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D1.1.1

Description of key macroeconomic variables, including regional GDP and employment for NUTS-2 regions.

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Abstract

Objectives

The current deliverable report has been prepared in the framework of PLUREL Work Package 1.1 (Economic Scenarios) by Paris 1 Université – Lab. ERASME.

This document presents four medium-term scenarios for the European economy at both national and NUTS-2 levels. These scenarios are based on assumptions on the main economic drivers of the NEMESIS model: demography, world demand and oil price as well as policies on energy and R&D.

Methodology

The NEMESIS economic model provides economic indicators such as economic growth, employment, energy consumption, sectoral dynamics, etc. It is a macro-sectoral econometric model for EU-27 (excluding Cyprus and Bulgaria, including Norway); each country is modelled individually through 30 production sectors (32 in an extended version of the model) and 27 consumption goods. The model also includes a land use sector that computes land claims for agriculture and built areas.

The four scenarios developed in this document are distinguished by a contrasted set of assumptions on demography, oil price, world demand, RTD effort and energy/environment regulation. They are called "A1 Hyper-tech", A2 "Extreme water", B1 "Peak oil" and B2 "Fragmentation".

Economic results are mainly provided at national scale but more geographically detailed results are produced at NUTS-2 level such as GDP and employment.

Results

The rendering of the PLUREL storylines in NEMESIS drivers were organised across the external trade for EU i.e. the demand addressed to EU from non-EU countries, the demography coming from IIASA projections, the oil price and some policy options such as R&D or climate

change policies. The following table summarises the evolution of those drivers for each PLUREL scenario.

	A1 - "Hyper tech"	A2 - "Extreme water"	B1 - "Peak oil"	B2 - "Fragmentation"
External trade	+120%	+61%	+92%	+71%
Demography	+15 million	3 million	-5 million	Constant
Oil Price ($2000)	Max: 107$ Min: 70$ Mean: 90$	Max: 71$ Min: 52$ Mean: 62$	Max: 130$ Min: 75$ Mean: 112$	Max: 65$ Min: 55$ Mean: 60$
R&D policy	National Action Plan (3% R&D intensity in 2015)	3% R&D intensity in 2025	Constant R&D intensity	Constant R&D intensity
Carbon value	20€/tCO2	20€/tCO2	30€/tCO2	40€/tCO2

The implementation of those drivers in the NEMESIS model allows the quantification of the four PLUREL scenarios in an economic point of view. To summarise, the A1 "Hyper Tech" scenario is characterised by a strong economic growth driven by high World economic growth, knowledge economy development and population growth. The only limiting factor for economic growth comes from a relatively high oil price. A2 "Extreme water" has an economic growth mainly driven by internal demand which is pushed up by process and products innovation coming from R&D investments. B1 "Peak Oil," that experiences high energy costs with nevertheless a strong World demand, has moderate economic growth. Finally, B2 "Fragmentation" also displays a restricted economic development but this time due to a weak World economic growth and more environmentally friendly growth.

% change between 2008 and 2025 (and thousand for employment)	GDP			Employment			Energy Intensity			External trade		
	EU	**EU-15**	**NMS**	**EU**	**EU-15**	**NMS**	**EU**	**EU-15**	**NMS**	**EU**	**EU-15**	**NMS**
A1 - "Hyper tech"	68.3%	64.2%	139.0%	10.6% 22669	9.3% 16168	16.2% 6502	-19.4%	-18.6%	-29.9%	18.5%	17.1%	86.0%
A2 - "Extreme water"	55.8%	52.0%	121.2%	7.9% 16806	6.6% 11480	13.3% 5327	-13.7%	-12.7%	-26.0%	5.9%	4.5%	69.3%
B1 - "Peak oil"	41.3%	38.1%	96.3%	0.9% 1835	-0.1% -160	5.0% 1995	-14.5%	-13.6%	-27.6%	8.2%	6.8%	76.6%
B2 - "Fragmentation"	39.4%	36.4%	89.9%	1.0% 2080	0.3% 447	4.1% 1633	-13.6%	-12.5%	-28.5%	3.5%	1.9%	69.1%

Keywords

Economic modelling, economic drivers, European policies and scenarios

Classification of results/outputs

Spatial scale for results:	EU-27 (excluding Bulgaria and Cyprus) EU countries (excluding Bulgaria and Cyprus) NUTS-2 (excluding Bulgaria and Cyprus)
DPSIR framework:	Drivers
Land use issues covered:	None directly covered in this deliverable
Scenario sensitivity:	Yes
Output indicators:	Socio-economic (GDP and its components, employment, sectoral production, etc)
Knowledge type:	Detailed applied economic model (using a land use module)

How many fact sheets will be derived from this deliverable:	**1**

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Introduction

NEMESIS is a macro-sectoral econometric model for EU-27 (less Cyprus and Bulgaria) plus Norway. In each country economic activity is divided into 32 production sectors: 3 for agriculture, 5 for energy, 13 for industry, 1 for construction and 10 for services[1].

Module 1 teams of PLUREL project have decided to elaborate four different scenarios, based on different sets of assumptions on urban and peri-urban land use drivers. These baselines are built following detailed storylines (see deliverable 1.3.1 for a detailed description of the 4 scenarios) where the main evolutions of drivers are described as well as general concern on scenarios. For NEMESIS, 4 main drivers are used: population which will be provided by IIASA, oil price projection, world demand addressed to EU-27 and specific assumptions on policy implementation and especially on RTD (Research and Technological Development) effort and energy/environment policies.
With each baseline being very specific, NEMESIS exogenous variables were fully updated and especially designed for each baseline. Other specific assumptions were made in order to reflect the storylines.

The deliverable is organised as follows: a first part is devoted to a short overview of the PLUREL scenarios. In the second part, we detail the description of all exogenous drivers chosen for each baseline as well as the methodology used to build them; and the third part presents the results of each baseline for macroeconomic and macro-sectoral indicators calculated by NEMESIS, as well as some NTUS2 indicators, notably regional GDP.

[1] For more information about NEMESIS model: www.erasme-team.eu, and for an example of application see, Zagamé *et al.* (2002) and Brécard *et al.* (2006).

1 PLUREL Scenarios short overview

A comprehensive scenario framework was developed, and led by CURE:

- based on the concept of the IPCC 'SRES' scenarios, adapted for the PLUREL
- applied to model settings, in economic, demographic and land use modelling;
- further extended with a series of 'shocks' i.e. accelerated change;
- flexible and arranged as a scenario 'cascade' in order to provide links from M1 to other Modules.

These scenarios are outlined in the figure below. Each shock is intended to reflect one of the M1 work packages. The variants are as follows (including interim titles, and showing the lead Work Packages for each):

- ***A1-hyper-tech***, rapid development in ICT leading to reduced commuting and transport needs, with no constraints on the location of new build.
- ***A2-water world*** **-** climate change reaches a tipping point leading to impacts including rapid sea level rise, flooding and water resource constraints
- ***B1-peak oil***, an energy price shock leading to rapidly increasing energy and transport costs and consequent changes in mobility and trade flows.
- ***B2-fragmentation***, a pandemic disease leading to major population declines and behavioural shifts within society.

This broad framework is summarized in Figure 1, and further detailed in Figure 1. For more details on PLUREL scenarios see the deliverable 1.3.1.

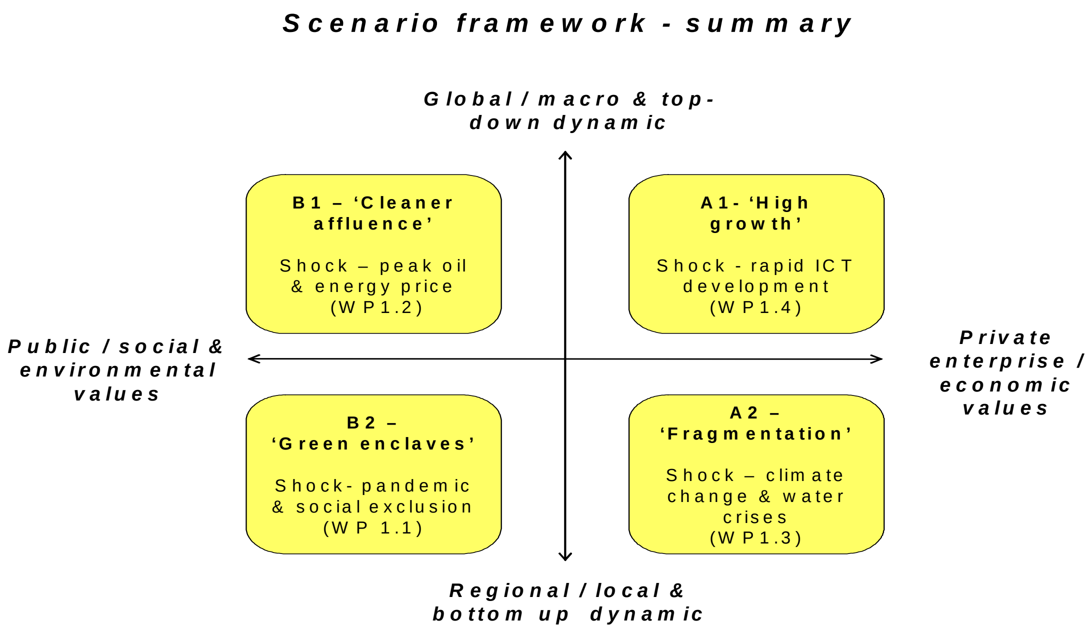

Figure 1: PLUREL scenarios framework

2 PLUREL Baselines exogenous variables for the NEMESIS Model

2.1 Methodology

Before presenting the main drivers of the NEMESIS model, it is appropriate to briefly present the model itself.
The NEMESIS model is a macro-econometric model for Europe (EU-27 plus Norway excluding Cyprus and Bulgaria) which details the economic activity for each of the Member States (MS) in thirty production sectors and twenty-seven consumption goods.

Box 1.1 : Short overview of the NEMESIS model[2]

The NEMESIS model (New Econometric Model of Evaluation by Sectoral Interdependency and Supply), has been funded under the fifth and sixth RTD Framework Programs of European Commission General Directorate of Research. It is a system of economic models for European countries (EU-27), devoted to study issues that link economic development, competitiveness, employment and public accounts to economic policies, and notably all structural policies that involve long term effects: RTD, environment and energy regulation, general fiscal reform, etc. The essential purpose of the model is to provide 'Business As Usual' (BAU) scenarios or counter-factual scenarios, up to 10 to 30 years. NEMESIS uses as main data source EUROSTAT, and specific databases for external trade (OECD, New CRONOS), technology (OECD and EPO) and land use (CORINE 2000). NEMESIS is recursive dynamic model, with annual steps, and includes more than 160,000 equations.

The main mechanisms of the model are founded on the behaviour of representative agents: Firms, Households, Government and Outside. These mechanisms are based on econometric~~s~~ works.

The main originality of the model lies in the belief that the medium and long term of the macroeconomic path is the result of strong interdependencies between sectoral activities that are very heterogeneous from a dynamic point of view, with leading activities grounded on Research and Development, and from environment and sustainable development with a huge concentration of pollutants on few activities. These interdependencies are exchanges of goods and services in markets but also external effects, such as positive technological spillovers and negative environmental externalities.

Main mechanisms

On the supply side, NEMESIS distinguishes 32 production sectors, including Agriculture, Forestry, Fisheries, Transportations (4), Energy (6), Intermediate Goods, (5) Capital goods (5), Final Consumption Goods (3), Private (5) and Public Services. Each sector is modelled with a representative firm that takes its production decisions given its expectations on production capacity expansion and input prices. Firms' behaviour includes very innovative features grounded on new growth theories, principally endogenous R&D decisions that allow firms to improve their process productivity and product quality. Production in sectors is in this way represented with CES production functions (with the exception of Agriculture which uses Translog functions, and

[2] Please see www.erasme-team.eu for a detailed description of the NEMESIS model and other information related to the model. For publication with the NEMESIS model see *e.g.* Brécard *et al.* (2006) or Chevallier *et al.* (2006).

Forestry and Fisheries where technology is represented with Leontief functions) with 4 production factors: capital, labour, energy and intermediate consumption, where also endogenous innovations of firms modify the efficiency of the different inputs (biased technical change) and the quality of output (Hicks neutral technical change). The production function was estimated by the dual approach and estimation and calibration of links between R&D expenditures, innovations and economic performance were picked up from the abundant literature on the subject. Interdependencies between sectors and countries are finally caught up by a collection of convert matrices describing the exchanges of intermediary goods, of capital goods and of knowledge in terms of technological spillovers, and the description of substitutions between consumption goods by a very detailed consumption module enhance these interdependencies.

On the demand side, representative household' aggregate consumption is dependent on expectations of lifetime earnings but with a slow adjustment to changes in current income. Total earnings are a function of regional disposable income, a measure of wealth for the households, interest rates and inflation. Variables covering child and old-age dependency rates are also included in an attempt to capture any change in consumption patterns caused by an ageing population. The disaggregated consumption module is based on the assumption that there exists a long-run equilibrium but rigidities are present which prevent immediate adjustment to that long-term solution. Altogether, the total households' aggregated consumption is indirectly affected by 27 different consumption sub-functions through their impact on relative prices and total income, to which demographic changes are added. Government public final consumption and its repartition between Education, Health, Defence and Other Expenditures, are also influenced by demographic changes.

