Global Climate Forum

Investment-oriented climate policy: An opportunity for Europe

Analysis of growth and employment effects of an EU climate target of 50% in 2030

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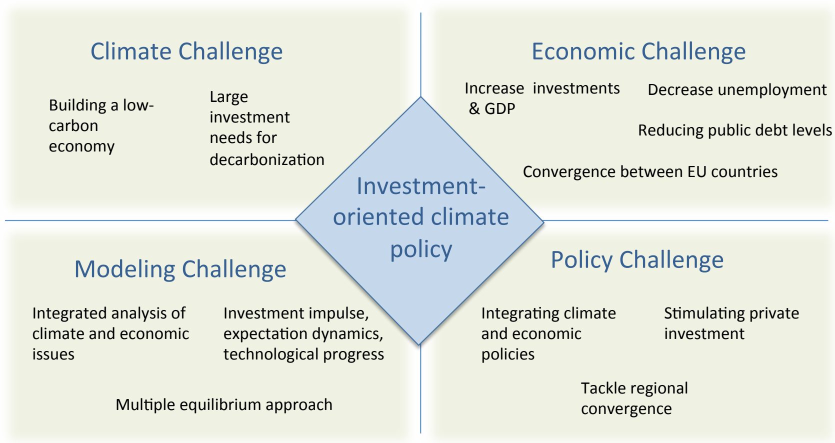
1 Executive Summary

This study shows that an investment-oriented climate policy based on credible climate goals can overcome the increasingly threatening stagnation of the European economy. Since other strategies to tackle the crisis are noticeably losing their plausibility, a constructive debate on this issue is urgently needed.

Assessing integrated policies such as an investment-oriented climate policy requires a good understanding of the climate challenge as well as the economic challenge of the European Union. The combination of these two challenges poses a modelling challenge for the analysis on the one hand and a policy challenge for the implementation on the other hand. The four challenges that are addressed in this study are depicted in Figure 1.

Figure 1: Four challenges and one solution



Source: Own illustration.

In currently used economic models which represent climate policy as the internalisation of a single intertemporal external effect, emission reductions lead to a deterioration of the present economic situation by design. Correspondingly, the traditional climate policy scenarios show a reduction of GDP and employment compared to the reference scenario when reducing Greenhouse Gas (GHG) emissions. In most assessments climate policy is treated as a reallocation of economic resources through market-based and regulatory instruments. In particular, investment flows are redirected from climate-damaging activities and technologies towards climate-friendly ones. Therefore, the total investment volume barely changes.

However, this picture of climate policy does not take into consideration a possible green investment impulse and the resulting innovation impulse (acceleration of technical progress) as well as resulting expectation dynamics. This study shows this connection by means of several climate-economic models, which was considered important to analyze the identified key mechanisms independently of the type of economic model. In this way, the study brings together robust insights from the different models.

Simulations taking into consideration the aforementioned mechanisms, show that an investment-oriented climate policy may lead to an increase of growth and employment, even with a 50% reduction of annual GHG emissions by 2030 in Europe (compared to 1990). An additional energy efficiency target strengthens the positive effect on employment noticeably.

A green investment impulse that can counteract overall European stagnation as well as economic and social divergence needs to go beyond the transformation of the energy sector. It requires increased energy efficiency investments across sectors, including the modernisation of the building stock. This is in the interest both of enterprises, whose business is threatened by a lack of effective demand, as well as of European citizens who are suffering from high unemployment rates in many places. Moreover, investors and insurances can also benefit from it, due to the present lack of attractive investment opportunities.

However, such an investment impulse is hindered by a coordination problem that arises in financial markets. The profits of individual investors depend on them correctly estimating the growth perspectives of the economy. But the overall economic perspective in turn depends on the individual expectations of precisely these investors. Currently, investors in Europe are very cautious: a growth of more than 1% is already considered high, and this assessment has become a self-fulfilling prophecy.

An investment-oriented climate policy can help solving this coordination problem of European investors and therefore open up a credible perspective for green growth in Europe. It requires a much stronger integration of climate policy and economic policy. Putting a stronger emphasis on investment can be beneficial in economic as well as environmental terms. Incentives to mobilize investment should target private capital (on the supply side) and pay special attention to Central and Eastern European countries, characterized by high energy intensity and low income per capita (on the demand side). To stabilize the positive employment effects this policy should be combined with an education and vocational training program across Member States.

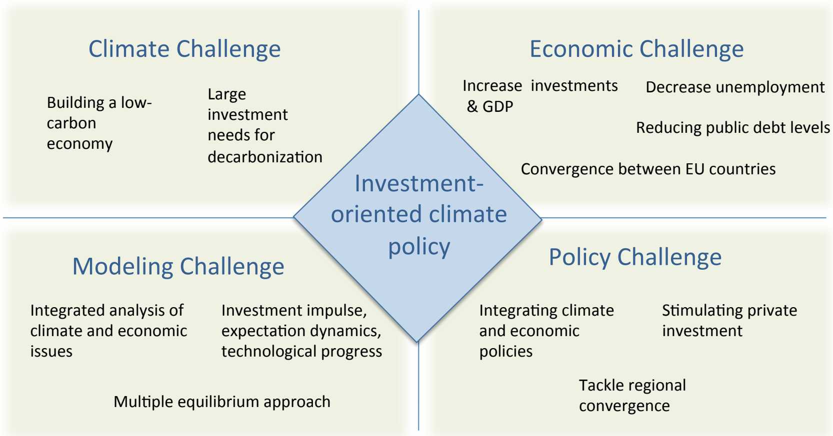
In the European Union, a stronger integration of the economic governance framework including the "Investment Plan for Europe" and the 2030 climate and energy framework should be an important first step. Since current investment initiatives are not sufficient for a transformation in terms of scale and scope, a clear commitment to an investment-oriented climate policy is required. Working towards this goal with stakeholders such as policy makers, industrial companies and financial institutions will play a key role.

2 Synthesis Report

Economic stagnation, income divergence and climate change are three of the most pressing global challenges. An investment-oriented climate policy can address all three of these challenges by stimulating sustainable growth in the European Union (in environmental, social and economic terms). The purpose of this study is to show that climate policy can have a positive effect if certain mechanisms are taken into consideration in economic evaluations, and to trigger a debate on opportunities posed by climate policy. Although European Greenhouse Gas (GHG) emissions only make up 10% of global emissions, it would be an important signal for international climate negotiations in December 2015 in Paris if Europe could show that a different growth path is possible.

In order to address this issue, four challenges are relevant and need to be analysed: The climate challenge and the economic challenge, as well as the subsequent modelling challenge for the analysis and the policy challenge for the implementation of a solution for both challenges.

Figure 2: Four challenges and one solution



Source: Own illustration.

The climate challenge, among others, consists of decarbonizing the economy on the one hand and of financing the required investment need on the other hand. In order to find out how a transformation to a low-carbon economy can come about, it is necessary to look at the sectoral and regional distribution of emissions. As described in Section 3.1, the energy sector is responsible for the largest share of GHG emissions, followed by the transport sector and the industrial sector (manufacturing industries, construction and industrial processes). However, this static views needs to be complimented with the dynamics of emission reduction efforts. In the past 20 years, industrial emissions have decreased the most, followed by agriculture, household and energy sector emissions. The transport sector on the contrary has increased its emissions by 20%. Furthermore, emissions in some sectors are more strongly tied to economic activity: In 2009, emissions from the industry decreased substantially whereas emissions in other sectors declined more slowly. This shows that a transformation of the energy sector alone would not be sufficient and that effective policies need to take into account sectoral differences. Regarding the regional distribution, the energy intensity of the different European Member States varies strongly. Bulgaria has the highest energy intensity, followed by Estonia, the Czech Republic, Romania, Slovakia and Latvia (compared to the EU average at 300 kgoe/ €1,000 GDP). Although these countries have the largest potential for GHG emission reductions, as discussed in Section 3.4, they are also the ones that have the smallest number and scale of implemented energy efficiency measures in Europe. The economic and institutional situation and challenges of these countries need to be taken into account when implementing climate policy measures.

Concepts which consider economic benefits of environmental policy originated in the policy sphere (see e.g. Jaeger et al. 2011), and have been embraced by international institutions such as the OECD, UNEP and others. However, so far the green growth research seems rather detached from the field of climate policy analysis which is analyzed in more detail in Section 3.5. In contrast to this, the current discussion in the EU on climate policy centers around minimizing the economic costs and on distributing them fairly among the Member States. The European Commission Impact Assessment Report of the “2030 framework for climate and energy policy” showed that a 40% GHG reduction target leads to a decrease of GDP between -0.1% and -0.45% in 2030 compared to the reference scenario. According to the analysis, additional energy efficiency targets lead to positive employment effect between 0.3% and 0.5% in 2030 compared to the reference scenario. As stated in Section 3.2 the investment requirements for a transformation are estimated to be around €200-250 bn annually in order to reach the mid-term and long-term climate targets of the EU.

