.0%	2.9%	3.1%
Italy	2.1%	2.3%	2.0%	1.9%	1.8%	2.0%
The Netherlands	2.5%	2.7%	2.5%	2.4%	2.3%	2.5%
Portugal	2.4%	2.5%	2.1%	2.0%	1.9%	2.2%
Spain	3.2%	3.0%	2.6%	2.4%	2.3%	2.7%
Sweden	2.4%	2.6%	2.5%	2.4%	2.3%	2.4%
UK	2.2%	2.4%	2.2%	2.1%	2.0%	2.2%
Hungary	4.4%	3.5%	3.1%	2.9%	2.7%	3.3%
Poland	3.9%	3.5%	3.3%	3.2%	3.0%	3.4%
Slovenia	2.4%	2.4%	2.2%	2.2%	2.1%	2.3%
Czech Republic	4.4%	3.8%	3.4%	3.2%	2.9%	3.6%
Slovakia	4.7%	4.1%	3.6%	3.4%	3.1%	3.8%
Estonia	4.5%	3.3%	2.9%	2.6%	2.4%	3.1%
Lithuania	4.2%	3.5%	3.0%	2.9%	2.7%	3.2%
Latvia	4.5%	3.4%	2.8%	2.5%	2.1%	3.1%
Bulgaria	4.3%	3.6%	2.6%	1.6%	0.5%	2.5%
Romania	4.2%	3.2%	2.5%	2.2%	2.1%	2.8%
EU	2.4%	2.5%	2.3%	2.2%	2.1%	2.3%

Source: GEM-E3 model. baseline projection. In annual growth rate

Labour productivity increases sharply in all countries induced by the higher real wage rate and this compensates the decrease in population growth and allows maintaining the competitiveness of the EU economy. Exports are still a main contributor to growth in the EU, as can be seen in Table 14. The exports growth rate in the new member states until 2010 reflects their integration in the EU market.

Table 14: Country exports

	2005/2010	2010/2015	2015/2020	2020/2025	2025/2030	2005/2030
Austria	2.7%	2.2%	3.4%	2.8%	2.3%	2.7%
Belgium	2.7%	2.5%	2.9%	2.7%	2.4%	2.6%
Germany	2.6%	1.3%	3.4%	2.2%	1.8%	2.3%
Denmark	2.9%	2.3%	2.9%	2.6%	2.4%	2.6%
Finland	3.7%	2.9%	3.6%	2.9%	2.5%	3.1%
France	4.3%	2.7%	4.8%	3.5%	3.0%	3.7%
Greece	4.8%	3.1%	4.5%	3.5%	3.1%	3.8%
Ireland	3.9%	3.3%	3.4%	3.2%	3.0%	3.4%
Italy	2.8%	1.8%	4.0%	2.8%	2.4%	2.8%
The Netherlands	3.1%	2.5%	3.3%	2.8%	2.5%	2.8%
Portugal	2.8%	1.3%	2.8%	2.0%	1.4%	2.0%
Spain	4.8%	2.8%	3.4%	2.6%	2.1%	3.1%
Sweden	3.3%	2.9%	3.4%	3.1%	2.7%	3.1%
UK	3.2%	2.4%	3.3%	2.6%	2.3%	2.8%
Hungary	5.8%	2.8%	3.4%	2.8%	2.3%	3.4%
Poland	8.2%	3.0%	5.2%	3.7%	3.1%	4.6%
Slovenia	2.9%	2.6%	2.5%	2.4%	2.2%	2.5%
Czech Republic	5.3%	3.0%	3.3%	2.7%	2.0%	3.3%
Slovakia	5.7%	3.7%	3.6%	3.1%	2.5%	3.7%
Estonia	5.1%	2.9%	2.6%	2.2%	1.8%	2.9%
Lithuania	7.4%	2.9%	3.6%	2.8%	2.3%	3.8%
Latvia	6.6%	2.9%	2.5%	1.8%	1.1%	3.0%
Bulgaria	6.3%	3.0%	1.5%	-0.8%	-3.0%	1.3%
Romania	7.3%	3.9%	2.9%	2.1%	1.9%	3.6%
EU	4.9%	2.8%	4.7%	3.4%	3.0%	3.8%

Source: GEM-E3 model. baseline projection. In annual growth rate

The higher wage rate has a positive impact on private income and thus sustains the private consumption which evolves rather close to the GDP evolution.

Table 15: Country Private Consumption

	2005/2010	2010/2015	2015/2020	2020/2025	2025/2030	2005/2030
Austria	1.9%	2.6%	1.5%	2.0%	2.0%	2.0%
Belgium	2.0%	2.7%	1.5%	2.1%	2.1%	2.1%
Germany	1.7%	2.4%	1.0%	1.6%	1.6%	1.7%
Denmark	1.5%	2.2%	1.4%	1.8%	1.9%	1.8%
Finland	1.9%	2.7%	1.7%	2.1%	2.1%	2.1%
France	1.9%	2.8%	1.3%	2.0%	2.0%	2.0%
Greece	2.3%	2.9%	1.8%	2.4%	2.4%	2.4%
Ireland	2.8%	3.3%	2.2%	2.7%	2.7%	2.7%
Italy	1.8%	2.4%	1.1%	1.6%	1.6%	1.7%
The Netherlands	2.2%	2.8%	1.7%	2.2%	2.3%	2.2%
Portugal	2.3%	3.1%	1.7%	2.2%	2.2%	2.3%
Spain	2.6%	3.2%	1.9%	2.4%	2.4%	2.5%
Sweden	2.0%	2.5%	1.8%	2.2%	2.2%	2.2%
UK	2.2%	2.7%	1.9%	2.3%	2.2%	2.3%
Hungary	2.1%	4.0%	2.1%	2.9%	2.7%	2.8%
Poland	2.1%	3.6%	2.3%	2.9%	2.9%	2.8%
Slovenia	2.3%	2.1%	2.1%	2.0%	2.0%	2.1%
Czech Republic	3.0%	4.0%	3.1%	3.4%	3.4%	3.4%
Slovakia	3.1%	3.9%	3.0%	3.3%	3.4%	3.3%
Estonia	3.3%	4.0%	3.1%	3.3%	3.1%	3.4%
Lithuania	2.0%	4.3%	2.0%	3.1%	3.0%	2.9%
Latvia	3.1%	3.7%	2.8%	3.0%	2.7%	3.1%
Bulgaria	2.6%	3.5%	2.9%	3.0%	2.7%	2.9%
Romania	2.1%	2.7%	1.8%	2.1%	2.1%	2.2%
EU	2.0%	2.7%	1.5%	2.0%	2.0%	2.1%

Source: GEM-E3 model. baseline projection. In annual growth rate

Overall the sectoral composition of the activities in the different countries remains rather stable over the entire horizon, though there is a slight shift towards more service in some countries. The country sectoral evolutions are given in annex.

4.2.4. GEM-E3 World

The world growth as derived with GEM-E3 World should be compatible with the world growth assumptions made for the European model for the policy evaluation in FORASSET. This is however an extremely difficult step as the evolution in the GEM-E3 world model is nearly entirely endogenous. Furthermore, as the main policy evaluation will be done with the EU model and as already said GEM-E3 is not a projection tool, it has been judged sufficient to get the same overall picture without trying to match perfectly the growth rates in both models. A certain convergence between developed and less developed regions as result, but at a very slow pace especially considering the still higher growth in population in the less developed world.

Table 16: Region GDP

	2005/2010	2010/2015	2015/2020	2020/2025	2025/2030	2005/2030
Canada	3.2%	2.8%	2.6%	2.5%	2.0%	2.6%
USA	3.6%	3.3%	3.1%	3.0%	2.2%	3.0%
Australia & New Zealand	2.6%	2.5%	2.7%	3.1%	2.7%	2.7%
Japan	1.7%	1.8%	2.1%	2.8%	2.2%	2.1%
EU27	2.5%	2.5%	2.4%	2.4%	1.6%	2.3%
Other European countries	2.4%	2.5%	2.9%	3.1%	2.6%	2.7%
South & East Mediterranean Countries	4.6%	3.7%	3.5%	3.1%	3.9%	3.8%
Former Soviet Union	6.3%	4.6%	3.5%	3.8%	2.9%	4.2%
Middle East	3.7%	3.3%	3.1%	2.2%	5.8%	3.6%
Middle Africa	3.6%	3.7%	4.0%	4.7%	5.1%	4.2%
South Africa	3.6%	3.9%	4.0%	4.7%	4.5%	4.2%
India	5.1%	4.6%	4.7%	4.6%	5.0%	4.8%
China	5.5%	4.7%	4.4%	4.1%	3.9%	4.5%
East South East Asia	4.1%	3.7%	3.4%	3.2%	3.1%	3.5%
Rest of Asia	4.1%	3.7%	3.2%	3.1%	3.4%	3.5%
Mexico & Venezuela	3.5%	3.5%	4.1%	4.6%	5.0%	4.1%
Brazil	3.2%	3.2%	3.3%	3.8%	4.2%	3.5%
Rest of Latin America	3.2%	3.5%	3.7%	4.1%	4.4%	3.8%
World	3.3%	3.1%	3.0%	3.0%	2.6%	3.0%

Source: GEM-E3 model. baseline projection. In annual growth rate

The sectoral composition of the activities in the different reflects the same evolution as in the EU model, remaining rather stable over the entire horizon. To conclude, a reference scenario with a CGE model such as GEM-E3 is not a projection. Its objective is to generate a consistent long term path for the economies under business as usual policies. It is the benchmark for the evaluation of policies and it must be interpreted as such.

5. Assessments of European RTD policies: the case of the 7th FP on R&D

5.1. Objectives

The NEMESIS model was adapted to assess for European R.T.D. policies and mainly the 7th R&D framework programme, and then to give an assessment for the economic impacts of European Framework Programmes at the horizon 2030. The implementation of the new developments on RTD based endogenous technical change into NEMESIS provides a version of the model in which technical change is endogenized on R&D and where R&D itself is endogenously determined by economic variables: prices, taxes and subsidies, production and demand, etc. The NEMESIS model is a useful tool to asses the economic impacts (Employment, growth, competitiveness…) of a doubling of European FP for research, from the 7th programme and onward. For this, the new mechanisms implemented are used together with the available literature onto crowding-in/crowding-out effect (complementarity/ substitutability between European subsidies for research and Member states RTD effort into private and public sectors).

Different scenarios are considered. First, the case of a doubling of funding during the 7th program followed after by a more voluntary policy (European funding for R&D are allowed to reach until about 0.3 point GDP in 2030, against 0.05 point today) is presented. Then, the analysis is deepened with an assessment for the 7th framework program grounded on a different allocation mode of funding based on performance and not on Grandfathering as previously. Funding for private R&D into Member States and production sectors depends on the number of patent applications; for public sector funding depends on the number of scientific publications. The analysis consists also into an assessment for the potential impact of an abandonment of European research programs. Two specific assumptions are alternatively made: Member States partially or fully (‘re-nationalization’) compensate the abandonment of European funding by National subsidies, or they do not. Finally, an overall assessment for the potential impacts of European research policy is proposed by comparing two hypothetical situations: There is no European funding for RTD versus there is a volontarist European policy for RTD. The main emphasis is put on competitiveness, growth, employment, research related employment, differentiation of impacts by production sector, etc.

5.2 Results

We present in this section the main results of different scenarios realized to assess for European FP funding for R&D. A detailed report (deliverable D13 and D14) is available, including also a description of the implementation of technical change into NEMESIS

5.2.1. Assessment for the direct effects on private RTD expenditures of European 7th FP subsidies

The assessment for the impacts of 7th PCRD is realized in reference to a scenario in which the 7th PCRD would simply prolong the 6th PCRD (Business as Usual Scenario). In this Business As Usual Scenario (B.A.U.), whereas the 6th PCRD dedicates 17500 millions of euros to the financing of research between 2003 and 2006, the 7th PCRD will have an increase of 3.87% per year of these funds between 2007 and 2010, already observed for the previous FP. After 2010, the size of the FP continues to grow 3.87% per year. For all the scenarios, we make the assumption that 60% of the European subsidies finance the applied research and the 40% remaining finance the fundamental research.

Table 17: Reference Scenarios Assumptions

	FP funding real growth rate 2007-2010	FP funding real growth rate 2011-2030	Allocation of FP funding to EU MS	Allocation of FP funding to basic and applied research	Allocation funding crowding-in/out factor	National research funding crowding-in/out factor
Reference scenario	3.87 percent	3.87 percent	Share of each MS and sector in European R&D expenditure	60 for applied, 40 for basic	1.1	1

Among the characteristics of public subsidies, the most important in that they may provoke a “crowding-in effect” that encourage the increase of private R&D effort and so help reaching an optimal level for R&D effort. Indeed, the R&D is source of positive externalities that are not taken into account by the enterprises at the time of their R&D decisions. This characteristic of public good explains the weakness of R&D private returns in relation to its public one. However, public R&D subsidies can have a less favourable effect on private research because they can substitute private expenditures: this is the “crowding-out effect”.

Recent econometric works like David, Hall and Toole (2000), David and alii (2000), Guellec and Van Pottelsberghe (2003) tried to study the effect of public subsidies onto private R&D. In the study by Guellec and Van Pottelsberghe (2003) for sixteen OECD countries, the main findings is that one euro of public funding generates a supplementary growth of private R&D of about 0.70 euro (crowding-in effect), and rise the total expense by 1.70 euro. Guellec and Van Pottelsberghe establish four groups of countries according to their average rate of subsidy to R&D. The largest crowding-in effects are found for countries belonging to the two ‘medium’ groups (with subsidy rates about 11-19% (medium-high) and about 4-11% (medium-low)) and inside this interval the efficiency of the subsidy increases with its rate until 13%. For these two groups of countries, the marginal impact of RTD subsidies onto RTD effort of private sector established respectively to 0.47 to 1.01 euros for every euro subsidy (crowding-in effect). On the contrary, countries with the highest and the lowest funding rates have non-significant impact onto private RTD effort. The heterogeneity of the countries is also very strong: whereas Finland, Ireland and Netherlands subsidize less 4% of the private R&D, Italy, United Kingdom, Norway and France subsidize more than 10%.

For the scenarios studies based on an allocation of RTD fundings among Member States following the “Grandfathering” principle” (The allocation is proportional to the share of each Member State into European RTD expenditure), we made an assumption that one euro of European subsidy generates a additional investment in R&D of 1.10 euros by the enterprise. The elasticity of private R&D effort to public funding vary actually accordingly to the source of financing. An European complementary network has a more important externality than a national based consortium. For this reason we supposed that for one euro European subsidy the enterprise will spend only one additional euro when the subsidy is national, (The average crowding-in effect found in the econometric literature), against 1.10 euros when it is European. Where the allocation of European RTD funding is based of performance criteria of firms and public laboratories, we made this time the assumption that one additional European euro funding gives an additional RTD effort of 1.4 euros in private sector.

The scenarios study the impact of a doubling of European RTD funding from the 7th PCRD, with different assumptions onto the repartition of funding between Member States and the importance of the crowding-in effect, as already stated above, the other differences between the scenarios depending on the assumption made onto the growth of FP after the 7th program: it is 3.87%, as in the reference (B.A.U.) scenario, respectively "grandfathering" and "Performance" scenarios, and 11.61% in "Volontarist" scenario that makes the assumption of a continuous re-enforcement of European funding after 7th FP. Other assumptions concern mainly the repartition of European funding between applied and basic research that was established to 60% for applied research and 40% to basic research in all scenarios. All these assumptions are summarized in Table 18.

Table 18: Assumption for Doubling FP funding

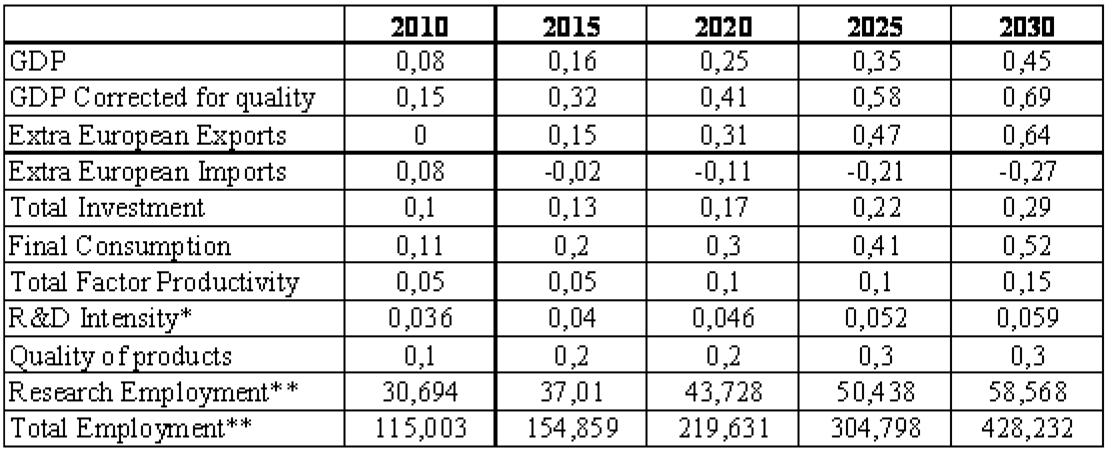
	FP funding real growth rate 2007-2010	**FP funding real growth rate 2011-2030**	**Allocation of FP funding to EU MS**	**Allocation of FP funding to basic and applied research**	**Allocation funding crowding-in/out factor**	**National research funding crowding-in/out factor**
Grandfathering	Doubling	3.87 percent	Share of each MS and sector in European R&D expenditure	60 for applied, 40 for basic	1.1	1
Voluntarist with Grandfathering	Doubling	11.61 percent	Share of each MS and sector in European R&D expenditure	60 for applied, 40 for basic	1.1	1
Performance	Doubling	3.87 percent	Publication and patent performance	60 for applied, 40 for basic	1.4	1

5.2.2. "*Grandfathering*" Scenario

In this Grandfathering scenario, the European funding to R&D is doubled compared to its B.A.U. level. In 2010, the GDP increases by 0.08% (and 0,15% if the GDP measure is corrected to account for the improvement in product quality) and European R&D intensity (as a percentage of GDP) rises of 0,036. Total factor productivity is increased by 0.05%.

The rise of GDP induces the creation of 115,000 jobs (one third being created directly into R&D sector) and a rise the households' real income reflected by 0.11% additional final consumption. The rise in final consumption is stringer than the rise in GDP as, in this first period GDP growth follows mostly the rise in real wage induced directly by the increased RTD effort, RTD being very intensive in employment. On the opposite direction, the rise in real wages increase production prices that lower competitiveness of European economy: Imports grow 0.08% while exports are stable. The investment increases by 0.1%, and domestic demand constitutes the motor of growth during this first period, where productivity gains are un-sufficient (due to the maturation delays of R&D expenditures: The time for expenditures to transform into product and process innovations, 3 years in average for private R&D, 5 years for public one) to compensate the price increase induced by the rise in demand for final consumption and investment goods.

Table 19: "Grandfathering" Scenario - Macroeconomic Results For Europe



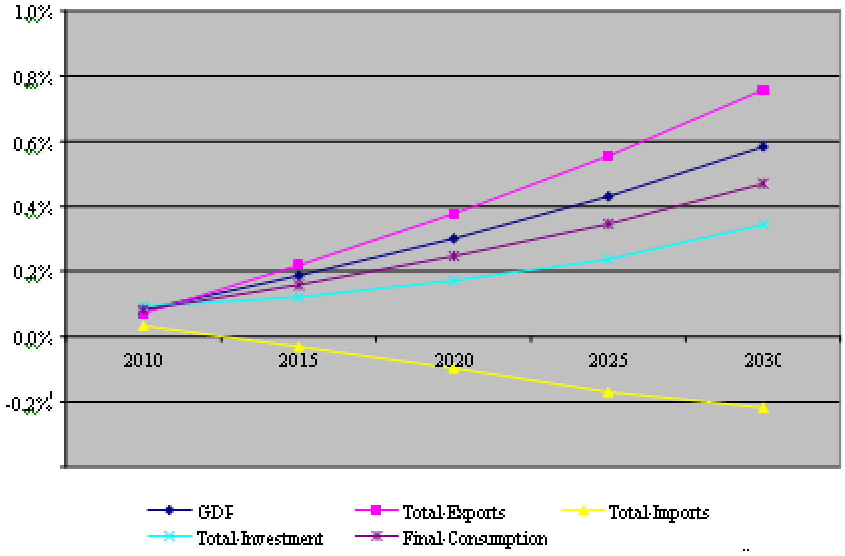
	2010	2015	2020	2025	2030
GDP	0,08	0,16	0,25	0,35	0,45
GDP Corrected for quality	0,15	0,32	0,41	0,58	0,69
Extra European Exports	0	0,15	0,31	0,47	0,64
Extra European Imports	0,08	-0,02	-0,11	-0,21	-0,27
Total Investment	0,1	0,13	0,17	0,22	0,29
Final Consumption	0,11	0,2	0,3	0,41	0,52
Total Factor Productivity	0,05	0,05	0,1	0,1	0,15
R&D Intensity*	0,036	0,04	0,046	0,052	0,059
Quality of products	0,1	0,2	0,2	0,3	0,3
Research Employment**	30,694	37,01	43,728	50,438	58,568
Total Employment**	115,003	154,859	219,631	304,798	428,232

In 2030, with a growth rate of R&D European subsidies of 3.87% after 2010, the R&D intensity increases by 0.06%. The twenty years that separate the end of the 7th PCRD to the end of the simulation exercise allow the R&D to produce all its positive effects on factors productivity and products quality. At this horizon, the positive gap in GDP, 0.45%, is stimulated by the increase in demand due to the decrease of production costs and prices. European competitiveness is re-unforced, with a rise of exports of 0.64%, while imports decrease about 0.27%. Employment gains are also very important, with 428,282 new jobs in 2030, 58,568 created directly in the research sector.

For Member States, the impact of the doubling of European RTD funding from the 7th program will be of course contrasted, depending principally on the extent to which they will beneficiate from the increase of European funding, that is to say, following the Grandfathering principle used here to allocate subsidies, to the initial level of their RTD effort. We decided for that reason, and for illustration, to select three representative countries: Germany who is one of the major actors in Europe in term of R&D effort and also the major beneficiary of European subsidies, Sweden with the higher level of RTD intensity, close to 4% GDP, that will benefit fully of the increase of R&D funding and Greece that is the EU-15 country having the lowest level of RTD intensity: 0.36% GDP in 2000 versus about 2% for the EU-15 average.

For Germany, the increase of European funding will raise Germany's GDP R&D intensity from 0.05% in 2010 to 0.07% in 2030. The GDP increases in a regular way from 2006 to 2030, with maximum increase of 0.06% in 2030 (deviation from reference scenario). Thanks to its high level of R&D intensity (2.1% in 2005), the absorption capacity of new innovations and externalities are very important in Germany

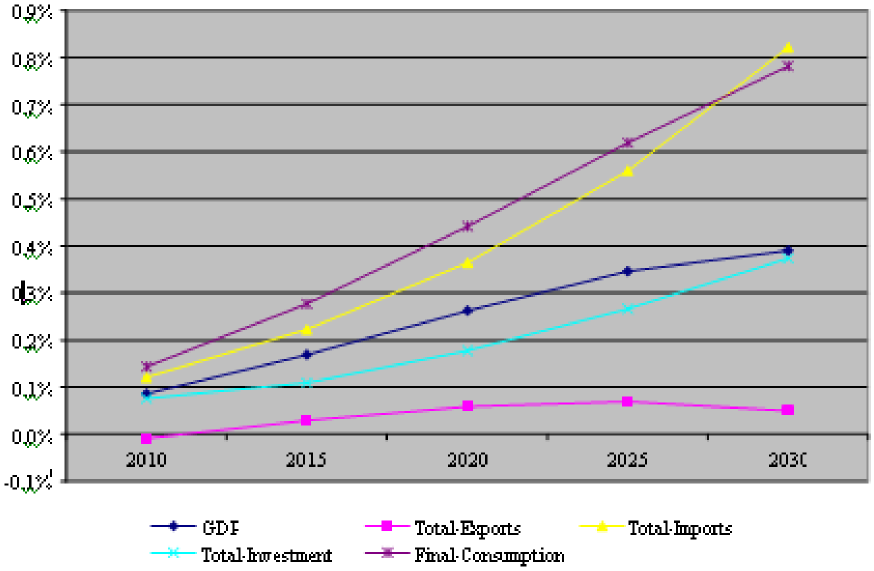
Figure 5: “Grandfathering” Scenario - Macro-Economic Results for Germany



Source: NEMESIS model

The doubling of European R&D funding from the 7th program allow Germany to improve its competitiveness, inside and outside Europe, as attested by the regular rise of its total exports that reach until 0.8% in 2030. In spite of the important rise of its interior demand, Germany imports decrease from 2010, and final consumption increases strongly, thanks to the important rise of Total Factor Productivity and of products quality, as also observed for Europe as a whole. Productivity gains limit the rise in investment that increases only 0.3%, against 0.8% for GDP. Productivity gains also limit jobs creation, but the 0.8% additional GDP growth allows nevertheless the creation of 147,000 additional jobs in 2030, 17,000 being linked directly to R&D activities.

Figure 6: “Grandfathering” Scenario - Macro-Economic Results for Greece



Source: NEMESIS model

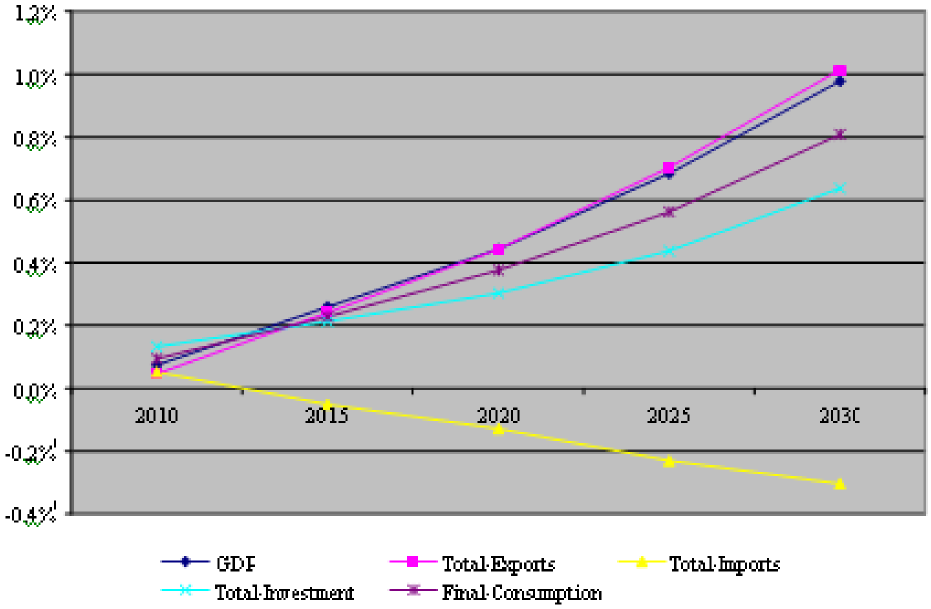
For Greece, the rise in GDP is among the weakest of Europe: Only 0.1% increase in 2010 and a maximum of 0.4% in 2030. More than the rise of its R&D effort, Greece beneficiates from the innovations realized in other European countries: Import prices decrease and this induces a reduction of final consumption (and investment) prices that stimulates final consumption. For this reason, the increase in final consumption (0.8% in 2030) is very important compared to the GDP increase in Greece (only 0.4% in 2030) where total imports grow at the same rate that final consumption: 0.8% in 2030, while, on the contrary, total imports tend to decrease in the most R&D intensive countries as Germany and Sweden.