For external trade, it is treated in NEMESIS as if it takes place through two channels: intra-EU, and trade with the rest of the world. The intra- and extra-EU export equations can be separated into two components, income and prices. The income effect is captured by a variable representing economic activity in the rest of the EU for intra-EU trade, and a variable representing economic activity in the rest of the world for extra-EU trade. Prices are split into two sources of impacts in each of the two equations (intra- and extra-EU trade). For intra-EU trade, they are the price of exports for the exporting country and the price of exports in other EU countries. For extra-EU trade, price impacts come through the price of exports for the exporting country, and a rest-of-the-world price variable.

Main uses

With its original characteristics and great detail in its results, NEMESIS can be used for many purposes as medium/long-term economic and industrial “forecasts” for business, government and local authorities; analysing various scenarios and economic long-term structural change, energy supply and demand, environment, land-use and more generally sustainable development; revealing the long term challenges of Europe and identifying issues of central importance for all European, national, regional scale structural policies; assessing for most of the Lisbon agenda related policies and especially knowledge (RTD and human capital) policies; emphasizing the RTD aspect of structural policies that allows new assessments (founded on endogenous technical change) for policies, and new policy design based on knowledge: Education, Skill and Human Capital and RTD.

NEMESIS has notably been used to study various scenarios for the economic future of the EU and reveal the implication for European growth, competitiveness and sustainable development of the Barcelona 3% GDP RTD objective, of the 7th Research Framework Program of European Commission, of National RTD Action Plans of European countries, of European Kyoto and post-Kyoto policies, etc. NEMESIS is currently used to assess the European Action plan for Environmental and energy technologies, for European financial perspective and for the Lisbon agenda.

2.1.1 *Population*

Population is a main exogenous variable of NEMESIS. In order to function, NEMESIS needs the population projections for each Member State by gender and four age groups ([0-15[, [15-25[, [25-65[and 65 and over). In fact, population structure has impacts on economic performance through different channels. Firstly, according to the employment dynamics in a scenario, a scarcity of "potential" workers, that is to say of population aged at least 15 years old, but more specifically between 25 and 65, could constrain economic growth:

- by putting pressure on real wages and so on competitiveness, or by limiting the potential output of the economy.
- by impacting households' and government's final consumption and investment expenditures: for example, on the repartition between education and health, etc.

Population projections are provided by IIASA for each baseline, at national and NUTS 2 levels.

2.1.2 *Oil price*

The starting point of the NEMESIS oil price assumptions is the results of projections made by the stochastic model PROMETHEUS for the European project MATISSE. The PROMETHEUS model is developed by the National Technical University of Athens. It puts coherently the world GDP projections with world demographic assumptions in order to give a range of possible values for oil prices at the 2050 horizon. But the model projections also take into account specific assumptions on oil supply and demand through production capacity, proved reserves, exploration and production costs, technical progress in production, exploration and uses, etc.
But oil price projections are modified by the NEMESIS team to take into account specificities of PLUREL storylines. This is particularly important for the B1 "high energy cost" scenario, where special emphasis is put on energy policies and energy costs for consumers and producers.

2.1.3 *Rest of World demand*

World demand is the major exogenous driver for economic performance. it determines the contribution to growth of external trade in each country. World demand assumptions follow for the different PLUREL scenarios, world GNP growth projections of IPCC SRES scenarios (IPCC, 2000).

In NEMESIS, for its external trade outside Europe, each country is in relation with 12 different world regions, for which specific growth assumptions are made. These regions are U.S.A., Japan, China, India, Russian Federation, Brazil, America, Asia, Asian OPEC, Africa, Europe without EU-27, and Oceania.

We process as follows:

$$I_{i,t} = g_i^{\rho_i}.I_{i,t-1} \text{ such that } \prod_{i=1}^{12} I_i^{S_{i,t}} = I_{W,t}^{IPCC}$$

with i the region index, t the time index, I the GDP index and g is equal to one plus the annual average growth rate, S the share of region i's GDP in world GDP, and I_w^{IPCC} is the IPCC world GDP index. ρ is a scale parameter allowing to render consistent the sum of regional GDP with IPCC scenarios assumption for world growth. In other words, we define a world GDP target, which is the IPCC world GDP index, and we find an average annual growth rate for each region leading to this target. As there are many possibilities, we take into account the past GDP growth trend for each region as reference for the regional growth rate. Furthermore, we use indications such as GDP per capita convergence described in PLUREL scenario storylines or IPCC SRESS scenarios to diversify each regional GDP growth rate.

We then create, for each EU-27 country, an aggregated demand (*ID*), that is built as a weighted average of regional GDP trend indexes, where the weights are the shares of each region in total exports towards non EU-27 countries. We use the data from the CHELEM database, which collects bilateral trade flows by product from 1995 to 2002 .

$$ID_{c,t} = \prod_{i=1}^{12} I_{i,t}^{SE_i}$$

We finally make distinct world demand assumptions per production sector, by applying corrections to macroeconomic trends, based on past trends from the CHELEM database and sectoral expertise.

2.1.4 Policy assumptions

We can distinguish two main policy orientations: RTD effort and energy policies. Regarding RTD, NEMESIS considered different assumptions according to the storyline: RTD effort can stay constant as percentage of GDP over the scenario horizon, or it can increase so as to reach part of the entire objective defined at Barcelona for the level of RTD effort in Europe (*i.e.* 3% of GDP). The National Action Plans for RTD of EU member states are also used so that the overall EU RTD effort stays in accordance with sub-national targets. And finally RTD effort is oriented toward sectors emphasized by the different storylines, i.e. either energy sectors or Information and Communication Technologies sectors.

Energy policies are also implemented in some storylines by adding taxes on fossil energies or GHG emissions, in order to orient agents' choices towards more ecological consumption and production patterns. In some scenarios, the receipts of environmental taxes are also redistributed in the form of R&D subsidies to clean technologies.

2.2 PLUREL baseline values for exogenous variables

In this section, we present the results of quantifications of the main assumptions made for PLUREL scenario. All these results are presented from 2005 to 2050. The NEMESIS model gives annual results until 2025 but we believe that quantifying of these exogenous variables until 2050 could be useful for other PLUREL partners.

2.2.1 Population

Population projections for NEMESIS are made by IIASA. Figure 2 displays the evolution of the total population between 2005 and 2050. There are some differences in absolute number between IIASA estimations and the population presented in the figure below. These differences are due to the initial values which are implemented in NEMESIS (based on Eurostat). Nevertheless, growth rates are the same.

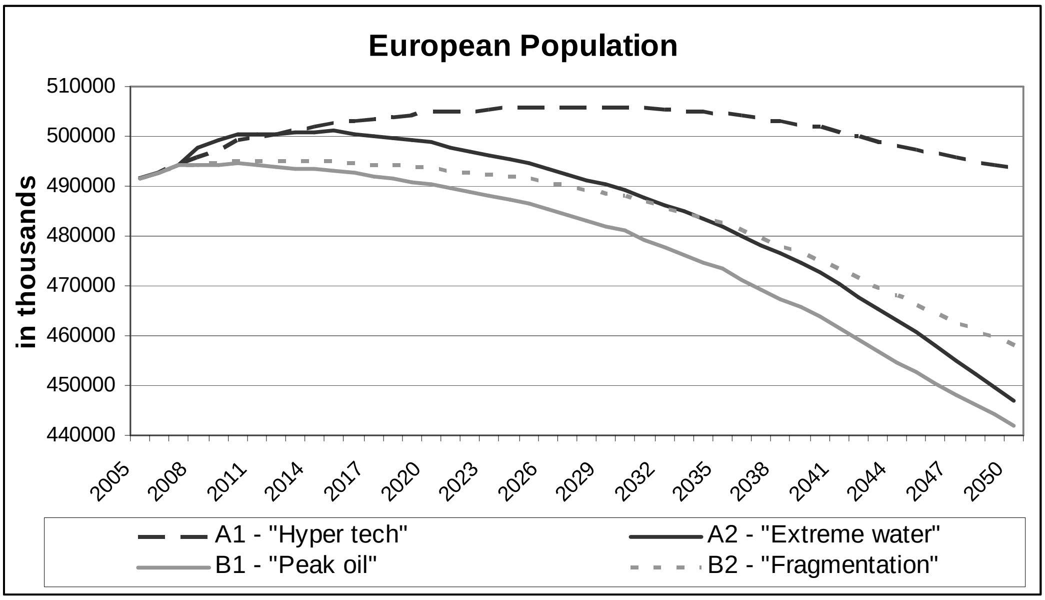

Figure 2: European total population in PLUREL four scenarios

For more details and explanation on population and the assumptions such as birth-rates, mortality rates, life expectancy by sex and net migration by aging class, please see the PLUREL deliverable 1.2.2 and detailed storylines on deliverable 1.3.1.

2.2.2 Oil price

Oil price assumptions are of major importance for NEMESIS. Oil prices affect households' cost of living, firms' production costs and consequently they affect general economic activity. Figure 3 presents the oil price profile, in $\$_{2000}$, for the four PLUREL scenarios. From 2000 to 2007, the oil price is identical for each scenario and reflects the historic (IEA). The A1 'Hyper-Tech" storyline defines a world where "global cooperation and high economic growth lead to innovation and rapid technological development" and where "energy prices decline because supply is driven by new developments in renewable energy production and nuclear fission". So, figure 1 shows an oil price which increases rapidly in between 2007 and 2020, and reaches $106\$_{2000}$ in 2018, in other words around 175 current dollars. The first step is due to a rapid increase in world demand for energy which is first oriented on fossil energy leading to pressure on the oil market that pushes the oil price up. In the longer term, efforts focussed on the development of new energy technologies based on renewable and nuclear fission push down the price of fossil free energy sources. Oil demand is consequently decreased, and the oil price falls to $85\$_{2000}$ in 2050.

The B1 "Peak Oil" baseline reproduces the same picture as A1, but in this scenario the increase in oil price is not only due to high economic growth, but also to a supply restriction. The oil price increases from $68\$_{2000}$ in 2007 to $130\$_{2000}$ in 2015 that is to say $82 current to $200 current. But as the B1 SRES scenario describes a future world where "there is a high level of environmental and social consciousness" and where "particular effort is devoted to increases in resource efficiency through incentive systems, [...] which allows for rapid development of cleaner technology", oil price decreases progressively after 2015 and stabilizes at $77\$_{2000}$ in 2050, which is the lowest price in 2050 of the four PLUREL baseline scenarios.

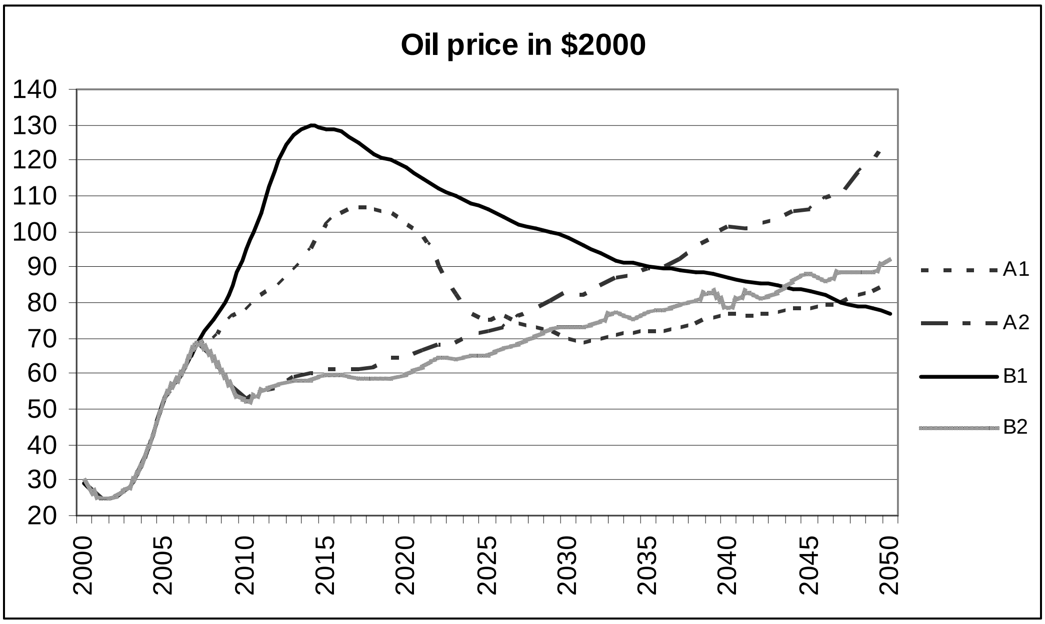

Figure 3: Oil price projections for PLUREL baselines (in $2000)

A2 and B2 PLUREL scenarios show oil price profiles more grounded on PROMETHEUS projections. In these scenarios, oil price increases progressively between 2010 and 2050. In B2, where there is higher environmental concerns, oil price is lower than A2, with 125$$_{2000}$ in 2050, versus 95$$_{2000}$ in B2. Furthermore, A2 displays a world where "economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than in other storylines". This translates into lower investment in non-fossil energy technologies, and a continuous high dependency on fossil fuel energy sources. Furthermore, in the B2 storyline "economic growth differentials are large among areas" and "mutual distrust implies that fewer [countries] are willing to share the burden of reducing greenhouse gas emission reductions."