This leads to the economic challenge in the European Union which is characterized by low growth rates, low investment levels and high unemployment in parts of Europe. In his well noted speech at the IMF Economic Forum, the economist Larry Summers (Summers 2013) argued that the recession might be far from over and that industrialized nations face the threat of a secular stagnation in the decade(s) to come. This describes the current state of the European economy very well. As described in detail in Section 4.1, European Economic Forecasts show that economic growth has fallen short of estimates since the financial crisis. The 2006 projections estimated an economic growth rate of 2.2% until 2020 and a long-term average growth rate of 1.7%. After the financial crisis, the 2015 projections were corrected to 1.1% until 2020 and a long-term average of 1.4%. Also, gross investments have dropped €203-370 bn below their long-term average after the financial crisis (currently at around 19.3% of GDP), which is in the same order of magnitude as the required investment needs for a substantial reduction of GHG emissions. The largest drop in investments occurred in countries such as Spain, Portugal, Greece and Ireland. The unemployment rate for the EU was at 10.2% in 2014, with large differences between Member States. The country with the lowest rates were Germany and Iceland with 5% and the countries with the highest rates were Greece and Spain (with 26.5% and 24.5%). Unemployment rates in the Central and Eastern European countries have remained relatively stable. Public debt and government deficit, the two most important variables for the economic governance framework, also vary strongly between

Member States. The EU28 average public debt ratio reached 86.8% in 2014 with highest rates in Greece and Italy (177.1% and 132.1%). Countries like Bulgaria and Romania had a public debt ratio of 27.6% and 39.8% in 2014 and therefore stayed well below the 60% threshold defined in the Stability and Growth Pact which is explained in more detail in Section 4.2. The EU average GDP/capita grew much slower after the crisis as compared to before the crisis and reached €27,300 in 2014. However, countries such as Croatia, the Czech Republic, Greece, Cyprus, Spain, Italy and Ireland have experienced a strong decline in GDP/capita and have not yet reached their pre-crisis levels in 2014. The decline was especially high in Greece from €21,600 in 2008 to €16,300 in 2014. On the opposite side, countries such as Germany have on the contrary experienced a higher growth of GDP/capita than before the crisis. The increasing differences between Member States in terms of unemployment, GDP/capita and public debt since the crisis pose a threat to the European project.

With several additions to the Stability and Growth Pact (SGP), post-crisis economic policies focused very much on fiscal responsibility (with public debt and government deficit rules), as described in detail in Section 4.2. Structural reforms aim at competitiveness and job creation. The announcement of the "Investment Plan for Europe" by EC-President Jean-Claude Juncker in November 2014 which is introducing a European Fund for Strategic Investment (EFSI) (European Commission and Juncker 2014), shows the will of the EU leaders to emphasize investment. As explained in more detail in Section 4.3, the fund is equipped with €21 bn: €5 bn from the European Investment Bank (EIB) and €16 bn as a guarantee under the EU budget. Through a public-private multiplier of 1:15, it is expected to mobilize €315 bn of private investment (European Commission and EIB 2014a). Additional country contributions to the fund will not be accounted for under the public debt rule, such that investment commitments under this program are not in conflict with the Stability and Growth Pact. An important investment criterion is additionality, such that existing investments are not crowded-out. Other criteria are that investments have to be viable and mature and ensure "high socio-economic returns". Although renewable energy and energy efficiency are among the focus investment areas, there is no specific reference to ensuring "environmental returns".

From a modelling perspective, combining these two challenges requires new approaches and the inclusion of additional mechanisms. In most models that assess climate policy, climate change is considered an external effect which is internalized with a peculiar temporal structure: GHG emissions today cause damages in the future, but the time scale of the analysis is shorter than that of the external effect. Hence, climate mitigation comes at an net economic cost in the short-run. However, as explained in Section 5, it is necessary to look beyond the allocation of resources when evaluating climate policy. If resources are just reallocated, learning takes place in a different sector but does not increase much overall. This changes when the overall investment level and thus production increases, causing a second external effect through learning-by-doing. Additionally, this effect can be accelerated by expectation dynamics: Once investors see the prospect of a new and growing market and its new business opportunities, they will invest more.

The structure of currently used models excludes the possibility of multiple equilibria, as for example identified by Mario Draghi in his famous "whatever it takes" speech in September 2012: "We are in a situation now where you have large parts of the euro area in what we call a bad equilibrium, namely an equilibrium where you may have self-fulfilling expectations that feed upon themselves and generate very adverse scenarios. So, there is a case for intervening, in a sense, to break these expectations" (Draghi 2012).

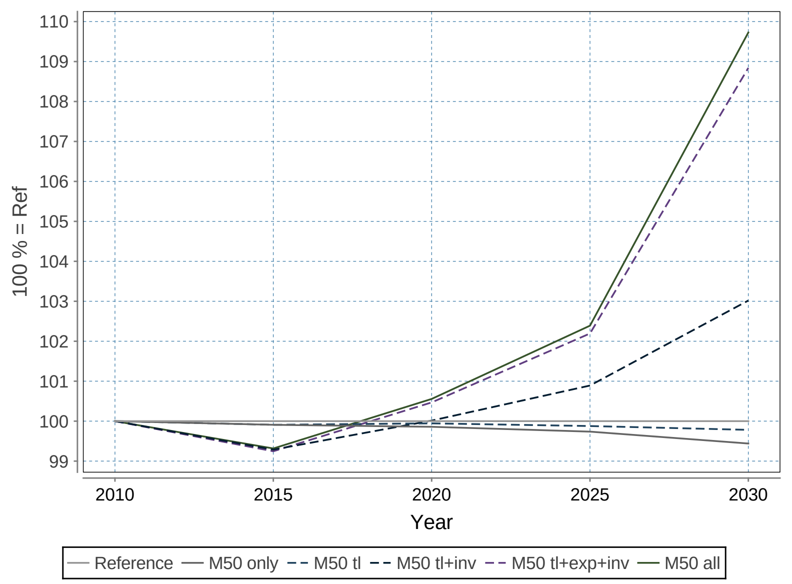
From a policy perspective, the challenge is to combine two areas of policy making: climate policy and economic policy. Climate policy will require more than a price on carbon emissions, which allocates current emission allowances to the most efficient emitter. It will require measures that substantially increase overall investments, direct a large share of these investments into energy efficiency measures across sectors and trigger a rethinking of business models in order to reduce current and future GHG emissions. From an economic policy perspective, the EU economic governance framework, and especially the "Investment Plan for Europe" require a stronger focus on investing in a low-carbon economy by regarding the necessary technologies as an economic opportunity for Europe. Furthermore, financial instruments that help to leverage private investment through public investment should be considered to take into account the high public debt levels and high liquidity in financial markets. An effective way of channeling financial resources towards countries with high energy intensity and low income will be crucial for an effective decarbonization of the European economy.

For the purpose of this study, different models have been employed to analyze the effects of mechanisms which can enable a green growth path for Europe. The main model used for this analysis is the computable general equilibrium (CGE) model GEM-E3 developed at E3M-Modelling and the Technical University in Athens. It is used for climate policy analysis by the European Commission. Although at a less mature stage, additional models have been employed to analyze the identified key mechanisms independent of the type of economic model. The second model is another CGE-model, IMACLIM, developed at CIRED, Paris. Furthermore, two agent-based modelling approaches have been used. The first is the modelling system StoemSys, developed at GCF, the second is the EURACE Agent-based model, developed at the University of Genoa.

The results of the simulations using GEM-E3 show that even with a 50% GHG emission reduction target, an investment-oriented climate policy can lead to an increase in economic growth and employment. Even if the order of magnitude of the positive effect cannot be stated for certain at this point, it is worth opening up the debate towards this possibility in both economic and climate policy.