For the same reasons, jobs creation stays very limited in Greece, with only 3 thousands.

For Sweden that has the higher level of R&D intensity in Europe, the rise of economic activity is the more important. GDP gains increase regularly and reach until close 1% in 2030. The important rise of total factor productivity and product quality allow Sweden improving importantly its competitiveness, with exports that increase also 1% in 2030, while its imports are reduced of 0.3% (due essentially to the decrease of 0.6% of the its intra-European imports).

The relative competitiveness of Sweden, on the European scene, is thus strengthened, and in Sweden, more than in others European countries, it is external trade that boosts GDP. Final consumption increase only 0.8% (against 1% for GDP) in 2030, while it increase faster than GDP in most others European countries. Finally, 30,000 new jobs are created in Sweden in 2030, with 10% in the domain of research.

Figure 7: “Grandfathering” Scenario: Macro-Economic Results for Sweden



Source: NEMESIS model

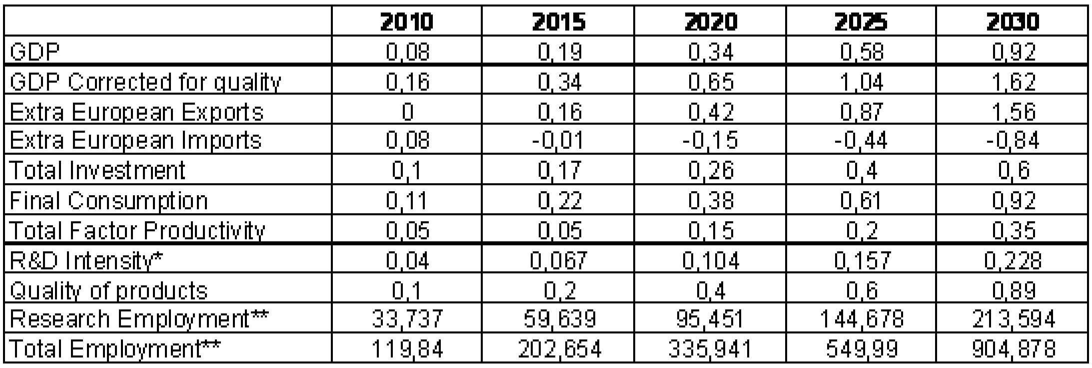
5.2.3. ”*Voluntarist*” Scenario

In this "voluntarist" scenario, we keep the hypothesis adopted in the "grandfathering" scenario according to which the European subsidies are allocated in function of the part of national R&D expenses in the European R&D expenditure. The difference with the previous stays into the assumption made onto the growth of the European R&D funding after the 7th FP: 11.61% per year from 2010 instead of 3.87% previously. The European R&D intensity rises consequently more importantly in this scenario, with an increase of 0.23 GDP point in 2030, versus only 0.06

in the Grandfathering scenario. This scenario can then be seen as ‘Voluntarist’ in that sense that, if one consider the European budget will stay constant and close from 1% European Gross National Income until 2030, the share of the research funding in that budget will reach about one quarter to one third of this budget in 2030, against only 4 to 5% now, a evolution that could illustrate the modifications needed in the way the budget is spent to conform to the Lisbon objective.

The economic mechanisms that play in this scenario stay the same as before, and it is thus only the size of the economic impacts that differ. This time, the GDP increases 0.92% in 2030, that is to say about two times the increase reached in the Grandfathering scenario: 0.45%. For employment, the results show similarly a doubling of impacts: 904,878 new jobs are created against 428,282 previously. It is thus interesting to observe that the economic impacts of the European funding to R&D are not linked linearly with the importance of its rise, but follow a square root relationship: The European funding to R&D increase four times more in this scenario and the impacts on economic performance of Europe are multiplied only by two. This can be explained in two ways: The decreasing of marginal returns to R&D, and the maturation delays of R&D: the sharp rise of the funding all along this scenario do not permit to assess for all the positive impacts on economic activity at the limited horizon 2030, at the difference with the Grandfathering scenario where the rise in R&D funding is made principally at the beginning of the simulation, during the 7th FP.

Table 20: “Voluntarist” Scenario - Macroeconomic Results For Europe



	2010	2015	2020	2025	2030
GDP	0,08	0,19	0,34	0,58	0,92
GDP Corrected for quality	0,16	0,34	0,65	1,04	1,62
Extra European Exports	0	0,16	0,42	0,87	1,56
Extra European Imports	0,08	-0,01	-0,15	-0,44	-0,84
Total Investment	0,1	0,17	0,26	0,4	0,6
Final Consumption	0,11	0,22	0,38	0,61	0,92
Total Factor Productivity	0,05	0,05	0,15	0,2	0,35
R&D Intensity*	0,04	0,067	0,104	0,157	0,228
Quality of products	0,1	0,2	0,4	0,6	0,89
Research Employment**	33,737	59,639	95,451	144,678	213,594
Total Employment**	119,84	202,654	335,941	549,99	904,878

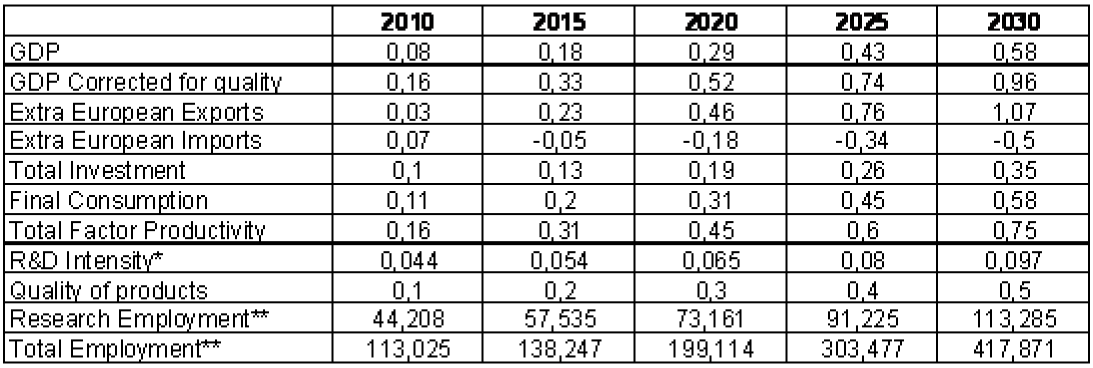
*Source: NEMESIS model. % deviation from reference scenario and ** thousands*

5.2.4. “*Performance*” Scenario

In this scenario, the allocation of additional European funding in made accordingly to the Research performance (Number of publications in scientific journals and number of patent applications) of member states, at the difference of the Grandfathering scenario where it is done proportionally to the initial involvement of Member States into research activities, measured by there respective share in overall European R&D expenditures. This new allocation mode of European funding for R&D as the consequence to concentrate the subsidies in countries and sectors with an initial competitive advantage into R&D activities, that is to say an higher productivity of these activities. Looking at the repartition of patent deposits at European Patent Office, one can state actually that three quarters of the patents deposited by European enterprises are made by German, French, English and Italian firms, with 42% for Germany only. These four countries are also at the origin of the three quarters of the scientific publications, and they will thus receive the four quarters of the additional European R&D funding in this scenario.

This modification of the allocation method of FP funding for the scenario, coupled with a slight increase in the FP funding Crowding-in effect (the crowding-in is 1.4 instead of 1.1 in the two previous scenarios) allow increasing significantly the positive economic impacts of European R&D subsidies at the horizon 2030. Compared to the Grandfathering scenario where the size on European R&D funding is identical, the rise in GDP reaches 0.58% against only 0.45% in this previous scenario, that is to say about one quarter more. But the strongest difference with the Grandfathering scenario stays into to re-enforcement of European competitiveness in this new scenario. The concentration of subsidies in the most efficient countries and production sectors allow in this way to multiply by 5 the impacts onto Total Factor Productivity that increase 0.75% against only 0.15% in the other scenario, with equally a doubled impact onto the rise in product quality. This improved competitiveness is also reflected by external trade figures, with also nearly doubled impacts compared to the Grandfathering scenario. But this re-enforcement of competitiveness through increased Total factor Productivity has also a negative aspect: Employment do not grow more than into the Grandfathering scenario, and is even slightly reduced compared to this scenario, the higher rise in productivity leading also to additional jobs destruction, not fully compensated by the additional rise in GDP and aggregated production.

Table 21: "Performance" Scenario - Macroeconomic Results For Europe



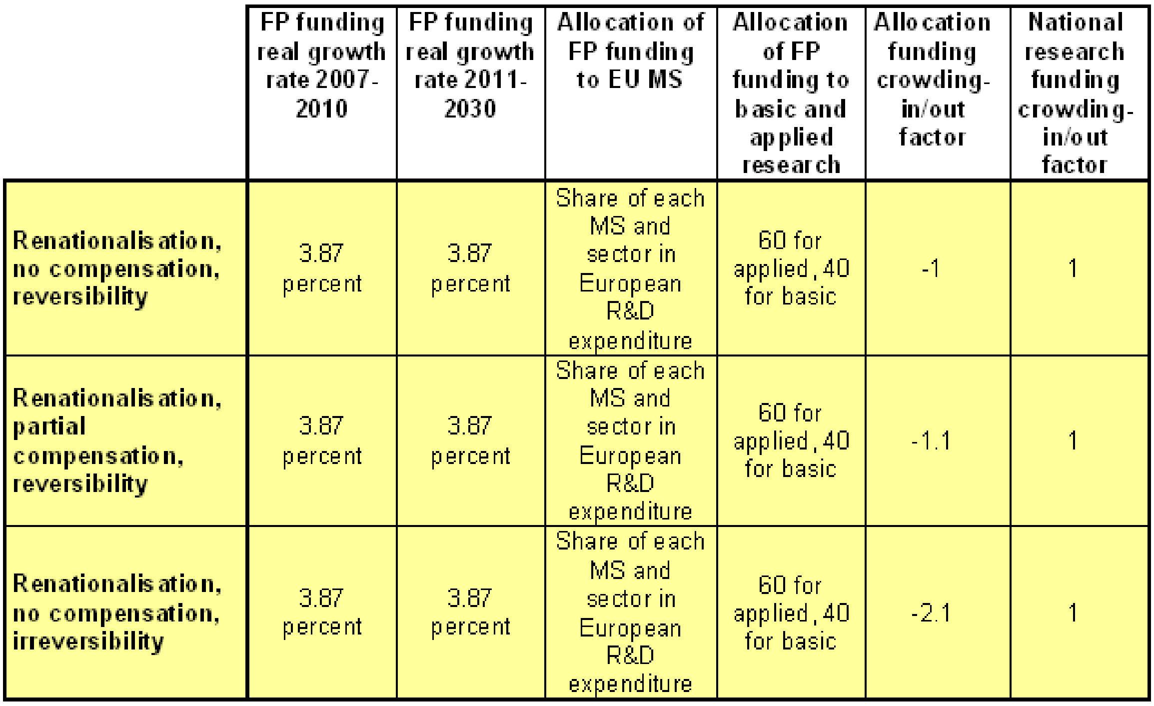
	2010	2015	2020	2025	2030
GDP	0,08	0,18	0,29	0,43	0,58
GDP Corrected for quality	0,16	0,33	0,52	0,74	0,96
Extra European Exports	0,03	0,23	0,46	0,76	1,07
Extra European Imports	0,07	-0,05	-0,18	-0,34	-0,5
Total Investment	0,1	0,13	0,19	0,26	0,35
Final Consumption	0,11	0,2	0,31	0,45	0,58
Total Factor Productivity	0,16	0,31	0,45	0,6	0,75
R&D Intensity*	0,044	0,054	0,065	0,08	0,097
Quality of products	0,1	0,2	0,3	0,4	0,5
Research Employment**	44,208	57,535	73,161	91,225	113,285
Total Employment**	113,025	138,247	199,114	303,477	417,871

5.2.5. An assessment of the impact of an abandonment of European research programs

The objectives were finally to assess for the impact of European R&D funding *per se*: What should be in the absence of European supports to R&D? and what is the economic impact of these supports?. It considers in this way abandonment an of European research programmes in two situations: Member States do or do not compensate, totally or partially, the abolishment of European subsidies by National subsidies.

The effects of the abolishment of European funding for R&D depends actually on the one hand, of the importance of national compensation, but also, on the other hand, of the reversibility of FP funding crowding-in effect onto European firms RTD effort. If the compensation of the European subsidies by the states is total, the macroeconomic impact of the "re-nationalisation" of the R&D funding will be very weak, coming mainly from the difference, 'in nature', between national and European subsidies. We considered for this reason, as displayed in Table 22, only the cases of no compensation by member-states of European supports with reversibly of the crowding-in effect of European subsidies onto firms RTD effort of partial compensation (50%) by Member States of European funding, with this time also reversibility of the crowding-in effect of European subsidies. We consider finally the case more favourable that case 5.1, of no compensation but irreversibility of the crowding-in effect.

Table 22: Assumptions for Scenarios of Abandonment of European Research Programs



	FP funding real growth rate 2007-2010	FP funding real growth rate 2011-2030	Allocation of FP funding to EU MS	Allocation of FP funding to basic and applied research	Allocation funding crowding-in/out factor	National research funding crowding-in/out factor
Renationalisation, no compensation, reversibility	3.87 percent	3.87 percent	Share of each MS and sector in European R&D expenditure	60 for applied, 40 for basic	-1	1
Renationalisation, partial compensation, reversibility	3.87 percent	3.87 percent	Share of each MS and sector in European R&D expenditure	60 for applied, 40 for basic	-1.1	1
Renationalisation, no compensation, irreversibility	3.87 percent	3.87 percent	Share of each MS and sector in European R&D expenditure	60 for applied, 40 for basic	-2.1	1

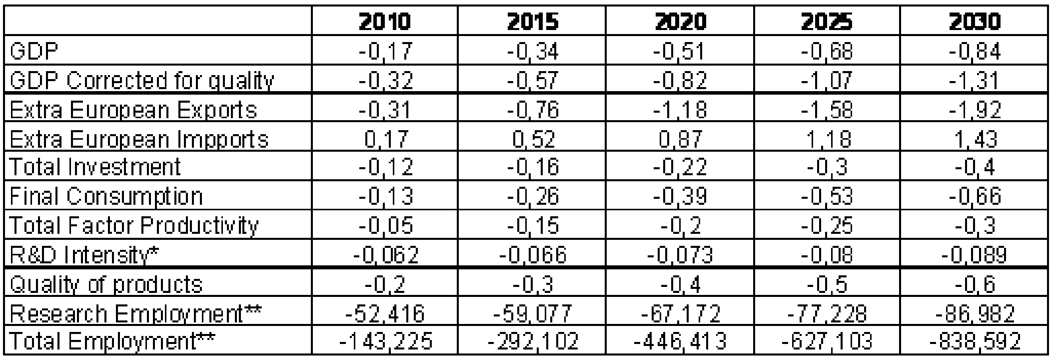
For the realism of the exercise, the results of both simulations are then compared with the results of ‘Grandfathering’ scenario that considers a doubling of European RTD funding from the 7th FP, as this increased into the size of FP was already adopted (The actual rise of FP size is about 80% for the 7th programme).

5.2.6. Renationalisation, no compensation, reversibility

We suppose in this scenario that European states maintain constant the level of national subsidies to R&D without compensation for FP funding abandonment, and that FP funding crowding-in effect onto private R&D expenditures is reversible (for one euro fall of European subsidies, enterprises spend 2,10 euros less R&D).

One can see that, in this scenario, GDP (valorised by the quality) decreases about 1,3% in 2030 (0,8% if we do not take into account the changes into product quality) and Europe loses about 838,000 jobs at this 2030 horizon. This case is thus by construction symmetric to ‘Grandfathering’ scenario, with impacts about two times more important, and in the inverse direction.

Table 23: Macroeconomic Results for Europe



	2010	2015	2020	2025	2030
GDP	-0,17	-0,34	-0,51	-0,68	-0,84
GDP Corrected for quality	-0,32	-0,57	-0,82	-1,07	-1,31
Extra European Exports	-0,31	-0,76	-1,18	-1,58	-1,92
Extra European Impports	0,17	0,52	0,87	1,18	1,43
Total Investment	-0,12	-0,16	-0,22	-0,3	-0,4
Final Consumption	-0,13	-0,26	-0,39	-0,53	-0,66
Total Factor Productivity	-0,05	-0,15	-0,2	-0,25	-0,3
R&D Intensity*	-0,062	-0,066	-0,073	-0,08	-0,089
Quality of products	-0,2	-0,3	-0,4	-0,5	-0,6
Research Employment**	-52,416	-59,077	-67,172	-77,228	-86,982
Total Employment**	-143,225	-292,102	-446,413	-627,103	-838,592

Source: NEMESIS model. % deviation from reference scenario and ** thousands

5.2.7. Renationalisation, partial compensation, reversibility

This additional scenario consisted in analysing the effects of a partial compensation of the abandonment of FP funding by Member States, with the assumption of reversibility of FP funding crowding-in effect (for 1 euro subsidies non allocated by the FP, enterprises decreases their R&D expenses of 2.10 euro, but a national subsidy of 0.50 euro allow them to increase their R&D expenses by 1 euro). The *ex-ante* effect of the European subsidies abandonment will then be 1.10 euro fall of R&D effort for 1 euro cut of R&D subsidies.

Table 24: Renationalisation, no compensation, reversibility scenario

	European Union	**Germany**	**Greece**	**Sweden**
GDP	-0,29	-0,34	-0,27	-0,63
GDP corrected for quality	-0,53	-0,58	-0,43	-0,94
Research Employment**	-38,548	-11,109	-0,191	-2,2
Total Employment**	-216,504	-65,848	-3,166	-15,648

Source: NEMESIS model. % deviation from reference scenario and ** thousands

One can see that this partial compensation of European funding abandonment by Member States limits the negative impacts on GDP that decreases only 0.29% in 2030, against 0.84% in the preceding scenario without compensation, but the negative impacts on employment remains not negligible (-216,504 jobs for the whole Europe).

5.2.8. Renationalisation, no compensation, irreversibility

In this scenario, there is no compensation of FP funding by the European countries and there is irreversibility of FP funding crowding-in effect (One euro European subsidies in less implies a decrease of private R&D expenditures by one euro). The *ex-ante* impact onto European countries RTD effort, 1 euro fall for 1 euro cut of European R&D subsidies, is very close from the situation in case 5.2 of partial compensation above, and, for this reason, the economic impacts are also similar but stronger, as stated in Table 25. The fall in GDP is 0.35% against 0.29% previously, and the fall in jobs creation reaches 343,631 against only 216,504 before

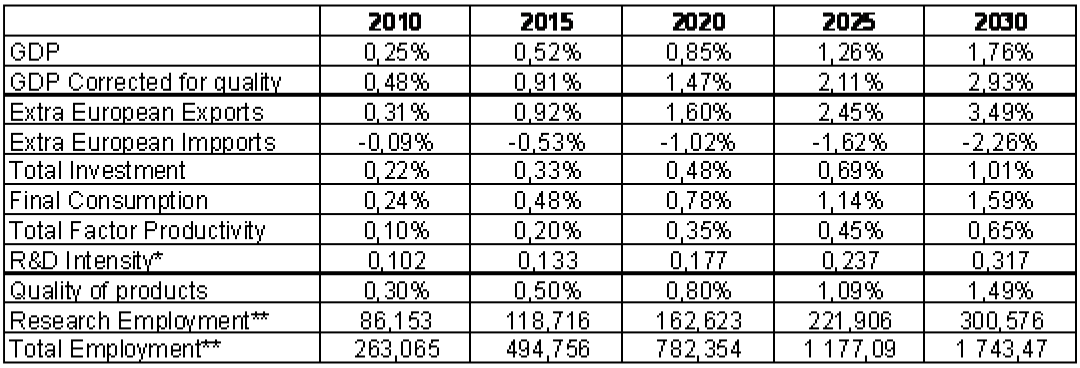
Table 25: Renationalisation, no compensation, irreversibility scenario:

	European Union	**Germany**	**Greece**	**Sweden**
GDP	-0,35	-0,4	-0,3	-0,7
GDP corrected for quality	-0,59	-0,63	-0,46	-1
Research Employment**	-35,74	-10,206	-0,175	-2,039
Total Employment**	-343,631	-92,649	-4,644	-20,682

Source: NEMESIS model. % deviation from reference scenario and ** thousands

Finally, we assess the potential economic impacts of European funding for R&D over the next 20-25 years. We considered for that the case of the volontarist scenario, that fixes an high objective for European research budget at 2030 horizon (about 0.25 European GNI point), compared with the hypothetical situation of inexistence of FP, that corresponds to the case of abandonment of FP funding with reversibility and no compensation. The difference between the results of these two variants provide thus well the potential economic impact of future FP programmes, in the context of the realization of Lisbon objective in the area of Research and knowledge formation. The macroeconomic results of this comparison are provided in Table 26.

Table 26: Assessment for Potential Impacts of FP funding



	2010	2015	2020	2025	2030
GDP	0,25%	0,52%	0,85%	1,26%	1,76%
GDP Corrected for quality	0,48%	0,91%	1,47%	2,11%	2,93%
Extra European Exports	0,31%	0,92%	1,60%	2,45%	3,49%
Extra European Impports	-0,09%	-0,53%	-1,02%	-1,62%	-2,26%
Total Investment	0,22%	0,33%	0,48%	0,69%	1,01%
Final Consumption	0,24%	0,48%	0,78%	1,14%	1,59%
Total Factor Productivity	0,10%	0,20%	0,35%	0,45%	0,65%
R&D Intensity*	0,102	0,133	0,177	0,237	0,317
Quality of products	0,30%	0,50%	0,80%	1,09%	1,49%
Research Employment**	86,153	118,716	162,623	221,906	300,576
Total Employment**	263,065	494,756	782,354	1 177,09	1 743,47

Source: NEMESIS model. % deviation from reference scenario and ** thousands

As one can state at the lecture of the figures, the European funding for Research could potentially impact very importantly, and positively growth and competitiveness of European countries at the horizon 2030. The potential gains for GDP establish to the level of about 1.76%, and 2.93% if one take into account the improvement in the quality of good and services produced by European firms. The impact on R&D intensity is about 0.32 GDP point increase in 2030, that is to say an additional annual GDP growth of about 0.15% in long term, as we assessed for by expanding the simulation horizon. The gains for European employments could also be very important, with about 1.7 million jobs in 2030, that could not be created in the absence of European framework Programmes for research.

6. Foresight and assessments for environmental policies

6.1. Objectives

The objectives were to provide useful tool to assess for European energy and environmental policies with the NEEM, NEMESIS and GEM-E3 models[1]. Furthermore, it assesses the different options for implementing R&D policies, renewable energy and GHG objectives taking into account the new proposition ″to achieve 20% reduction greenhouse gases by 2020 compared to 1990 for EU-27″ (which should be increased to 30% in case of a comprehensive international climate change agreement), ″to establish a bonding target of 20% for the renewable energy share of EU final energy consumption″ and the 10% biofuels share in transports gasoline and diesel sub-target .

The policy scenarios that were examined in this work-package 5 are the following:

- NEEM, limited to EU-15 countries, examines different cases of efficient implementation of EU ‘Energy and Environment package’, that calculate the carbon balance price for ETS sectors and one unique carbon price for non EU ETS sectors. The results of NEEM were notably used to calibrate some mechanisms of NOMEDE;
- GEM-E3 was similarly used to study efficient implementation of EU ‘Energy and Environment package’ for EU-27, with two types of auctioning revenue recycling: an increase in households’ social benefits, and a combination of R&D subsidy, up to 25% and increase in social benefits. Other policy scenarios were studied with GEM-E3 as R&D subsidy policies, and local pollutants abatement policies. All policies studied with GEM-E3 compare also the case were R&D is endogenous and when it is considered exogenous, and use consequently two different versions of the model;
- with NEMESIS/NOMEDE, the focus was put on the economic consequences in 2020 of the joint implementation of the ‘EU ETS review’, ‘non ETS effort-sharing’ and ‘renewables’ directive and decision proposals. Different scenarios were explored depending on the way auctioning revenues are recycled by States, and compared on the basis of economic and environmental efficiency criteria defined by the Commission.

6.2. Results

6.2.1. Cost Effectiveness Scenarios for EU ‘Energy and Environment package’ with NEEM (EU-15)

In order to address the twin sustainability challenges of: a) leading the way towards a stronger post-Kyoto climate mitigation policy and b) promoting energy security through the development of indigenous energy resources, the European Council has decided in the spring of 2007 to propose the following targets for the EU: a) reduce GHG at least by 20% in 2020 compared to 1990 levels; b) supply 20% of final energy needs by 2020 with renewable energy sources (RES), including the use of biofuels at 10% of liquid fuels in road transport; c) give priority to energy efficiency in all energy domains.

In response to the Council proposal the European Commission has, in January 2008, proposed a full policy package of implementation measures to meet the EU's objectives on climate change and

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[1] In accordance with the Commission, the objectives of the WP5 have been updated to take into account the *Climate Action and Renewable Energy Package* Package (January 2008) instead of the assessments for environmental technology policies. Moreover, part of the results presented in the deliverable D7 is discussed here.

renewable energy for 2020.The package consists of legislative proposals including three actions: a) Amendment of Directive 2003/87/EC so as to improve and extend the EU greenhouse gas emission allowance trading system; b) Decision on the effort of Member States to reduce their greenhouse gas emissions to meet the Community’s greenhouse gas emission reduction commitments up to 2020; c) Directive on the promotion of use of renewable energy sources.

The analysis of the implications on the energy system with particular emphasis on technology deployment for the scenario of the implementation of European Commission proposal was carried out using the NEMESIS Energy-Environment Module (NEMESIS-EEM). The main quantitative characteristics of the scenario as implemented with NEMESIS-EEM is summarised in the Table 27. It covers only fourteen member states in accordance of present regional classifications within the module.