These oil price assumptions for the four scenarios were compared with IEA (2007) projections. IEA distinguish three scenarios: a medium scenario in which the oil price is around 50 $$_{2005}$ in 2014 and 59 $$_{2005}$ in 2030, a high scenario where the oil price reaches 100 $$_{2005}$ in 2030, and a low price scenario. Our projections are, for all scenarios, within the range of IEA medium and high scenarios, except for the B1 scenario where we made strong assumptions on oil supply scarcity, leading to a real oil price higher than IEA projections for 2030 in its more pessimistic scenario.

2.2.3 Rest of World demand

In order to feed the equations of section 2.1.3, we need to make exogenous assumptions on economic development in the rest of the world that is decomposed into 12 geographical zones in NEMESIS: U.S.A., Japan, China, India, Russian Federation, Brazil, America, Asia, Asian OPEC, Africa, Europe without EU-27, and Oceania.

The A1 "hyper-tech" scenario is characterized by high economic growth throughout the world and a strong convergence of GDP per capita (figure 4). High economic growth and regional GDP convergence are due to strong efforts devoted to R&D investments all over the world. There is an important eruption of new technologies and a catching-up of developing countries for GDP per capita. For example, the share of China's GDP in world GDP (without including EU-27 + Norway GDP) changes from 7.8% in 2006 to 15.5% in 2050 whereas the USA's GDP share decreases from 38% in 2006 to 21% in 2050.

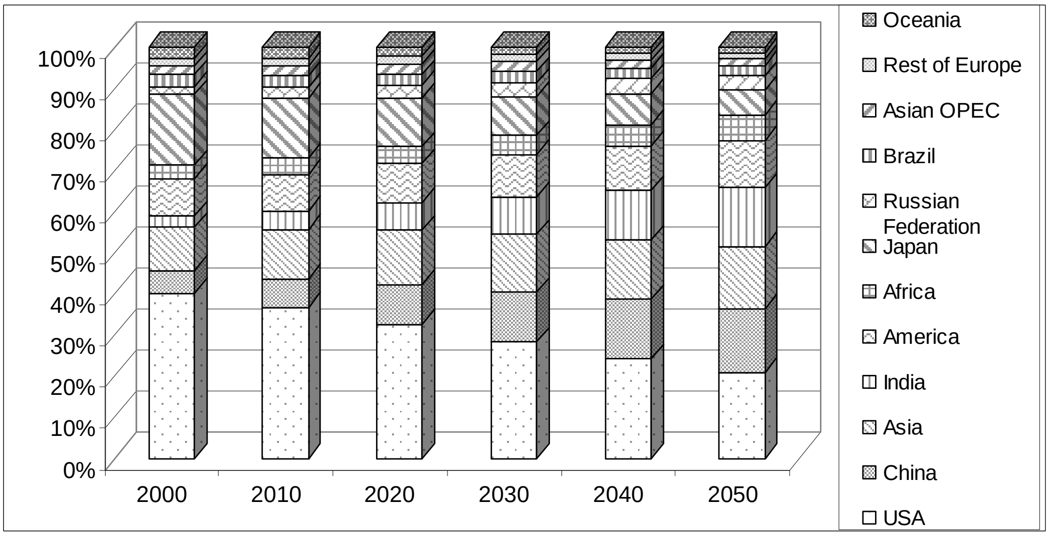

Figure 4: GDP share in World GDP (except EU-27 + Norway)

The world GDP (including Europe) is 34,700 billion $\$_{1990}$ in 2006 and reaches 199,000 billion $\$_{1990}$ in 2050, with an average annual growth rate of about 4% per year. The heterogeneity of economic growth rates between areas remains important, with for example an average annual rate of 7.9% for India and of only 2.3% for Japan.

Table 1 displays world demand indexes for all EU-27 Members States in the A1 scenario, built according to the methodology presented in the previous section. One can see that on the period 2002-2050 this index grows from one in 2002 to a maximum of 8.9 for Romania and a minimum of 6.7 for Hungary.

	2002	2010	2020	2030	2040	2050
FR	1.00	1.42	2.25	3.49	5.28	7.76
BE & LU	1.00	1.44	2.35	3.71	5.68	8.37
DE	1.00	1.41	2.24	3.44	5.14	7.40
IT	1.00	1.42	2.26	3.48	5.21	7.55
UK	1.00	1.39	2.17	3.28	4.82	6.88
NL	1.00	1.43	2.30	3.59	5.43	7.94
IE	1.00	1.34	1.99	3.87	5.05	7.57
DK	1.00	1.39	2.16	3.26	4.78	6.80
FI	1.00	1.46	2.39	3.78	5.74	8.29
NO	1.00	1.37	2.14	3.27	4.87	7.04
SE	1.00	1.40	2.21	3.37	5.00	7.13
AT	1.00	1.40	2.22	3.40	5.05	7.26
SE	1.00	1.43	2.30	3.64	5.63	8.47
GR	1.00	1.42	2.30	3.56	5.38	7.86
PT	1.00	1.40	2.19	3.39	5.15	7.69
SI	1.00	1.41	2.25	3.44	5.11	7.35
EE	1.00	1.46	2.40	3.82	5.87	8.58
LV	1.00	1.42	2.27	3.53	5.30	7.62
LT	1.00	1.46	2.40	3.79	5.77	8.35
BG	1.00	1.43	2.32	3.62	5.51	8.13
CZ	1.00	1.43	2.32	3.59	5.40	7.79
SK	1.00	1.40	2.22	3.38	5.01	7.16
HU	1.00	1.39	2.16	3.24	4.72	6.67
PL	1.00	1.44	2.37	3.74	5.73	8.41
RO	1.00	1.46	2.43	3.87	6.00	8.93

Table 1: Index of World Demand addressed to EU-27 for A1

A2 "Water World" scenario provides a more heterogeneous world in which GDP convergence and world GDP growth are lower than in A1. World GDP increases by 2.3% on average in annual growth rates and reaches 91 trillion $\$_{1990}$ in 2050, in other words two times less than in A1 scenario. For illustration, in the A2 scenario, the USA's GDP share in world GDP is close to 30% in 2050, whereas it decreases to 21% in A1. Consequently, China's GDP share is only 13% in 2050, under 15.5% in A1 for the same year.

Table 2 displays the world demand indexes for EU-27 Members States in the A2 scenario and illustrates the important fall in the development of world trade in this scenario compared to A1. The lowest value for this indicator in 2050 is 3 for Ireland, and the highest is still Romania at 3.7, but with a value less than half that in A1.

	2002	2010	2020	2030	2040	2050
FR	1.00	1.39	1.83	2.31	2.82	3.36
BE & LU	1.00	1.41	1.89	2.38	2.93	3.51
DE	1.00	1.39	1.85	2.32	2.84	3.39
IT	1.00	1.39	1.84	2.31	2.82	3.38
UK	1.00	1.37	1.78	2.21	2.68	3.19
NL	1.00	1.40	1.86	2.34	2.88	3.44
IE	1.00	1.32	1.78	2.25	2.67	3.04
DK	1.00	1.37	1.79	2.23	2.71	3.24
FI	1.00	1.44	1.94	2.46	3.02	3.62
NO	1.00	1.36	1.77	2.20	2.67	3.17
SE	1.00	1.39	1.82	2.28	2.77	3.31
AT	1.00	1.38	1.83	2.31	2.84	3.41
SE	1.00	1.39	1.84	2.32	2.85	3.42
GR	1.00	1.38	1.85	2.35	2.91	3.52
PT	1.00	1.37	1.79	2.25	2.74	3.25
SI	1.00	1.37	1.83	2.32	2.88	3.51
EE	1.00	1.42	1.93	2.45	3.04	3.67
LV	1.00	1.38	1.83	2.31	2.83	3.41
LT	1.00	1.41	1.91	2.44	3.02	3.66
BG	1.00	1.39	1.86	2.35	2.91	3.52
CZ	1.00	1.40	1.87	2.36	2.91	3.50
SK	1.00	1.37	1.82	2.29	2.83	3.41
HU	1.00	1.36	1.78	2.21	2.70	3.22
PL	1.00	1.41	1.90	2.42	3.00	3.63
RO	1.00	1.45	1.96	2.48	3.06	3.68

Table 2: Index of World Demand addressed to EU-27 for A2

In the B1 "Peak Oil" scenario, world GDP average annual growth rate is about 3.3%. World GDP reaches 145,000 billion $\$_{1990}$ in 2050, a level between that of the A1 and A2 scenarios. In this baseline, economic development is balanced if one considers the convergence speed of GDP per capita between developed and developing countries. Some developing countries like China or India have a GDP in 2050 close to its level in A1, whereas very developed countries such as those in North America or Japan have, in 2050, about half of the GDP in A1.

Table 3 displays the world demand indexes for EU-27 Members States, also within the range of A1 and A2 scenarios.

	2002	2010	2020	2030	2040	2050
FR	1.00	1.42	2.10	2.92	3.94	5.20
BE & LU	1.00	1.45	2.16	3.04	4.16	5.56
DE	1.00	1.43	2.11	2.96	4.02	5.34
IT	1.00	1.43	2.10	2.94	3.98	5.28
UK	1.00	1.40	2.01	2.76	3.68	4.82
NL	1.00	1.44	2.13	2.99	4.06	5.41
IE	1.00	1.34	1.86	2.89	4.27	5.20
DK	1.00	1.40	2.02	2.80	3.76	4.95
FI	1.00	1.48	2.24	3.23	4.46	6.00
NO	1.00	1.39	2.00	2.74	3.65	4.75
SE	1.00	1.42	2.08	2.89	3.90	5.14
AT	1.00	1.41	2.09	2.95	4.04	5.40
SE	1.00	1.43	2.11	2.94	3.98	5.27
GR	1.00	1.42	2.11	3.00	4.15	5.61
PT	1.00	1.40	2.04	2.80	3.73	4.87
SI	1.00	1.40	2.09	2.99	4.16	5.68
EE	1.00	1.46	2.22	3.21	4.47	6.08
LV	1.00	1.41	2.09	2.95	4.03	5.38
LT	1.00	1.44	2.19	3.17	4.43	6.05
BG	1.00	1.42	2.11	2.97	4.09	5.51
CZ	1.00	1.43	2.14	3.03	4.17	5.61
SK	1.00	1.40	2.07	2.92	4.01	5.39
HU	1.00	1.39	2.01	2.77	3.73	4.92
PL	1.00	1.44	2.19	3.15	4.38	5.96
RO	1.00	1.49	2.26	3.22	4.44	5.97

Table 3: Index of World Demand addressed to EU-27 for B1

Finally in the B2 “Fragmentation” scenario, economic growth is relatively low. The average annual growth rate of world GDP is about 2.6% per year, less than in the A1 and B1 scenarios, and a little higher than in A2. World GDP reaches 107 trillion $\$_{1990}$ in 2050, compared to 91 in A2. Convergence between areas is relatively important, close to A1, as illustrated by the share taken by United States and China of world GDP in 2050: 28.5% and 15% respectively, very close to the levels of A1.

Values of world demand indexes for EU-27 Members States in this scenario, displayed in table 4, are consequently close to those of scenario A2, although higher.

	2002	2010	2020	2030	2040	2050
FR	1.00	1.40	1.93	2.52	3.21	3.99
BE & LU	1.00	1.42	1.98	2.61	3.34	4.19
DE	1.00	1.40	1.93	2.53	3.22	4.02
IT	1.00	1.40	1.93	2.53	3.22	4.02
UK	1.00	1.38	1.86	2.41	3.05	3.79
NL	1.00	1.41	1.96	2.57	3.28	4.11
IE	1.00	1.33	1.74	2.21	2.75	3.38
DK	1.00	1.38	1.87	2.43	3.08	3.84
FI	1.00	1.45	2.03	2.70	3.47	4.35
NO	1.00	1.37	1.86	2.42	3.08	3.86
SE	1.00	1.40	1.91	2.49	3.16	3.94
AT	1.00	1.39	1.91	2.50	3.18	3.97
SE	1.00	1.40	1.95	2.57	3.30	4.15
GR	1.00	1.39	1.93	2.54	3.25	4.06
PT	1.00	1.38	1.88	2.44	3.09	3.83
SI	1.00	1.37	1.89	2.47	3.15	3.94
EE	1.00	1.43	2.01	2.67	3.43	4.32
LV	1.00	1.39	1.91	2.50	3.20	4.00
LT	1.00	1.42	1.98	2.63	3.37	4.23
BG	1.00	1.40	1.94	2.56	3.28	4.12
CZ	1.00	1.41	1.95	2.57	3.28	4.10
SK	1.00	1.38	1.89	2.47	3.14	3.92
HU	1.00	1.37	1.85	2.40	3.03	3.75
PL	1.00	1.42	1.98	2.63	3.38	4.24
RO	1.00	1.46	2.07	2.75	3.55	4.47

Table 4: Index of World Demand addressed to EU-27 for B2

2.2.4 Policy assumptions

We describe now specific policy assumptions made for four PLUREL scenarios. For policies, two main axes were favoured: Research and Energy policies. Following the storylines, one gets different evolutions of demography, World GDP growth and convergence, oil price, RTD effort and energy concerns, that must be reflected in policy assumptions.