The most important scenarios and outcomes of the simulations using GEM-E3 are the following: The reference scenario (assuming that the current policies stay in place) is compared with several scenarios, introducing several mechanisms as discussed in Section 7.2: endogenous technological progress, expectation dynamics, labour market inefficiencies and an investment stimulus. Two scenarios are the most interesting: One with a more ambitious climate policy target only (50% emission reduction by 2030) and one in which an investment-oriented climate policy is introduced. Investment-oriented climate policy means a 50% emission reduction target by 2030, an ambitious energy efficiency target, plus an investment impulse which increases overall investment. Results using GEM-E3 show that GDP as well as employment are higher in the investment-oriented climate policy scenario, which shows that an investment impulse is required to obtain positive economic effects. The GDP results can be seen in Figure 3, more results can be found in Section 7.5.

Figure 3: GDP EU28 compared to Reference



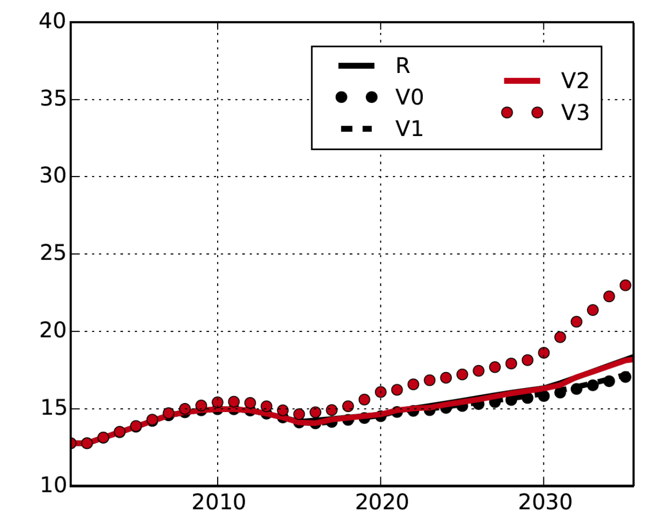
Source: Own computations using GEM-E3-M50.

The most important scenarios and outcomes of the simulations using IMACLIM are as follows. First, the reference scenario, assuming that the current policies stay in place. Here the reference scenario is different in the sense that it takes into account the most recent data. As a result, it gets close to a (Japan-like or Larry Summers-like) economic stagnation and risk of deflation. This scenario is then compared with several intermediate scenarios, introducing a price on carbon (V0), structural reforms (V1) as well as a recycling of the carbon revenues (V2) and the introduction of an investment stimulus (V3). The last scenario, introducing an investment impulse, show a strongly positive effect on GDP and employment. The GDP results can be seen in Figure 4, more results can be found in Section 8. Although the reference scenario is different from the one using GEM-E3, conclusions about the effect of the introduced mechanisms can be drawn, because results of all other scenarios should be analysed as compared to the reference scenario.

Furthermore, additional work has been conducted with agent-based modelling approaches, using StoemSys and the EURACE model. Both models are still under development, but are promising with regards to their properties.

StoemSys is a modelling system under development which aims at simulating a sustainability transition. Technically this means that it is able to deal with multiple equilibria and to provide a dynamic for the transition between them. Its modular structure allows for coupling of sector-specific models, which is important because GHG emissions are distributed unevenly throughout the economy and some sectors therefore need to be represented more

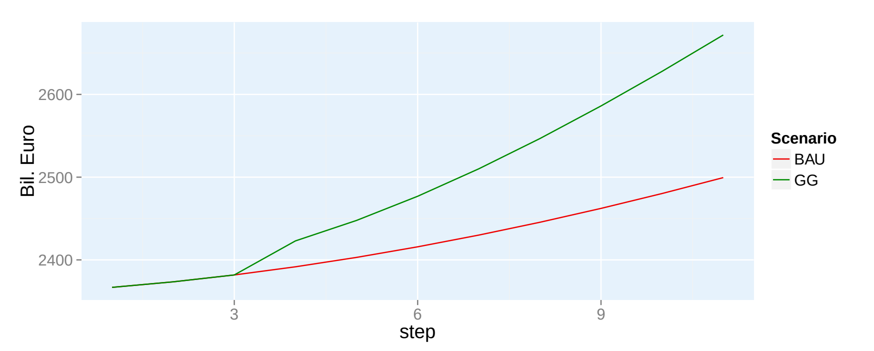
Figure 4: GDP EU28



Source: Own computations using IMACLIM-R. June 1st, 2015.

fine-grained. Preliminary simulation results show two scenarios in the case of a macro-module coupled with a buildings-module (sectoral-module). Here, a Green Growth (GG) scenario is compared with a reference scenario (BAU). In the GG scenario, the rate at which buildings are renovated (retrofit rate) is increased from 0% to 3%, which triggers an investment impulse. Results also show positive economic effects, as can be seen in Figure 5 and in Section 9.

Figure 5: GDP Germany



Source: Own computations using StoemSys Jaeger et al. 2015.

EURACE is not yet at the stage where the effects of a “green” investment impulse can be shown. What has been simulated so far using the EURACE model is the transition from fossil power production to renewable power production via the introduction of a feed-in-tariff. Next steps will be to also incorporate the mechanisms that have been identified in this report and through simulations with GEM-E3 and IMACLIM. It is particularly promising that EURACE represents financial markets more realistic and in-depth and therefore offers the possibility of including financial market dynamics and financial market interventions, such as “green” quantitative easing or “green” banking regulations into the analysis.

The simulations using GEM-E3 showed that emission reduction efforts and subsequent investment needs will be much higher in low income and low energy efficiency countries (mainly Eastern European countries), due to their large emission reduction potential. On the positive side, the simulation results also show that the economic opportunities can be much higher in these regions. However, we see substantial problems in tapping this potential in reality. Therefore, the question of how to stimulate investments in countries characterized by low income and high energy intensity was addressed with a short study in Section 10. It combines a review of relevant scientific literature, sectoral and policy reports and data, as well as expert interviews and an in-depth case study for Bulgaria, the Czech Republic and Romania.

It was found that their economic structure differs from others, as their shares of energy-intensive sectors (metallurgy, cement, petrochemicals and the like) is still much higher than in other countries. According to experts, the main reason for the lack of investment in energy efficiency is that discounted cash flows are low (or negative) due to low energy prices and higher interest rates (as compared to other countries). Additionally, the low investment capacity of households (due to low incomes) and the lack of appropriate financing schemes are the main financial barriers. Furthermore, experts mentioned a lack of public awareness and acceptance and a missing or frequently changing regulatory framework.

Possible drivers for investment that were mentioned by experts were a stable regulatory framework, the introduction of “White Certificates” [1] for energy efficiency, effective communication campaigns, effective financing schemes for ESCOs as well as minimum qualification requirements in the tendering process for the relevant professions.

The case study, described in Section 10.4, was conducted on a successful case of increasing investments through the “European Energy Efficiency Fund” (EEEF) in cooperation with a local bank, Banca Transsilvania, in Romania. The EEEF has started a cooperation with Banca Transsilvania by providing a refinancing facility of €25 million over 10 years where it can select potential projects at its own discretion provided that they are in compliance with the EEEF eligibility criteria. One large project was an energy efficiency project, initiated by the municipality of Bucharest. It was divided into three stages, the first stage was financed by the municipality via a loan from the European Investment Bank (EIB) to provide a proof-of-concept. In the second stage, apartment owners were asked to contribute 50% of the investment, the other 50% were financed by the Bucharest City Hall from national and local budgets. For social housing, the total investment was covered by the City Hall. Banca Transsilvania provided the consortium of construction firms with a bridge financing facility for the first 18 months of construction. Achieved energy savings amount to 40% on average which has brought considerable reduction of energy bills for the tenants and has improved living conditions. From the EEEF point of view, this project is a very successful approach for the fund to enter the Central and Eastern European market. Banca Transsilvania, as a typical SME bank, has client relationships that provide opportunities to support smaller projects via bundling projects. These

[1] All energy suppliers are obliged to meet specific energy savings targets and can trade the certificates if they over- or underperformed.

kind of projects should be analysed in more detail regarding their scalability to other countries, such that energy efficiency investments can be implemented at large scale in countries with low income and high energy intensity.

This directs us back to the policy challenge. Section 3.4 listed several good practice examples of climate policies that should be investigated in the context of these countries. For example the "Investment and Employment Initiative" implemented as an anti-cyclical program after the financial crisis in Portugal as well as new joint research and innovation programs in the UK, Italy and France are positive examples. A good practice example for raising public awareness for energy efficiency comes from Latvia. The country ran an information campaign called "Let's live warmer" where the ministry of finance and (by now) 30 companies signed a "memorandum of cooperation" to provide information and education and to promote quality standards for building renovation. The Ministry of Economy developed a new website which contains information on activities, supporting material and so forth. Furthermore, regarding energy efficiency, "White Certificates" have been introduced successfully in several countries and were proposed by the experts interviewed for this study. More emphasis should be put on the exchange of expertise and good practises between countries and on technical assistance to increase the administrative capacity, which in many countries is still low.