Table 27: Scenario objectives

	2020	2025
GHG emissions compared to 1990	-20%	-25%
Renewables in final demand	At least 20%	
Biofuels share in road transport	At least 10%	

• The baseline scenario

It is assumed that the Baseline scenario does not address Kyoto and post-Kyoto objectives. However, for this scenario it is assumed that the current ETS system continues to operate and that it balances at low prices of emission permits. This reflects absence of further climate policy measures in the European Union. It is assumed that the ETS system induces a carbon permit price of 20€/tCO2, which is increasing to 23€/tCO2 by 2025. This is applied as an opportunity cost on all uses of fossil fuels in proportion to their emission of CO2.

Regarding the electricity generation from nuclear energy the current decisions concerning it are assumed to persist also in the longer term. This implies that the announced nuclear phase-out is implemented and that member states which do not have already installed nuclear plants do not invest in the long term.

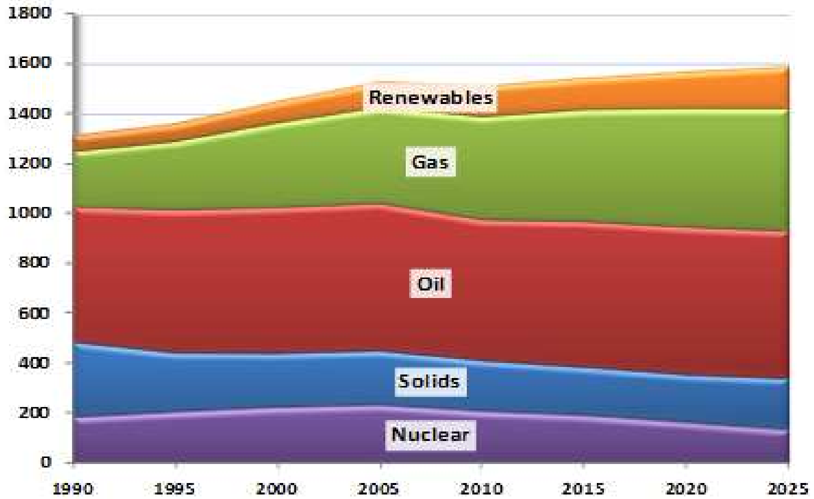
The baseline scenario assumes that high prices, as observed in the past two years, will persist in the future as result of resource constraints, continuous growth of global energy demand and increasing dependence on non conventional oil, which is associated with high extraction costs. Natural gas prices are projected to continue to be tightly linked with oil prices and Natural gas is potentially a substitute to oil, the demand for gas is expected to rise worldwide and its cost-supply relationship reflects highly increasing marginal costs. Coal prices are projected to rise at much lower rates than oil and gas because of high coal resources and more favourable geopolitics. This implies that the competitiveness of gas vis-à-vis coal steadily deteriorates. The relationships between world energy demand, fossil fuel resources and world energy prices have been analysed by using the Prometheus stochastic world energy model, which ensures consistency of world energy developments and the trajectory of energy prices.

The results of the baseline scenario show that, despite the evidence of relative saturation for certain energy uses in the EU-14, energy demand is likely to continue to grow, albeit at rates significantly lower than those experienced in the recent past. The average annual growth rate in the regions’ gross inland consumption over the 2000-2025 period is projected to be 0.5%, which is half the rate observed over the 1990-2000 period. This slowdown results from improvements in energy efficiency, the continuing de-materialisation of industrial production and the restructure of the European economies away from the primary and secondary sectors towards services.

The projection to 2025 for the baseline scenario shows a slight acceleration of the decoupling of energy consumption from GDP growth, as compared to past trends, a trend which is also attributed to the assumption that oil and gas prices are following an increasing pace throughout the projection horizon. Renewable energy forms are projected to remain the fastest growing energy forms in the EU-14 energy system, as was the case over the last few years and Renewable energy forms are projected to grow at a rate of 2.5% per year on average between 2005-2025 (the growth rate for the decade 2000-2010 is expected to be 3.5% per year). This trend is partly due to the supportive policies for renewables but is also an outcome of economic considerations given that power from renewables, particularly wind power, displays increasing economic competitiveness over time. Biomass is also likely to develop as a result of policies imposing a certain share of bio-fuels in automotive fuel supply and the increasing use of biomass and waste in certain niche market applications, particularly in CHP.

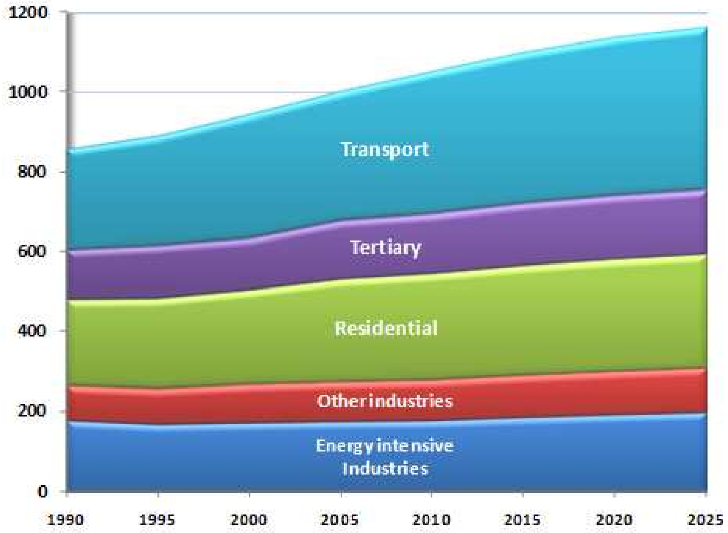
Despite high oil prices, the baseline scenario shows that total energy demand for petroleum products is likely to remain at a high level and to be more or less stable in volume throughout the period until 2025. Oil products tend to be used almost exclusively in specific energy uses (transport and petrochemical). Solid fuels are experiencing a decline in their market share during the forecasting horizon from 14% in 2005 to 12.5% in 2025. However, the trajectory of solid fuels use is in some ways reciprocal to gas use trajectory since their annual growth rate is -1.2% pa for the period 2005-2015 and +0.6%pa for the period 2015-2025. Especially in the last five years of the projection, the growth rate of solids in primary energy needs is +1.3% pa. This is due to the fact that, besides certain specific uses of coal in industry which remain rather stable in time, coal and lignite compete mainly against gas in power generation. In the long term and especially beyond 2015, the increasing competitiveness of imported coal drives power expansion through new coal plants. In addition, decommissioning of nuclear plants and phase-out in some countries drives further growth of the use of solid fuels.

Figure 8: Primary energy needs in the baseline scenario in EU-14 in Mtoe



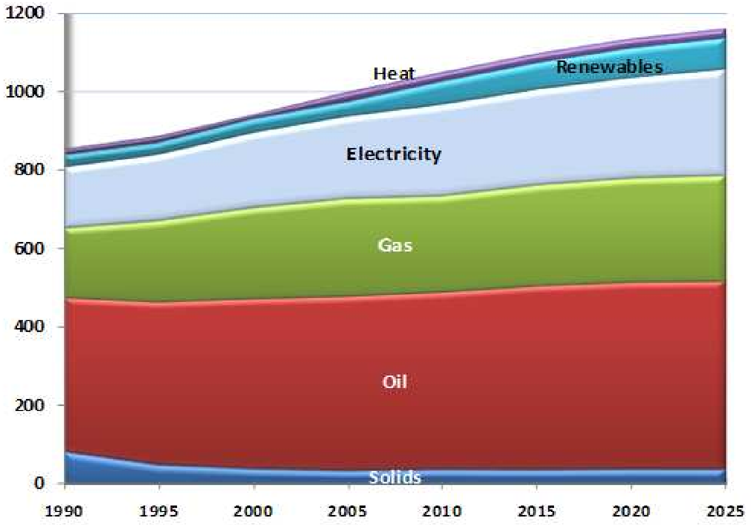
By 2025 the level of indigenous production of fossil fuels will be 70% lower than in 2005 for oil and 37% for natural gas. Increasing primary energy demand for oil and gas together with declining primary production leads to a considerable increase of dependence of the EU-14 energy system on imports. The overall import dependence indicator, from 55% in 2005, rises to 68% in 2025. The dependence on imports is more pronounced for natural gas than for oil. The share of energy intensive industry in total final energy consumption displays a small decrease throughout the projection period, going from 18% in 2005 down to 17% in 2025. Energy consumed in the trade and services sector, agriculture and households increases at an average annual growth rate of 0.5% p.a from 2005 to 2025. The share of this sector in final energy consumption also displays a small decrease from 41% in 2005 to 40% in 2025 as a result of the saturation in energy uses and efficiency gains. Energy demand for transport grows considerably in the short and medium term. Energy used in transport increases its share in final demand from 32% in 2005 to 34% in 2025.

Figure 9: Final demand by sector in Mtoe (EU-14)



Final demand for the more polluting fuels (see also Figure 12), such as solids and residual fuel oil, is declining. Conversely, the demand for lighter oil products, mainly diesel oil and gasoline, reserved primarily for transport and secondarily for chemicals remains stable. Final demand for natural gas increases throughout the projection period albeit at rates that are slowing down over time. The expanding use of electricity in all sectors is projected to continue in the baseline scenario, as also exhibited in past trends. According to baseline results, electricity demand grows at an average annual rate of 1.3% in the period 2005-2025 and reaches a market share of 23% by 2025 steadily growing from a share of 18% in 1990. This is due to the clear advantages of electricity use such as easy controllability and cleanliness at the point of use as well as to the technological progress, comfort and competitiveness of the numerous processes, appliances and applications that can use energy only in the form of electricity. The use of renewable energy in thermal uses of final energy demand sectors advances over time, particularly in the long term driven by the increasing use of bio-fuels in automotive transportation. For the baseline scenario it is projected that bio-fuels penetrate up to 10% in total use of oil products in cars.

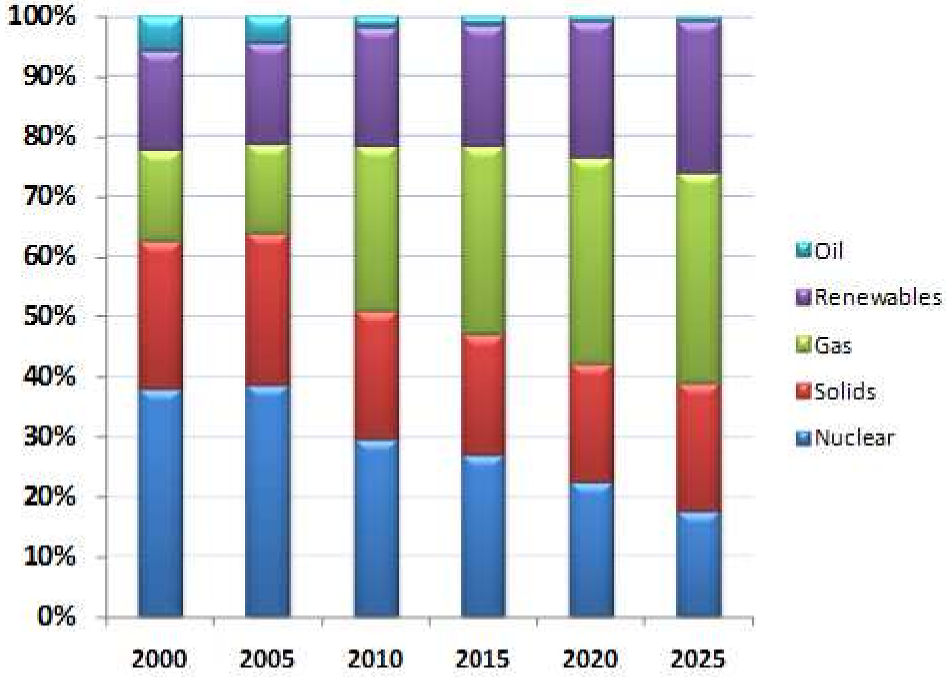
Figure 10: Final demand by fuel in EU-14 (Mtoe)



The demand of electricity, which is driven by the expansion of specific electricity uses, results in considerable investment in power generation sector in the baseline scenario. In the short term power generation investment is dominated by combined cycle gas as a result of construction commitments taken in the past. Coal-based power is also favoured by the diminishing contribution of nuclear in base load, since nuclear energy gradually decreases as a result of nuclear policy assumed in the baseline. Coal-based power, which represented 24% of total power generation in 2005, decreases in the short term to 20% in 2015 and then increases to 22% in 2025.

Renewables used for power generation show a remarkable development. Wind power, in particular, displays economic competitiveness over time and as a consequence onshore wind develops rapidly in the short and medium term: the installations of wind onshore turbines increases from 40GW in 2005 to 116GW in 2025. Biomass based power generation displays significant development in the baseline scenario. This development includes power from waste energy which is an attractive option in certain specific cases but is limited in volume, as well as co-firing of solid fuels with biomass in conventional power plants. Finally, the development of solar energy, mainly photovoltaic technology, is far slower. Despite the business-as-usual character of the baseline scenario, renewables-based electricity (including large hydro) develops fast and becomes in 2025 larger than total coal generation and also larger than nuclear electricity.

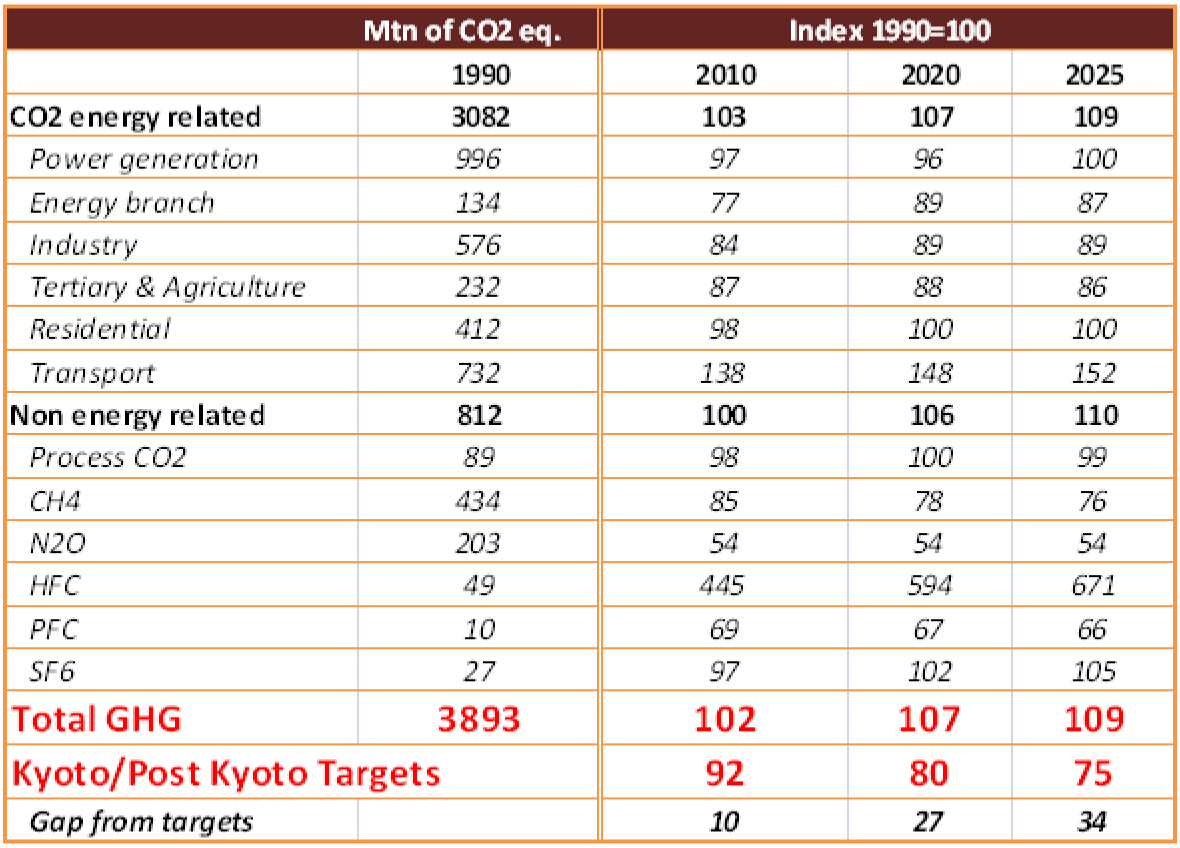
Figure 11: Electricity generation by source in the baseline scenario (EU-14)



The Baseline scenario shows that business-as-usual trends imply increasing carbon dioxide emissions. The gap between business-as-usual emissions and the emissions permitted by Kyoto and post-Kyoto policies is widening continuously. The gap is almost 12% of total energy-related emissions in 2012 and rises to slightly above 30% in 2025 (for a target of -25% from 1990). The Baseline scenario clearly fails with respect to climate change mitigation aspirations. The emissions could be considerably higher if the Baseline scenario did not involve significant decrease of energy intensity of the economy. For energy efficiency, resulting from structural changes in the economy, technological progress and saturation, are the main reasons for obtaining stabilisation or low growth of carbon intensity of GDP in the Baseline scenario.

The carbon intensity of electricity generation drops throughout the projection period at an average rate of 2% per year. Average emissions from 0.44 tCO2 per MWh in 2005 decline to 0.3 in 2025. This is mainly the outcome of using more gas in power generation. Beyond 2020, the carbon intensity of power generation almost stops to improve, despite the rapid growth of renewables used in power generation. This long term trend is a result of using more coal in power generation and the decline of nuclear energy. The improvement in the carbon intensity of the power generation is due to changes in the mix of fossil fuels in the medium term, the improvement of thermal efficiency and the high growth of renewables in the long term. The growth of renewable energy in power generation does not counterbalance the decline of nuclear energy as regards CO2 emissions. Carbon-free power, albeit its increase in volume keeps a non increasing share in total power generation. The share of power generation in total energy CO2 emissions remains almost stable during the forecasting horizon at around 30%.

Table 28: Evolution of GHG emissions in the baseline scenario compared to their 1990 levels in EU-14 and gap of the baseline scenario from Kyoto target



	Mtn of CO2 eq.	Index 1990=100		
	1990	2010	2020	2025
CO2 energy related	**3082**	**103**	**107**	**109**
Power generation	*996*	*97*	*96*	*100*
Energy branch	*134*	*77*	*89*	*87*
Industry	*576*	*84*	*89*	*89*
Tertiary & Agriculture	*232*	*87*	*88*	*86*
Residential	*412*	*98*	*100*	*100*
Transport	*732*	*138*	*148*	*152*
Non energy related	**812**	**100**	**106**	**110**
Process CO2	*89*	*98*	*100*	*99*
CH4	*434*	*85*	*78*	*76*
N2O	*203*	*54*	*54*	*54*
HFC	*49*	*445*	*594*	*671*
PFC	*10*	*69*	*67*	*66*
SF6	*27*	*97*	*102*	*105*
Total GHG	3893	102	107	109
Kyoto/Post Kyoto Targets		92	80	75
Gap from targets		***10***	***27***	***34***

Carbon intensity of industry declines by 0.4% pa, as result of the improvements in energy efficiency and the de-materialisation of the sector. Similar to the power generation, the share of industry energy-related CO2 emissions remains almost constant in the period 2005-2025 at around 15%. Direct energy CO2 emissions from the residential sector remains at their 1990 levels, due to the further electrification of the sector. In this sense, the share of households in total energy related CO2 emissions remains stable at around 13%. The electrification of the tertiary sector, on one hand, and the further decline of agriculture sector on the other hand, result in a constant share in total direct emissions also for trade and services sectors at 6%. The sector which increases its share in CO2 emissions is the transport sector. In the absence of new and clean technologies for road transport in the period up to 2025, the biofuels introduction is not sufficient to reduce the emission of the sector. As a result, the share of transport increases from 32% in 2005 to 33% in 2025.

The share of energy related CO2 emissions in total GHG emissions remains constant through the forecasting period at around 80%. As it can be seen from Table 28, the energy related CO2 emissions are 9% higher than their 1990 levels in 2025, while the non-energy GHG are 10%. For Methane emissions, most of these emissions are emitted in gas production and transportation together with venting and flaring of gaseous compounds in oil production. Methane emissions from these sectors in the EU are projected to decrease (oil) or marginally increase (gas) due to the declining primary production of these sources (from 9% in 2005 to 7.5% in 2025). HFC emissions are projected to increase strongly in the medium term. Their growth is expected to decelerate in the longer term due to the phasing out of HCFC-22 production in 2020. PFCs emissions related to primary aluminium production are expected to decrease; this is both due to the reduction of aluminium production and to the actions taken by the aluminium smelting companies to reduce the frequency and duration of the anode effects that cause the emissions. As a result the share of HFC emissions in total GHG emissions is 5.4% in 2005, 7% in 2020 and around 7.5% in 2025. The PFC share declines from 17% in 2005 to 15.5% in 2025. N2O emissions are projected to stagnate at around 2.6% of total GHG emissions due to the stable demand for nylon and fertilizers and the Sulphurhexafluoride (SF6) emission is expected to decrease due to the voluntary agreement on SF6 emission reduction partnership of the magnesium industry.

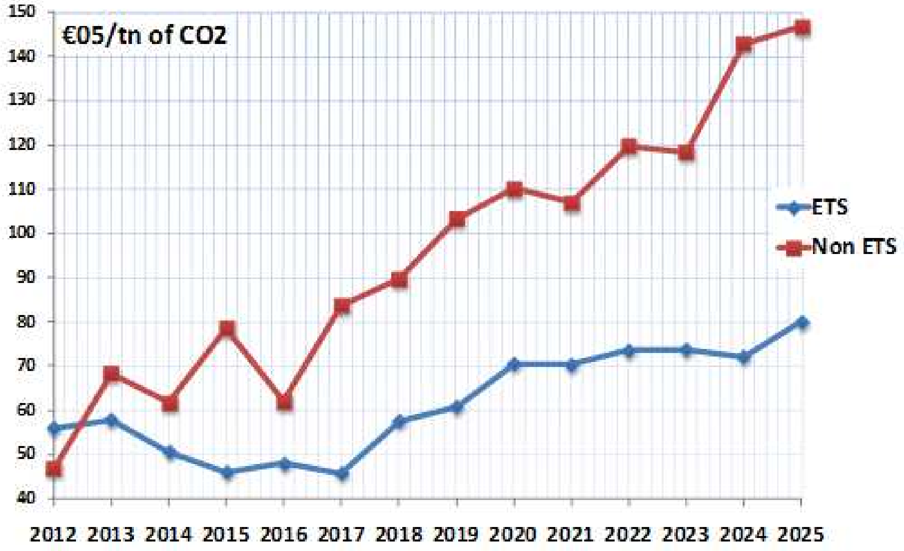
In summary, the Baseline scenario represents an energy future which is efficient with respect to cost of energy but is unsustainable with respect to GHG emissions. According to the Baseline, carbon emissions deviate from targets, both with respect to the Kyoto protocol commitments and to the post-Kyoto. Also, according to baseline projections, energy import dependence of Europe is likely to increase dramatically. Concerns particularly refer to exposure to risk regarding gas procurement conditions and the adverse effects on Europe's power generation sector.

• The abatement scenario

The scenario implementation has involved introducing specific targets for the so called ETS sectors, the rest of the sectors of the economy (non ETS) and the renewable and biofuels constraint. The EU-ETS is a policy instrument already in place involving an EU-wide CO2 emissions cap for electricity plants and major industrial installations that can trade emission permits across member states. The principle on which permit allocation has been made so far is the so called grandfathering principle endowing agents according to historical emissions, total endowments being gradually reduced to ensure overall compliance to the EU-wide cap. For the period to 2020 the major departure is a marked tightening of caps (21% lower than emissions in 2005 by 2020) for the ETS sectors and the gradual introduction of auctioning of permits (full auctioning is foreseen for power plants starting in 2013 and a gradual increase towards the full use of auctioning to allocate allowances to the rest of the ETS sectors, with the exception of those installations exposed to a significant risk of carbon leakage).

Non-ETS sectors, consist of a wide range of sectors covering mostly small scale emitters, such as transport (e.g. cars, trucks), residential and services buildings, small industrial installations, agriculture, etc., including all types of greenhouse gases. These are sectors where energy represents a relatively low portion of costs with very limited possibilities for substitution away from fossil fuels. Consequently the implicit carbon values required to obtain even modest reductions are relatively high. The competence to implement policies regarding the non-ETS sectors is reserved to individual member states, supplemented by EU policies. For the purpose of the current scenario and in order to minimise adverse impact on these sectors or widely differentiated welfare losses it has been assumed that an optimal allocation is made ex-ante implying a uniform marginal abatement cost.

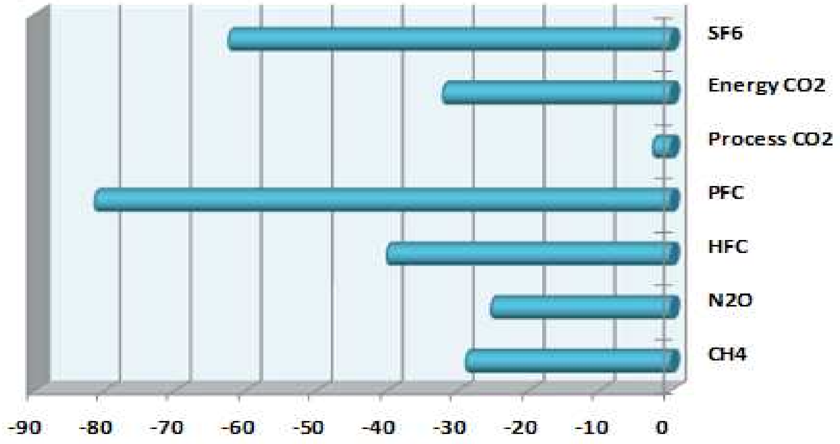
Figure 12: Permit price in ETS and implicit carbon value for non-ETS in €05/tn of CO2



Emission abatement in the scenario is achieved through explicit or implicit carbon values. Explicit carbon values are the prices of emission permits as they emerge from supply-demand equilibrium in the ETS market. In order to achieve the ambitious targets set for the ETS sectors permit prices start around 55€/tn of Co2 in 2012, come down to under 5o€ in the middle of the decade, increase shortly to 70€/tn of CO2 by 2020 and thereafter remain essentially stable. For the non-ETS sectors the scenario does not assume trading and the carbon value indicated represents the marginal cost (the cost of the most expensive ton of emission saved) implicit by the target set across the EU. This marginal value increases almost steadily from around 50€05/tn of CO2 in 2012 to around 150€05/tn of CO2 in 2025. This higher marginal cost value emerges even despite the fact that the target set for the non-ETS sectors are much more modest than those set for the ETS sectors and constitute an indication of the relatively limited potential for abatement in non-ETS. The third legislative proposal, namely the Directive on renewables, also defines differentiated quantitative targets by Member-State and assigns to the Member-States the corresponding responsibility. The proposed Directive improves and extends the Guarantees of Origin (GO) which may be used by the Member-State to trade renewable energy and meet their obligation in a more cost-effective way. The 10% biofuels objective is set as an EU-wide obligation and is included in the renewables target.