For RTD, policies can be implemented in NEMESIS either through direct incentives to private investment in R&D, or by public investments in R&D, and public orders to innovative sectors. The general methodology consists of establishing targets for the RTD effort in GDP points in the different scenarios, and to put them in coherence with European and National RTD objectives, as expressed by European Lisbon and Barcelona objectives for RTD, and Member States strategies for R&D (National Action Plans). Following the Lisbon strategy, we favoured situations where Private sector plays an increasing role in the execution and financing of R&D in Europe,

to reach a private financing of about two thirds of overall RTD effort in EU-27.
For energy policy different possibilities are available in NEMESIS: such as introduction of fossil fuel energy taxation, of Greenhouse Gas Emissions (GHGE) taxation or of tradable emissions permits. Specific targets in terms of CO2 emissions can also be defined and the corresponding carbon value, or the equivalent taxation level (to reach the same emissions target) of fossil fuel energies, endogenously determined by the model.
A combination of policies is of course also possible, such as the recycling of part or all of energy and CO2 taxation revenue with subsidies to RTD, as will be illustrated below.
For the A1 baseline scenario, describing a world with rapid economic development resulting from important investments in ICT technologies, and more generally in R&D, we assumed that the states respect their commitment regarding the Lisbon National Reform Programs (European Commission, 2005). For R&D, the Member States Lisbon objectives are summarized in table 5.

R&D Intensity(1)	2005	Target 2010	2010	2030	2050
BE	1.84%	3%	2.5%	3.5%	4%
BG	0.49%	--	2%	2%	3%
CZ	1.41%	1% (public)	1.9%	3%	3.5%
DK	2.45%	> 3%	3%	3.5%	4%
DE	2.48%	3%	3%	3.5%	4%
EE	0.93%	1.90%	1.9%	2.5%	3%
IE	1.26%	2.5% (2013)	1.7%	3%	3.5%
GR	0.58%	1.50%	1%	2.5%	3%
ES	1.12%	2%	1.8%	3%	3.5%
FR	2.13%	3%	2.8%	3.5%	4%
IT	1.10%	3%	1.8%	3%	4%
CY	0.40%	0.65% (2008)	1%%	2%	3%
LV	0.56%	1.1% (2008)	1.1%	2.5%	3%
LT	0.76%	2%	2%	3%	3.5%
LU	1.57%	3%	2.5%	3.5%	4%
HU	0.94%	--	1%	2.5%	3%
MT	0.54%	--	0.4%	2%	3%
NL	1.73%	Top 5 of EU	2.3%	3.5%	4%
AT	2.41%	3%	3%	3.5%	4%
PL	0.57%	2.20%	1%	3%	3.5%
PT	0.81%	--	1.1%	2.5%	3%
RO	0.41%	--	0.5%	2%	3%
SI	1.46%	3%	2.2%	3.5%	4%
SK	0.51%	--	0.6%	2%	3%
FI	3.48%	4%	4%	4.5%	4.5%
SE	3.80%	1% (public)	3.9%	4.5%	4.5%
UK	1.76%	2.5% (2014)	2.1%	3%	3.5%
NO	1.52%	--	1.9%	3%	3.5%

(1) Ratio between Gross Domestic Expenditure on Research and Development and GDP. Source for 2005: Eurostat.

Table 5: R&D Intensity and 2010 targets in EU-27 + Norway in A1

The national R&D intensity objectives can appear relatively ambitious for some member states in 2010 (column 2 in table 5), for instance Italy where the R&D intensity is about 1.1% in 2005, and the target for 2010 is about 3%. Italy is expected to triple its RTD effort in 5 years to reach its Lisbon objective. So in order to keep the scenarios credible, we reduce the R&D intensity in 2010 (column 3 in table 5) by a small amount for countries which are far from their target. After 2010, we supposed that the European R&D intensity increases again by 0.5 point every 20 years in countries that have reached their National objectives.

For Energy and Environment, the A1 baseline does not retain any specific assumption, apart for the policies already in place, that were supposed to be pursued along the scenario horizon.

In the A2 baseline scenario, where economic growth in the Rest of the World is among the lowest of the four PLUREL baselines, we supposed a reduced RTD effort compared with A1, but also a higher convergence of RTD effort inside European Countries, New member states and southern countries continuing to be the most ambitious with respect to their relative RTD objective. RTD intensity converges to 3% for the 2050 horizon except for the following countries:

- Malta and Poland which start with a very low R&D intensity in 2005
- Sweden and Finland which keep their intensity constant.

National RTD intensities for this scenario are displayed in table 6, where one can see that there is convergence to 3% GDP in 2050 in most of Members States.

R&D Intensity(1)	2005	2010	2030	2050
UE-27	1.84%		--	--
BE	1.84%	2%	2.5%	3%
BG	0.49%	0.7%	1.5%	2%
CZ	1.41%	1.8%	2.5%	3%
DK	2.45%	2.6%	3%	3%
DE	2.48%	2.6%	3%	3%
EE	0.93%	1.3%	2.5%	3%
IE	1.26%	1.75%	2.8%	3%
GR	0.58%	0.8%	2%	2.5%
ES	1.12%	1.6%	2.5%	3%
FR	2.13%	2.4%	3%	3%
IT	1.10%	1.8%	2.5%	3%
CY	0.40%	0.7%	1.5%	3%
LV	0.56%	0.8%	1.5%	2.5%
LT	0.76%	1%	2%	2.5%
LU	1.57%	1.9%	2.5%	3%
HU	0.94%	1.3%	2 %	2.5%
MT	0.54%	0.8%	2%	2.5%
NL	1.73%	2%	3%	3%
AT	2.41%	2.6%	3%	3%
PL	0.57%	0.8%	1.5%	2%
PT	0.81%	1.1%	2%	2.5%
RO	0.41%	0.8%	1.5%	2%
SI	1.46%	1.9%	2.5%	3 %
SK	0.51%	0.9%	1.5%	2%
FI	3.48%	3.5%	3.5%	3.5%
SE	3.80%	3.8%	3.8%	3.8%
UK	1.76%	2%	3%	3%
NO	1.52%	1.9%	2.5%	3%

(1) Ratio between Gross Domestic Expenditure on Research and Development and Gross Domestic Product.

Table 6: R&D Intensity in EU-27 + Norway for A2 baseline

As in A1, there are no specific assumptions on energy and environment policies, apart for the European policies already in place that are supposed to be pursued.

The B1 scenario is more oriented towards environmental problems. In this scenario, RTD effort is supposed to stay constant in most production sectors, along the baseline horizon. But the revenue of Energy and CO2 taxation that is partly recycled by RTD subsidies goes to favour the development of clean technologies. The increase in RTD intensity is concentrated in energy sectors. This additional RTD effort precisely consists of promoting the development of clean technologies in the area on energy production, and it is equal up to three times the research and expenditures on energy in 2050 which would be reached without the recycling of revenues from energy/environment taxations.

For CO2 emissions, B1 assumes that member states respect their Kyoto 2010-12 targets (Burden sharing) (table 7), and by 2012 achieve their post-Kyoto objective with a reduction of GHG emissions of 30% in EU-27 in 2020 with respect to 1990, and a constant emissions level after 2020.

	2005 national greenhouse gases emissions(2)	Allowed emissions annual average 2008-2012 under Kyoto Protocol(2)	Difference 2005 / 2012	National allowed emissions 2020 EU target(3)
BE	143.85	135.93	5.8%	99.72
DK	63.95	54.76	16.8%	40.17
DE	1001.47	973.90	2.8%	714.44
IE	69.95	63.00	11.0%	46.22
GR	139.24	138.84	0.3%	101.85
ES	440.64	332.81	32.4%	244.14
FR	553.41	564.18	-1.9%	413.87
IT	582.19	485.70	19.9%	356.30
LU	12.73	9.13	39.4%	6.70
NL	212.13	201.80	5.1%	148.04
AT	93.28	68.71	35.8%	50.40
PT	85.53	77.41	10.5%	56.79
FI	69.26	71.08	-2.6%	52.14
SE	66.96	75.14	-10.9%	55.12
UK	657.40	682.49	-3.7%	500.67
CZ	145.62	180.51	-19.3%	132.42
EE	20.65	39.59	-47.8%	29.04
CY	9.87	--	--	--
LV	10.87	23.83	-54.4%	17.48
LT	22.57	44.26	-49.0%	32.47
HU	80.53	115.70	-30.4%	84.88
MT	3.43	--	--	--
PL	398.95	552.01	-27.7%	404.94
SI	20.29	18.58	9.2%	13.63
SK	48.71	67.51	-27.9%	49.53
BG	69.81	121.53	-42.6%	89.16
RO	153.65	259.74	-40.8%	190.54
EU-27	5176.94	5371.45	-3.6%	3940.41
EU-15	4191.98	3936.26	6.5%	2886.57
New countries(1)	984.96	1436.57	-31.4%	1049.86
NO	54.15	50.25	7.8%	34.83

(1) For Cyprus and Malta, we suppose that the targets are equal to the emissions value of 2005 for the sum. (2) Source Eurostat..

Table 7: Greenhouse gases for EU-27 + Norway in Mt equivalent CO2

For the B2 scenario, RTD and CO2 objectives are identical to B1, also with a redistribution of part of the CO2 and energy taxation from subsidies to clean energy technologies. The main difference with B1 is that in B2 there are no international agreements for Climate and Environment, while in B1 we suppose that not only Appendix 1 countries but also developing countries collaborate to reduce world GHG emissions. The introduction of this scenario of Clean Development Mechanisms in B1, and tradable permits for CO_2 at the world level, allows the lowering of the CO_2 cost targets in Member States. On the contrary, in B2, there are no new trading mechanisms apart those already implemented at the EU level.

3 NEMESIS Macroeconomic and sectoral results for PLUREL scenarios[3]

In this section we present the results of the simulation of PLUREL scenarios with the macro-sectoral econometric model NEMESIS. All of the results are strongly dependant upon the hypothesis made on exogenous drivers, so it is very important to keep in mind the elements described in the last section. To be precise, we give the results for European economy, which include the EU-27 Members States except Cyprus and Bulgaria, plus Norway. This section is organized as follows: in the first part we present the macroeconomic results, namely gross domestic product, employment, etc, at European and national level, then we display some European sectoral results and finally we provide an overview of the NUTS 2 GDP results.

3.1 Macroeconomic results

3.1.1 Gross Domestic Product

- ***European Results***

Figure 5 displays the evolution of European GDP from 2006 to 2025 for the four scenarios. As we can see, there is a huge difference between scenarios. In 2025 the European GDP growth rate is about 3.8% in the A1 "Hyper-tech" scenario. R&D investment efforts implemented by member states boost European economic performance. In this scenario the European GDP growth rate is relatively similar to other scenarios until 2012. Progressively, R&D investment effects start and the European GDP growth rate is around 3% until 2020. And after 2020, the complete effects of R&D investments are realised; the GDP growth rate reaches 4.6% in 2025 versus 4.4% in the rest of the world. In fact, in this second phase, R&D investment effects boost external trade as well as internal consumption through improvement in process and quality goods.

Opposite to the B2 "Fragmentation" scenario, European GDP grows at 2.1% in 2025, due to both the demand addressed to the EU and low R&D intensity, which strongly constrains the European economy. In addition, in this scenario the European population is slowly increasing, with an

[3] A part of NEMESIS results is available on PLUREL Data warehouse, for specific results not being in PLUREL Data warehouse, please contact Baptiste BOITIER (baptiste.boitier@ecp.fr).

increase of 2.9% from 2005 to 2025. It is especially young Europeans (i.e. less than 25 years old) which restrict total population growth, with a loss of 16 million in 20 years. And yet, the class of less than 25 years is an important driver of households' expenditure, so households' consumption is reduced. The combined effects of weak investment in R&D, a weak external demand, and weak internal consumption lead to the European GDP growth rate falling by about 1% between 2010 and 2015, decreasing from 2.6% to 1.6% in 2015. After 2015, the European GDP growth rate increases progressively before stabilizing at around 2% until 2025.