A credible and convincing investment-oriented climate policy can offer a new perspective for Europe, and lead to an improvement in economic, social and environmental terms. This requires additional incentives for private investment, a special investment program for countries with low energy efficiency and low income, accompanying communication campaigns, education and training initiatives as well as improved coordination between relevant economic and political actors.

Part I

The 4 Challenges

3

The Climate Challenge

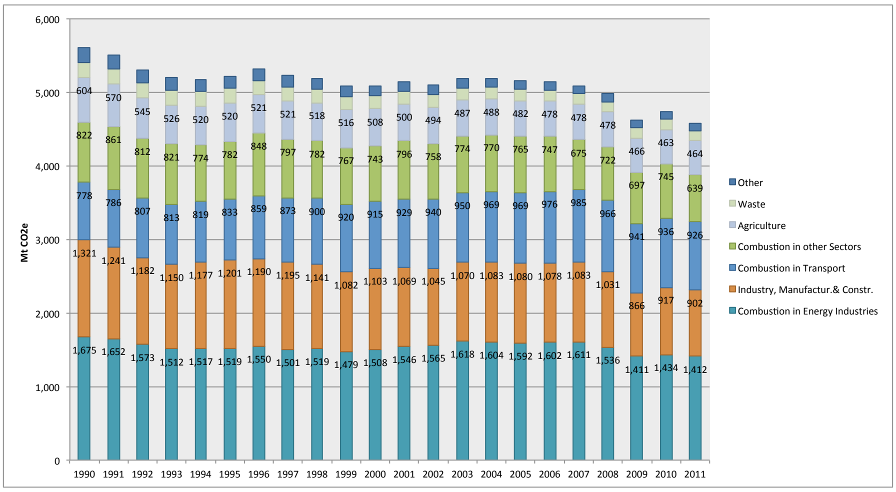
3.1 Building a Low-Carbon Economy

The main climate challenge is to transform the economy into a low-carbon economy, that is value adding with regard to economic, social and environmental aspects. Although European emissions only amount to 10% of global emissions, if Europe, as a union of industrialized countries, can show a new growth path, this could change the discussion at global level. For this reason, the geographical focus of this study is Europe.

To show where the challenges lie in detail we need to investigate the evolution of GHG emissions by sectors and country.

Figure 6 shows the total GHG emissions from 1990 until 2011 for the EU28, as well as the contributions by different sectors to total GHG emissions. Total emissions show a decreasing trend since 1990, despite economic growth at the same time. What is visible from the graph is that emissions are distributed rather unevenly between sectors and emission reductions have been realized in some sectors but not in others.

Figure 6: GHG emissions EU28 by sector



Source: Eurostat 2015[env_air_gge].

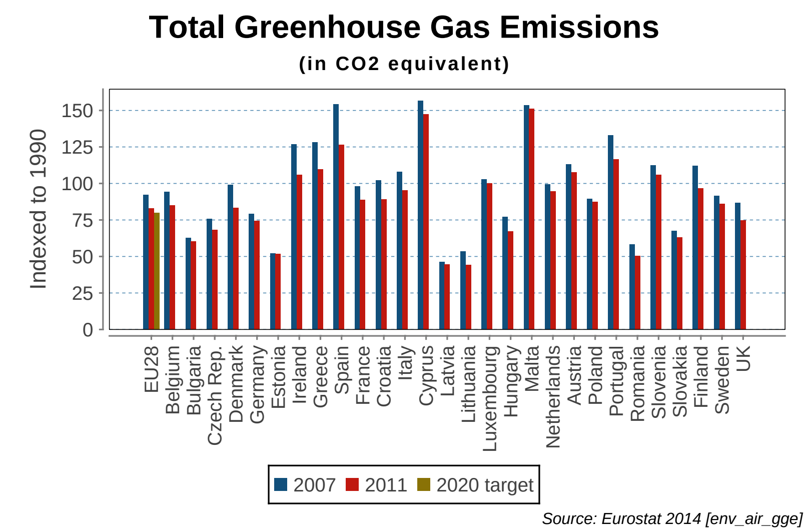
The EU energy sector has the highest emissions, with 1412 $MtCO_2e$ in 2011. GHG emissions from industry (direct emissions from industry plus industrial processes) were 902 $MtCO_2e$ in 2011. The transport sector caused almost 25% of emissions in 2011 in the EU (1215 $MtCO_2e$), of which 70% are due to road transportation (of which again 70% are due to passenger cars), 14% due to water transportation, 12% due to air traffic, 1% due to railway transportation. Emissions from households (from energy combustion, not electricity) amounted to 409 MtCO_2e in 2011.

With 34% the industry sector showed the largest decline in GHG emissions from 1990 until 2011. The agricultural sector and other sectors including households decreased emissions by slightly more than 20%. The emissions of the energy sector decreased by about 15%. The transport sector, however, is the only one where GHG emissions increased by about 20% in the same period. This shows that it would not be sufficient to only focus on the energy sector when investigating a transformation to a low-carbon economy. Especially reversing the trend of increasing GHG emissions in the transport sector is a challenge.

As could be expected, the financial crisis of 2008/09 had a strong effect on total GHG emissions, first and foremost on GHG emissions by industry, with a decrease of about 15-20% (and an increase of about 5% in the subsequent years). The effects on energy sector emissions and transport emissions were lower, with 10% and 5% respectively. However, there was no noticeable effect on the emissions of the agricultural and other sectors (including households), which shows that some GHG emissions are more related to economic activity than others.

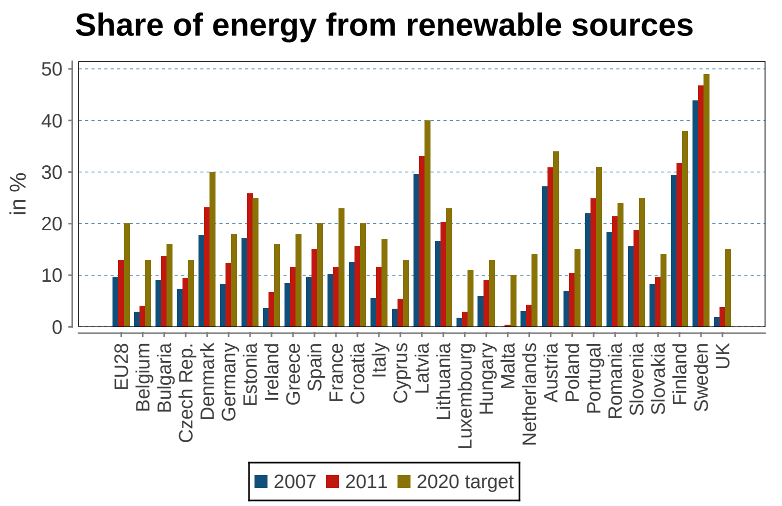
Figures 7 - 9 show the regional differences regarding the development of GHG emissions, renewable energy and energy consumption. Numbers are reported for all EU28 member states for 2007 and 2011, as well as the respective target for 2020, compared to 1990 levels. By 2007 several countries, have increased their primary energy consumption and GHG emissions as compared to 1990. However, between 2007 and 2011, all countries have decreased their GHG emissions and primary energy consumption and increased their share of renewable energy.