Energy related CO2 emission reductions dominate the efforts in meeting the overall target accounting for 73% of total GHG reduction in 2020 target and 80% in 2025 target. As regards other GHGs, PFC emissions experience the sharpest reduction (about 81% in 2025) followed by SF6 and HFC at considerably lower rates (62.5% and 40% respectively). CH4 and N2O emissions are projected to be the least responsive to the introduction of the carbon value, as they decline by around 30% and 25% respectively in 2025. Non-energy CO2 is barely affected at all, as CO2 emissions are an integral part of the process of producing Portland cement and there appears to be no credible alternative to this type of cement in the horizon.

Figure 13: Abatement of GHG emissions per pollutant in EU-14 in 2025 (% changes from baseline)

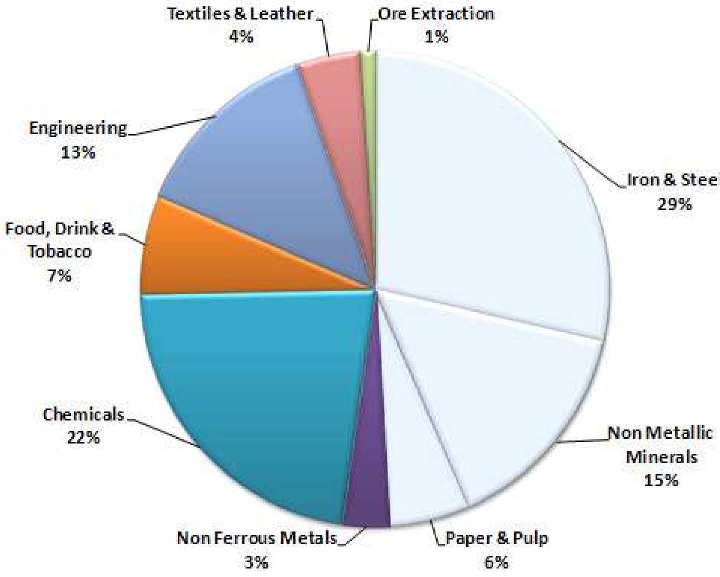


By scenario design the ETS sectors are projected to decline by 50% compared to 1990 levels by 2025. On the other hand non-ETS sectors achieve only a 5% reduction (21% lower than baseline). In the following Figure 16 the CO2 emission percentage changes from 1990 levels and from baseline are presented for each sector.

The abatement effort in industry can be classified in three major categories (see Figure 15 above):

- sectors that make more than 50% reduction in emissions compared to baseline (power generation, non ferrous metals, engineering);
- sectors with reduction between 40% and 50% (ore extraction, chemicals, textiles and leather);
- the other industries that make reductions of about 35% to 20% and include the most of the non energy ETS sectors.

Figure 14: Percentage of contribution of each industrial sector in the CO2 emissions reduction in industry (compared to baseline) in 2025 (EU-14)



Looking at industry as a whole, out of the emission reduction of 38% (compared to baseline in 2025) less than 2% can be attributed to lower industrial activity while just under 13% is due to fuel switching. This implies that the bulk of the abatement is done via a reduction in energy intensity. Some of the latter can be explained by structural movements within the sector away from energy intensive activities/products in response to cost increases passed on to intermediate and final consumers. Reduction is also achieved through investment in less energy intensive processes but also as a result of a large number of small actions leading to a more rational use of energy and often involving little investment in equipment but better organisation and practices.

Emission reductions are also achieved through changes in the fuel mix. Looking at the industry as a whole the main characteristic movement is towards electrification in view of the wide range of low and zero carbon options available for power generation.

Table 29: % fuel shares in industrial final demand in 2025 (EU-14)

	Solids	Oil	Gas	Steam from CHP	Biomass & Waste	Electricity
Baseline	11.2	13.4	32.2	2.7	4.9	35.5
Scenario	7.7	10.9	28.3	3.8	7.1	42.3

The industrial sector also makes a contribution towards the overall renewable target by increased use of biomass and waste to fire boilers. Steam from CHP plants also makes an increased contribution while the electricity they produce enhances the movement towards electrification, while oil and solids naturally lose their share. The biggest reduction occurs for natural gas, which in the baseline played a major role in meeting industrial energy requirements. Unlike the industrial sector, in the trade and services sector fuel switching is more important than demand reduction in explaining emission abatement in the scenario. Apart from an increase in electrification, the services sector also response by increasing renewable energy use, especially in the form of passive solar energy. Like in the case of industry, the main loss in share concerns natural gas (see Table 29).

Table 30: % fuel share in trade and services demand in 2025 (EU-14)

	Solids	Oil	Gas	Steam from CHP & District Heating	Biomass & Waste	Solar & other Renewables	Electricity
Baseline	0.2	10.4	31.8	4.6	1.1	1.3	50.5
Scenario	0.1	8.3	27.4	5.2	1.8	3.6	53.5

The higher electricity prices that characterise the scenario affect specific electricity demand (lighting and electrical appliances) only modestly. On the other hand, according to the scenario, demand for heating, water heating and cooking as a whole declines by 8% between 2005 and 2025 instead of increasing by 6% in the baseline. Both natural gas and gas oil use are heavily influenced by the higher costs implied by the carbon value. On the other hand, unlike the tendency towards electrification observed for other sectors, residential electricity does not change its share. The major shift occurs with regard to solar energy, especially in the form of passive solar systems, and increased use of biomass.

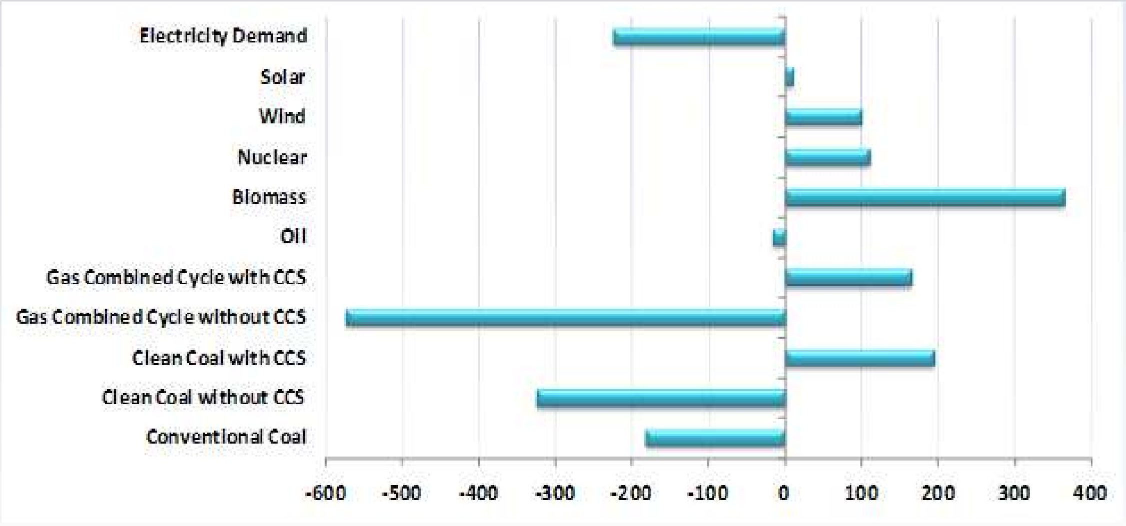
Table 31: % change from baseline in residential demand in EU-14

	2015	2020	2025
Total final demand	**-4.7**	**-8.5**	**-11.4**
Specific electricity use	**-2.5**	**-3.1**	**-4.5**
Heating, Water Heating, Cooking	**-5.3**	**-10.0**	**-13.4**
Solids	*-20.2*	*-34.8*	*-44.8*
Oil	*-20.3*	*-32.3*	*-39.4*
Gas	*-14.1*	*-24.9*	*-33.1*
Heat from CHP & District Heating	*-3.2*	*-4.7*	*-4.9*
Biomass	*35.0*	*45.7*	*54.0*
Solar & other Renewables	*189.1*	*242.5*	*274.8*
Electricity	*-11.2*	*-13.0*	*-15.1*

The power generating sector of different countries is affected differentially depending on the dependence on fossil fuels in the baseline, the ability of the respective electricity sectors to switch to less carbon intensive sources of production as well as the relative cost of the generating options adopted in response to the climate and renewable policies. At the EU-14 level electricity demand stands at 4% below baseline values in 2015, 5% in 2020 and 7% in 2025.

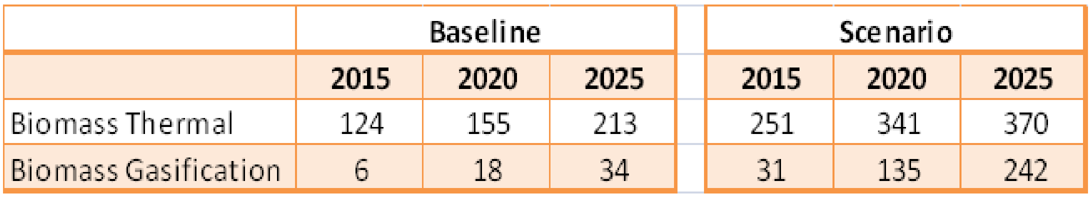
The demand reduction effect is stronger for industrial applications because of a more pronounced activity impact of the scenario as a whole and generally higher long term price elasticities of demand with respect to price especially in the energy intensive sectors. Of course the reduction in demand goes only a small way in explaining the emission abatement associated with the power sector (41% and 57% below baseline in 2020 and 2025 respectively). The remainder is affected through changes in the generation mix favouring low or zero emission options at the expense of carbon intensive ones. Figure 17. below summarises the main shifts in electricity production according to broad options.

Figure 15: Difference in electricity demand and production from the baseline scenario in 2025 (in TWh)



The main vehicle through which the renewable target within the power generating sector is achieved is through a massive search of biomass use. A small part of the feedstock is obtained from urban wood waste and mill residues. These feedstocks tend to be cost effective but very limited in terms of potential. The bulk of the expansion occurs through the use of agriculture residues with a large potential in most member states. Energy crops play a more limited role and are introduced mostly towards the end of the forecast horizon. Due to relatively high projected food crop prices worldwide the crops that are mostly utilised are those that can be grown on marginal land. Finally forestry residues play an important role mostly in Finland and Sweden. In these countries this source has a large potential but the cost is relatively high even for limited applications.

Table 32: Electricity production from biomass in EU-14 in TWh



	Baseline			Scenario		
	2015	**2020**	**2025**	**2015**	**2020**	**2025**
Biomass Thermal	124	155	213	251	341	370
Biomass Gasification	6	18	34	31	135	242

6.2.2. Cost Effectiveness Scenarios for EU 'Energy and Environment package', R&D and local pollutants abatement policies with GEM-E3 (EU-27)

This section examines what is the impact of modelling the R&D decisions on the assessment of environmental policies with the computable general equilibrium model GEM-E3. A climate policy and a local pollution policy are considered. Further the climate and R&D the R&D policies are combined. The climate policy considers the EU climate/energy package for 2020. The policy assumptions are taken from one of the scenarios run with GEM-E3 for the impact assessment of the 2020 EU climate target, i.e. an EU wide permit system with auctioning for the ETS sectors and a domestic CO_2 tax for the other sectors.

The allocation between ETS and non ETS sectors at EU level is based on cost efficiency, while the allocation between countries for the non ETS sectors is based on a combination of cost efficiency and GDP per head. The local pollution scenario is derived from the impact assessment of the Thematic Strategy on Air Pollution with the GAINS model and GEM-E3. The reduction targets imposed in GEM-E3 for the local pollutants are those derived by the GAINS model for the cost-efficient allocation between EU countries of the air quality target, assuming that a climate policy is in place.

The scenarios are implemented in the two GEM-E3 models, with and without R&D modelling, to evaluate the contribution of R&D modelling. Besides the environmental policy assumptions, it is also assumed that the country public budget and the EU current account have to remain constant in terms of GDP compared to the reference.

- **The climate policy**

Macroeconomic impact at EU and country level

The overall impact of climate policy is small, approximately -0.6% of GDP in 2020 in both modelling frameworks. In terms of welfare, the differences are a bit larger, mainly because the efficiency improvement through R&D expenditure reduces the competitiveness loss due to the climate policy and allows a slightly higher recycling effect. These results should be re-examined when better estimation for the substitution elasticities between quality and factors and a re-evaluation of the factor substitution elasticity will be available. It could be that modelling endogenous technical change allows a better representation of the reaction of the firms through innovation demand above the factor substitution but without large macroeconomic effect.

The role of spillovers is certainly essential in this respect but here also further data are needed because the data available concern mainly general quality/product improvement and not so much process innovation. The R&D expenditures in terms of GDP are rather stable: the cost increase due to the policy induces more innovation demand partly compensated by the negative impact of the decrease in activity.

Table 33: Macroeconomic impact of climate policy at EU level with the two modelling frameworks

	GEM-E3 without R&D modelling	**GEM-E3 with R&D modelling**
Macroeconomic Aggregates	**2020**	**2020**
Gross Domestic Product	-0.61%	-0.56%
Employment	-0.39%	-0.40%
Private Consumption	-0.10%	0.02%
Investment	-0.41%	-0.40%
Final Energy Consumption	-7.59%	-7.53%
Share Coal*	-2.24%	-2.22%
Share Oil*	0.66%	0.65%
Share Gas*	-0.60%	-0.62%
Share Electricity*	2.18%	2.19%
Exports to RW	-1.79%	-1.72%
Real Wage Rate	-1.31%	-1.24%
Relative Consumer Price	1.19%	1.21%
Real Interest Rate	0.21%	0.18%
Terms of Trade	1.80%	1.73%
Current Account (% of GDP)*	0.00%	0.00%
Total Atmospheric Emissions		
CO2 Emissions	-25.00%	-24.99%
NOX Emissions	-15.99%	-15.91%
SO2 Emissions	-20.12%	-20.00%
VOC Emissions	-6.69%	-6.55%
PM Emissions	-12.58%	-12.37%
NH3 Emissions	-0.94%	-0.88%
Environmental Policy		
Energy Tax (% of GDP)*	-0.10%	-0.11%
Environmental Tax (% of GDP)*	2.59%	2.58%
Increase of Social Benefits	8.77%	9.10%
CO2 marginal abatement cost (Euro00/tn CO2)	54.79	55.32
R&D expenditure		-0.03%
Welfare		
Economic Welfare	0.05%	0.16%
Local pollution benefits (% of GDP)*	0.10%	0.11%

Source: GEM-E3 model. % difference compared to reference scenario except for * where difference

The distribution of the cost among the countries is rather differentiated mainly because the differences in the reduction target imposed and in the share of energy intensive sectors. The R&D modelling has only a small impact as already observed at EU level.

Table 34: Macroeconomic impact of Climate Policy at country level in 2020

	GEM-E3 without R&D modelling					GEM-E3 with R&D modelling					
	Economic Welfare	Gross Domestic Product	Employ.	Exports	Final Energy Consump.	Economic Welfare	Gross Domestic Product	Employ.	Exports	Final Energy Consump.	R&D exp (% GDP)
Austria	0.10%	-0.47%	-0.25%	-1.69%	-9.38%	0.20%	-0.42%	-0.25%	-1.54%	-9.07%	-0.03%
Belgium	0.62%	-0.75%	-0.43%	-2.18%	-9.63%	0.83%	-0.69%	-0.47%	-2.07%	-9.79%	-0.05%
Bulgaria	4.20%	-1.94%	-1.06%	-6.31%	-16.39%	4.28%	-1.81%	-1.06%	-6.04%	-16.21%	-0.02%
Czech Rep.	-0.50%	-1.29%	-0.58%	-2.27%	-22.33%	-0.38%	-1.20%	-0.58%	-2.14%	-22.27%	0.00%
Denmark	1.28%	-0.98%	-0.57%	-2.69%	-13.26%	1.52%	-0.94%	-0.62%	-2.64%	-13.55%	-0.03%
Estonia	1.09%	-1.42%	-0.87%	-2.27%	-10.98%	1.13%	-1.27%	-0.86%	-2.07%	-10.75%	0.00%
Finland	0.87%	-0.77%	-0.38%	-2.55%	-10.72%	1.06%	-0.67%	-0.40%	-2.35%	-10.51%	-0.06%
France	-0.20%	-0.93%	-0.43%	-2.69%	-8.19%	-0.02%	-0.87%	-0.46%	-2.54%	-8.25%	-0.06%
Germany	-0.13%	-0.31%	-0.17%	-1.18%	-7.55%	-0.02%	-0.27%	-0.19%	-1.13%	-7.55%	-0.02%
Greece	-0.55%	-0.60%	-0.19%	-1.57%	-14.61%	-0.47%	-0.53%	-0.19%	-1.46%	-14.45%	0.00%
Hungary	-0.24%	-0.79%	-0.31%	-1.63%	-10.20%	-0.15%	-0.72%	-0.32%	-1.53%	-10.09%	0.00%
Ireland	-1.06%	-0.57%	-0.67%	-0.63%	-19.60%	-0.89%	-0.43%	-0.67%	-0.49%	-19.08%	-0.02%
Italy	-0.05%	-0.36%	-0.15%	-1.72%	-8.16%	0.04%	-0.34%	-0.16%	-1.67%	-7.97%	-0.01%
Latvia	-0.21%	-0.30%	-0.13%	-0.84%	-2.78%	-0.12%	-0.27%	-0.13%	-0.82%	-2.69%	0.00%
Lithuania	1.28%	-0.31%	-0.33%	-2.05%	-3.73%	1.34%	-0.23%	-0.33%	-1.93%	-3.61%	-0.01%
The Netherlands	0.55%	-0.61%	-0.24%	-1.91%	-8.05%	0.65%	-0.56%	-0.25%	-1.81%	-7.93%	-0.04%
Poland	0.23%	-1.12%	-0.59%	-3.48%	-17.32%	0.30%	-1.04%	-0.58%	-3.29%	-17.21%	-0.01%
Portugal	-0.47%	-0.25%	-0.12%	-1.11%	-5.62%	-0.40%	-0.24%	-0.12%	-1.07%	-5.30%	0.00%
Romania	4.61%	-2.36%	-1.29%	-6.72%	-26.76%	4.60%	-1.88%	-1.28%	-6.05%	-26.45%	-0.01%
Slovakia	0.89%	-1.07%	-0.51%	-2.94%	-9.26%	0.96%	-1.03%	-0.51%	-2.85%	-9.11%	-0.02%
Slovenia	-0.68%	-0.48%	-0.25%	-0.75%	-7.01%	-0.60%	-0.43%	-0.25%	-0.70%	-6.87%	0.00%
Spain	1.01%	-0.93%	-0.64%	-3.95%	-10.33%	1.11%	-0.87%	-0.64%	-3.83%	-10.19%	-0.01%
Sweden	0.31%	-0.59%	-0.34%	-1.63%	-5.93%	0.59%	-0.47%	-0.39%	-1.42%	-5.71%	-0.11%
UK	-0.23%	-0.50%	-0.25%	-0.81%	-9.53%	-0.14%	-0.46%	-0.26%	-0.78%	-9.45%	-0.02%
EU	0.05%	-0.61%	-0.39%	-1.79%	-7.59%	0.16%	-0.56%	-0.40%	-1.72%	-7.53%	-0.03%

*Source: GEM-E3 model. % difference compared to reference scenario except for * where difference*

Sectoral impact of the climate policy

The sectoral impact remains rather similar in both modelling framework, with a slightly lower impact with R&D modelling, especially in the equipment goods.

Table 35: Sectoral impact of Climate Policy at EU level in 2020

	GEM-E3 without R&D modelling	GEM-E3 with R&D modelling
Sectoral Aggregates	**2020**	**2020**
Domestic Production in Volume		
Agriculture	-0.95%	-0.89%

Energy Production	-8.22%	-8.15%
Ferrous and non ferrous metals	-2.81%	-2.70%
Chemical Products	-1.66%	-1.51%
Other energy intensive	-2.27%	-2.16%
Electric Goods	-0.99%	-0.69%
Transport equipment	-1.31%	-1.15%
Other Equipment Goods	-0.97%	-0.91%
Consumer Goods Industries	-0.98%	-0.93%
Construction	-0.45%	-0.44%
Telecommunication Services	-0.32%	-0.26%
Transport	-2.44%	-2.40%
Services of credit and insurances	-0.31%	-0.26%
Other Market Services	-0.38%	-0.38%
Non Market Services	-0.04%	-0.08%
Exports in Volume		
Agriculture	-1.82%	-1.78%
Energy Exports	-6.51%	-6.44%
Ferrous and non ferrous metals	-5.00%	-4.79%
Chemical Products	-2.13%	-1.95%
Other energy intensive	-3.81%	-3.63%
Electric Goods	-1.19%	-0.77%
Transport equipment	-1.60%	-1.41%
Other Equipment Goods	-1.21%	-1.13%
Consumer Goods Industries	-1.95%	-1.92%
Construction	-1.12%	-1.10%
Telecommunication Services	-0.52%	-0.51%
Transport	-5.24%	-5.22%
Services of credit and insurances	-0.31%	-0.34%
Other Market Services	-0.58%	-0.60%
Non Market Services	0.00%	0.00%

*Source: GEM-E3 model. % difference compared to reference scenario except for * where difference*

Table 36: Sectoral impact of Climate Policy at EU level in 2020 on price of exports

Price of Exports rel. EU average	**GEM-E3 without R&D modelling (2020)**	**GEM-E3 with R&D modelling (2020)**
Agriculture	1.39%	1.40%
Ferrous and non ferrous metals	3.07%	2.91%
Chemical Products	1.01%	0.91%
Other energy intensive	2.38%	2.27%
Electric Goods	0.44%	0.23%
Transport equipment	0.65%	0.57%
Other Equipment Goods	0.50%	0.48%
Consumer Goods Industries	1.07%	1.08%
Construction	0.81%	0.79%
Telecommunication Services	0.39%	0.39%
Transport	3.33%	3.35%
Services of credit and insurances	0.19%	0.23%
Other Market Services	0.28%	0.32%
Non Market Services	0.28%	0.33%

*Source: GEM-E3 model. % difference compared to reference scenario except for * where difference*

- **The Local pollution policy**

Macroeconomic impact at EU level

The impact of a local pollution scenario above the climate policy is very small for both modelling frameworks: -0.02% of GDP in 2020 and around -0.04% of welfare losses. The emission reduction of local pollutants is a bit higher in the R&D model with higher associated marginal abatement cost. This is partly due to the fact that the emissions in the reference are a bit higher in the reference.

Table 37: Macroeconomic impact of the local pollution policy at EU level

	GEM-E3 without R&D modelling	GEM-E3 with R&D modelling
Macroeconomic Aggregates	**2020**	**2020**
Gross Domestic Product	-0.02%	-0.02%
Employment	-0.02%	-0.02%
Private Consumption	-0.04%	-0.04%
Investment	-0.03%	-0.03%
Final Energy Consumption	-0.23%	-0.25%
Share Coal*	-0.26%	-0.27%
Share Oil*	0.06%	0.05%
Share Gas*	0.10%	0.11%
Share Electricity*	0.11%	0.11%
Exports to RW	0.01%	0.01%
Imports from RW	-0.01%	-0.01%
Real Wage Rate	-0.05%	-0.06%
Relative Consumer Price	-0.01%	-0.01%
Real Interest Rate	-0.04%	-0.04%
Terms of Trade	-0.08%	-0.09%
Current Account (% of GDP)*	0.00%	0.00%

*Source: GEM-E3 model. % difference compared to reference scenario except for * where difference*

Table 38: Environmental impacts of the local pollution policy at EU level

Total Atmospheric Emissions	**GEM-E3 without R&D modelling (2020)**	**GEM-E3 with R&D modelling (2020)**
CO2 Emissions	-0.70%	-0.70%
NOX Emissions	-9.17%	-9.51%
SO2 Emissions	-20.60%	-20.85%
VOC Emissions	-4.22%	-4.72%
PM Emissions	-19.65%	-19.97%
NH3 Emissions	-14.19%	-14.21%
Environmental Policy		
Energy Tax (% of GDP)*	0.00%	0.00%
Environmental Tax (% of GDP)*	-0.15%	-0.15%
Increase of Social Benefits	-0.60%	-0.65%
CO2 marginal abatement cost (Euro00/tn CO2)	-2.75	-2.99
NOx marginal abatement cost (Euro00/tn NOx)	1012.38	1080.70
SO2 marginal abatement cost (Euro00/tn SO2)	1196.37	1326.05
VOC marginal abatement cost (Euro00/tn VOC)	76.54	133.73

PM marginal abatement cost (Euro00/tn PM)	13620.29	14709.65
Welfare		
Economic Welfare	-0.03%	-0.04%
Local Environmental Benefits (% of GDP)*	0.11%	0.11%

*Source: GEM-E3 model. % difference compared to reference scenario except for * where difference*

Emission reduction in the EU countries in 2020

As can be seen from Table **39**39, the reduction efforts needed to meet the environmental targets are the higher in the R&D modelling framework, but as already said, this is mainly due to higher emissions in the reference scenario.