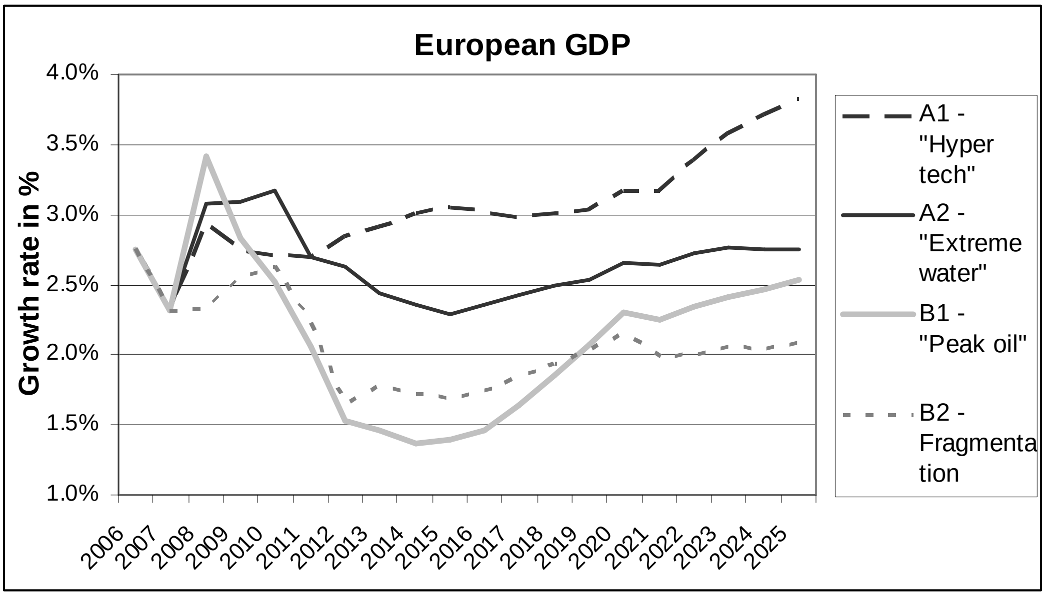

Figure 5: European GDP growth rate in the 4 scenarios

In the B1 "Peak Oil" scenario, we can see that European GDP grows faster at the beginning of the period compared to the other scenarios. It is mainly due to an external demand which is relatively strong and to the fact that the European economy does not face a loss in competitiveness generated by the cost of R&D investment, like in the A1 scenario. In fact, there is no specific R&D investment in the B1 scenario, whereas in the A1 and to a lesser extent in A2, the initial cost created by the financing of firms' R&D efforts which must invest in equipment and labour increases the firms' production costs and reduces their competitiveness. But after 2010, the inflationary impact of a high oil price on Europe and other economies reduces the B1 GDP growth rate. The European GDP growth rate starts at 3.4% in 2009, reaching 1.4% in 2015 when the oil price is at its maximum, 130$$_{2000}$, or around 140 current Euros in 2015. Substitution of oil energy with other energies and the reduction of energy consumption lead to a decrease in the oil price. This reduction in payment for energy allows the European economy to progressively reach 2.5% of the GDP growth rate in 2025.

In the A2 "Extreme water" scenario, where the oil price decreases until 2010, the European GDP growth rate is higher than in A1 and B2

scenarios. After 2010, the European GDP growth rate in A2 is relatively steady, fluctuating between 2.3% to 2.75%. This relative stability is due to the fact that between 2010 and 2015, the fall of the oil price counterbalances the cost of R&D investment. After 2015 it is the opposite, the economic growth gains due to firms' R&D efforts are lessened by the increase of oil price.
To sum up, in the A1 "hyper tech" and A2 "extreme water", the financing of investment in R&D reduces the competitiveness of the European economy at first, whereas in the B1 "peak oil" scenario where external demand is strong, economic growth is higher. That is not the case in the B2 "fragmentation" scenario, where economic performance in other parts of the world is too weak to drive economic growth.
But in a second phase, when R&D investments produce their effects on internal demand and external competitiveness, as in the A1 and A2 scenarios, European GDP increases faster and enables stronger economic development in Europe.

After looking at the GDP results of the four PLUREL scenarios at the European level, it is interesting look at the national results and also to point out important differences between countries.

- ***National results***

Figures 6 to 9 show the average annual GDP growth rate for each EU member state. There is an important heterogeneity between member states and between scenarios.

Eastern countries face a higher growth rate, for instance Estonia and Poland's GDP grow respectively by 6.7% and 4.5% in the A1 scenario, whereas Germany and France's GDP increase respectively by 2.1% and 2.3% in the same scenario. This difference in GDP performance between Eastern and Western countries exists in all scenarios with different amplitude. So there is a relative convergence in terms of GDP per capita in all of the scenarios. Scenarios with a strong economic growth are also the ones that exhibit a more rapid convergence.

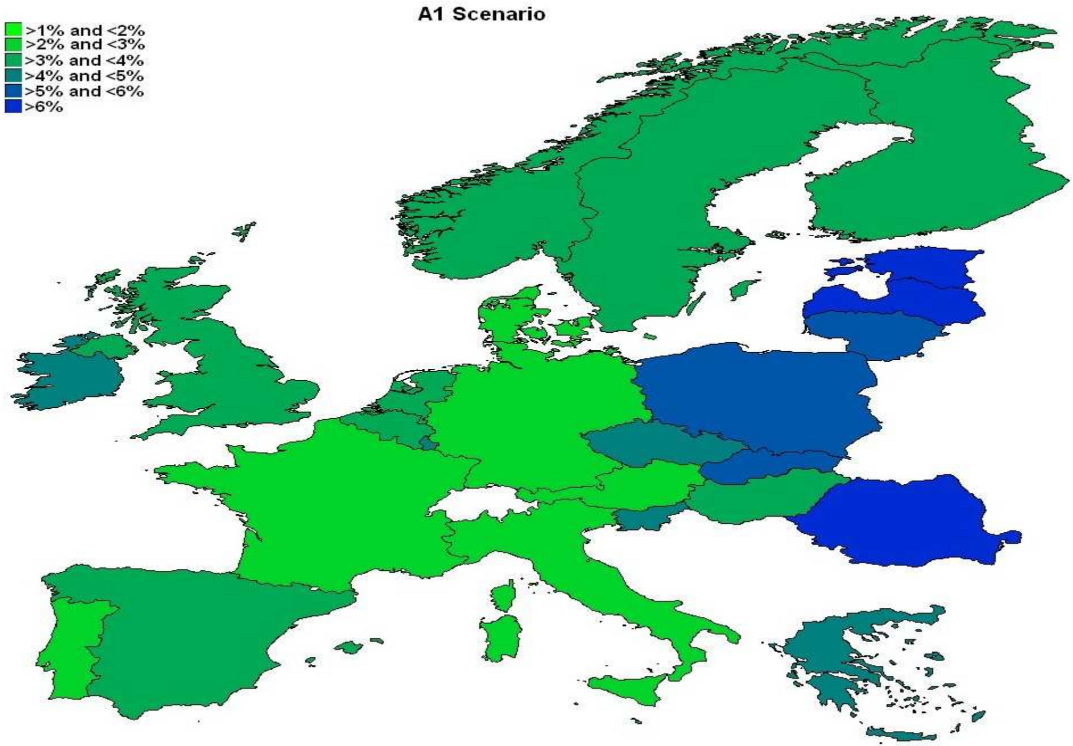

Figure 6: Members States GDP average annual growth rate for the A1 "hyper-tech" scenario

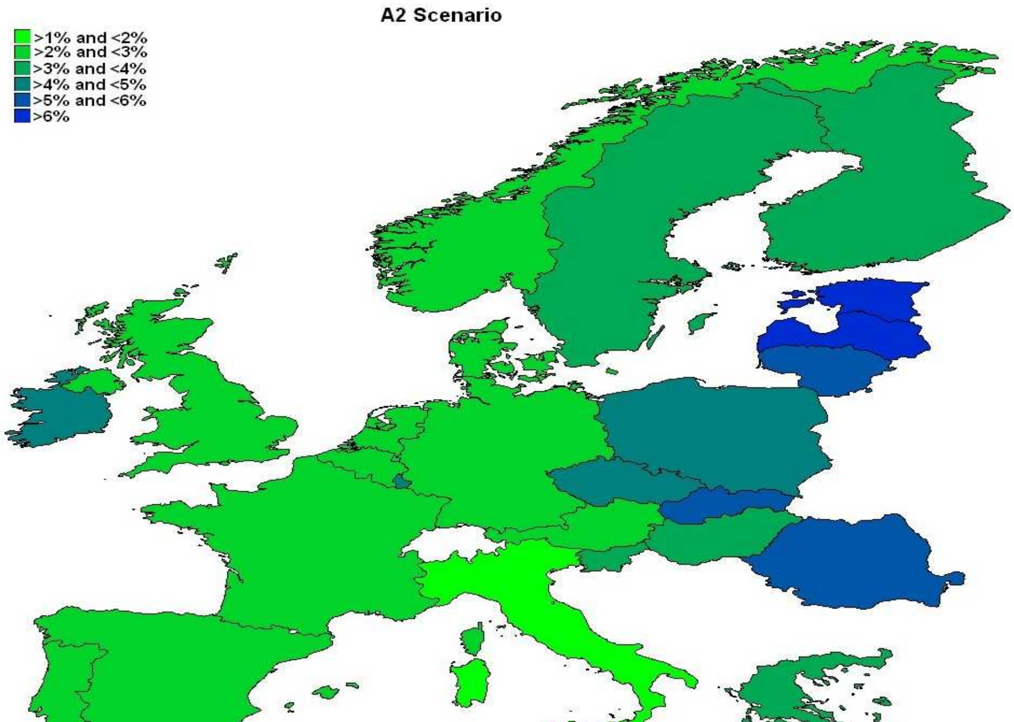

Figure 7: Members States GDP average annual growth rate for the A2 "extreme water" scenario

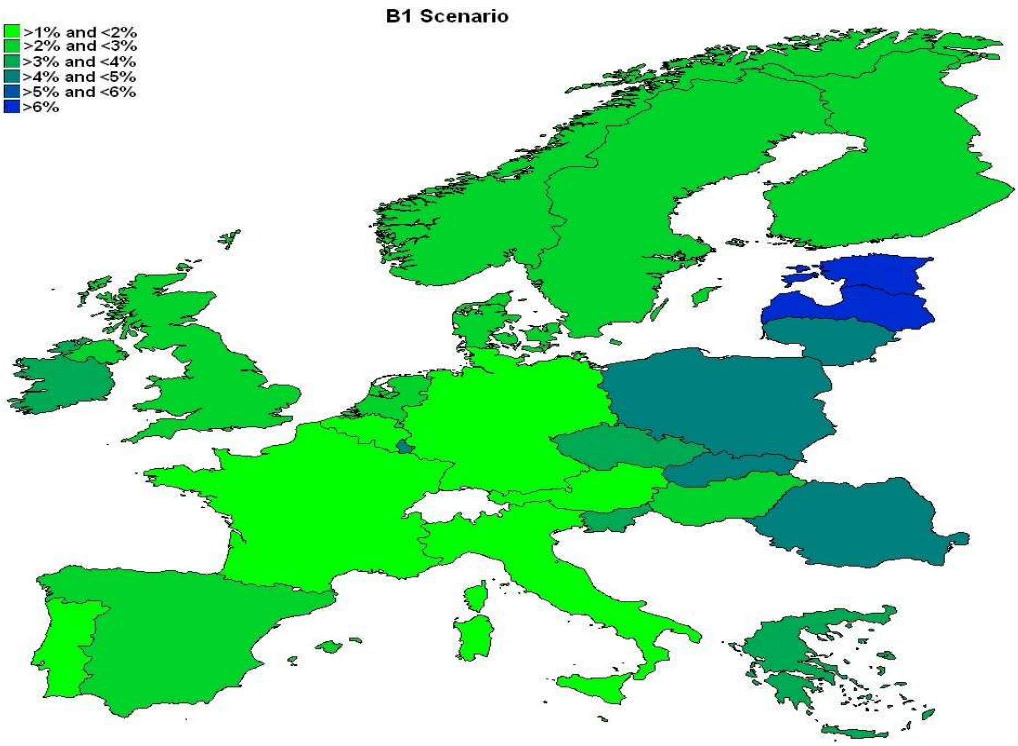

Figure 8: Members States GDP average annual growth rate for the B1 "Peak oil" scenario