Figure 7: GHG emissions EU28 by country



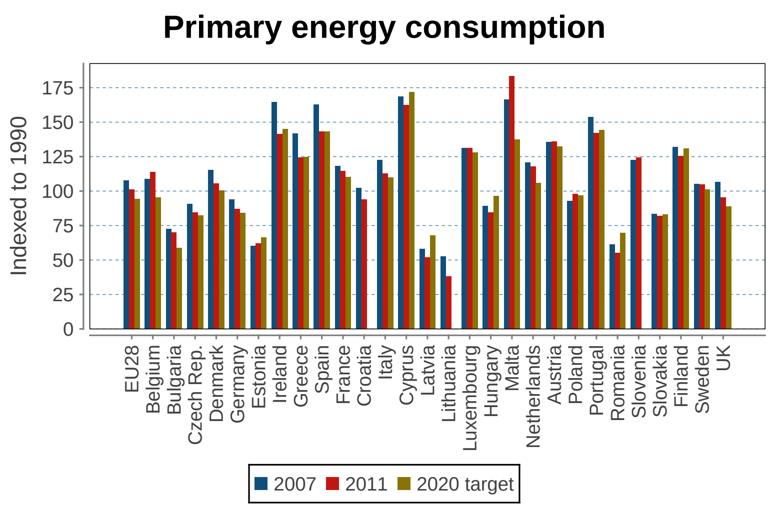
Source: Eurostat 2014 [env_air_gge]

Figure 8: Shares of renewable energy in EU28



Source: Eurostat 2014 [nrg_id_335a]

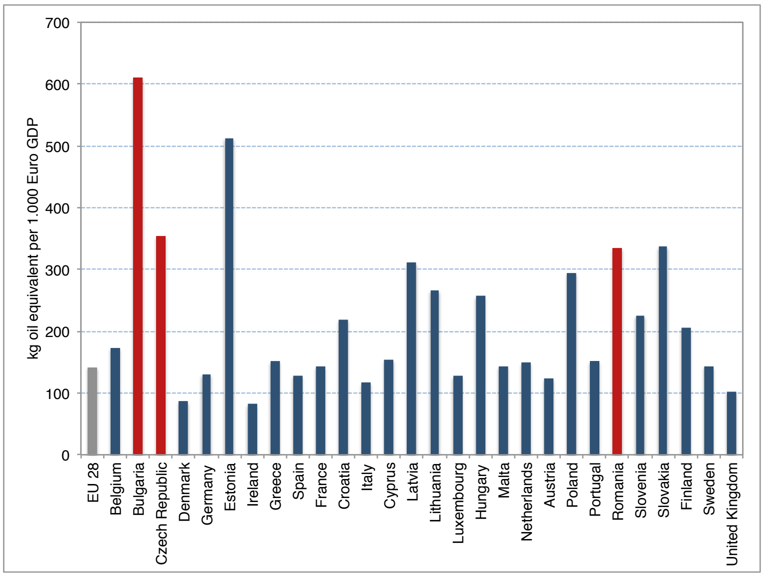
Figure 9: Primary energy consumption in EU28



Source: Eurostat 2014 [nrg_ind_334a]

As can be seen from Figures 7 - 9, the European Union as a whole is already close to its 2020 target regarding GHG emissions, however, less close regarding the share of renewable energy sources as well as energy consumption. The share of renewable energy is very different in the Member states, but the 2020 targets for all countries are at least 10%. Furthermore, the energy intensity differs strongly between Member States. Figure 10 shows the energy intensity of all Member States in 2013. Bulgaria has by far the highest energy intensity,

Figure 10: Energy intensity in the EU member states (2013)



Source: Eurostat 2015[tsdec360].

and is followed by Estonia, the Czech Republic, Romania, Slovakia and Latvia (with an energy intensity above 300 kgoe/ €1,000 GDP).

3.2 Financing the Transition

The second related challenge is how to finance the large investments needed for a decarbonization. Large investments are necessary for two reasons, for renewing the existing carbon-intensive capital stock and for triggering innovation and technological learning effects.

At EU level, estimated additional annual investments according to the Energy Roadmap 2050 (European Commission 2011d) amount to €257.6 bn for clean energy, of which €105.4 bn into energy supply (generation and transmission) and €152.3 bn for energy efficiency are required between 2010-2050. Similar estimates on investment requirements come from the EIB: To implement the 2030 climate and energy framework, investment needs are around €209 bn p.a. until 2030, of which 23% is needed for power generation and 23% for power grids, 40% for energy efficiency in buildings, 15% for energy efficiency in industry. This would mean investments of around 1.5-2% of EU GDP.

This is as much as currently invested globally in climate-related activities (direct investments), which was around $364 bn in 2012 and $359 bn in 2013 (Buchner et al. 2013). Buchner et al. (2013) reported that in 2013 the private sector contributed the largest share of investments with $224 bn. Within private sources, the main contribution came from commercial project developers ($95 bn), companies ($64 bn) and private households ($33 bn). Private financial institutions only stand on fourth place with $20 bn. Institutional investors contributed less than $1bn. In 2013, the public sector contributed $135 bn globally, through bilateral development banks (Kfw with $15 bn), multilateral development banks (MDBs) (EIB and EBRD with $31 bn) and national development banks with $61 bn. The national budgets followed on fourth place with $12 bn.

This shows the investment gap that needs to be closed in order to decarbonize the economy. Especially buildings are often seen as a large untapped potential for energy savings and emission reductions. Energy Efficiency Financial Institutions Group (EEFIG) (2014) estimated that:“Yet, notwithstanding the win-win characteristics of energy efficiency investments, present investment flows in energy efficiency are sub-scale. Prominent studies on assessing greenhouse gas mitigation potential agree that the building sector has the largest longer-term, cost-effective saving potential of any industrial sector. Estimates suggest that €60-100 bn is needed to be invested annually in EU buildings to achieve Europes 2020 energy efficiency targets yet current investments are below half of these requirements.”

The recent growth of green bonds sold in financial markets might have the potential to fill the investment gap and to trigger the necessary investments. The Climate Bond Initiative has reported green bonds issuance of $11bn in 2013 and $36.6bn in 2014 and is expecting that this value will again triple in 2015 as compared to 2014. Labelled green bonds outstanding reached a volume of $65.9bn by June 10, 2015 (Climate Bond Initiative 2015).

3.3 2030 Climate and Energy Framework - the Cost Approach

The analysis and results presented in this study are embedded in the context of the development and current state of EU climate and energy policy. For this purpose, the main documents and decisions at the EU level are described here.

The most important targets currently in effect are the 2020 targets. These targets were set in 2007 and enacted in 2009 through the "climate and energy package”. Today they are widely known as the "20-20-20” targets, which stands for 20% reduction in EU GHG emissions[2], a 20% share of renewable energy in gross final consumption and 20% reduction in total primary energy consumption of the EU (all 2020 levels compared to 1990).

In 2011, the European Commission defined the long term GHG emission reduction target for 2050 to 80%-95% below 1990 levels, which is argued to be in line with the EU’s contribution to the global political goal of staying below a 2 °C temperature increase. For this purpose, the European Commission published the "Energy Roadmap 2050” (European Commission 2011b) and the "Roadmap Towards a Competitive Low-carbon Economy Until 2050”, often called Climate Roadmap 2050 (European Commission 2011c). The Energy Roadmap analyses seven scenarios, which are differentiated by the kind of energy related support policies applied. First, there is a "Reference” scenario, applying all policies adopted until March 2010 and long-term projections on economic growth of 1.7% p.a. and, quite similar, a "Current Policy Initiative” scenario applying the energy 2020 framework, including the Energy Efficiency Plan. Additionally there is a "High Energy Efficiency”, a "High Renewable Energy Sources” scenario, a "Diversified Supply Technologies” scenario, a "Delayed CCS” scanerio, and a "Low Nuclear” scenario.

[2]Emissions cover of all sectors and all greenhouse gases not controlled by the Montreal Protocol, i.e. Carbon Dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF6) and Nitrogen trifluoride (NF3).

The "Climate Roadmap 2050" states that 25% emission reductions until 2020, 40% until 2030, and 60% until 2040 ist the most cost-efficient way to reach the 2050 target of 80%. It is estimated that this path reduces fuel costs by €175-320 bn p.a., that it requires additional public and private investments of €240 bn p.a., and that it can create 1.5 million additional jobs within the EU.

In 2012, the European Commission analysed the effects of raising the 2020 targets, due to the effects of the financial crisis and the Euro crisis. A Commission staff working paper "Options to move beyond 20% emission reductions" (European Commission Staff 2012) was published, investigating three scenarios: 1) A baseline scenario with 14% GHG-emission reduction until 2020 (compared to 1990), 2) a reference scenario with 20% reduction and 3) a 30% reduction scenario where 25% come from domestic reduction and 5% from using international carbon credits (offsets). Results estimate average annual additional investment needs (energy related) were estimated to be €34 bn (0.24% of GDP) for the reference scenario and €52 bn (0.37% of GDP) for the 30% scenario, compared to the baseline scenario. [3]

Despite the small effects on economic development, no agreement to raise the 2020 targets was achieved.

Instead, in 2013 the European Commission has started a discussion process around the intermediate goals for 2030 by publishing a proposal called the "Green paper: A 2030 framework for climate and energy policy 2030" (European Commission 2013). This was followed by a public consultation process.