Table 39: Emission reductions through local pollutant policy in the EU countries in 2020

	GEM-E3 without R&D modelling						**GEM-E3 with R&D modelling**					
	NOX Emissions	SO2 Emissions	VOC Emissions	PM Emissions	NH3 Emissions	CO2 Emissions	NOX Emissions	SO2 Emissions	VOC Emissions	PM Emissions	NH3 Emissions	CO2 Emissions
Austria	-4.90%	-2.92%	-4.59%	-8.28%	-8.75%	0.05%	-5.40%	-3.41%	-5.38%	-9.90%	-8.89%	0.03%
Belgium	-10.38%	-24.27%	-3.37%	-21.41%	-4.61%	0.17%	-10.96%	-25.13%	-4.89%	-22.82%	-4.62%	0.19%
Bulgaria	-14.13%	-1.36%	-3.50%	-41.52%	-4.83%	-1.60%	-15.54%	-1.35%	-3.51%	-42.33%	-4.85%	-1.59%
Czech Republic	-7.36%	-14.69%	-0.76%	-1.34%	-10.49%	0.49%	-7.85%	-15.29%	-1.06%	-2.09%	-10.50%	0.40%
Denmark	-8.09%	-4.72%	-1.49%	-5.12%	-3.24%	0.13%	-7.98%	-3.97%	-2.70%	-5.46%	-3.25%	0.17%
Estonia	-20.30%	-7.45%	-2.69%	-11.40%	-12.91%	-3.63%	-20.90%	-8.01%	-2.80%	-12.20%	-13.02%	-3.91%
Finland	-7.69%	-1.61%	-1.71%	-12.91%	-6.73%	0.14%	-7.40%	-1.66%	-1.35%	-12.94%	-6.73%	0.22%
France	-7.11%	-14.81%	-1.31%	-12.03%	-16.87%	-0.11%	-7.63%	-15.47%	-2.04%	-12.91%	-16.88%	-0.12%
Germany	-10.14%	-5.52%	-0.57%	-8.92%	-20.44%	-0.15%	-10.60%	-6.16%	-2.02%	-9.76%	-20.45%	-0.18%
Greece	-3.29%	-1.95%	-11.46%	-19.93%	-13.74%	0.30%	-3.12%	-2.02%	-11.60%	-20.07%	-13.75%	0.36%
Hungary	-11.68%	-55.76%	-5.41%	-14.93%	-27.18%	-2.04%	-12.21%	-56.01%	-5.48%	-15.30%	-27.20%	-2.07%
Ireland	-6.66%	-18.18%	-2.61%	-12.08%	-8.85%	-0.22%	-6.63%	-17.81%	-2.21%	-11.24%	-8.82%	-0.17%
Italy	-8.43%	-23.83%	-6.94%	-22.95%	-14.39%	0.15%	-9.13%	-24.08%	-6.98%	-24.11%	-14.43%	0.17%
Latvia	-14.40%	-15.20%	-14.70%	-24.04%	-23.97%	-10.44%	-14.29%	-14.94%	-14.47%	-23.60%	-23.95%	-10.24%
Lithuania	-7.27%	-13.63%	-9.30%	-18.37%	-14.20%	-2.92%	-6.89%	-13.61%	-8.81%	-17.24%	-14.15%	-2.68%
The Netherlands	-0.11%	-0.12%	-0.05%	-6.12%	-3.12%	0.20%	-0.45%	-1.45%	-0.13%	-7.22%	-3.14%	0.00%
Poland	-5.17%	-31.38%	-10.01%	-26.19%	-13.98%	-6.98%	-5.13%	-31.62%	-9.95%	-26.25%	-13.98%	-6.88%
Portugal	-10.12%	-23.60%	-12.50%	-40.70%	-12.26%	-1.43%	-10.60%	-23.75%	-12.80%	-41.65%	-12.32%	-1.74%
Romania	-7.88%	-30.82%	-7.80%	-34.40%	-19.03%	-3.43%	-6.23%	-29.85%	-7.44%	-32.05%	-19.05%	-2.92%
Slovakia	-8.08%	-23.29%	-8.32%	-24.37%	-10.71%	-2.45%	-9.00%	-24.41%	-8.44%	-25.01%	-10.73%	-2.49%
Slovenia	-3.86%	-33.40%	-5.17%	-14.23%	-16.56%	-0.52%	-4.32%	-33.99%	-5.25%	-14.59%	-16.58%	-0.54%
Spain	-15.61%	-30.48%	-7.71%	-19.61%	-14.35%	-0.29%	-15.57%	-30.71%	-8.58%	-20.02%	-14.37%	-0.28%
Sweden	-5.04%	-1.50%	-1.27%	-4.42%	-8.46%	-0.01%	-5.06%	-1.97%	-2.01%	-5.02%	-8.46%	-0.01%
UK	-10.86%	-18.74%	-1.65%	-14.82%	-10.69%	-0.15%	-11.57%	-18.30%	-1.76%	-15.02%	-10.72%	-0.15%
EU	-9.17%	-20.60%	-4.22%	-19.65%	-14.19%	-0.70%	-9.51%	-20.85%	-4.72%	-19.97%	-14.21%	-0.70%

Source: GEM-E3 model. % difference compared to reference scenario

- **Climate and R&D policy**

In this scenario, the climate policy is associated with a R&D subsidy policy. The subsidy, as in the previous scenario, is general and not associated with a specific production factor. As can be seen from Table 40, the R&D subsidy decreases the negative effect of the climate policy, both in terms of GDP and welfare through the increase in R&D expenditure. The same is observed in all countries. It might be interesting to examine what is the importance of the spillover effect compared to the impact of the proper expenditure but it is difficult at this stage given the quality of the data.

Table 40: Macroeconomic impact of R&D policy at EU level

	Climate Policy (with RD modelling)	Climate Policy and R&D subsidy (with RD modelling)
Macroeconomic Aggregates	**2020**	**2020**
Gross Domestic Product	-0.56%	-0.19%
Employment	-0.40%	-0.47%
Private Consumption	0.02%	0.55%
Investment	-0.40%	-0.38%
Final Energy Consumption	-7.53%	-7.40%
Share Coal*	-2.22%	-2.22%
Share Oil*	0.65%	0.65%
Share Gas*	-0.62%	-0.62%
Share Electricity*	2.19%	2.19%
Exports to RW	-1.72%	-1.45%
Imports from RW	-0.26%	-0.20%
Real Wage Rate	-1.24%	-0.91%
Relative Consumer Price	1.21%	1.23%
Real Interest Rate	0.18%	0.00%
Terms of Trade	1.73%	1.55%
Current Account (% of GDP)*	0.00%	0.00%
Total Atmospheric Emissions		
CO2 Emissions	-24.99%	-24.98%
NOX Emissions	-15.91%	-15.83%
SO2 Emissions	-20.00%	-19.86%
VOC Emissions	-6.55%	-6.31%
PM Emissions	-12.37%	-12.17%
NH3 Emissions	-0.88%	-0.65%
Environmental and R&D Policy		
Energy Tax (% of GDP)*	-0.11%	-0.11%
Environmental Tax (% of GDP)*	2.58%	2.59%
Increase of Social Benefits	9.10%	9.43%
CO2 marginal abatement cost	55.32	55.63
R&D expenditure (% of GDP)*	-0.03%	0.03%
Welfare		
Economic Welfare	0.16%	0.71%
Local Benefits (% of GDP)*	0.11%	0.11%

Source: GEM-E3 model. % difference compared to reference scenario

Table 41: Macroeconomic impact of R&D Policy at country level in 2020

	Climate Policy (with RD modelling)						**Climate Policy and R&D subsidy (with RD modelling)**					
	Economic Welfare	Gross Domestic Product	Employ.	Exports	Final Energy Consump.	R&D exp (% GDP)	Economic Welfare	Gross Domestic Product	Employ.	Exports	Final Energy Consump.	R&D exp (% GDP)
Austria	0.20%	-0.42%	-0.25%	-1.54%	-9.07%	-0.03%	0.48%	-0.25%	-0.28%	-1.38%	-8.98%	0.04%
Belgium	0.83%	-0.69%	-0.47%	-2.07%	-9.79%	-0.05%	1.00%	-0.46%	-0.46%	-1.80%	-9.69%	0.05%
Bulgaria	4.28%	-1.81%	-1.06%	-6.04%	-16.21%	-0.02%	4.71%	-1.50%	-1.09%	-5.70%	-16.05%	0.01%

Czech Republic	-0.38%	-1.20%	-0.58%	-2.14%	-22.27%	0.00%	0.12%	-0.80%	-0.63%	-1.71%	-22.05%	0.05%
Denmark	1.52%	-0.94%	-0.62%	-2.64%	-13.55%	-0.03%	1.87%	-0.71%	-0.67%	-2.37%	-13.51%	0.03%
Estonia	1.13%	-1.27%	-0.86%	-2.07%	-10.75%	0.00%	2.27%	-0.15%	-0.96%	-0.95%	-10.31%	0.01%
Finland	1.06%	-0.67%	-0.40%	-2.35%	-10.51%	-0.06%	1.23%	-0.30%	-0.40%	-1.76%	-10.40%	0.02%
France	-0.02%	-0.87%	-0.46%	-2.54%	-8.25%	-0.06%	0.37%	-0.53%	-0.51%	-2.14%	-8.17%	0.03%
Germany	-0.02%	-0.27%	-0.19%	-1.13%	-7.55%	-0.02%	0.54%	0.07%	-0.26%	-0.91%	-7.45%	0.03%
Greece	-0.47%	-0.53%	-0.19%	-1.46%	-14.45%	0.00%	0.21%	-0.02%	-0.24%	-0.83%	-14.38%	0.00%
Hungary	-0.15%	-0.72%	-0.32%	-1.53%	-10.09%	0.00%	0.58%	-0.01%	-0.39%	-0.78%	-9.82%	0.04%
Ireland	-0.89%	-0.43%	-0.67%	-0.49%	-19.08%	-0.02%	-0.35%	0.16%	-0.79%	0.04%	-18.90%	0.05%
Italy	0.04%	-0.34%	-0.16%	-1.67%	-7.97%	-0.01%	0.52%	-0.11%	-0.20%	-1.58%	-7.84%	0.01%
Latvia	-0.12%	-0.27%	-0.13%	-0.82%	-2.69%	0.00%	0.86%	0.54%	-0.20%	0.09%	-2.36%	0.02%
Lithuania	1.34%	-0.23%	-0.33%	-1.93%	-3.61%	-0.01%	2.41%	0.58%	-0.41%	-1.03%	-3.14%	0.01%
The Netherlands	0.65%	-0.56%	-0.25%	-1.81%	-7.93%	-0.04%	0.77%	-0.29%	-0.23%	-1.35%	-7.87%	0.08%
Poland	0.30%	-1.04%	-0.58%	-3.29%	-17.21%	-0.01%	0.87%	-0.68%	-0.66%	-2.98%	-17.07%	0.02%
Portugal	-0.40%	-0.24%	-0.12%	-1.07%	-5.30%	0.00%	0.27%	0.09%	-0.21%	-0.93%	-5.16%	0.00%
Romania	4.60%	-1.88%	-1.28%	-6.05%	-26.45%	-0.01%	5.75%	-0.82%	-1.41%	-4.82%	-26.01%	0.01%
Slovakia	0.96%	-1.03%	-0.51%	-2.85%	-9.11%	-0.02%	1.38%	-0.62%	-0.53%	-2.37%	-8.85%	0.04%
Slovenia	-0.60%	-0.43%	-0.25%	-0.70%	-6.87%	0.00%	0.13%	0.18%	-0.34%	-0.08%	-6.60%	0.04%
Spain	1.11%	-0.87%	-0.64%	-3.83%	-10.19%	-0.01%	1.74%	-0.43%	-0.75%	-3.36%	-10.06%	0.00%
Sweden	0.59%	-0.47%	-0.39%	-1.42%	-5.71%	-0.11%	0.72%	-0.23%	-0.38%	-1.18%	-5.66%	0.06%
UK	-0.14%	-0.46%	-0.26%	-0.78%	-9.45%	-0.02%	0.72%	0.04%	-0.40%	-0.72%	-9.29%	0.02%
EU	0.16%	-0.56%	-0.40%	-1.72%	-7.53%	-0.03%	0.71%	-0.19%	-0.47%	-1.45%	-7.40%	0.03%

Source: GEM-E3 model. % difference compared to reference scenario.

The explicit modelling of R&D decisions allows a better evaluation of the role of endogenous technical change and the simulation of policy directly aiming at promoting sustainable development in the EU27 countries. As shown in the policy scenario evaluation, they can have significant positive effect on growth and on environmental policies.

6.2.3. NEMESIS/NOMEDE Assessment for the "Climate Action and Renewable Energy Package" (EU-27)

This section provides an assessment with NEMESIS model (*New Econometric Model for Evaluation by Sectoral Interdependencies and Supply*) of the EU 'Climate Action and Renewable Energy Package'. The focus is put on the economic consequences in 2020 of the joint implementation of the 'EU ETS review', 'non ETS effort-sharing' and 'renewables' directive and decision proposals. Different scenarios are explored depending on the way auctioning revenues are recycled by States, and compared on the basis of economic and environmental efficiency criteria defined by the Commission. A special emphasis is also put on the influence of technological change on economic and environmental indicators in the different scenarios studied with NEMESIS. NEMESIS includes an endogenous R&D decisions module, and this feature of the model is actually important to assess for climate and energy policies, which induce substitution and revenue effects, but come also modify R&D investment decisions of agents and the rate and direction of technical change.

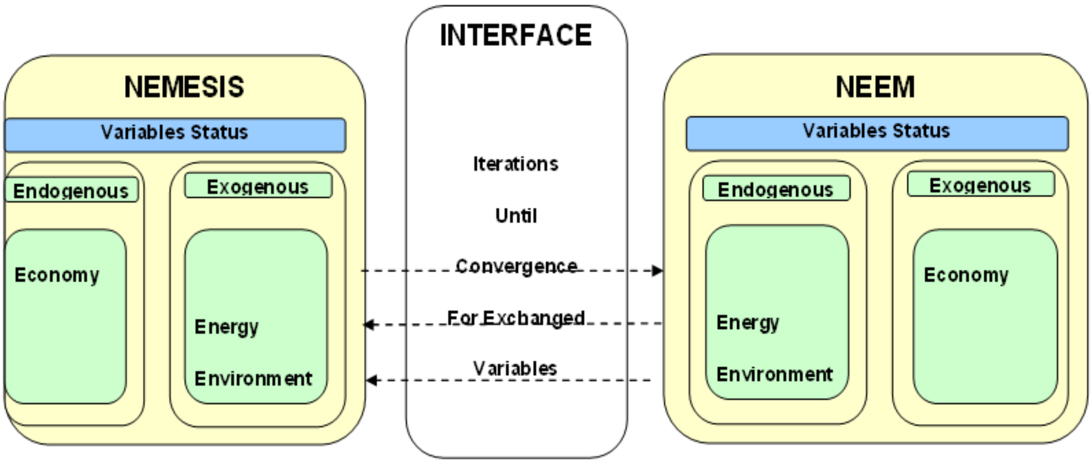
- **The methodology used**

NEMESIS model is composed of two main components:

- a large scale economic macro-econometric model, the ‘core’ of NEMESIS[2], designed for EU-27 countries (with the exception of Cyprus and Bulgaria for which data are missing) plus Norway, to which a set of optional or satellite modules can be added for Agriculture, Land-Use and NUTS-2 regions, which account altogether about 200.000 equations and calculated variables;
- a detailed technico-economic model for EU-15 countries, NEEM (NEMESIS Energy Environment Module) of about 100.000 equations, which is a partial equilibrium model for energy demand and supply, and GHG emissions calculation, developed by National technical University of ATHENS (NTUA).

NEMESIS core economic model can be linked to NEEM through an interface that exogenizes in NEMESIS the energy/environment variables calculated by NEEM. During a policy simulation exercise, NEMESIS and NEEM exchange, as described on figure 16, variables that are endogenous in one model (energy/environment in NEEM economic in NEMESIS) and exogenous in the other, with iterations that stop once the value of the variables exchanged in the interface do not modify any more between the *n* (convergence attained) and *n-1* iterations, or change with a percentage inferior to a predefined convergence criteria.

Figure 16: Functioning of Interface between NEMESIS and NEEM



The linkage between NEMESIS and NEEM was in this way used in deliverable D7 to assess for different efficient scenarios on carbon taxation policies for EU ETS and non EU ETS sectors. But NEEM was developed for EU-15 countries only, and the assessment for the EU ‘Climate Action and Renewable Energy Package’ presented here, needed to be realized at EU-27 level. Furthermore, it was not foreseen in FORASSET description of work, to extend NEEM to new EU member states, and no budget was allocated for this task. For these reasons, it was decided by the ERASME team to develop, with the help of NTUA, a new energy/environment module (NOMEDE, Nemesis Optional Module for Energy Demand and Environment), limited to energy demands and substitutions system, and GHG emissions (CO_2, CH4, N2O, SF6, HFC and PFC), that was included directly in NEMESIS core economic model, as a new optional module (see deliverable 15 for more details on NOMEDE).

The key characteristics of this NEMESIS Optional Module for Energy Demand and Environment (NOMEDE) allow accounting for the main objectives, targets and sub-targets of the EU ‘Climate Action and Renewable Energy Package’. It calculates notably, for each EU-27 country (except Cyprus and Bulgaria), the renewable share in final energy consumption and the

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[2] see NEMESIS web site: www.erasme.ecp.fr/nemesis.

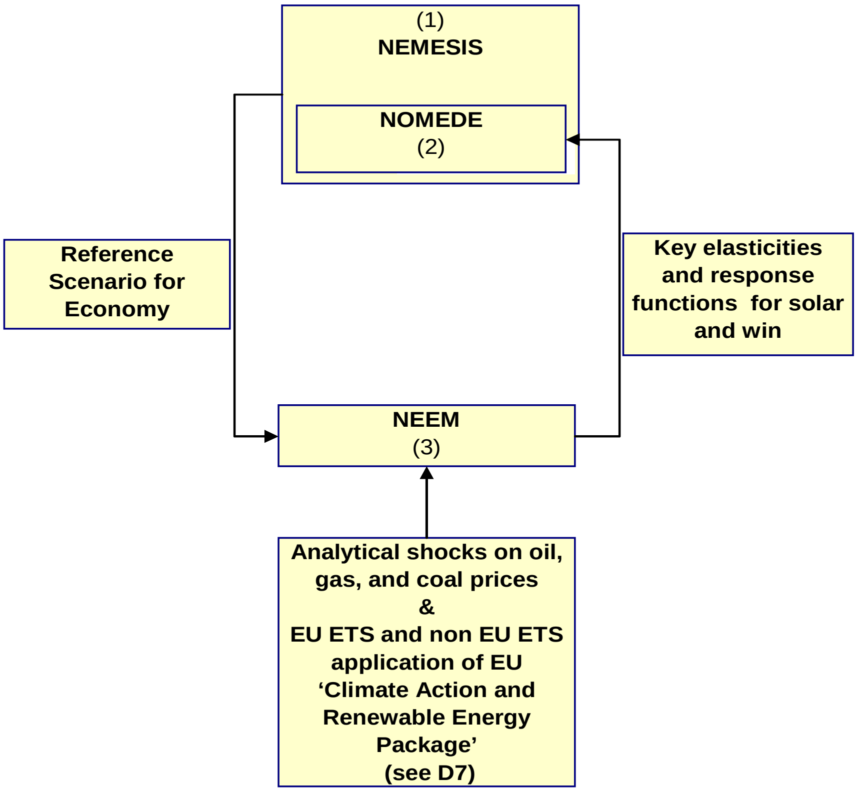
share of biofuels in gasoline and diesel used by transports sector. It can also compute the share of renewable in power generation sector.

NOMEDE was based on EUROSTAT data for energy products (Coal, Gas, Petrol, and Electricity), biomass (Biofuels, Biogas, Wood and Wood Wastes) and Urban Wastes, and on European Environmental Agency for GHG emissions data. It is more detailed that NEEM, that do not includes biomass, for energy demand categories, but is less detailed in the area of energy demand and supply technologies.

For energy demand, NOMEDE takes the global quantities calculated by NEMESIS core economic model from the 30 production functions of NEMESIS sectors and households energy consumption categories (Coal, Gas, Petrol, and Electricity), and calculates energy demand by product, including biomass categories, and energy prices, that are sent back to NEMESIS. Energy supply in then determined by NEMESIS production functions for energy sectors, on the basis of energy demand by product calculated by NOMEDE, and energy import and export functions included in NEMESIS. For the power sector, response functions, derived from NEEM simulation exercises (see figure 17), allow calculating the shares of solar and wind, while geothermal, hydraulic and nuclear production capacities were considered exogenous, and were based on PRIMES latest projections[3] for EU DG-Trend.

NOMEDE includes finally a tradable permits module, that cans implement endogenous carbon taxes and simulate different tradable permit systems (free allocation, full auctioning and combination of the two, as in the EU ‘Climate Action and Renewable Energy Package’), and different taxes and auctioning revenue recycling scheme.

Figure 17: NOMEDE calibration procedure



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[3] “European Energy and Transport: Trends to 2030 – Update 2007”, European Commission/ Directorate-General for Energy and Transport.

For policy experimentations, NOMEDE baseline was partly calibrated onto PRIMES results. It was the case for renewable share evolution in power generation sector and electricity production from Geothermal, Hydraulic and Nuclear sources; for biofuels share in gasoline and diesel; for fuel inputs in power generation sector and fuels' efficiency factors in power generation and in transport sector (passengers and freight).

Consequently, NOMEDE allows calculating in baseline energy consumptions and GHG emissions close from PRIMES model, that was already used to assess for EU 'Climate Action and Renewable Energy Package' together with GAINS, GEM-E3, PACE and POLES models. This presents the advantage that the differences in results between the assessments presented here, and the previous assessments that were performed for the commission, can be attributed to these discrepancies in model mechanisms and in policy assumptions, not to baseline evolutions.

- **Baseline evolutions for energy and environment indicators**

For the baseline scenario, it is assumed that only policies already in place in 2007 are active and that current ETS system continues to operate, with a low price for carbon that rises from 20 constant € 2005 /ton CO_2 equivalent in 2008 up to 23 constant € 2005 euros in 2020.

Baseline evolutions were actualized in mid-2008, to take into account for the most recent trends onto energy prices (see figure 18). The high oil prices observed on the past two years are supposed to persist but with a slow decrease from 107 € in 2008 to 68 € 2015, and then progressive re-augmentation until 76 € in 2020. Oil price is derived from PROMETHEUS projections (NTUA). It accounts for continuous resource constraint, rapid growth of world oil demand and high extraction costs. Gas prices were indexed on oil price while coal price was supposed to grow at lower rates in reason of high coal resources level.

These high oil and energy prices have a negative impact on GDP growth rate in EU-27, that establish to 2.34% in annual average growth rate for the period 2005-2020 (table 42).

GDP growth stays higher for new Member States, with an increase of 78% on the period 2005-2020 against only 37% for EU-15 countries, and 39% for EU-27.

Figure 18: Evolution of oil price in constant € 2005

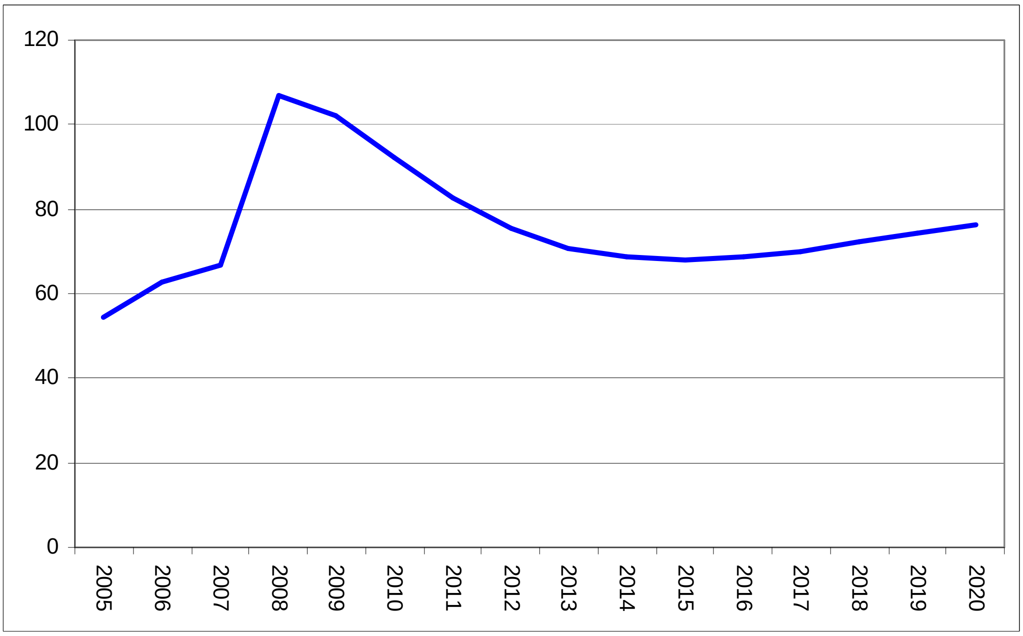

Table 42: Evolution of GDP in EU-27 countries between 2005 and 2020, baseline scenario

Table 1: GDP growth in reference scenario

	2005	2010	2015	2020	2005-10	2010-15	2015-20	2005-20
					Annual % Change			
Austria	100	108	122	134	1.64	2.30	2.05	2.00
Belgium	100	105	119	133	0.93	2.55	2.26	1.91
Denmark	100	106	125	130	1.19	3.34	0.84	1.78
Germany	100	105	116	128	0.91	2.16	1.90	1.65
Finland	100	115	136	156	2.87	3.32	2.78	2.99
France	100	107	121	137	1.34	2.58	2.42	2.11
Greece	100	112	136	158	2.38	3.85	3.02	3.08
Irland	100	121	149	176	3.85	4.27	3.42	3.85
Italy	100	101	112	124	0.22	2.13	1.97	1.44
Luxembourg	100	121	147	174	3.88	3.94	3.50	3.78
Netherlands	100	110	127	144	1.85	3.07	2.45	2.45
Portugal	100	101	113	128	0.17	2.21	2.65	1.67
Spain	100	113	134	154	2.46	3.46	2.86	2.93
Sweeden	100	114	138	160	2.71	3.84	3.06	3.20
United Kingdom	100	111	128	144	2.03	3.04	2.36	2.47
Czech Republic	100	124	151	181	4.37	4.04	3.69	4.03
Estonia	100	150	223	290	8.50	8.17	5.40	7.35
Latvia	100	141	197	250	7.15	6.93	4.86	6.31
Lithuania	100	130	172	211	5.40	5.72	4.20	5.11
Hungary	100	111	134	157	2.08	3.83	3.23	3.04
Malta	100	111	130	153	2.07	3.29	3.31	2.89
Poland	100	116	143	172	3.09	4.25	3.70	3.68
Slovenia	100	121	150	179	3.84	4.41	3.65	3.97
Slovakia	100	126	157	193	4.71	4.57	4.12	4.47
Romania	100	117	152	185	3.14	5.48	3.96	4.19
EU-15	100	107	122	137	1.40	2.69	2.28	2.12
EU-12	100	119	148	178	3.52	4.48	3.77	3.92
EU27	100	108	123	139	1.86	2.66	2.49	2.34

Source: NEMESIS model

At sectoral level, production growth in EU-27 stays strong in EU-ETS sectors (Energy intensive sector including power generation plus air transports) , with an increase of 42% between 2005 and 2020 (table 43), due notably to the dynamism of chemical and air transports industries. Non EU ETS sectors (all other sectors)grow about 35% on the same period.