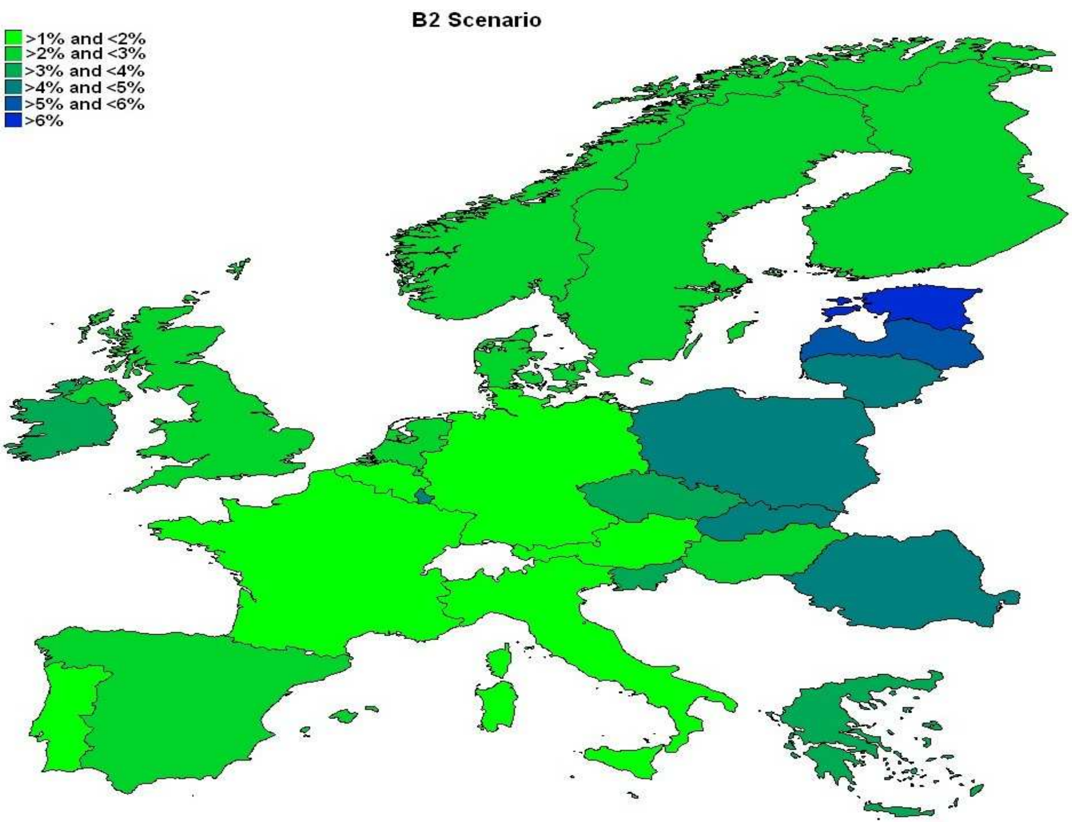

Figure 9: Members States GDP average annual growth rate for the B2 "Fragmentation" scenario

3.1.2 Employment and wages

Figure 10 displays European employment annual growth rates for the four scenarios. As we can see, employment grows relatively quickly at the beginning of the period in all scenarios. This is mainly due to the initial situation of the European economy. In fact, most European countries have a higher number of unemployed people. Finally, new workers are therefore relatively easy to find for firms. But year after year, the labour becomes scarcer, leading to an increase in wages, and finally reducing the employment growth rate. Furthermore, there is a deceleration, until 2015, and a decrease after, of the growth rate of the 25 to 65 years old age class which is the major class contributor to the labour force. So the labour market is also stressed by population structure. In order to reduce the impact of the scarcity of workers in Europe, the NEMESIS model supposes that there is an increase of the participation rate in each aging class (expect the people less than 25 years old) either by an increase of the participation in the labour market, or by an increase of the retirement age. On average three jobs created leads to one more person participating in the labour market.

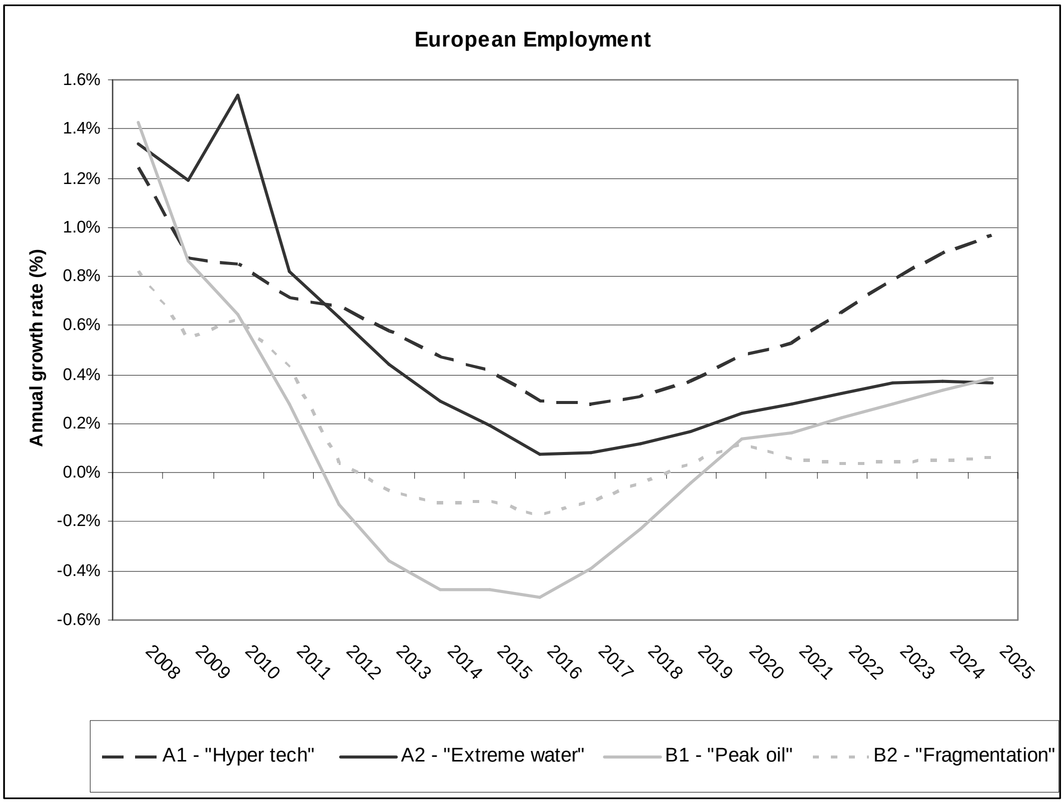

Figure 10: European employment growth rate in the 4 scenarios

As figure 9 shows, the European employment growth rate follows the GDP growth rate. In fact the A1 scenario has the highest employment growth as of 2012, and the B1 scenario has the weakest one into 2020 as for European GDP growth rates. But we can see that the difference between the European GDP growth rates in each scenario is higher than for the European employment growth rate. That could be first explained by wages (see figure 11), which induces substitution and variation of production factors. The second aspect is the increase in labour productivity which is reinforced in the scenarios A1 and A2, where there is investment in R&D.

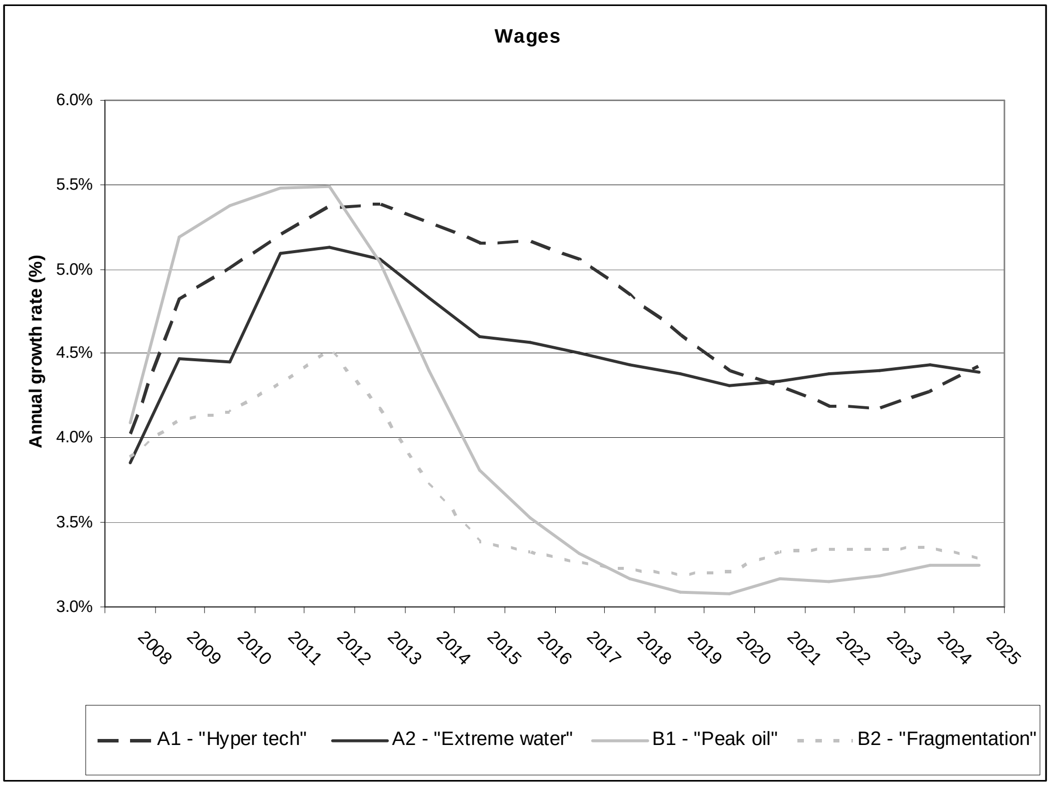

Figure 11: European wages growth rates n the 4 scenarios

To conclude, employment evolution in PLUREL scenarios is driven by 6 opposite forces: population structure and participation rate, firms' labour demand and wages, and finally labour productivity and wages.

3.1.3 Competitiveness and external trade

Figure 12 displays European exports and imports. We can see that the average growth rate of exports outside of the EU is driven by the hypothesis made on external demand and on R&D investment. Scenarios where demand is high, face a higher increase of exports and vice versa. On the other hand scenarios with huge investment in R&D increase competitiveness, and consequently increase European exports.

Therefore, in the A2 "extreme water" scenario, in which external demand is relatively weak, exports from Europe grow on average at 2.9% that is a little bit more than in B1 "Peak oil" (2.8%) and B2 "Fragmentation" (2.5%) which have a higher external demand. In fact in the A2 "Extreme water" scenario, the weakness of external demand is counterbalanced by the increase in competitiveness due to a relative decrease of product price. This "decrease" of product price comes from investment in R&D which generates quality or process innovation.

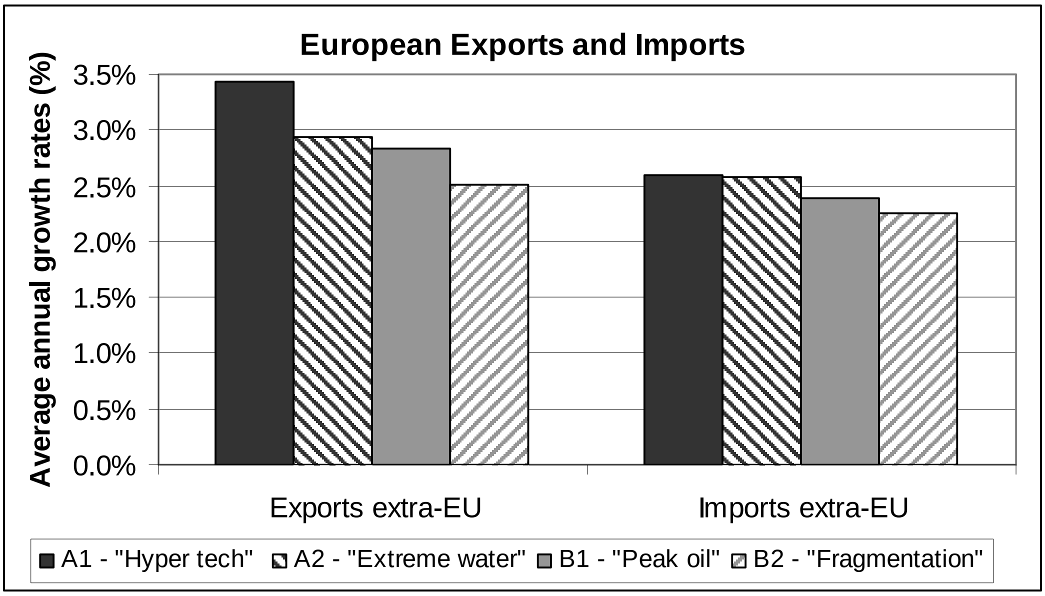

Figure 12: Average annual growth rate of European Exports and Imports between 2008 and 2030 for the 4 scenarios

We can see the same mechanisms at work with the A1 "Hyper-tech" scenario where the difference in the average annual growth rate between imports and exports in Europe is important. European imports are still higher in the scenarios including R&D investment because of a higher national demand but trade balances are strongly increasing. For instance, trade balance is more than 5 times superior in 2025 than in 2005, going from 126 billion €$_{2000}$ to 727 billion €$_{2000}$.

3.1.4 Final energy consumption

We can see in figure 13 the evolution of the final energy consumption intensity for Europe. Scenarios A2 "Extreme Water" and B2 "Fragmentation" show a constant decrease of European final energy intensity of around -0.8% per year; close to the past trends.