In January 2014, the Commission made an announcement on the planned targets, accompanied by an Impact Assessment Report (European Commission Staff 2014), which analyses the outcome of different scenarios for 2030 and 2050: A reference scenario, three scenarios with different GHG targets (GHG35/EE, GHG37, GHG40), a GHG40 scenario, and three scenarios with additional energy efficiency and renewable energy targets (GHG40/EE, GHG40/EE/RES30, GHG45/EE/RES35). Results estimate that additional average annual investment expenditures (2011 - 2030) are between €17-30 bn for the scenarios with different GHG targets, and €55-93 bn for the scenarios with additional RE and EE targets, both compared to the reference scenario. [4] The negative impact of a 40% reduction scenario on GDP is estimated to be between -0.1% and -0.45% (2030 change compared to the reference scenario), depending on whether a carbon price is implemented in all sectors and how the revenues are reused in the economy. However, comparing a 40% scenario with the 32% reference scenario (both assuming auctioning of carbon credits only in the power sector and no tax for non-ETS emissions) results in no difference in terms of GDP and even an increase of

[3] Furthermore, additional system costs in 2020 are estimated to be €41.8 bn for the reference scenario and €66 bn for the 30% scenario, compared to the baseline scenario. Average annual fuel expenses are estimated to be reduced by €10.7bn in the reference scenario and by €31.3 bn in the 30% scenario, compared to the baseline scenario (all numbers in 2008 prices).

[4] Furthermore, aadditional average (between 2011 - 2030) annual energy system costs of €6-7 bn for the scenarios with different GHG targets, and €22-35 bn for the scenarios with additional RE and EE targets compared to the reference scenario. Average annual energy purchases (2011 - 2030) are reduced by €8-26 bn for the scenarios with different GHG targets, and €23-34 bn for the the scenarios with additional RE and EE targets, both compared to the reference scenario (all numbers in 2010 prices).

0.2% compared to reference if all sectors are included in the auctioning system and carbon taxes are applied for non-ETS emissions. The scenarios with additional EE and RE measures (assuming all sectors are included in the auctioning system, carbon taxes applied for non-ETS emissions and using revenues to lower labour taxation) even show a potential increase in GDP of 0.46% to 0.55% by 2030. Overall, the impact on GDP is less than 1% by 2030. The employment effect is estimated to be slightly negative in the case of auctioning carbon credits only in the power sector and no carbon taxes applied to the non-ETS sector (-0.44% to -0.66% of employment or -0.96 to -1.33 million jobs). However, the employment effect is estimated to be positive in case of additional EE and RE targets, leading to an increase of 0.3% and 0.5% of employment (0.7-1.25 million jobs) compared to the reference scenario.

The decision process regarding the 2030 targets is still ongoing. The new targets were proposed by the Commission in January 2014 (European Commission 2014) and included a 40% (domestic) GHG emission reduction target for 2030 (compared to 1990) as well as an EU-wide target for renewable energy of at least 27%, however, without binding national targets for the latter. [5]

The energy efficiency target was not part of the initial proposal, since the Commission wanted to await the outcomes of the review of the Energy Efficiency Directive (EED), which came into force in December 2012 and had to be implemented by June 2014 by all member states. It includes obligations for each member state to set an indicative national energy efficiency target. The review of the EED resulted in a proposal by European Commission for a 30% target for energy savings (reduction against the 2007 projections for 2030), which would be equal to 1307 Mtoe primary energy consumption.

In October 2014, the European Council European Council (2014b) decided on a 40% (domestic) GHG emission reduction target, a 27% renewable energy target and a 27% energy savings target (with the latter being reviewed in 2020). The GHG emission reduction target is divided into -43% emission reductions in the ETS sectors (energy sector and industry) and -30% in the non-ETS sectors (transport, housing, agriculture), both compared to 2005. Another important component of the 2030 framework is to strengthen the Internal Energy Market by liberalization of electricity and gas markets and the construction of more interconnections between countries' electricity and gas infrastructure.

In 2015, the European Commission has launched several more consultation processes regarding the Effort Sharing System between Member states in non-ETS sectors, as well as regarding the integration of agriculture and land use change and forestry (LULUCF) into the 2030 EU Energy and Climate Framework. Furthermore, there is a pending proposal by the European Commission for a Market Stability Reserve, which would take emission allowances out of the EU-ETS as a reserve that can help stabilize the market.

[5] The EU contribution envisages that the specified target for 2030 will be implemented domestically with no contribution from international credits and (non-EU) market based mechanisms, such as emissions trading with other regions via the Clean Development Mechanism and Joint Implementation programs.

3.4 National Implementation of EU Level Targets

One level is the EU targets for GHG emissions, renewable energy and energy efficiency and related decisions. The other level is the implementation of specific national measures which assure that countries will reach their individual targets and that EU as a whole reaches its joint target. The aim here is to analyse current policies and good practices in Europe, mainly regarding investment incentives.

The *Treaty of Lisbon* or *Treaty of the Functioning of the European Union* (TFEU) describes three categories of EU competences, which lay down the supremacy of EU law over national law. These competences are: exclusive-, shared, and supporting competences. The area of the environment is part of the shared competences (Art. 4 (2) (e), TFEU), where the laws and decisions at the European level have primacy over national law.[6] There are different types of legal acts at European level: regulations, directives, decisions, and recommendations and opinions.[7]

The reduction targets of GHG emissions in the sectors covered under the European Emission Trading System (EU-ETS), such as energy producers and energy-intensive industries, are implemented via the ETS mechanism. For this purpose, the overall emission target is broken down to the level of individual installations that produce GHG emissions. The owners of these installations can decide how to reduce their emissions, by buying additional emission rights, by using carbon capture and storage technologies or investing in energy efficiency is up to them to decide. At national level there can be additional policies to complement these targets.

The reduction targets for GHG emissions not covered under the EU-ETS (transport, agriculture, construction and others), are under the responsibility of the Member States.

According to Columbia Law School (Columbia Law School 2014), around 50 climate related EU key legislative instruments took place since 1999, of which 19 are regulations, 22 are directives and 6 decisions. Most of them were adopted in the years 2009 (10), 2012 (8) and 2013 (9). In terms of triggering national legislations, the *Directive on end-use efficiency and energy services* (2006/32/EC) was the most adopted, resulting in 198 related national policies, followed by the *Directive on the promotion of the use of energy from renewable sources* (2009/28/EC) with 187 resulting related national policies. Other important directives with a fairly high responsiveness on national level were the *Recast of the Energy Performance of Buildings* (2002/91/EC), amended in 2010 and the *Directive on the promotion of the use of energy from renewable sources* (2001/33/EC). Moreover, there is a clear trend in EU-level decisions towards energy efficiency, renewable energies as well as the transport sector. Since only 469 of 1558 climate change mitigation policies are not related to EU policies, most measures named in this study are results of EU level decisions (Columbia Law School 2014).

As discussed in section 3.1 a large part of the emission reduction potential lies in reducing the energy intensity in the EU, especially in countries with energy intensities above the EU

[6] Shared competences mean that member states can take policies in that field, given that they "respect state aid legislation and exercise their competences only to the extent that the Union has not exercised its competence." In other words, they are only allowed to take additional measures in a field of climate change if this has not already been occupied by the European Union.

[7] Regulations are directly applicable and binding, directives are not directly applicable: goals are set but not the concrete policies, decisions address specific Member States and natural or legal persons, recommendations and opinions do not assign any obligations but may provide guidance for interpretation or content of Union law.

average. The database of the International Energy Agency (2014) provides information about all energy-efficiency related policies of a certain country.[8] Comparing the number of measures by EU member state shows that Germany has by far the highest number of energy-efficiency related policies with 155 measures in total. Germany is followed by the United Kingdom (89), Italy (87), and France (76). Denmark, Sweden, and notably Hungary are still significantly above the average with about 60 measures in total. All other countries are equally distributed between 10 and 50 measures in total. With only very few measures in place, Eastern European countries like Bulgaria, Lithuania, Romania, and Estonia are at the lower end of the distribution (see Table 1). From the quantity of measures one cannot draw final conclusions on their effectiveness. However, as seen in section 3.1, these countries are also the ones with the highest energy intensity of their economy. Hence, introducing new energy efficiency measures will most certainly help reducing their energy intensity.