Table 43: Production growth in EU ETS and non EU ETS sectors, baseline scenario

	2005	2010	2015	2020	2005-10	2010-15	2015-20	2005-20
					Annual % Change			
Agriculture	100	99	101	103	-0.12	0.26	0.47	0.20
Industry	100	109	121	137	1.74	2.17	2.43	2.11
- energy Intensive industries	100	110	123	140	1.86	2.36	2.66	2.29
- other industries	100	109	120	135	1.67	2.06	2.30	2.01
Construction	100	109	121	139	1.66	2.27	2.72	2.22
Tertiary	100	108	120	136	1.56	2.18	2.51	2.08
Transport	100	111	126	146	2.08	2.66	2.89	2.54
- see & air	100	114	134	156	2.64	3.22	3.21	3.02
- road & rail	100	109	123	140	1.80	2.35	2.72	2.29
EU-ETS sectors	100	110	124	142	1.94	2.45	2.72	2.37
Non EU-ETS sectors	100	108	120	135	1.56	2.12	2.45	2.04

For energy demand, the baseline evolutions show the continuation of energy efficiency improvement already observed in the past period[4]. Final energy consumption increases 20% in EU-27 over the period 2005-2020 (table 44) against 39% for GDP.

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[4] For Agriculture, the rise in energy intensity comes from products substitutions inside the sector, notably the replacement of pasture by animal feedstocks.

Table 44: Final energy demand in EU-27, baseline scenario

	2005	2010	2015	2020	2005-10	2010-15	2015-20	2005-20
in toe	Index				Share in Total			
Agriculture	100	107	118	129	0.03	0.03	0.03	0.03
Energy branch	100	97	101	106	0.07	0.07	0.07	0.07
Industry	100	101	106	112	0.25	0.24	0.24	0.23
- energy Intensive industrie	100	99	103	107	0.18	0.18	0.17	0.16
- other industries	100	105	114	123	0.07	0.07	0.07	0.07
Residential	100	105	116	128	0.16	0.17	0.17	0.17
Tertiary	100	104	113	122	0.11	0.11	0.11	0.11
Transport	100	103	113	124	0.38	0.38	0.39	0.39
- see & air	100	109	128	147	0.04	0.05	0.05	0.05
- road & rail	100	102	111	121	0.34	0.34	0.34	0.34
EU-ETS sectors	100	100	106	113	0.29	0.28	0.28	0.27
Non EU-ETS sectors	100	104	113	123	0.70	0.71	0.71	0.72
Total	100	103	111	120	1.00	1.00	1.00	1.00

Source: NEMESIS model

Gains in energy efficiency come partly from exogenous assumptions for fuel efficiency in passengers and freight transport and in thermal electricity production, that were taken from PRIMES model[5], that was used to assess for the EU ‘Climate Action and Renewable Energy Package’[6]. Energy efficiency gains result also from the high oil and gas prices that combined with the carbon value in EU ETS sector lead to high energy prices, and from continued de-materialization of industrial production and the development of services in European economies.

Table 45: Primary energy demand by product in EU-27, baseline scenario

	2005	2010	2015	2020	2005-10	2010-15	2015-20	2005-20
in toe	Index				Share in Total			
Solids	100	96	96	97	0.16	0.15	0.14	0.13
Oil	100	98	106	113	0.35	0.34	0.34	0.34
Gas	100	103	113	122	0.27	0.27	0.28	0.28
Electricity	100	105	115	126	0.17	0.18	0.18	0.18
Other	100	132	152	181	0.04	0.06	0.06	0.07
Total	100	102	110	118	1.00	1.00	1.00	1.00

Source: NEMESIS model

Despite high oil prices, the demand for petroleum products is expected to stay at a high level during the period 2005-2020, with a rise of 13% of oil demand that concentrates for specific uses: Transports and petrochemical. The demand for gas rises 22% over the period, while the demand for solids (coal and lignite) reduces 3%. The evolution for gas is mainly attributable to the massive substitution of gas to coal and oil in power generation (see table 46). Electricity takes an increasing share in primary energy demand, with a demand that increases 26% over the period, an evolution supported by the development of renewables in power sector, which gain economic competitiveness over the period. Other energy sources, mainly biomass, play also an increasing role, with a demand growing about 4% per year over 2005-2020.

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[5] “Energy and Transport: Trends to 2030 – Update 2007”, European Commission/ Directorate-General for Energy and Transport.

[6] The package consists of legislative proposals including three actions: a) Amendment of Directive 2003/87/EC so as to improve and extend the EU greenhouse gas emission allowance trading system; b) Decision on the effort of Member States to reduce their greenhouse gas emissions to meet the Community’s greenhouse gas emission reduction commitments up to 2020; c) Directive on the promotion of use of renewable energy sources.

Table 46: Fuels inputs in thermal power generation in EU-27, baseline scenario

	2005	2010	2015	2020	2005-10	2010-15	2015-20	2005-20
in toe	Index				Share in Total			
Solids	100	97	98	99	0.55	0.53	0.51	0.49
Oil	100	77	71	60	0.09	0.07	0.06	0.05
Natural Gas	100	108	121	135	0.30	0.32	0.35	0.37
Biomass and Waste	100	132	154	185	0.06	0.08	0.09	0.10
Total	100	101	106	112	1.00	1.00	1.00	1.00

Source: NEMESIS model

Table 46 illustrates the rising importance of biomass for the power sector, which demand increases 85% on 2005-2020. The use of solids in power sector stabilizes around its 2005 level, and benefits from the gradual diminution of nuclear contribution in base load, resulting from the assumptions mad in baseline. Assumptions for nuclear follow PRIMES[7] projections, as well as projection for hydro-electricity, that grow 9% (table 47) over 2005-2020 period, and for geothermal electricity that grow 35%, but with a potential that stay limited.

Table 47: Main energy system indicators for EU-27, baseline scenario

	2005	2010	2015	2020	2005-10	2010-15	2015-20	2005-20
in toe					Annual % Change			
Gross inl. Consumption/Capita (100 in 2005)	100	101	106	115	0.18	1.06	1.57	0.93
Gross inl. Consumption/GDP (100 in 2005)	100	95	90	87	-1.02	-1.03	-0.82	-0.96
Electricity generation	100	105	114	127	0.94	1.76	2.19	1.63
- Nuclear	100	92	96	104	-1.55	0.74	1.61	0.26
- Hydro	100	99	102	109	-0.21	0.68	1.24	0.57
- Wind	100	273	556	1023	22.22	15.33	12.95	16.77
- Solar	100	221	428	761	17.21	14.13	12.19	14.49
- Geothermal	100	99	113	135	-0.22	2.77	3.63	2.05
- Thermal	100	106	116	129	1.18	1.84	2.08	1.70

Source: NEMESIS model

Table 47 shows finally the increasing importance of wind and nuclear for electricity generation, these energy sources growing respectively 17% and 15% per year over the 2005-2020 period. The expansion of electric sector in baseline scenario, results then from the development of specific electricity uses and a demand rising 1.6% per year in average, and from massive investments in combined cycle gas, biomass based power, wind and to a lesser extent solar.

Table 48: GHG emissions by sector in EU-27, baseline scenario

	2005	2010	2015	2020	2005-10	2010-15	2015-20	2005-20
in CO_2 units	Index				Share in Total			
Power Generation	100	92	89	86	0.29	0.27	0.26	0.24
Energy Branch	100	97	103	109	0.06	0.06	0.06	0.06
Agriculture	100	100	103	106	0.13	0.13	0.13	0.13
Industry	100	101	108	115	0.14	0.14	0.15	0.15
- energy Intensive industries	100	100	107	113	0.10	0.11	0.11	0.11
- other industries	100	104	113	121	0.03	0.03	0.04	0.04
Residential	100	102	112	121	0.09	0.09	0.10	0.10
Tertiary	100	103	111	119	0.04	0.05	0.05	0.05
Transport	100	96	101	106	0.26	0.26	0.26	0.27
- see & air	100	108	126	143	0.03	0.04	0.04	0.05
- road & rail	100	94	97	100	0.22	0.22	0.22	0.22
EU-ETS sectors	100	95	97	99	0.47	0.47	0.46	0.45
Non EU-ETS sectors	100	98	103	108	0.51	0.52	0.53	0.53
Total	100	97	100	103	1.00	1.00	1.00	1.00

Source: NEMESIS model

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[7] "Energy and Transport: Trends to 2030 – Update 2007", European Commission/ Directorate-General for Energy and Transport.

These energy and economic trends of the baseline scenario result in a moderate increase of GHG emissions over the period 2005-2020 in EU-27 countries (see table 48).

From 2005 to 2010, GHG emissions first decrease, in a context of very high oil and gas prices. Emissions decrease 8% in the power sector, where the decrease results from using more gas and oil and solids, and more renewable. The stabilization of emissions in other energy intensive industries in this first period of low economic growth, allow GHG emissions to reduce 5% in the EU ETS sector. For non EU ETS sector, emissions reduce 2% in 2010 compared to 2005. In 2010, GHG emissions are 3% lower their 2005 level in EU-27, that is to say 14.3% their 1990 level. This is below the Kyoto objective of 8% emissions reduction for 2010-2012 period compared to 1990.

For the period 2010-2020, the economic growth that was hampered by the very high oil and gas price of the first period recovers. Energy prices stay high and favorable to the development of renewable energy sources, but the important rise in energy demand (16% between 2010 and 2020 against only 2% between 2005 and 2010) does not allow stabilizing the level of CO_2 and of other GHG emissions. GHG emissions re-augment 3% between 2010 and 2015 and again 3% between 2015 and 2020, to establish 3% above their 2005 level, and 7.7% below their 1990 level. Compared to 2005 level, emissions are stabilized in EU ETS sector, where the 23 € 2005 /ton CO_2 carbon value allow satisfying EU-27 Kyoto objective. For non EU ETS

Table 49: Green house gases emissions per EU-27 country, baseline scenario

	2010	2015	2020	2010	2015	2020	2010	2015	2020
100 in 2005	CO_2			Other GHG emissions			Total GHG emissions		
Austria	97	100	104	103	109	116	98	102	106
Belgium	97	102	108	101	106	114	98	103	108
Denmark	90	91	84	102	112	113	92	94	89
Germany	93	91	89	101	106	111	94	93	92
Finland	93	91	90	105	112	120	94	94	94
France	96	100	104	101	106	112	98	101	106
Greece	96	98	98	105	116	128	98	101	104
Irland	102	105	109	100	101	104	101	104	107
Italy	93	99	106	98	105	113	94	100	107
Luxembourg	103	105	111	110	121	135	103	106	112
Netherlands	99	106	111	105	115	125	100	107	113
Portugal	94	98	105	95	98	103	94	98	104
Spain	94	98	102	103	114	124	96	101	106
Sweeden	98	105	117	103	110	117	99	106	117
United Kingdom	98	98	97	104	111	117	99	100	100
Czech Republic	93	91	91	104	109	116	95	94	95
Estonia	96	97	97	104	109	115	97	99	99
Latvia	114	131	149	111	121	132	113	129	144
Lithuania	111	124	135	113	137	160	112	129	143
Hungary	99	104	112	104	111	121	100	105	114
Malta	98	99	100	109	124	143	99	99	100
Poland	95	95	97	105	111	119	97	98	100
Slovenia	99	102	107	108	119	132	102	107	114
Slovakia	107	118	131	107	117	130	107	117	130
Romania	107	123	141	109	123	139	108	123	141
EU-15	95	97	99	102	108	115	96	99	102
EU-12	98	102	107	106	115	126	100	104	111
EU27	96	98	100	103	110	117	97	100	103

Source: NEMESIS model

GHG emissions show contrasted evolutions at member States level (table 49). For CO_2, (only energy related emissions are measured) the global stabilization at EU-27 level over the period 2005-2020 dissimulates a 7% increase in new member State, while emissions are reduced about 1% in EU-15 countries were economic growth rate is 46% inferior to the one of new member States. For other GHG, we have a stabilization of CH4 emissions form agriculture, but an increase notably from waste production, gas production and transportation. They increase globally 9% between 2005 and 2020. The strongest emissions increases are HFC (49%), PFC (46%) and SF6 (39%). For N2O, emissions are projected to increase 18%. Globally, non CO2 GHG emissions increase 17% over the 2005-2020 period, with also an higher increase in new member states, with +26% against +15 % in EU-15 countries.

Table 50: Main environmental indicators for EU-27 countries, baseline scenario

	2005	2010	2015	2020	2005-10	2010-15	2015-20	2005-20
in toe					Annual % Change			
CO2 emissions/Capita	100	95	96	98	-0.93	0.03	0.57	-0.12
CO2 emissions to GDP	100	90	81	74	-2.12	-2.03	-1.80	-1.99
Carbon intensity (CO_2 on gross energy inl. consumption)	100	95	90	85	-1.12	-1.02	-0.99	-1.04
Share of renewables in power generation (%)	0.16	0.18	0.21	0.26	2.89	3.16	3.83	3.29
Share of renewables in final energy consumption (%)	0.10	0.10	0.11	0.13	0.49	2.12	2.25	1.62
Biofuels share in transport gasoline and diesel (%)	0.00	0.03	0.04	0.06	42.48	10.15	6.56	18.70

Source: NEMESIS model

The baseline evolutions for GHG emissions over 2005-2020 period reveal moderate increases despite the relatively high economic growth and rise in energy demand foreseen in this scenario. This is shown in table 50 for CO_2 by decreases of 2% of emissions in EU-27 between 2005 and 2020, of 26% of emissions per constant k-euros GDP and of 15% of energy carbon intensity. Emissions intensity reduction of GDP in then the result of both increased decoupling of energy consumption from GDP growth, and from high energy prices that strengthen energy substitutions away from fossil fuel and carbon intensive energies. This last phenomena pass notably through the development of renewable energy forms, which share increases 10% in power generation on the period, from 16% in 2005 to 26% in 2025, and from respectively 9.5% to 13% in final energy consumption, while the share of biofuels in transport gasoline and diesel increase from about 0.5% in 2005 to nearly 6% in 2020.

Table 51: Share of renewables in final energy consumption by country, baseline scenario

	2005	2010	2015	2020	2005-10	2010-15	2015-20	2005-20
in % (1 = 100%)					Annual % Change			
Austria	0.24	0.25	0.26	0.26	0.52	0.46	0.04	0.34
Belgium	0.05	0.06	0.07	0.07	1.44	2.47	2.19	2.03
Denmark	0.16	0.19	0.22	0.26	3.05	3.73	3.33	3.37
Germany	0.08	0.10	0.13	0.15	4.38	4.60	4.04	4.34
Finland	0.27	0.28	0.29	0.30	1.25	0.39	0.74	0.79
France	0.11	0.12	0.12	0.12	1.52	0.31	0.89	0.90
Greece	0.07	0.08	0.09	0.10	3.27	2.34	2.65	2.75
Irland	0.03	0.04	0.05	0.07	3.34	6.41	5.87	5.20
Italy	0.08	0.09	0.10	0.11	2.02	2.18	1.94	2.04
Luxembourg	0.02	0.03	0.04	0.05	6.90	8.80	5.11	6.92
Netherlands	0.04	0.04	0.05	0.06	1.54	2.85	3.82	2.73
Portugal	0.19	0.21	0.21	0.21	1.32	0.51	0.13	0.65
Spain	0.09	0.10	0.12	0.13	3.63	2.10	2.79	2.84
Sweeden	0.33	0.34	0.34	0.34	0.27	-0.03	-0.04	0.07
United Kingdom	0.03	0.04	0.05	0.06	4.64	5.51	5.88	5.34
Czech Republic	0.06	0.08	0.09	0.09	4.97	2.25	1.53	2.90
Estonia	0.20	0.20	0.19	0.19	-0.31	-1.53	0.20	-0.55
Latvia	0.37	0.36	0.35	0.34	-0.45	-0.76	-0.12	-0.44
Lithuania	0.16	0.16	0.16	0.18	-0.07	0.98	1.60	0.83
Hungary	0.06	0.06	0.07	0.07	0.78	1.22	0.24	0.74
Malta	0.00	0.01	0.01	0.04	30.34	19.51	25.65	25.09
Poland	0.09	0.09	0.11	0.12	2.02	2.77	2.60	2.46
Slovenia	0.16	0.16	0.16	0.16	0.24	0.31	-0.05	0.17
Slovakia	0.06	0.06	0.06	0.06	-0.49	0.61	1.30	0.47
Romania	0.17	0.18	0.17	0.17	0.30	-0.51	-0.79	-0.33
EU27	0.09	0.10	0.11	0.13	2.24	2.12	2.25	2.20

Source: NEMESIS model

The increase of renewables in final energy consumption (table 51) is particularly the fact of big countries as Germany (from 8% to 15%) , Italy (from 8% to 11%) Spain (from 9% to 13%) and United Kingdom (from 3% to 6%), where the initial share or renewable is initially low, but there is increase in every countries with the exceptions of Estonia (24% to 19%), Latvia (37% to 34%) and Slovenia (16%), Slovakia (6%) and Romania (17%) where it is stable.

Table 52: Share of renewables in power generation sector in EU-27, baseline scenario

	2005	2010	2015	2020	2005-10	2010-15	2015-20	2005-20
	in % (1 = 100%)				Annual % Change			
Austria	0.71	0.69	0.68	0.68	-0.39	-0.30	-0.09	-0.26
Belgium	0.03	0.03	0.03	0.04	4.46	1.88	4.35	3.56
Denmark	0.25	0.34	0.41	0.53	6.74	3.89	5.01	5.21
Germany	0.11	0.19	0.30	0.45	12.81	9.51	8.16	10.15
Finland	0.35	0.39	0.42	0.45	2.46	1.62	1.25	1.78
France	0.14	0.14	0.14	0.15	-0.25	0.25	1.37	0.45
Greece	0.10	0.12	0.15	0.19	3.72	4.57	5.60	4.63
Irland	0.05	0.07	0.09	0.14	4.03	6.82	8.78	6.53
Italy	0.19	0.18	0.18	0.18	-0.35	-0.32	-0.11	-0.26
Luxembourg	0.13	0.13	0.13	0.14	0.58	0.40	0.68	0.55
Netherlands	0.07	0.08	0.09	0.10	3.65	1.76	3.40	2.93
Portugal	0.30	0.29	0.30	0.32	-0.17	0.40	1.29	0.50
Spain	0.21	0.26	0.34	0.47	4.35	5.50	6.69	5.51
Sweeden	0.56	0.55	0.53	0.53	-0.34	-0.56	-0.32	-0.41
United Kingdom	0.03	0.05	0.06	0.09	6.59	6.18	8.33	7.03
Czech Republic	0.04	0.05	0.06	0.06	5.08	2.15	1.07	2.75
Estonia	0.00	0.01	0.01	0.01	14.17	5.44	4.22	7.85
Latvia	0.72	0.80	0.85	0.89	2.22	1.22	0.92	1.45
Lithuania	0.07	0.12	0.18	0.26	10.29	8.42	7.42	8.71
Hungary	0.01	0.01	0.02	0.02	3.97	3.53	3.92	3.80
Malta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	0.02	0.03	0.04	0.07	7.15	8.75	11.28	9.05
Slovenia	0.28	0.27	0.26	0.26	-0.59	-0.65	-0.54	-0.59
Slovakia	0.16	0.15	0.14	0.13	-0.97	-1.54	-1.54	-1.35
Romania	0.28	0.28	0.27	0.28	-0.46	-0.29	0.35	-0.13
EU27	0.16	0.18	0.21	0.26	2.89	3.16	3.83	3.29

Country evolutions are more contrasted for renewables share in power generation sector (Table 52) with huge increases in countries as Germany, Denmark, Spain and Latvia, and stabilization or slight decreases in other countries, as Austria, France, Italy, Luxembourg, Sweden in EU-15 and Estonia, Hungary, Malta, Slovenia, Slovakia and Romania in new member States.

Baseline scenario evolutions for biofuels in transports gasoline and diesel show on the contrary quite homogenous evolutions across EU countries (table 53), from share levels inferiors to 0.5% in 2005 that increase up to 5 to 9% in 2020 for most countries. This can be explained by the fact that biofuels penetration is more directly linked to oil price and other market considerations, than other renewables of which penetration depend heavily on country specific potentials, and historic characteristics of energy supply and demand system.

Table 53: Share of biofuels in transport gasoline and diesel

	2005	2010	2015	2020	2005-10	2010-15	2015-20	2005-20
in % (1 = 100%)					Annual % Change			
Austria	0.00	0.03	0.04	0.06	42.48	10.15	6.56	18.70
Belgium	0.00	0.01	0.03	0.05	752.61	19.21	9.44	123.22
Denmark	0.00	0.03	0.05	0.07	745.89	13.24	8.40	118.16
Germany	0.02	0.04	0.05	0.06	14.08	5.66	2.91	7.45
Finland	0.00	0.01	0.03	0.05	613.51	19.77	7.10	109.18
France	0.01	0.03	0.04	0.05	28.62	9.80	4.82	13.97
Greece	0.00	0.02	0.03	0.05	769.54	13.34	6.28	118.80
Irland	0.00	0.02	0.04	0.05	150.34	15.25	8.07	46.09
Italy	0.00	0.03	0.04	0.06	56.79	9.45	7.05	22.47
Luxembourg	0.00	0.02	0.05	0.07	119.06	18.69	8.05	41.10
Netherlands	0.00	0.02	0.05	0.07	880.09	19.12	9.27	133.66
Portugal	0.00	0.02	0.04	0.05	769.95	14.36	7.81	120.53
Spain	0.01	0.04	0.07	0.09	43.46	12.11	3.24	18.42
Sweeden	0.02	0.04	0.05	0.07	11.29	7.91	4.67	7.92
United Kingdom	0.00	0.02	0.04	0.06	67.71	14.56	8.25	27.64
Czech Republic	0.00	0.05	0.07	0.09	147.39	8.70	4.91	41.30
Estonia	0.00	0.04	0.06	0.07	565.85	8.57	3.81	95.79
Latvia	0.00	0.03	0.05	0.08	64.68	9.97	8.01	25.06
Lithuania	0.00	0.01	0.02	0.06	29.09	26.14	19.02	24.68
Hungary	0.00	0.04	0.06	0.08	760.80	9.25	6.23	115.37
Malta	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00
Poland	0.00	0.03	0.06	0.09	44.29	13.84	8.98	21.42
Slovenia	0.00	0.01	0.04	0.05	382.29	19.51	9.04	84.54
Slovakia	0.01	0.03	0.06	0.09	30.18	16.25	9.97	18.50
Romania	0.00	0.01	0.02	0.03	593.54	14.73	5.15	103.01
EU27	0.00	0.03	0.04	0.06	42.48	10.15	6.56	18.70

Source: Modèle NEMESIS

- **Presentation of scenarios**

Three distinct scenarios were assessed for with NEMESIS. The scenarios differ from the use made by states of the revenue of auctioning in the EU-ETS sector. In the Scenario S1, auctioning revenue is kept by states and is used for decreasing national debt. There is no recycling through public investment or revenue redistribution to private agents. In scenario S2, the revenue of auctioning in the EU ETS sector is recycled through an equivalent reduction, in terms of revenue, of employers' social contribution rate. In scenario S3, auctioning revenue is recycled in two ways: A reduction, as in scenario S2, of employers' social contributions rate, and a general subsidy to private R&D expenditures up to 30%. The R&D subsidy in calculated first, and only the difference between auctioning revenue and R&D subsidies is used to reduce employers' social contribution rate.

The other characteristics of the scenarios are identical, and follow the lines of EU 'Climate Action and Renewable Energy Package':

- for the EU-ETS sectors, tradable permits are introduced for CO_2, based on 2008-2012 average emission level. CO_2 quotas impose an annual reduction of –1.74% of CO_2 emissions in EU-ETS sectors from 2013 to 2020, compared to 2008-2012 average emission level, that is to say a reduction of –18.2% CO_2 emissions compared to 2005 level. Tradable permits are allocated by auctioning in the Power Generation sector, from 2013 to 2020, but in other EU-ETS sectors there is a free allocation for 80% of the quotas in 2013, the remaining being distributed with auctioning. The share of the quotas being attributed by auctioning increases linearly and reaches 100%, as in power generation sector, in 2020. The share of quotas allocated freely decreases consequently linearly from 80% in 2013 to 0% in 2020;
- for non EU ETS sectors, GHG emissions reduction target are fixed according to verified emissions levels in 2005, with a sharing of emission reduction effort amongst member states based on the principles of growth, fairness and solidarity, and assuring to reach the EU's

20% emission reduction commitments. GHG emissions target goes from -20% in richer member states as Denmark to +20% in poorest countries as Bulgaria, as set in EU ‘Climate Action and Renewable Energy Package’. National targets are reached in NEMESIS by imposing for each country GHG emissions caps that are lowered linearly from 2013 to 2020. Emissions caps are imposed by introducing national endogenous taxes on non EU-ETS CO_2 emissions, identical for all production sectors and for households. This carbon taxation is integrally redistributed to firms and households by equivalent subsidies to production and increases in disposable income. In this way, carbon taxation induces substitutions effects (between energy products and energy and other products and production factors) necessary to reach the target, but no revenue effects. It is in this sense fiscally neutral, and this was the best option in the absence of precise information onto the preferred actions for limiting GHG emissions in the different countries;

- auctioning revenue in each Member state takes into account the fact that 10% of auctioning revenue should be used for the purpose of community solidarity. Consequently, some member states, especially in new accessing countries, receive and redistribute more than their auctioning quotas;
- the targets on renewable energies share in final energy consumption (20% in 2020) and on biofuels share in transports gasoline and diesel consumption are also examined, but no specific policies, as subsidies to renewable, are introduced to reach these objectives that are spontaneously reached in the scenarios, or closely approached in 2020.

Figure 19 resumes the GHG emissions reduction effort to be achieves in EU-27 in order to reach the EU post-Kyoto objective of 20% emissions reductions compared to 1990 level. One can see on this table that at European scale baseline evolutions over 2005-2020 period implies a reduction of 12.7% of GHG emissions to reach EU post-Kyoto objectives (from index 92.7 to 80), whereas situation of European countries toward post-Kyoto objective are very contrasted.

In EU-15 countries, emissions level in 2020 should be identical to 1990 level from NEMESIS baseline projections, with very high increases of emissions levels in southern countries as Spain (62% increase compared to 1990) and Portugal (47% increase). On the other hand, countries as Germany, that is 25% below 1990 level in 2020, and also Denmark and united Kingdom, respectively 18 and 16% their 1990 level show very virtuous evolutions.

For new member States, the decline of heavy, energy intensive industries in the 90s, allowed to lower considerably the level of GHG emissions that was in 2005 35.4% below their 1990 level, that is to say quite far below EU Kyoto and post-Kyoto objective. With the economic recover in recent years, that is expected to continue in the baseline scenario with average GDP growth rates close from 4% in average over 2005-2020 period, GHG emissions in new Member States should re-increase 11.5% up to 2020, from NEMESIS baseline evolutions, but stay 28 below their 1990 level. The only exceptions are Malta and Slovenia where GHG emissions are in 2020 respectively 55 and 15% above their 1990 level.