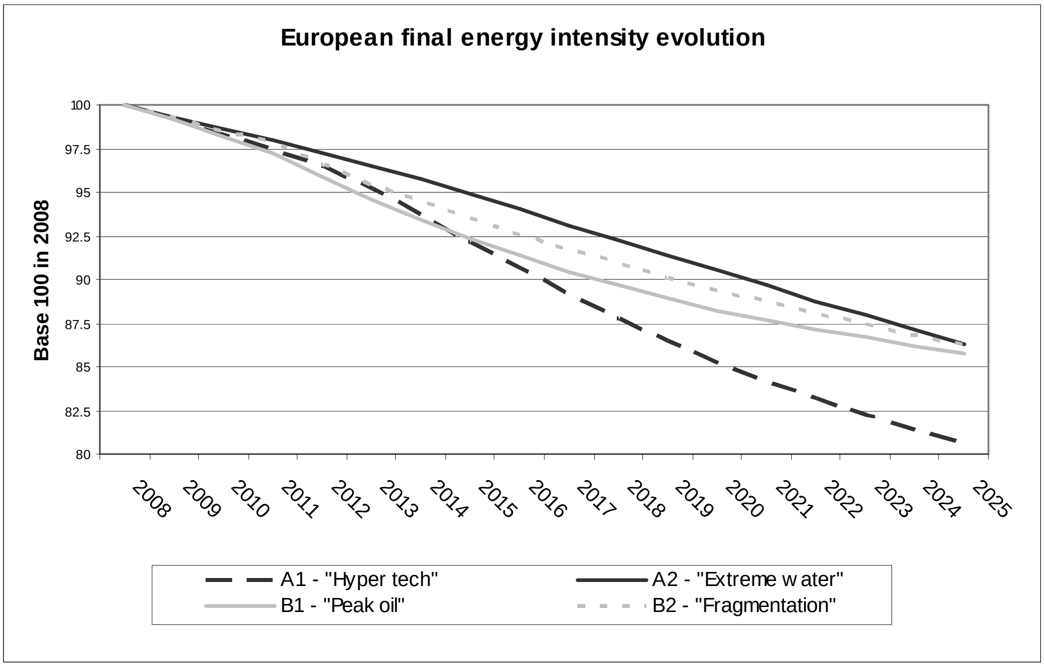

Figure 13: Final energy intensity in Europe for the 4 scenarios (Base 100 in 2008)

These final energy intensity reductions are explained by two mechanisms: a substitution effect and a productivity effect. Oil price increases lead firms to change their production factor allocation in away from energy, and reduces the households' demand of energy goods. But, there is equally an increase in energy productivity due to R&D investments. These two mechanisms are reinforced for A1 "Hyper-tech" and B1 "Peak oil" scenarios. In the former scenario, the important investment in R&D realized by firms leads to process innovation allowing firms to reduce their final energy consumption for the same production level. We can see for the B1 "peak oil" scenario a high oil price has impacts on economic growth as presented in the section below, but equally on energy consumption, for which the intensity faces a faster decrease when the oil price increases, between 2008 and 2015.

3.2 Sectoral results

In this section, we present some sectoral results for the PLUREL scenario. The NEMESIS model currently covers 32 sectors, but in order to clarify the presentation of the results, we aggregate them into 8 sectors. The NEMESIS sectoral nomenclature and the current aggregation are fully presented in Appendix 1. We expose in this section the evolution of European production and employment for these 8 aggregated sectors.

3.2.1 European sectoral production

Figure 14 displays the average annual growth rate of European sectoral production between 2008 and 2025 for PLUREL scenarios. Globally, we can see that there is a general evolution of the economic sectoral components. In fact, agriculture shows the weakest growth rate in all scenarios. Agricultural goods are quite unaffected by the total consumption increase. Furthermore there are no specific assumptions on agricultural trade policies in the scenario.

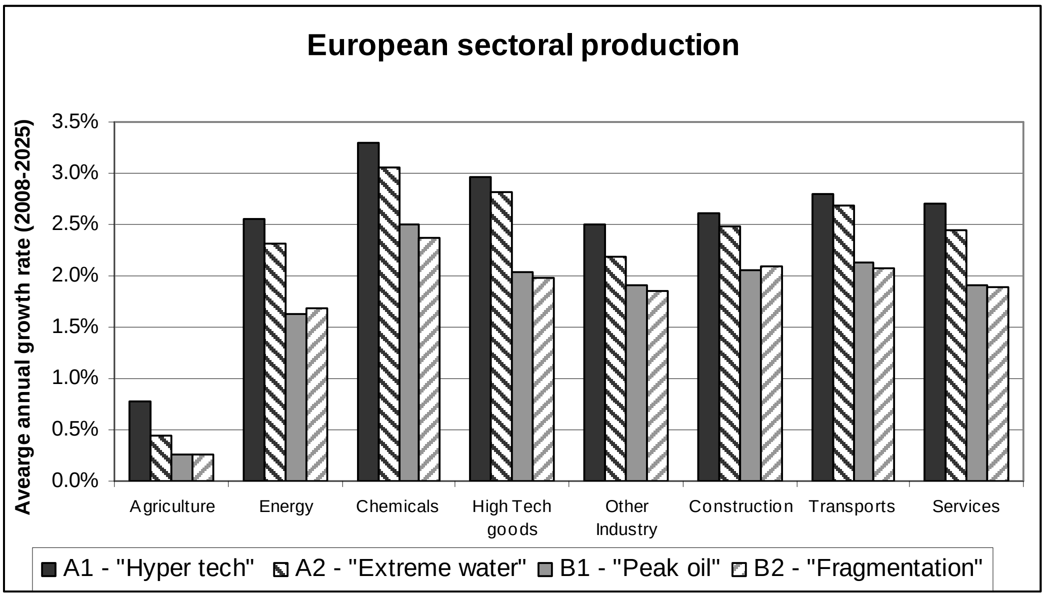

Figure 14: Average annual growth rate (2008-2025) of European sectoral production for the 4 scenarios

The energy sector also grows relatively slower than other sectors, as we explained in the section 3.1.4. A moderate increase in energy consumption and a decrease in energy intensity also result in moderate economic development in the energy sector. We can also see that in the B1 “Peak Oil” scenario, the average growth rate is weaker than in the B2

"Fragmentation" scenario, whereas it is nearly the opposite in all other sectors. This change is due to the high oil price in the B1 scenario. Then, for 2010 to 2015, there is more of a contrast in energy sector production growth between scenarios because of the difference in the oil price growth rate. In fact, in the B1 "Peak oil" scenario energy grows on average at 0.58% during 2010 and 2015 whereas in the B2 "Fragmentation" it grows at 1.08%.
Finally, figure 13 shows equally the sectoral dynamic generated by the R&D investment. High technological goods sectors exhibit strong growth in the A1 and A2 scenarios; these sectors being boosted by product innovation. Services benefit from households' purchasing power increase while industrial sectors face a moderate growth rate of their production penalized by an increase in productivity.

3.2.2 European sectoral employment

The evolution of sectoral European employment is very heterogeneous, in most of the scenarios. The only two sectors showing an increase employment are chemicals and services. But one must keep in mind the macroeconomic results presented in section 3.1.2. In all the scenarios, employment grows or stays stable between 2008 and 2025, in fact services represent around 50% of total employment so even a weak increase in this sector can compensate for higher job losses in other sectors.

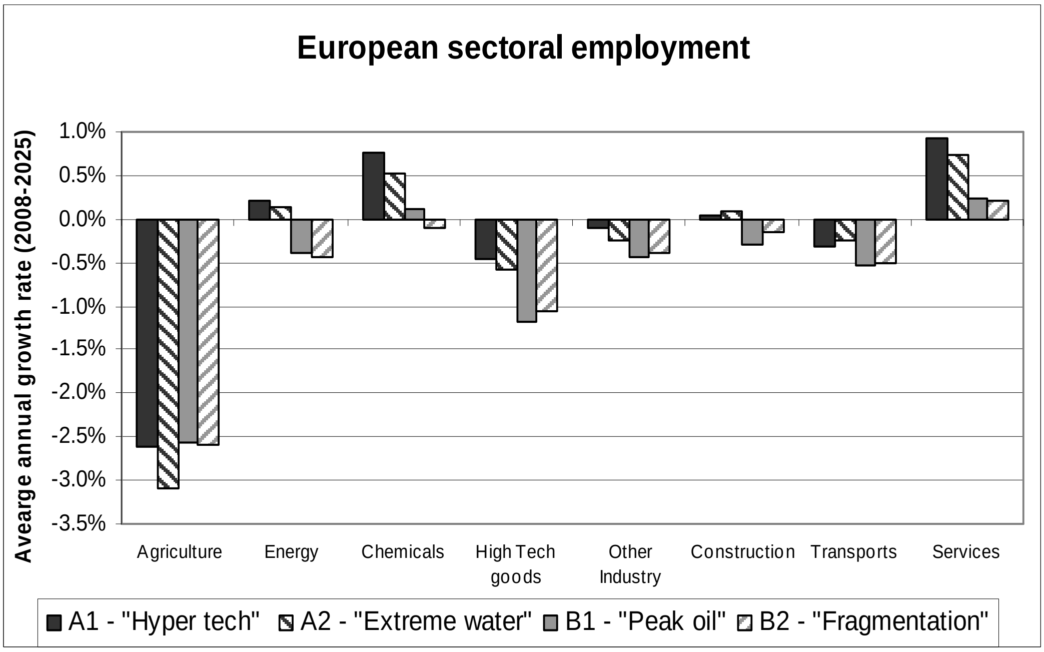

Figure 15: Average annual growth rate (2008-2025) of European sectoral employment for the 4 scenarios

In agriculture, employment destruction is between 6.4 million and 5.5 million depending on the scenario, with job destruction of about 1.5 million in Romania. The weakness of revenue generated by agricultural production as well as the increase in agricultural productivity lead farmers to withdraw from agriculture to other activities.
Other sectors like high technological goods, have strong production growth, destroying many jobs. This reflects past trends of this sector where labour productivity is very important since the 90's.

Finally, productivity gains lead to a reduction in the jobs in industry and agriculture, but the employment created in services counterbalance this loss and allow at least to maintain the number of jobs.

3.3 NUTS-2 Results

This section presents a short overview of the NUTS-2 results. We focus only on the GDP results in order to avoid an information overflow, other results being available on the PLUREL Data warehouse.

We first must specify that the NEMESIS model provides NUTS-2 results for GDP, 10 sectoral value-added, 10 sectoral employment, 10 sectoral Compensation of employees and value added prices. But the NEMESIS model is a macro-sectoral econometric model, and so it does not model economic behaviour at the NUTS-2 level. At the NUTS-2 level, all results come from a downscaling approach based on sectoral split of macroeconomic results. So the NUTS-2 results must be viewed as the result of sectoral dynamics and must be used as indicators, which are necessary for PLUREL partners, and especially for Edinburgh University that needs NUTS-2 GDP to use their detailed land-use model.

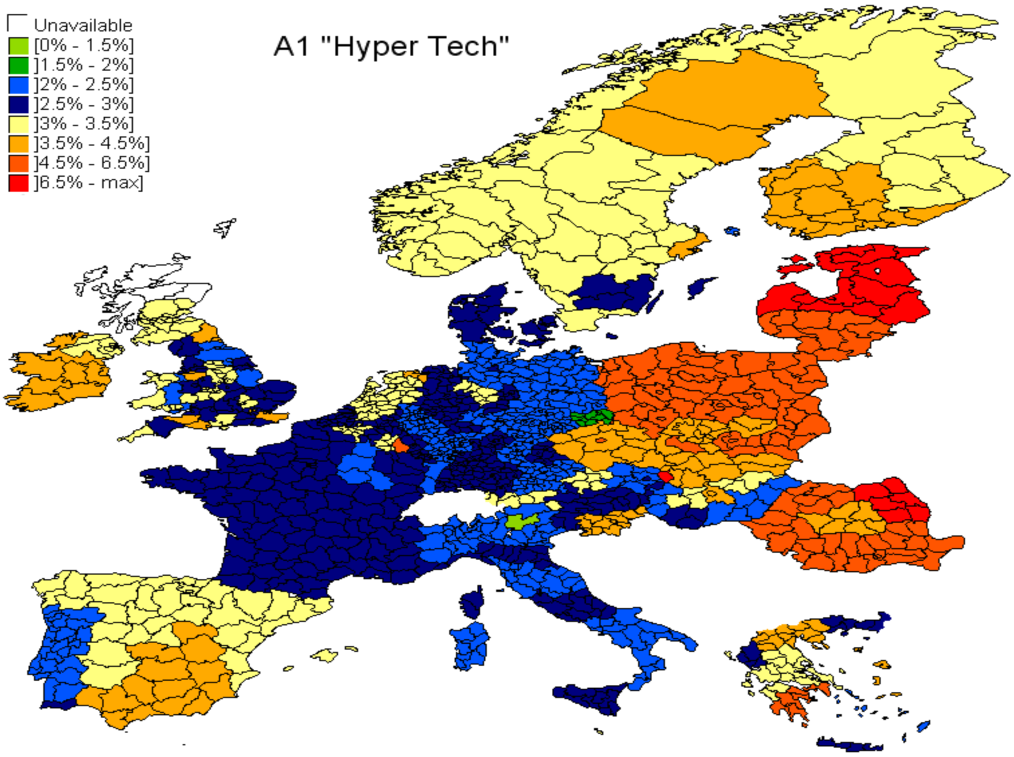

Figure 16: NUTS-2 GDP average annual growth rates in scenario A1 "Hyper-tech" (2008-2025)

Figures 16 to 19 display GDP average annual growth rates between 2008 and 2025. We can see that there is a relative heterogeneity between NUTS-2 regions. Generally, GDP growth rates of NUTS-2 regions are close to the national GDP growth rate and differences between regions are less than 1%.