Table 1: Energy Efficiency Measures per Country

Country	Number of Measures	Country	Number of Measures
Germany	155	Czech Republic	36
United Kingdom	89	Finland	34
Italy	87	Greece	30
France	76	Switzerland	29
Hungary	69	Poland	26
Belgium	62	Slovakia	16
Denmark	62	Cyprus	4
Sweden	57	Estonia	4
Luxembourg	47	Romania	4
Ireland	45	Slovenia	3
Portugal	45	Lithuania	2
Spain	44	Malta	2
Netherlands	40	Bulgaria	1
Austria	38	Latvia	/
		Σ	1107

European Environment Agency 2014

Taking a look at the different sectors, Germany and the United Kingdom are again high-ranking. In buildings and industry sectors they occupy the highest positions, whereas France and Hungary are leading in the transport sector. Interestingly, Italy has the most energy-efficiency measures in the energy-supply sector, closely followed by Germany. Also worth mentioning is that Belgium is on the third position in almost all categories in the sectoral comparison, before Italy and the Scandinavian countries. The eastern- and southern European countries occupy the last positions with few measures, which is another identifiable trend. However, countries like Hungary, Poland, and Slovakia are above average in specific sectors.

[8]The European Environment Agency (EEA) on the other hand offers a database (European Environment Agency 2014) about all climate change mitigation policies. However, one must be careful with these numbers since their classification is quite imprecise and some measures are not accurately illustrated due to missing information (like dates, etc.)

Classification of Policy Instruments

In order to judge the effectiveness of certain policies, it is useful to complement the above with a qualitative analysis. We adopt the classification of EEA and IEA and investigate specific “good practice” policies in each category.

The following classification of measures is taken from the European Environmental Agency (EEA) (International Energy Agency 2014) and the International Energy Agency (IEA) (European Environment Agency 2014) databases. The three main categories, sub-categories as well as examples can be found in Table 2. In terms of “transferability between countries” and “high impact”, the *Odyssee-Mure* database (Odyssee-Mure 2014) identifies particularly successful policies. These are highlighted in “good practice” boxes, see Boxes 1 - 5.

Table 2: Policy Instruments

Category	Sub-Category	Example
Economic Instruments	Direct Investments	Funds
		Infrastructure Investments
		Procurement rules
		"Research, development and demonstration"
	Fiscal and Financial Incentives	Feed-in-tariffs
		Grants and subsidies
		Loans
		Tax reliefs
		User charges
	Market-based Instruments	GHG emission allowances
		Green certificates (energy production)
		White certificates (energy consumption)
Structural Instruments	Regulatory Instruments	Auditing
		Codes and Standards (e.g. energy performance)
		Obligation schemes
		Other mandatory requirements
	Policy Support and Planning	"Guidelines, goals, targets"
		Institutional creation
		Strategic planning
Research. Information and Education		Advice/ aid in implementation
		Performance labels
		Information provision
		Professional training programs and qualification

Economic instruments are policies and measures seeking to influence the market through a stimulation of certain activities or investments, e.g. price signals, subsidies, or financial supports. Feed-in tariffs (FIT) are very common in most EU member states (UK, AU, PT, GR, IR, SK, FIN, FR, ES, etc.). Renewable energy producers are offered a long-term contract, based on the costs of generation of each technology rather than on the market price. GHG allowances, green and white certificates can be traded between different actors: GHG allowances can be traded at European level (EU-ETS), green and white certificates can only be traded at national level.

Box 1: Good practice example for economic instruments - Incentives and Market-based instruments in France

Tax relief

Launched in 2005, the French **Sustainable Development Tax Credit (CIDD)** is a financial instrument to increase attractiveness of the most efficient equipment in terms of energy consumption and greenhouse gas emissions of both new and existing buildings. In detail, its purpose is to trigger insulation works, efficient hot water equipment, and energy producing facilities.
Currently existing tax credit rates are 25% and 15%, depending on the type of work performed and the level of income. Moreover, the expenditures taken into account for the tax credit must not exceed EUR 8.000 for a single person and EUR 16.000 for a couple. Eligible for refurbishment works are existing buildings older than 2 years only, whereas the installation of renewable energy production could be financed also for new buildings. In addition, since January 2015, only professionals with a quality label (RGE) must conduct the works to be eligible for the tax credit.
Through this measure more than 7 million housings were refurbished from 2005 to 2011, with an overall tax credit of EUR 13 billion. In 2012, 1,26 million households benefited with an average tax credit of EUR 1.107 for a declared amount of EUR 5.549 of spending.

Market-based instruments

France introduced the **White Certificate Trading** in 2006: All suppliers of energy (electricity, gas, heating oil, LPG, heat, refrigeration) were obliged to meet energy saving targets mandated by the government through their residential and tertiary customers. It is up to the suppliers to decide about the sort of measures to reduce energy consumption like running promotional programs, providing incentives to customers etc. A supplier that exceeds or falls behind the objectives is allowed to trade energy saving certificates (white certificates) to meet the obligation. Suppliers who do not meet their duties must pay a fine of EUR 0.02 per kWh. The first phase ran from 2006 to 2009 and exceeded by far the expected energy savings (54 TWh) with 65.2 TWh saved in total. The target of the second phase (2011-2013) has been set at 115 TWh/year and for the third period 660 TWh within 3 years.

3.5 New Climate Economy Report - the Benefit Approach

While the cost approach is predominant in climate policy analysis, rather recently, there have been studies that focus on economic benefits of climate change mitigation.

An emerging literature around the concepts green growth and green economy comprises climate protection as an important topic, while addressing environmental protection in a broader sense. The concepts, which consider economic benefits of environmental policy possible, originated in the policy sphere (see e.g. Jaeger 2014), and have been embraced by international institutions such as the OECD, UNEP and others. On the global map, Asia is a focal point for green growth, reflected for example by work of the Economic and Social Commission for Asia and the Pacific (UN-ESCAP[9]). A number of institutions provide platforms for green growth and related research via events, publications, and websites, examples are listed in Box 6. However, for the time being the field of green growth research seems rather detached from the field of climate policy analysis.

[9] See http://www.greengrowth.org/.

Box 2: Good practice example for economic instruments - direct investment in Portugal and Sweden

Public investment program

A good example for a direct investment instrument is the **Investment and Employment Initiative (IEI)** program of Portugal in 2009, which was aimed at generating an anti-cyclical economic impact on employment and investment within the framework of the Lisbon Strategy. It consisted of five structural programs: to modernize secondary school buildings, to boost economic activity and exports, to raise social protection and employment, and to promote renewable energies and energy efficiency. This initiative was adopted in the light of the European Council's decision to simplify and accelerate the implementation of programs financed by the Cohesion Fund, Structural Funds, or by the European Agricultural Fund. In detail, one of the five measures was aimed at improving the energy efficiency of the most energy-intensive public buildings (hospitals, universities, law courts, offices of public services, etc.) in order to promote the construction, mechanical engineering, and energy consultancy sector. Moreover, additional gains were expected through the reduction of energy expenditure. In 2009, an investment in 100 public buildings with a budget of EUR 100 million was planned. All in all the impact of these stimulatory measures on the public accounts was estimated at EUR 1.3 billion (or around 0.8 percent of GDP). Although it was meant to be temporary, some of these measures were maintained until 2011 and an important part of the fiscal stimulus was effectively carried over into the next years.

Procurement rules

The Swedish Transport Administration aims at **decreasing the total energy usage of roads and railways** as a focal area in its activities. In detail, the construction, maintenance and operation of infrastructure should be addressed, which accounts for up to 10% of emissions according to some estimates. In a long-term perspective, the goal is to influence the energy consumption of future transport systems at the planning, design and construction stage. For this, the Swedish Transport Administration develops new energy procurement requirements on contractors and fuel use in various operational areas. In general, subcontractors are encouraged to suggest more energy efficient methods for building roads and railways.

For example a new lighting strategy was developed: switching off unnecessary lighting, introducing more energy efficient equipment, and removing lighting from roads to bicycle and pedestrian paths. An optimized use of timers will provide additional efficiency gains not only for lighting, but also for tunnel fans. Moreover, on road ferries eco-driving has been introduced (e.g. cable ferries where appropriate) and airport services and harbors have been equipped with energy efficient lamps (e.g. lighthouses). In rail transportation, significant scope for improvement was identified. The Transport Administration estimated that installation of new switch equipment could save up to 50 % of energy used.