It is this ‘Hot Air’ reserve in new Member States, and also the solidarity principle consisted to do not penalize EU countries with GDP per capita below EU average that conducted EU authorities adopting the burden sharing agreement for sectors not covered by EU ETS (Figure 20) where emissions reduction, that represent about 60% to EU GHG emissions, are costly to achieve.

Figure 19: GHG emissions in EU-27 countries compared to 1990

100 in 1990	Actual (EEA)	Baseline
	2005	2020
Austria	118.1	125
Belgium	97.9	106
Denmark	92.2	82
Germany	81.3	75
Finland	97.5	92
France	98.1	104
Greece	125.3	130
Ireland	125.3	134
Italy	112.1	120
Luxembourg	100.0	112
Netherlands	98.8	112
Portugal	140.4	147
Spain	152.2	162
Sweeden	92.7	109
United Kingdom	84.3	84
Czech Republic	74.2	70
Estonia	48.1	48
Latvia	42.1	61
Lithuania	47.0	67
Hungary	65.4	74
Malta	154.5	155
Poland	68.0	68
Slovenia	100.5	115
Slovakia	66.3	87
Romania	54.4	77
EU-15	98.0	100
EU-12	64.6	72
EU-27	**89.7**	**92.7**

As one can see on figure 20, this burden sharing agreement will allow new Member States increase their GHG emissions in non EU ETS sectors from 3 (Malta) to 20% (Bulgaria), while in EU-15 countries emissions should be reduced about 15 to 20% in northern countries, objectives being less important for southern countries.

For CO_2 emissions only, that represent more than 80% of overall GHG emissions, evolutions displayed in Figure 21 are of course similar: For 2020, EU-27 countries should globally situate 1.7% below their 1990 level, EU-15 countries increasing 3% their emissions above this 1990 level, and new Member States reducing 20% their emissions compared to it.

Figure 20: Reduction targets per country for non EU-ETS sectors for 2020 compared to 2005

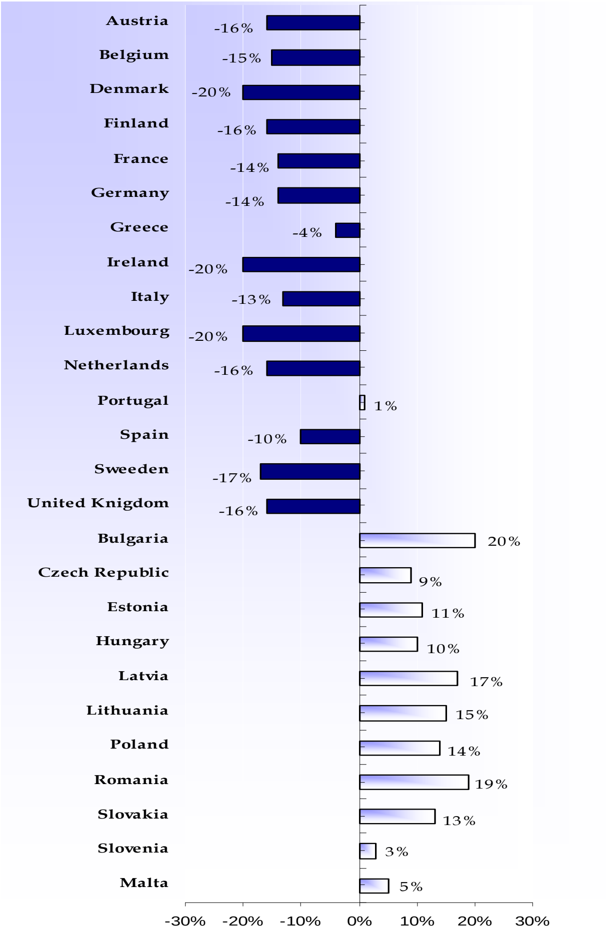

Figure 21: CO_2 emissions in EU-27 countries compared to 1990 level

100 in 1990	Actual (EEA)	Baseline
	2005	2020
Austria	130.2	135
Belgium	102.5	110
Denmark	94.0	79
Germany	84.3	75
Finland	99.5	90
France	107.5	112
Greece	135.9	133
Ireland	149.0	163
Italy	114.7	121
Luxembourg	107.8	120
Netherlands	111.5	124
Portugal	156.9	164
Spain	164.5	168
Sweeden	92.6	108
United Kingdom	94.9	92
Czech Republic	78.1	71
Estonia	45.0	44
Latvia	40.5	60
Lithuania	38.6	52
Hungary	85.2	95
Malta	144.2	144
Poland	86.2	83
Slovenia	114.7	122
Slovakia	63.1	82
Romania	60.3	85
EU-15	104.3	103
EU-12	74.9	80
EU-27	**97.9**	**98.3**

- **Results of scenario S1: ‘no recycling of auctioning revenue’**

In this first scenario, there is no recycling of auctioning revenue. This scenario allows consequently, when compared to results for scenarios S2 and S3, to assess for the efficiency of recycling schemes used in these last scenarios. It shows also the direct economic costs of increasing carbon price in EU ETS sectors and of imposing stronger limitations on GHG emissions in non EU ETS ones.

The simulation results show a decrease of EU-27 GDP of 0.65% in 2020 (see table below) reflecting the fall in private demand that follows the rise of carbon value in EU ETS sectors that reaches in 2020 61.17€/ton CO2-equivalent 23 € in the baseline scenario. This permits price is the balance associated to the emission commitment introduced in the *Climate Action and Renewable Energy Package*. This rise in carbon value represents an auctioning revenue of about 102.21 billions Euros for European states, taken on EU ETS firms that are constrained to increase their production price. This increases final consumptions prices by 1.15%, and households reduce 0.6% their final consumption, with an equivalent reduction of their real disposable income.

Table 54: Macroeconomic results for Europe EU-27 in 2020 (S1)

Main Macroeconomic Results	
GDP	-0.65
Final consumption	-0.60
Firms' investment	-2.18
Energy consumption	-7.68
Extra-EU Exports	-0.86
Extra-EU Imports	-1.09
Private R&D	1.33
Employment	-0.17

Energy consumption falls 7.68%, as a consequence of high EU ETS carbon value, but also of carbon taxation in non EU ETS sectors. Firms’ investment reduces –2.18%, that is more than the fall in production and reflects the complementarity existing between energy consumption and investment in capital goods in NEMESIS. Conversely the evolution of employment, which falls only 0.17%, reflects favorable substitutions from energy and capital intensive production techniques, to more labour intensive ones.

Table 55: Impact on the sectoral industrial production in 2020

Power Generation	1.2%
Other Energy Branches	-10.7%
Agriculture	-1.2%
Industry	-1.0%
- energy Intensive industries	-0.9%
- other industries	-1.0%
Construction	-1.4%
Tertiary	-0.4%
Transport	-0.8%
- see & air	-1.5%
- road & rail	-0.4%
EU-ETS sectors	-1.7%
Non EU-ETS sectors	-0.7%
Total	-0.8%

Source: Modèle NEMESIS

This higher balance price for carbon in EU ETS and the introduction of carbon penalties in non EU ETS impact also negatively on EU-27 foreign competitiveness, with a 0.86% fall of exports in 2020. The reduction of EU-27 imports, by -1.09% in 2020, due to the lower internal consumption and the fall of energy imports, allows nevertheless EU external balance to evolve favorably. There is an also positive impact onto private R&D expenditures that rises 1.33%, with a much more important impact in EU ETS, energy intensive sectors, and especially power sector, where productivity improvements offset partially the cost of carbon penalty.

EU ETS, energy intensive sectors encounter nevertheless a sharp fall of production in EU-27 for 2020 (table 55), with -1.7%, and -10.7% for energy branches excluding Power sector, where the development of renewable energies production, and favorable substitutions between energy products, induces a 1.2% increase in electricity production. Fall of production in non EU ETS sectors are less important, and closely related to GDP evolution.

At country level, table 56 show contrasted impacts for GDP, that range in 2020 from +0.20% in Luxembourg, to –0.41% in France, –0.61% in Sweden and Belgium, –1.23% in Portugal, and – 1.46% in Spain.

Table 56: Macroeconomic impacts for the EU15 countries in 2020

	GDP	Final consumption	Firms' investment	Energy consumption	Private R&D	Employment
Austria	-0.58	-0.94	-2.33	-5.89	1.24	-0.04
Belgium	-0.61	-0.25	-3.38	-9.27	1.49	0.47
Denmark	-0.02	0.30	-1.95	-6.02	0.36	0.22
Germany	-0.30	-0.42	-1.10	-6.21	1.02	-0.09
Finland	-0.39	-0.23	-0.67	-7.32	0.89	0.07
France	-0.41	-0.26	-2.01	-10.97	1.22	0.30
Greece	-1.07	-1.15	-1.74	-5.64	2.15	-0.80
Ireland	-0.34	1.20	-4.40	-6.07	0.79	1.10
Italy	-1.14	-1.26	-3.25	-8.08	1.87	-0.46
Luxembourg	0.20	0.38	-1.03	-5.15	-0.99	1.20
Netherlands	-0.98	0.18	-4.57	-11.98	1.43	0.89
Portugal	-1.23	-1.21	-1.60	-3.52	1.91	-0.61
Spain	-1.46	-1.71	-2.93	-8.40	2.45	-0.59
Sweeden	-0.61	-0.59	-0.49	-5.72	1.37	-0.19
United Kingdom	-0.65	-0.24	-2.16	-7.03	1.91	0.27
EU27	-0.65	-0.60	-2.18	-7.68	1.33	-0.17

deviation w.r.t. baseline (in percentage points)

Source: NEMESIS model

Table 57: Macroeconomic impacts in 2020 for Members with a GDP per capita below EU-27 average

	GDP	Final consumption	Firms' investment	Energy consumption	Private R&D	Employment
Czech Republic	-0.78	-0.52	-1.70	-2.99	1.40	-0.13
Estonia	-0.09	-0.05	-1.64	-3.95	1.50	0.22
Latvia	-0.54	-0.68	-1.62	-4.68	1.19	-0.36
Lithuania	0.01	0.17	-0.99	-2.33	-0.57	0.30
Hungary	-0.21	-1.09	-2.77	-6.79	2.49	-0.29
Malta	-0.20	-0.54	-0.86	-2.05	1.46	-0.12
Poland	-0.96	-1.22	-1.81	-3.97	3.47	-0.82
Slovenia	-0.96	-0.84	-1.35	-3.28	1.85	-0.44
Slovakia	-2.27	-4.39	-6.77	-10.74	7.72	-3.00
Romania	-2.20	-1.31	-8.89	-13.47	8.53	-1.85
EU27	-0.65	-0.60	-2.18	-7.68	1.33	-0.17

There are remarkable facts:

- fall in GDP are mainly driven by private consumption, for example in Austria (-0.98%), in Portugal (–1.21%) and in Spain (–1.71%), where the consumer price index rise importantly;
- Greece and the Netherlands encounter the worse performances for investment with respectively –1.50% and –1.63% in 2020.
- pressure on employment differs across European countries. The EU-15 member countries are less impacted by the drop of employment with –0.59% in Spain, –0.46% in Italy, –0.29% in Hungary and –0.09% in Germany. There is even increases of employment in several EU-15 countries as France (+0.30), Belgium (+0.47%), Netherlands (+0.89%) or Ireland (+1.30%), as a consequence of the positive substitution effects already quoted above It contrasts with evolutions in new member States where employment decreases everywhere except Lithuania;
- fall in GDP tends to be similar for States with a GDP per capita below EU average than for EU-15 countries, with –0.09% in Estonia, –0.20% in Hungary, and –0.96% in Poland and Slovenia. But, it is two of these countries, Slovakia and Romania, that experience the highest negative impact on GDP with respectively –2.27% and –2.20% in 2020, due to importance of coal in their energy system. These countries encounter also the biggest fall in employment, with respectively–3% and –1.85%, and also –0.82% in Poland.

Scenario shows finally the necessity to recycle auctioning revenues for lowering GDP, final consumption and employment costs of the “Climate Action and Renewable Energy Package”. It shows also the necessity to use part of these revenues for the purpose of community solidarity to lower the policy cost in new member states as Romania, Slovakia and Poland, where EU ETS sectors represent a large part of economic activities with also higher energy intensity of these activities and of GDP, than in EU-15 countries.

Table 58: GHG emissions reductions in EU-27 countries for 2020, S1 scenario

	2020					
	Baseline (100 in 2005)			Reductions (in % dev. from baseline)		
	EU ETS	non EU ETS	Total	EU ETS	non EU ETS	Total
Austria	104.5	107.5	106.4	-9.0	-16.2	-13.6
Belgium	110.7	105.6	107.6	-9.7	-16.7	-13.8
Denmark	85.3	97.8	91.7	-11.3	-7.4	-9.3
Germany	83.5	100.8	92.1	-19.4	-11.4	-14.8
Finland	90.9	100.7	95.1	-9.4	-10.8	-10.1
France	108.1	105.1	105.9	-8.9	-12.3	-11.3
Greece	101.8	109.0	104.9	-11.1	-7.9	-9.6
Ireland	96.6	114.2	108.1	2.6	-23.0	-15.1
Italy	112.1	100.1	105.5	-10.4	-11.0	-10.7
Luxembourg	99.4	122.7	112.3	-6.6	-30.7	-21.3
Netherlands	113.1	113.0	112.9	-7.3	-22.1	-14.4
Portugal	105.9	102.0	104.0	-12.6	-3.0	-7.9
Spain	95.5	116.7	106.7	-12.8	-15.7	-14.4
Sweeden	136.5	101.5	115.8	-12.2	-10.8	-11.5
United Kingdom	96.5	104.4	100.8	-7.8	-13.9	-10.9
Czech Republic	79.6	123.8	95.5	-10.4	-10.8	-10.1
Estonia	84.4	149.7	101.2	-9.9	-23.2	-14.8
Latvia	141.9	152.5	148.7	-10.3	-19.3	-16.1
Lithuania	149.7	140.7	145.0	-7.1	-14.3	-10.7
Hungary	101.9	124.7	114.4	-13.2	-11.4	-12.0
Malta	99.5	106.1	100.7	-7.5	-0.3	-6.1
Poland	91.5	113.9	99.7	-10.1	-3.4	-6.9
Slovenia	117.7	112.3	114.5	-6.2	-5.9	-6.0
Slovakia	130.2	134.9	131.6	-14.7	-19.6	-16.5
Romania	137.9	147.3	139.7	-19.7	-26.6	-21.8
EU-27	98.8	107.6	103.3	-11.9	-13.0	-12.3

For GHG emissions (table 58), the evolutions in scenario S1 compared to baseline figures for 2020 show that the EU-27 12.3% reduction effort in % deviation from baseline, is quite fairly shared between EU-15 and new Member States countries, the former group of countries reducing in average more its emissions than this later, despite lower growth of GHG emissions level over the period 2005-2020. Emissions in non EU ETS sectors, that reduce 13% for EU-27, are constraint in countries by the burden sharing agreement, while emissions for EU ETS, that reduce 11.9% for EU-27, result in the different countries mainly from their respective marginal abatement costs for CO_2 and from the free trade that occurs inside and between European industries and countries for CO_2 allowances in scenario S1.

Table 59: CO_2 emissions reductions in EU-27 countries for 2020, S1 scenario

	2020					
	Baseline			Objectives		
	EU ETS	Non EU ETS	Total	EU ETS	Non EU ETS	Total
Austria	100.6	106.9	104.3	-9.5	-20.7	-16.3
Belgium	109.3	105.2	106.9	-10.2	-19.7	-15.5
Denmark	82.0	93.7	87.2	-13.0	-12.5	-12.5
Germany	81.4	99.3	89.4	-20.7	-14.2	-17.4
Finland	86.1	99.5	91.0	-10.5	-14.8	-12.2
France	102.1	104.6	103.8	-10.7	-17.9	-15.6
Greece	93.5	108.7	99.2	-13.3	-10.3	-12.0
Irland	90.8	128.3	110.3	2.0	-36.3	-21.3
Italy	110.2	99.1	104.5	-11.1	-13.4	-12.2
Luxembourg	98.8	121.7	111.0	-6.6	-34.1	-22.8
Netherlands	108.8	113.7	110.8	-7.9	-26.2	-16.1
Portugal	105.0	103.4	104.3	-13.1	-3.7	-9.1
Spain	91.5	116.1	102.7	-13.8	-21.6	-17.8
Sweeden	135.1	97.7	115.5	-13.1	-15.3	-14.1
United Kingdom	93.6	102.5	98.2	-8.1	-17.6	-12.6
Czech Republic	76.7	127.6	92.1	-11.0	-13.6	-12.1
Estonia	83.2	164.1	99.2	-10.5	-29.5	-16.8
Latvia	136.0	168.2	153.9	-10.7	-26.0	-19.9
Lithuania	124.8	152.6	137.6	-11.8	-21.4	-16.7
Hungary	94.7	129.3	112.3	-16.7	-14.3	-15.2
Malta	98.9	105.2	100.0	-7.6	-0.3	-6.3
Poland	86.9	117.0	95.9	-10.9	-4.2	-8.2
Slovenia	100.4	114.0	107.0	-8.4	-9.2	-8.8
Slovakia	123.8	147.5	132.0	-15.3	-22.8	-18.2
Romania	126.2	179.3	140.4	-22.3	-34.9	-26.6
EU-27	94.6	107.3	100.5	-13.0	-16.9	-14.9

Table 59, that displays the results for CO_2 emissions, shows little higher reductions for CO_2 than for global GHG emissions in 2020, with for EU-27 in deviation from baseline, reductions of 13% in EU ETS sectors, 16.9% in non EU ETS sectors and 14.9% for global CO_2 emissions. Results *per* country for CO_2 are comparable to results obtained for global GHG emissions, since in EU ETS sectors only CO_2 is constrained, and in non EU ETS sectors the emissions constraint bears on all gases but sole CO_2 emissions were taxed as NEMESIS cannot deal with taxes for other GHG categories than CO_2.

As a result of the absence of specific emissions reduction policies other than for CO_2 in EU ETS sector, the post Kyoto target in not exactly reached in 2020, the reduction of GHG emissions for EU-27 being 19.1% compared to 1990 only. An additional abatement effort, for example 10% additional reduction of non GHG emissions in EU ETS sectors, should thus be imposed through statutory measures, to reach the 20% post-Kyoto objective.

For the other objectives of the EU ‘Climate Action and Renewable Energy Package’, one can state equally that the targets are also closely satisfied in this scenario S1.

For the share on renewables in final energy consumption (table 60), one reaches in 2020 18% for EU-27 countries, against 8.5% in 2005 and 13% in 2020 in the baseline scenario. The high oil and gas prices in the baseline scenario, in conjunction to the high prices for carbon in EU ETS and non EU ETS sectors in scenario S1, create thus very strong incentives for renewable energies development, even without introduction of additional specific policies for renewable energy sources, as foreseen in the EU renewable energies directive proposal. The 20%

renewable share could be reached from 2022 if one will pursue the scenario horizon until 2025, with this time a 25% reduction objective for GHG emissions in 2025 compared to 1990, as it was studied with NEMESIS[8].

Table 60: Share of renewables in EU-27 countries, scenario S1

1 = 100%		Baseline	S1
	2005	2020	
Austria	0.24	0.26	0.34
Belgium	0.05	0.07	0.15
Denmark	0.16	0.26	0.20
Germany	0.08	0.15	0.14
Finland	0.27	0.30	0.35
France	0.11	0.12	0.21
Greece	0.07	0.10	0.12
Irland	0.03	0.07	0.21
Italy	0.08	0.11	0.15
Luxembourg	0.02	0.05	0.23
Netherlands	0.04	0.06	0.13
Portugal	0.19	0.21	0.23
Spain	0.09	0.13	0.20
Sweeden	0.33	0.34	0.38
United Kingd	0.03	0.06	0.11
Czech Repub	0.06	0.09	0.15
Estonia	0.20	0.19	0.38
Latvia	0.37	0.34	0.48
Lithuania	0.16	0.18	0.26
Hungary	0.06	0.07	0.11
Malta	0.00	0.04	0.05
Poland	0.09	0.12	0.13
Slovenia	0.16	0.16	0.20
Slovakia	0.06	0.06	0.10
Romania	0.17	0.17	0.40
EU27	0.09	0.13	0.18

Source: NEMESIS model

Nevertheless, the development of renewable is unequal between countries. Most of EU countries reach their renewable energies potential as defined by European Commission (COM(2008) 30 final, available also in deliverable D15) for 2020, or approach it by less than 3%. Apart Slovakia, where 4% renewable share could be reach in 2020, the other exception is Denmark, where there exists for 2020 an additional 10% potential compared to scenario S1 results.

For 10% biofuels in transports gasoline and diesel consumption objective for 2020, the high price of petroleum products, allow also reaching the objective in scenario S1, with a share of 12% for EU-27. Eight European countries stay below 8% share in 2020 (Belgium, Finland, Greece, Ireland, Portugal, Malta, Slovenia and Romania), for which additional policies for biofuels could be envisaged.

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[8] Results for 2025, are available on request for S1, S2 and S3 scenarios.

Table 61: Biofuels share in transport gasoline and diesel, scenario S1

1 = 100%		Baseline	S1
	2005	2020	
Austria	0.00	0.06	0.12
Belgium	0.00	0.05	0.05
Denmark	0.00	0.07	0.08
Germany	0.02	0.06	0.08
Finland	0.00	0.05	0.05
France	0.01	0.05	0.09
Greece	0.00	0.05	0.05
Irland	0.00	0.05	0.07
Italy	0.00	0.06	0.10
Luxembourg	0.00	0.07	0.09
Netherlands	0.00	0.07	0.09
Portugal	0.00	0.05	0.06
Spain	0.01	0.09	0.17
Sweeden	0.02	0.07	0.09
United Kingd	0.00	0.06	0.11
Czech Repu	0.00	0.09	0.14
Estonia	0.00	0.07	0.09
Latvia	0.00	0.08	0.15
Lithuania	0.00	0.06	0.14
Hungary	0.00	0.08	0.09
Malta	0.00	0.02	0.02
Poland	0.00	0.09	0.10
Slovenia	0.00	0.05	0.06
Slovakia	0.01	0.09	0.19
Romania	0.00	0.03	0.04
EU27	0.00	0.06	0.12

- **Results of scenario S2: Recycling of auctioning revenue by a cut in employers' social contributions rate**

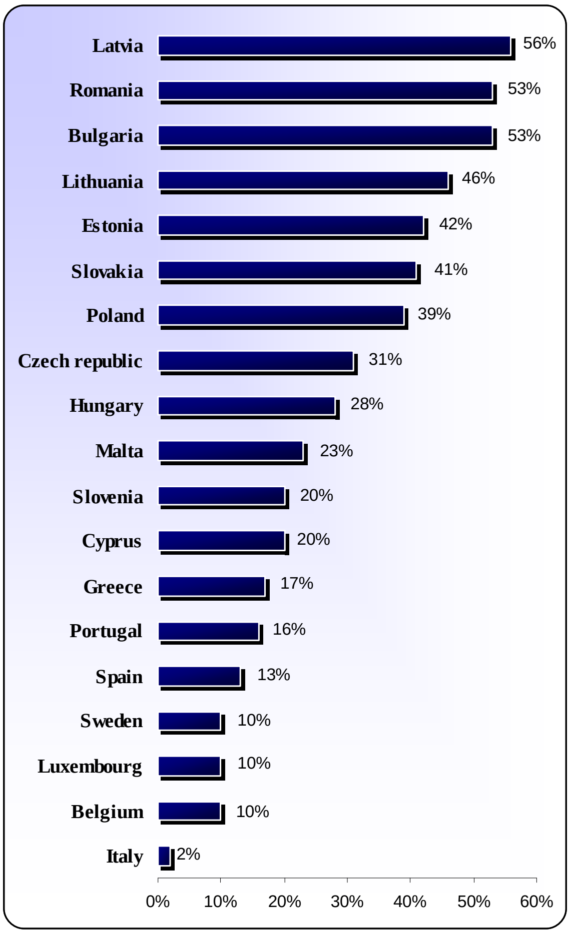
This scenario S2 deepers the analysis by a recycling of auctioning revenues generated by the implementation of the *Climate Action and Renewable Energy Package*. The recycling takes into account the community solidarity principle. 90% of auctioning rights are distributed accordingly to Member States share in 2005 emissions in the EU ETS, and the remaining 10% are redistributed to low income countries, taking into account their GDP per capita and their overall growth expectations, with the repartition displayed on figure 22.

This distribution of auctioning rights results in significant reduction of overall direct costs experienced by member states with a low GDP per capita, with limited direct costs increases for richer countries. Revenues generated by auctioning are actually substantial. They reach 0.8% European GDP in 2020, for a carbon price of 74.34€/ton CO2-equivalent, and they can exceed 2% GDP in countries as Romania with 2.8%, Czech Republic with 3% and Poland with 2.7% that beneficiate the more from the solidarity principle.

These auctioning revenues are used in scenario 2 to lower employers' social contribution rate. This recycling consisting in transferring part of labour taxation onto carbon taxation was actually extensively studied in economic literature, for the reason that labour is generally considered too heavy taxed in European countries, leading to high unemployment rates.

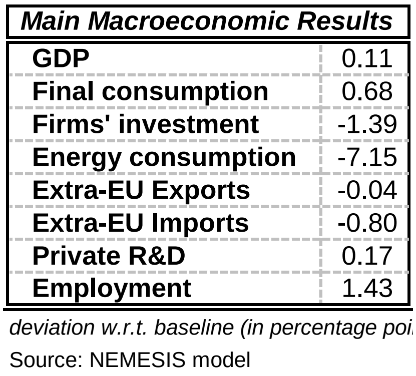
The recycling of auctioning revenues by a reduction in employers' social contribution rate in scenario S2, allows in that direction to obtain a 'double dividend Environment/Employment' at EU-27 level (table 62), with a rise of total employment of 1.43% in 2020, compared to a decrease of –0.17% in the scenario S1.