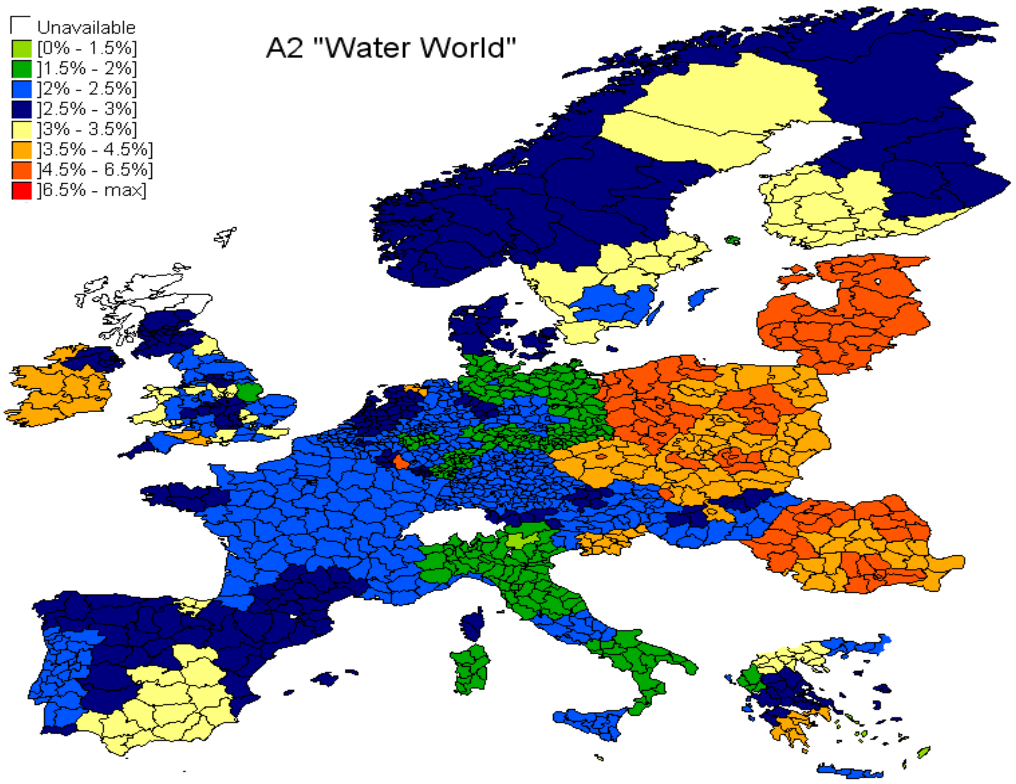

Figure 17: NUTS-2 GDP average annual growth rates in scenario A2 "Water world" (2008-2025)

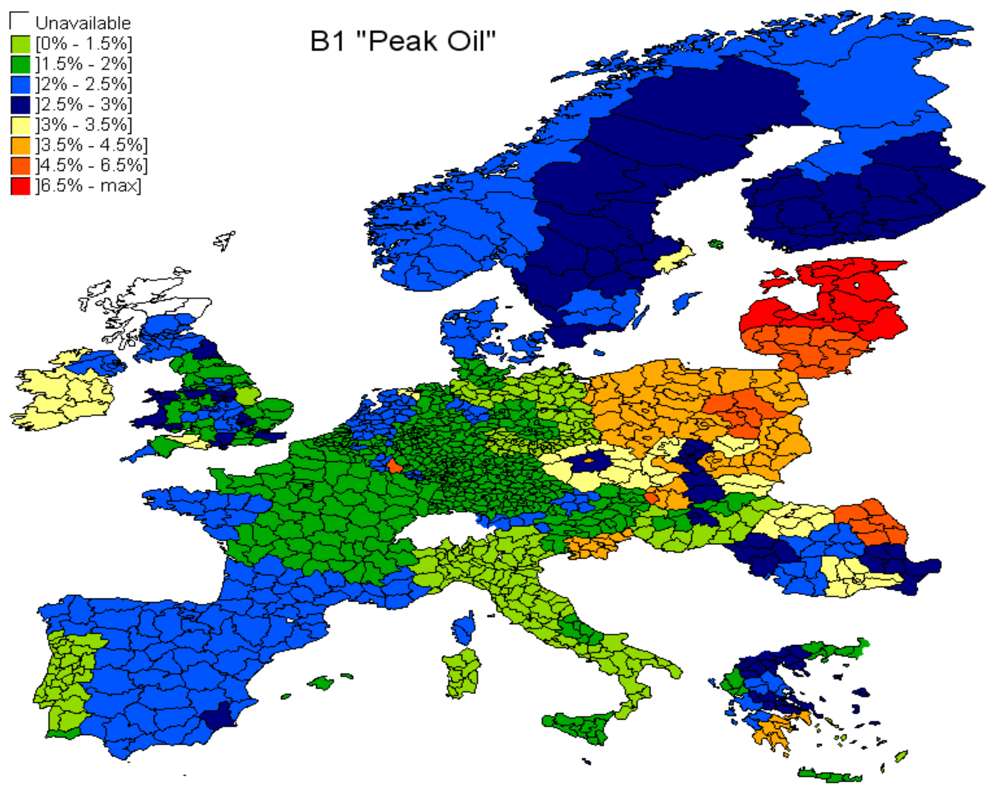

Figure 18: NUTS-2 GDP average annual growth rates in scenario B1 "Peak Oil" (2008-2025)

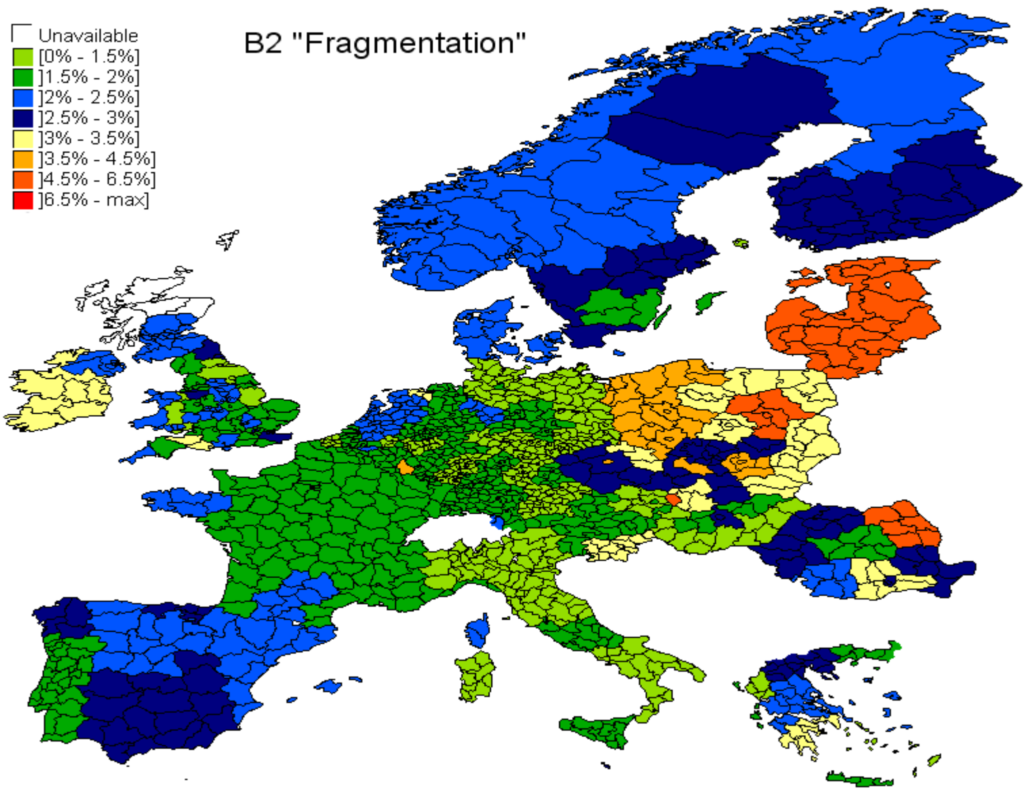

Figure 19: NUTS-2 GDP average annual growth rates in scenario B2 "Fragmentation" (2008-2025)

Conclusion

From an economic point of view, the differences between PLUREL scenarios come from differences in the main NEMESIS drivers that can be summarised at follows:

- World demand, weak in A2 “Extreme water", moderate in B2 “Fragmentation” and strong in A1 “Hyper-tech” and B1 “Peak oil” is an important contributor to economic development in EU countries, by creating export outlets for EU firms.
- After a phase of maturation, the R&D investments which are strong in the A1 “Hyper-tech” scenario, accelerated in A2 “Extreme water" and trending in B1 “Peak oil" and B2 “Fragmentation”, boost, in scenarios where R&D efforts is strong, the competitiveness of EU countries through a rise in productivity and an increase of good . In addition, the productivity gains limit inflation inside the EU that could occur with labour force scarcity and then contribute yet further to GDP growth.
- Energy cost is also an important factor for economic performance, noteworthy in B1 “Peak oil” scenario, the energy prices, boosted by a high oil price and a carbon price of about 30€/tCO2 in 2025, constrain powerful economic development in EU countries by increasing transportation costs, heating costs and production costs. The same mechanisms work in B2 “Fragmentation” but this time only through the carbon price (40€/tCO2).

The combination of these three drivers, in addition to the demography in the four alternative scenarios determines the EU countries’ economic performance. Indeed, with powerful R&D investment, a strong World demand and a moderate oil price in the end of the simulation period, the economic growth in A1 “Hyper-tech” scenario is very important with an average EU GDP growth rate of about 3.5% between 2020 and 2025. Despite R&D investments growing more quickly than GDP, economic growth in A2 “Extreme water" is relatively stable around 2.6% per year, penalised by a weak World demand. Whereas, B1 “Peak oil" and B2 “Fragmentation” display a relatively weak GDP growth rate with 2% annual average, the first scenario being constrained by a high oil price reaching 200 current dollars and the second penalised by a moderate World demand and by a high cost of fossil energy.

Table 8 summarises the main economic results for each PLUREL scenario:

% change between 2008 and 2025 (and thousand for employment)	GDP			Employment			Energy Intensity			External trade		
	EU	**EU-15**	**NMS**	**EU**	**EU-15**	**NMS**	**EU**	**EU-15**	**NMS**	**EU**	**EU-15**	**NMS**
A1 - "Hyper tech"	68.3%	64.2%	139.0%	10.6% 22669	9.3% 16168	16.2% 6502	-19.4%	-18.6%	-29.9%	18.5%	17.1%	86.0%
A2 - "Extreme water"	55.8%	52.0%	121.2%	7.9% 16806	6.6% 11480	13.3% 5327	-13.7%	-12.7%	-26.0%	5.9%	4.5%	69.3%
B1 - "Peak oil"	41.3%	38.1%	96.3%	0.9% 1835	-0.1% -160	5.0% 1995	-14.5%	-13.6%	-27.6%	8.2%	6.8%	76.6%
B2 - "Fragmentation"	39.4%	36.4%	89.9%	1.0% 2080	0.3% 447	4.1% 1633	-13.6%	-12.5%	-28.5%	3.5%	1.9%	69.1%

Table 8: Summary of NEMESIS main results for PLUREL scenarios

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Appendix 1: Nomenclature

Country nomenclature:

Country	Abbreviation
France	FR
Belgium	BE
Germany	DE
Italy	IT
United-Kingdom	UK
Netherlands	NL
Ireland	IE
Denmark	DK
Finland	FI
Norway	NO
Sweden	SE
Austria	AT
Spain	ES
Greece	GR
Portugal	PT
Slovenia	SI
Estonia	EE
Latvia	LV
Lithuania	LT
Bulgaria	BG
Czech Republic	CZ
Slovakia	SK
Hungary	HU
Poland	PL
Romania	RO
Luxembourg	LU

Sectoral Nomenclature and Aggregation:

	Agriculture	Energy	Chemicals	High Tech goods	Other Industry	Construction	Transports	Services
Agriculture, etc ..	X							
- Agriculture	X							
- Fisheries	X							
- Forestry	X							
Coal & Coke		X						
Oil & Gas Extraction		X						
Gas Distribution								X
Refined Oil		X						
Electricity		X						
Water Supply								X
Ferrous & non-Ferr. Metals					X			
Non Metallic Products					X			
Chemicals			X					
Metal products					X			
Agr. & Indus. Machines					X			
Office Machines				X				
Electrical Goods				X				
Transp. Equipment					X			
Food, Drink & Tobacco					X			
Textile, Cloth. & Footw.					X			
Paper & Print. Products					X			
Rubber & Plastic					X			
Other Manufactures					X			
Construction						X		
Distribution								X
Lodging & Catering								X
Inland Transports							X	
Sea & Air Transp.							X	
Oth. Transp. Services							X	
Communication								X
Bank, Fin. & Insurance								X
Other Market Services								X
Non Market Services								X