Figure 22: Percentage of increase in allowances to be auctioned for the purpose of community solidarity



Source: European Commission (Proposal Directive to Improve and extend the Greenhouse Gas Emission Allowance Trading System COM (2008))

Table 62: Macroeconomic results for Europe EU27 in 2020

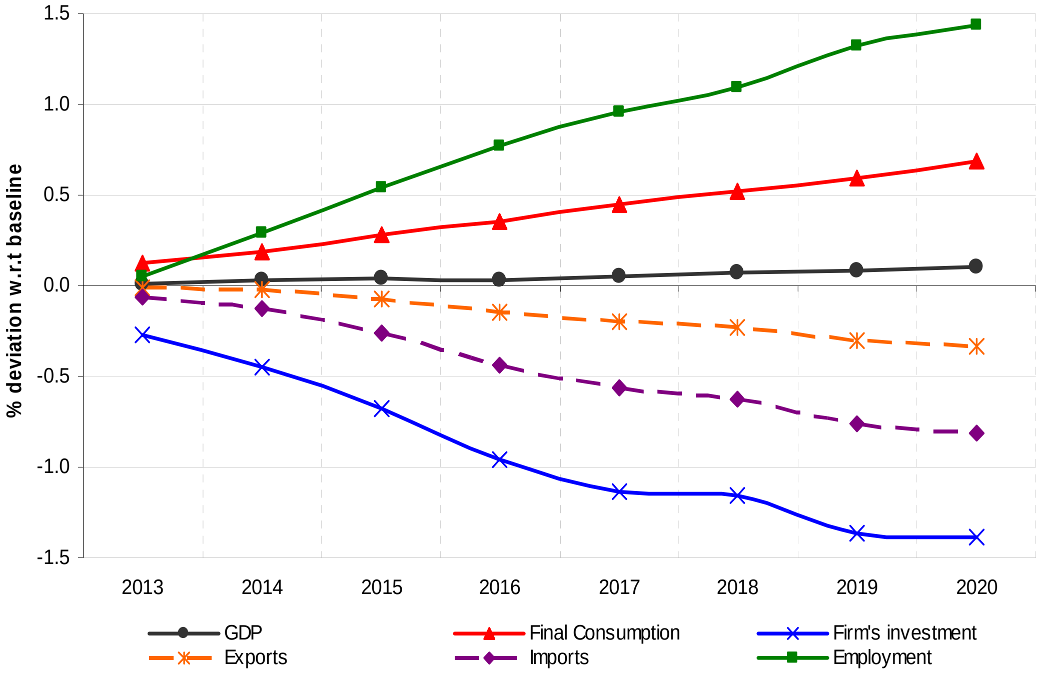


Main Macroeconomic Results	
GDP	0.11
Final consumption	0.68
Firms' investment	-1.39
Energy consumption	-7.15
Extra-EU Exports	-0.04
Extra-EU Imports	-0.80
Private R&D	0.17
Employment	1.43

deviation w.r.t. baseline (in percentage poi

Source: NEMESIS model

Figure 23: Macroeconomic trends for Europe EU27



Source: Nemesis model

This increase in employment level is caused by the direct substitution effect due to the lowering of labor costs, and by the consecutive rise in final consumption (+ 0.68%) due to the fall in unemployment rate. There is even a slight positive impact on GDP in that scenario, that rises 0.11% in 2020, for the main reason that fossil fuels imports are reduced, and replaced by increased consumption for goods produced principally inside Europe. Also, reduced labour costs allow decrease production costs, despite the fact that carbon price is high and increases But this high energy (and oil) prices context renders more profitable substitutions from labour to energy, that result in a decrease of –0.89% of consumption price index, that come reduce the negative impacts of the policy on European exports, that fall only 0.04%, against 0.89% in scenario S1.

The results of S2 scenario are, of course, contrasted amongst European countries, as a consequence of different energy consumption and production systems, added to different labour market structure. In EU-15, some countries have still negative impact on GDP, as Spain (–0.77%), Netherlands (–0.55%) or France (–0.18%), but all have important employment gains, that reach from 0.08% in Sweden to 1.99% in Luxembourg and 0.59% in France, 0.91% in Germany and 1.03% in United Kingdom, the biggest European economies.

Table 63: Macroeconomic impacts for the EU-15 countries in 2020

	GDP	Final consumption	Firms' investment	Energy consumption	Private R&D	Employment
Austria	-0.15	-0.55	-2.00	-5.74	0.41	0.46
Belgium	-0.18	0.26	-3.12	-9.19	0.70	1.11
Denmark	1.27	3.60	-0.58	-4.48	-0.33	1.45
Germany	0.59	0.63	-0.30	-5.74	-0.37	0.91
Finland	0.38	1.26	0.32	-6.61	-0.26	1.07
France	-0.18	-0.02	-1.85	-10.99	0.66	0.59
Greece	0.16	-0.23	-0.81	-4.93	-0.92	1.62
Ireland	0.17	2.14	-3.98	-5.83	0.04	1.71
Italy	-0.21	-0.10	-2.48	-7.43	0.52	0.70
Luxembourg	0.80	1.37	-0.61	-4.91	-1.80	1.99
Netherlands	-0.55	0.29	-4.31	-11.88	0.18	1.54
Portugal	-0.47	-1.21	-1.14	-2.97	-0.28	0.70
Spain	-0.77	-0.84	-2.27	-8.16	1.15	0.30
Sweeden	-0.37	-0.23	-0.44	-5.70	0.89	0.08
United Kingdom	-0.12	0.19	-1.74	-6.83	0.67	1.03
EU27	0.11	0.68	-1.39	-7.15	0.17	1.43

deviation w.r.t. baseline (in percentage points)

Source: NEMESIS model

Table 64: Macroeconomic impacts in 2020 for Members with a GDP per capita below EU-27 average in 2020

	GDP	Final consumption	Firms' investment	Energy consumption	Private R&D	Employment
Czech Republic	3.82	8.12	2.99	1.22	-5.01	6.27
Estonia	2.03	5.37	1.33	-1.25	-3.50	4.12
Latvia	0.00	0.26	-1.15	-4.42	-0.25	0.35
Lithuania	1.44	2.76	0.19	-1.67	-2.95	2.02
Hungary	1.54	2.37	-1.01	-5.69	-0.54	2.42
Malta	0.58	1.73	0.00	-1.28	-2.14	1.63
Poland	2.61	4.19	1.81	-0.67	-4.04	4.01
Slovenia	-0.02	0.90	-0.39	-2.33	0.06	0.91
Slovakia	1.32	-0.13	-4.39	-8.83	3.26	0.59
Romania	4.58	10.27	-2.73	-8.63	-0.89	7.96
EU27	0.11	0.68	-1.39	-7.15	0.17	1.43

Most importantly, new EU Member States, with GDP per capita below European average, are now the countries that know the most positive impacts from the policy. This contrasts strongly from the results of scenario S1, and demonstrates that the implementation of the EU *Climate Action and Renewable Energy Package*, with the community solidarity principle that was retained here, could represent a true opportunity for employment and growth in these countries.

For CO_2 and GHG emissions, results for scenario 2 are very similar than for scenario 1 (and also scenario 3) for the reason that emissions reduction objectives are identical in all scenarios. These results will consequently not be presented, the important being that the scenario conform again the EU post-Kyoto objectives in terms of GHG emissions and burden sharing agreement for non EU ETS sector. For renewable objectives also, the changes are too small to be commented in this report.

- **Results of scenario S3: Recycling of auctioning revenue combining a cut in employers' social contributions rate and a subsidy to firms' private R&D**

This scenario S3 differs from scenario S2 only in the way auctioning revenue is recycled. The auctioning revenue is recycled in two ways: A reduction, as in scenario S2, of employers' social contributions rate, and a general subsidy to private R&D expenditures limited to 30%. The rate of R&D subsidy was limited to 30% in order to stay in orders of plausible magnitude.

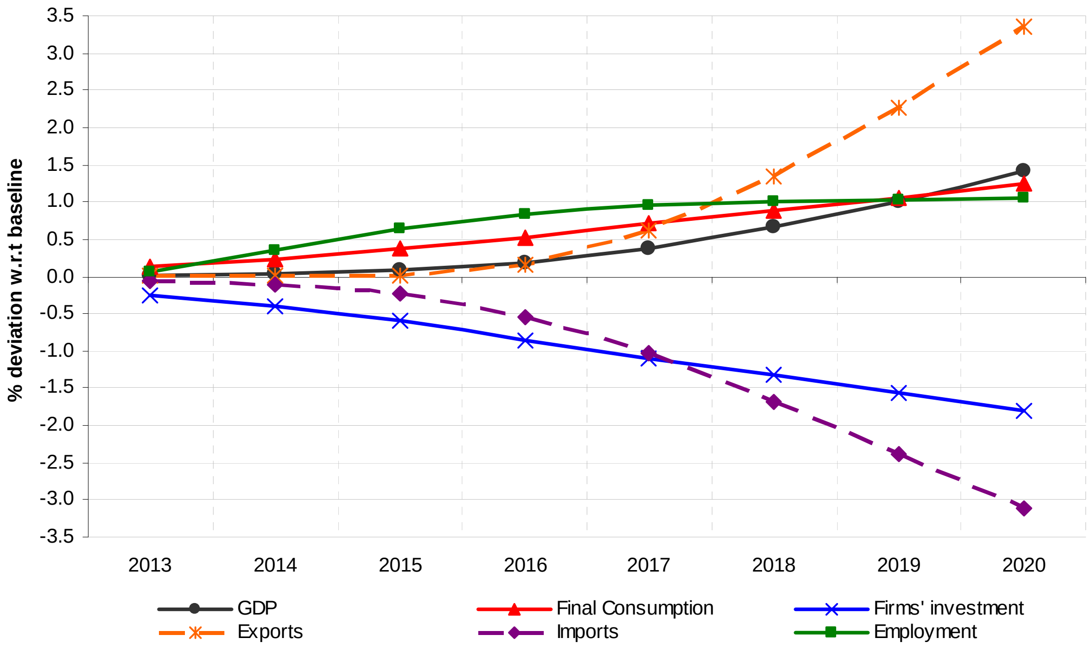
Table 65: Macroeconomic results for Europe EU27 in 2020

Main Macroeconomic Results	
GDP	1.41
Final consumption	1.25
Firms' investment	-1.80
Energy consumption	-8.46
Extra-EU Exports	3.34
Extra-EU Imports	-3.10
Private R&D	25.90
Employment	1.07

deviation w.r.t. baseline (in percentage poin

Source: NEMESIS model

Figure 24: Macroeconomic trends for Europe EU27



Source: Nemesis model

The results of this last scenario for 2020, presented in Table 65 above for EU-27, show this time very positive evolutions for all macro-economic indicators. The European GDP increases about +1.41% in 2020, compared to a decrease of 0.65% in scenario S1 and an increase limited to +0.11% in S2. The strong stimulation of firms R&D expenditures in this scenario, that increase 26%, provoke important positive competitiveness effects, that traduces by a decrease of consumer (and GDP) price index of 3.5%. The underlying mechanisms are the rise in total factor productivity and in the quality of goods produced resulting from important process and product innovations by European firms.

The decreases in consumer and GDP price are re-enforced, as in scenario S2, by the fall in labour cost implied by the cut in firms' social contributions rate. It results in a rise of 1.25% of households' private consumption, to compare to –0.60% in scenario S1 and only +0.68% in scenario S2.

The results for employment, when compared to those of scenario 2 are more contrasted. It increases +1.07%, against 1.43% in scenario S2 for the reason that the subsidy to R&D come limit the importance of the cut in employers' social contribution rate, and that the increase in productivity come also reduce employment.

This reduced positive impact on employment in S3 compared to scenario S2 is nevertheless compensated by better evolutions for GDP and final consumption. The impacts, compare to S2, are also very positive for external trade, with a rise of exports of 3.34% (against -0.04% for S2) and a fall of imports 3.1% (against only -0.8% in S2). This increased competitiveness of European countries in scenario S3 should then guaranty durable macroeconomic and employment gains, compared to S2 where part of the benefices could be only transitory.

Table 66: Macroeconomic impacts for EU-15 countries in 2020

	GDP	Final consumption	Firms' investment	Energy consumption	Private R&D	Employment
Austria	1.51	0.59	-2.25	-7.54	18.50	0.50
Belgium	1.73	0.81	-3.49	-9.84	26.71	0.75
Denmark	1.21	1.22	-2.23	-7.77	23.76	0.23
Germany	1.76	1.13	-0.65	-7.27	22.40	0.64
Finland	2.85	1.28	-0.97	-7.70	16.34	0.66
France	0.77	0.33	-2.15	-11.64	12.14	0.33
Greece	1.74	1.49	-0.35	-4.88	66.11	2.00
Ireland	1.62	2.31	-4.89	-7.36	37.19	1.53
Italy	1.91	1.48	-2.41	-8.81	71.56	0.80
Luxembourg	2.04	1.42	-3.28	-7.99	33.11	0.35
Netherlands	1.19	1.49	-4.14	-12.25	39.09	1.61
Portugal	-0.24	-0.90	-2.32	-4.98	71.29	-0.10
Spain	0.43	-0.06	-2.64	-10.01	74.09	-0.10
Sweeden	1.73	-0.18	-0.82	-7.29	4.48	-0.24
United Kingdom	1.30	1.36	-1.72	-7.87	28.80	1.00
EU27	1.41	1.25	-1.80	-8.46	25.90	1.07

deviation w.r.t. baseline (in percentage points)

Source: NEMESIS model

This scenario S3 aims thus reaching an authentic triple dividend 'growth-environment-employment', showing the interest to couple a policy designed for fighting climate change and promoting renewable energies use across European countries, with a policy accelerating technological change. It contributes also achieving the Barcelona R&D target (increasing R&D to 3% European GDP) included in the Lisbon Agenda of EU-27.

Furthermore, scenario S3 allow reaching the *Climate Action and Renewable Energy Package* objectives for GHG emissions reduction at a lower price for carbon, with 57.12 €/ton CO2-equivalent in 2020, against respectively 61.17€ and 74.34€ in scenarios S1 and S2. This is caused by the increased productivity of production factors in this last scenario.

Table 67: Macroeconomic impacts in 2020 for Members with a GDP per capita below EU-27 average

	GDP	Final consumption	Firms' investment	Energy consumption	Private R&D	Employment
Czech Republic	4.15	5.99	0.75	-2.11	66.34	4.05
Estonia	3.71	3.76	-0.43	-3.81	69.10	2.51
Latvia	0.91	-0.54	-2.74	-6.21	73.05	-0.46
Lithuania	1.63	2.66	-0.62	-2.75	66.72	1.79
Hungary	4.12	2.61	-1.63	-6.55	70.17	2.11
Malta	1.75	1.83	-0.39	-2.97	69.72	1.28
Poland	2.70	3.07	0.07	-2.93	67.56	2.85
Slovenia	1.31	1.21	-1.12	-4.61	70.92	0.70
Slovakia	0.53	-0.82	-6.11	-10.74	78.89	-0.50
Romania	5.93	8.61	-3.68	-10.23	71.13	6.48
EU27	1.41	1.25	-1.80	-8.46	25.90	1.07

deviation w.r.t. baseline (in percentage points)

Source: NEMESIS model

Scenario S3 shows also, as scenario S2, that the most favorable macro-economic impacts occur in new Member States (see tables 66 and 67). The impacts on GDP and final consumption are positive in every countries and generally superiors than in scenario S2. As in scenario S2, in S3 the new member states beneficiate of the highest cuts in employers' social contribution rate, but also, in S3, of the highest increases in R&D expenditures and productivity. R&D expenditures, which level is initially very low in the baseline scenario, increase about 70% in average in new member states, against 26% only for EU-27 average. Scenario S3 demonstrates again that the implementation of the EU *Climate Action and Renewable Energy Package* and its community solidarity principle, could represent a true opportunity for employment and growth in countries with GDP per capita below European average.

• Comparison of NEMESIS results with Commission assessment for EU Climate Action and Renewable Energy Package of 27 February 2008 (SEC(2008) 85 Vol. II)

The 'Package of implementation measures for the EU's objectives on climate change and renewable energies for 2020' issued by European Commission the 23 January 2008, was accompanied with an impact assessment by Commission staff (SEC(2008) 85/3), that was updated the 27 February 2008 (SEC(2008) 85 Vol. II) to account for 'the high energy import price environment of recent years, sustained economic growth and new policies and measures implemented in the Member States.

For purpose of comparison, the assessment for EU *Climate Action and Renewable Energy Package* presented here was based on common assumptions with 27 February 2008 assessment, concerning notably:

- GDP growth in line with DG ECFIN expectations (2.2% on average up to 2030);
- Inflation rate;
- renewables shares;
- policy measures up to 2006 that were included in the baseline scenario;
- directive of the nuclear phase-out;
- continuation of the EU ETS over the projection period without extension to new sectors, with a balance carbon price of 20€ (2005)/t CO_2 to 22€ (2005)/t CO_2 in 2020.

Commission staff assessment was realized notably with by GAINS and PRIMES model for energy, GHG emissions, and renewables indicators, and by GEM-E3 general equilibrium model for the calculation of economic impacts of the scenarios that were studied.

For policy experimentations, NEMESIS baseline was notably calibrated on PRIMES results for key indicators:

- renewable share evolution in power generation sector and electricity production from Geothermal, Hydraulic and Nuclear sources;
- biofuels share in gasoline and diesel;
- fuel inputs in power generation sector and fuels efficiency factors in power generation and in transport sector (passengers and freight).

Slight differences exist as NEMESIS used slightly higher oil (and gas prices) to account for the most recent context (up to third quarter 2008) for the price of imported energies.

Table 68: Prices for oil in $ / boe in money of 20005

	2005	2010	2015	2020
PRIMES/GAINS/GEM-E3	54.5	54.5	57.9	61.1
NEMESIS	54.5	92.2	67.8	76

The purpose of this section is then to compare the results of evaluations made by the different models. The comparison will bear only on economic indicators as the scenarios studied with the different model follow the same policy objectives for GHG reduction and renewables.

Table 69: Comparison of assessments, ‘no Community Solidarity Principle Case’

	PRIMES/GAINS/GEM-E3			NEMESIS S1		
	Change GDP 2020	Change private Consumption 2020	Change Employment 2020	Change GDP 2020	Change private Consumption 2020	Change Employment 2020
EU-27	-0.35%	0.19%	-0.04%	-0.65%	-0.60%	-0.17%
AT	0.00%	0.30%	0.40%	-0.58%	-0.94%	-0.04%
BE	-0.40%	0.20%	0.00%	-0.61%	-0.25%	0.47%
CZ	-1.70%	0.20%	-0.70%	-0.78%	-0.52%	-0.13%
DK	-0.10%	-0.10%	0.40%	-0.02%	0.30%	0.22%
EE	-2.30%	-0.40%	-1.10%	-0.09%	-0.05%	0.22%
FI	-0.60%	0.40%	-0.30%	-0.39%	-0.23%	0.07%
FR	-0.30%	0.10%	0.00%	-0.41%	-0.26%	0.30%
DE	-0.30%	0.10%	-0.10%	-0.30%	-0.42%	-0.09%
EL	-0.80%	-0.20%	-0.30%	-1.07%	-1.15%	-0.80%
HU	-1.50%	-0.80%	-0.40%	-0.21%	-1.09%	-0.29%
IE	0.20%	-0.10%	1.30%	-0.34%	1.20%	1.10%
IT	-0.10%	0.50%	0.30%	-1.14%	-1.26%	-0.46%
LV	-0.90%	-0.80%	-0.20%	-0.54%	-0.68%	-0.36%
LT	-0.60%	0.90%	-0.50%	0.01%	0.17%	0.30%
NL	-0.40%	0.50%	0.10%	-0.98%	0.18%	0.89%
PL	-1.50%	-0.80%	-0.70%	-0.96%	-1.22%	-0.82%
PT	-0.30%	0.40%	-0.10%	-1.23%	-1.21%	-0.61%
RO	-2.40%	1.60%	-0.80%	-2.20%	-1.31%	-1.85%
SK	-1.70%	1.30%	-0.80%	-2.27%	-4.39%	-3.00%
SI	-0.60%	-0.40%	-0.50%	-0.96%	-0.84%	-0.44%
ES	-0.10%	0.70%	0.80%	-1.46%	-1.71%	-0.59%
SE	-0.20%	0.10%	-0.10%	-0.61%	-0.59%	-0.19%
UK	-0.30%	-0.10%	-0.10%	-0.65%	-0.24%	0.27%

In table 69, NEMESIS scenario S1, where the EU *Climate Action and Renewable & Energy Package* is introduced without recycling of auctioning revenue by States, is compared with PRIMES/GAINS/GEM-E3 scenario ‘Cost efficiency case with auctioning in all EU ETS and no revenue generation in the non ETS), that differ from NEMESIS scenario S1 mainly by the fact that there is auctioning revenue recycling through increases in households’ disposable income (increase in social transfers).

The GDP cost with NEMESIS for 2020 is close from twice the cost measured by GEM-E3 (-0.65% against -0.35%) for the reason that there is no recycling of auctioning revenues in NEMESIS. In GEM-E3, there is a 0.19% rise in Households’ final consumption, resulting from the increase in real disposable income resulting from the rise in social transfers, while final consumption fall 0.6% in NEMESIS, and follows GDP evolution. For employment changes are respectively -0.04% for GEM-E3 and -0.17% for NEMESIS. Fall in employment is less important that the fall in GDP in both models, for the reason that in both models favorable factor substitutions take place for employment implied by the rise in energy prices. For both models, results by country are much contrasted, and similarities can be found for relative GDP and employment changes. The most important differences are of course found for final consumption, boosted in GEM-E3 by revenue recycling on households’ real disposable income.

Table 70 compares NEMESIS results for scenario S2 where this time auctioning revenues are recycled with an equivalent fall in employers’ social contributions. Furthermore, following the solidarity principle, the distribution of auctioning rights takes into account GDP/capita discrepancies between Member States. The comparison is made with PRIMES/GAINS/GEM-E3 scenario ‘Cost efficiency case with auctioning in all EU ETS and distribution auctioning rights taking into account GDP/capita and no revenue generation in the non ETS’. It is the same scenario that the preceding, but with also application of the solidarity principle for distribution of auctioning revenue among Member States.

Table 70: Comparison of assessments, ‘Community Solidarity Principle Case’

	PRIMES/GAINS/GEM-E3			NEMESIS S2		
	Change GDP 2020	Change private Consumption 2020	Change Employment 2020	Change GDP 2020	Change private Consumption 2020	Change Employment 2020
EU-27	-0.34%	0.21%	-0.09%	0.11%	0.68%	1.43%
AT	0.00%	0.10%	0.05%	-0.15%	-0.55%	0.46%
BE	-0.40%	0.10%	0.00%	-0.18%	0.26%	1.11%
CZ	-2.00%	6.20%	-1.60%	3.82%	8.12%	6.27%
DK	-0.10%	-0.10%	0.40%	1.27%	3.60%	1.45%
EE	-3.10%	8.20%	-2.40%	2.03%	5.37%	4.12%
FI	-0.60%	0.40%	-0.30%	0.38%	1.26%	1.07%
FR	-0.30%	0.00%	0.00%	-0.18%	-0.02%	0.59%
DE	-0.30%	0.00%	-0.10%	0.59%	0.63%	0.91%
EL	-0.80%	0.90%	-0.40%	0.16%	-0.23%	1.62%
HU	-1.50%	-0.40%	-0.50%	1.54%	2.37%	2.42%
IE	0.20%	-0.10%	1.30%	0.17%	2.14%	1.71%
IT	-0.10%	0.30%	0.30%	-0.21%	-0.10%	0.70%
LV	-0.90%	-0.60%	-0.30%	0.00%	0.26%	0.35%
LT	-0.60%	0.50%	-0.50%	1.44%	2.72%	2.42%
NL	-0.40%	0.20%	0.10%	-0.55%	0.29%	1.54%
PL	-1.50%	1.60%	-0.90%	2.61%	4.19%	4.01%
PT	-0.30%	0.50%	-0.10%	-0.47%	-1.21%	0.70%
RO	-2.40%	7.90%	-1.40%	4.58%	10.27%	7.96%
SK	-1.80%	2.50%	-1.00%	1.32%	-0.13%	0.59%
SI	-0.70%	0.40%	-0.70%	-0.02%	0.90%	0.91%
ES	0.00%	0.40%	0.90%	-0.77%	-0.84%	0.30%
SE	-0.20%	0.00%	-0.10%	-0.37%	-0.23%	0.08%
UK	-0.30%	-0.20%	-0.10%	-0.12%	0.19%	1.03%

For GEM-E3, at EU-27 level, there is very little change in GDP and employment compared to the former scenario, for the reason that the only difference between scenarios stays is repartition of auctioning revenue among Member States. For NEMESIS on the contrary, we find this time a positive evolution for GDP, with +0.11% (against -0.65% previously) and +1.43% for employment (against -0.17%). NEMESIS illustrates the double dividend Environment/Employment that most studies aiming redeploying fiscal charges from employment toward environment put in evidence. By contrast, the recycling of auctioning revenue with increased social transfers to households in GEM-E3 does not allow reaching such double dividend. The reason is that increase in social transfer first increases household final consumption, and then GDP and employment, but in longer term, higher production costs resulting from the introduction of carbon penalties bear on European competitiveness. In NEMESIS, the reduction in employers' social contributions rate allow increasing employment and consequently final consumption an GDP, without deterioration of European firms competitiveness. There is even a net gain in terms of GDP, that traduce the reduction of energy imports that are replace by the consumption of goods produced with a lesser content in imports than energy products.

At country level, the results of the two models demonstrate the important economic gains that European countries below European average for their GDP *per* capita could get from the implementation of the EU *Climate Action and Renewable 1Energy Package* , if the solidarity principle between European countries is applied. For Romania, final consumption gains establish in 2020 7.9% for GEM-E3, and 10.27% for NEMESIS. These gains reach respectively 6.2 and 8.12% in Czech Republic, 8.2 and 5.37% in Estonia and 1.6 and 4.19% in Poland. For these last countries, that figure among the countries that beneficiate the more from the increase in CO_2 allowances to be auctioned in ETS for the purpose of community solidarity, one can finally state that the increase of revenues from auctioning, while rising the level of final consumption, do not change results for GDP, or very slightly, and have limited and mitigated impacts on employment. It results from the general equilibrium properties of this model that imply very inelastic labor supply and strong eviction of internal demand stimulation by prices and external trade. NEMESIS were unemployment prevails on labor market will certainly deliver different results, but this GEM-E3 scenario was not studied with NEMESIS and no comparisons are possible here.

This comparison of PRIMES/GAINS/GEM-E3 and NEMESIS assessments for EU *Climate Action and Renewable 1Energy Package* , with two models, one general equilibrium and one econometric, that have very different mechanisms but share same principal assumptions for baseline evolutions, have shown a lot of convergence, and complementarities in results:

- the implementation of EU *Climate Action and Renewable 1Energy Package* should have only a limited cost in terms of GDP for EU-27, or even a negative one, depending the way auctioning revenues are recycled by Member States;
- important gains could be obtained for consumers if recycling of auctioning revenue is used to increase households' disposable income;
- employment could also be importantly stimulated if the recycling of revenue, and the stimulation of households' final consumption, passes through a reduction of labor cost (NEMESIS S2 scenario) and not by an increase in social transfer that could impact negatively on European firms competitiveness;
- lastly the application of the community solidarity principle could EU *Climate Action and Renewable & Energy Package* represent an important opportunity for growth and employment in EU countries with GDP below European average like Romania and Poland, that are also very carbon intensive.

Tables

Figures