In the context of the Eurozone crisis, the idea of green recovery programmes is present already in a set of works from 2009, notably the Green New Deal proposed by the European Green Party (see, e.g., Schepelmann et al. 2009)[10]. Also, Bowen et al. 2009 find that "the

[10] In particular, the website for this first publication of the Green New Deal Series introduces: "Over the past year, billions of Euros have been spent in Europe, the US and other industrialised countries on so-called "recovery packages" to overcome the economic crisis. However, these unprecedented amounts of pub-

Box 3: Good practice example for structural instruments in the UK

An example for institutional creation and strategic planning is the establishment of the **Energy Technologies Institute (ETI)** in the United Kingdom in 2007. Founded as a limited liability partnership, it is financed by the private and the public sector, each providing up to GBP 550 million over 10 years. In this way, it brings together the UK government, BP, Caterpillar, EDF Energy, E.ON UK, Rolls-Royce and Shell. The focus lies on energy and the UK government, in particular "to invest in research and development to accelerate the development of secure, reliable, and cost-effective low-carbon energy technologies towards commercial deployment." The first technical programs were named "Offshore Wind", "Wave and Tidal Stream Energy" and "Distributed Energy". The ETI also coordinates support for RD&D by working closely with the Research Council Energy Program (RCEP), the Technology Strategy Board, the Carbon Trust and the Environmental Transformation Fund (ETF) in the area of low-carbon technologies.

Box 4: Good practice example for research and innovation in France

A first example is the **National Electric System Research Program** in Italy 2010. EUR 221 million will be provided to finance research activities in the area of the national electricity system. Three priorities have been identified: 1) Governance, management, and development of the national electricity system, 2) electricity production and environment protection, 3) rationalization and saving of use of energy. 77% of the EUR 221 million will be allocated to the Italian National Agency for New Technologies (ENEA), the National Research Council (CNR) and the Ricerca sul Sistema Energetico (RSE). Their activities are related to strategic issues like cogeneration fuel cells, air-conditioning and lighting systems for residential and tertiary sectors, governance and energy efficiency and the promotion of efficient technologies.

A second example for research and information instruments is the **Green innovation funding: the French program of investments for the future** adopted in 2010. In total, this program offers EUR 2.54 billion for cooperation and facilitation of innovation between companies and research institutes. In line with the French Agency for the Environment and Energy Management's (ADEME) roadmap, the specific fields include: renewable energy and green chemistry (EUR 1.1 billion), smart grids (EUR 165 million), circular economy (EUR 210 million), low-carbon vehicles (EUR 950 million). In order to combine the French public objectives of job creation, innovation stimulation, environmental benefits, and economic competitiveness ADEME developed specific financial tools: A combination of refundable grants (performance-based) and non-refundable grants, as well as a new form of public-private partnerships, based on a risk/gain sharing policy where two-thirds of allocated credits generate financial returns for the state. Therefore there are two equity tools in place: one for SMEs and one for mid-cap and large enterprises.

objectives of economic recovery and urgent action on climate change complement each other" [p. 2], and Edenhofer/Stern 2009 recommended green recovery measures to the G20 London summit.

lic money could also be focused on fostering an ecological transformation of our economies, and not on safeguarding the economic patterns that brought about the crisis in the first place." (See http://gef.eu/publication/a-green-new-deal-for-europe-towards-green-modernization-in-the-face-of-crisis/)

Box 5: Good practice example for knowledge building in Latvia

Following Latvia's first National Energy Efficiency Plan (NEEAP), the information campaign **Let's Live Warmer** is included in the second NEEAP. The main objective is to raise awareness for energy efficiency on all levels that deal with the energy end-use in buildings: flat owners, residential buildings management companies as well as building companies, material producers and traders.

In order to establish an effective and transparent co-operation among different stakeholders, the Ministry of Finance developed a "Memorandum of Co-operation", originally signed by 18 organizations in 2010, in the meantime by more than 30. The task of the memorandum is in principle to provide access to information and education and the promotion of quality standards in renovation processes, related issues to multi-apartment buildings and potential benefits of energy-efficient renovation.

Since 2009 and over different stages, more than 100 workshops, several round-table discussions including the key actors of multi-dwelling buildings renovation took place. Reflecting the results of these activities, numerous publications and campaigns were run in national and regional mass media at the same time. All activities are presented on a new website developed by the Ministry of Economy, including a YouTube channel with all video materials, examples of standard contracts for construction works and construction works supervision as well as a map documenting all renovated buildings.

According to an impact evaluation by the European Commission, total energy savings in the residential sector of 2701 GWh are envisaged in 2016. Therefore, in 2013, "Lets Live Warmer" received the *EU Sustainable Energy Week Winner Award* in the category "Communicating".

The reference to Roosevelt's New Deal, a series of domestic programs focusing on relief, recovery and reform after the Great Depression in the US, suggests public spending and stimulus packages as a source of the needed investment. Public money is then supposed to stimulate private investments. For example, Kapoor/Osksnes/Hogart 2011, who discuss how to fund the Green New Deal, consider a mix of funding sources (consumers purchasing green goods or making efficiency related investments, private financial investors or existing businesses using their balance sheet, and taxpayers, that is, public support) with "by far the largest component [. . .] funded by the private sector making commercially profitable investments" [p. 7].

A recent and prominent example study that uses a benefit approach to climate change mitigation at the global level is the New Climate Economy Report (The Global Commission on the Economy and Climate 2014). It finds that

> . . . countries at all levels of income now have the opportunity to build lasting economic growth at the same time as reducing the immense risks of climate change. This is made possible by structural and technological changes unfolding in the global economy and opportunities for greater economic efficiency. The capital for the necessary investments is available, and the potential for innovation is vast. What is needed is strong political leadership and credible, consistent policies. [p. 8]

and proposes a "10-point Global Action Plan of key recommendations" [p. 9].

Box 6: Green Growth / Green Economy Platforms

- OECD work on green growth[a] includes mainstreaming green growth in its national and multilateral policy surveillance exercises and a yearly Green Growth and Sustainable Development Forum. Studies by the OECD review green growth issues faced by different sectors, papers aim to stimulate discussion and analysis on specific topics, and reports focus on sustainable development.
- UNEP's Green Economy Initiative[b] aims to provide the analysis and policy support for investing in green sectors and in greening environmental unfriendly sectors via the Green Economy Report, advisory services and research activities.
- The Global Green Growth Forum (3GF) "convenes governments, businesses, investors and international organisations to act together for inclusive green growth"[c] in a yearly large scale conference.
- The Green Growth Knowledge Platform is a global network of international organizations and experts that "identifies and addresses major knowledge gaps in green growth theory and practice"[d].
- The Global Green Growth Institute[e] was founded as "an open, global platform to support experimentation and collective learning by developing countries seeking to leapfrog the resource-intensive and environmentally unsustainable model of industrial development".
- The Global Commission on the Economy and Climate wants "to help governments, businesses and society make better-informed decisions on these crucial issues"[f].

[a] http://www.oecd.org/greengrowth/
[b] http://www.unep.org/greeneconomy/
[c] http://3gf.dk/
[d] http://www.greengrowthknowledge.org
[e] http://www.gggi.org/
[f] http://newclimateeconomy.net/

At European level, the "Green Growth Group" of ministers from 13 countries[11] similarly argues that economic growth and sustainability are not mutually exclusive (The Green Growth Group 2013). Stressing rising fuel import costs and energy security as the potential economic costs and building a modern and competitive low-carbon economy as the economic opportunity of immediate action, they call for resolving the current policy uncertainty in the EU in order to increase urgently needed private sector investments. The most important steps in this direction according to the group are reforming the EU ETS and setting ambitious targets for the 2030 framework for climate and energy policy.

When starting from a growth perspective, greening the economy or climate change mitigation is often considered an appropriate target for the necessary investments, e.g.: "a clear and credible policy to encourage investment in welfare-enhancing activities that need public

[11] UK, Germany, France, Italy, Spain, Netherlands, Belgium, Portugal, Sweden, Denmark, Finland, Slovenia and Estonia

support to be commercially viable would be a powerful instrument to restore growth. The low-carbon and wider ‘green’ sector is taken as an exemplar field for this.” (Zenghelis 2012).

With its focus on (additional) investment, the benefit approach begins to bridge the gap between the climate challenge and the economic challenge that need to be addressed. The following section provides more detail on the latter.

4 The Economic Challenge

4.1 European Stagnation

Since the financial crisis in 2008/2009, the European economy is characterized by low levels of investment and economic growth, high unemployment rates and high levels of debt, especially in some parts of the European Union. The convergence trend between European countries (especially new Member states that picked-up relatively fast) before the crisis, has been reversed after the crisis.

In his speech at the IMF Economic Forum, the economist Larry Summers (Summers 2013) has argued that the recession might be far from over and that industrialized nations face the threat of a secular stagnation in the decade(s) to come. He argues that we need to "[. . .] think about how we manage an economy in which the zero nominal interest rate is a chronic and systemic inhibitor of economic activities, holding our economies back below their potential".

Stagnation of economic growth: For Europe, the long-term economic growth projections for the European Union are reported every 3 years (2006, 2009, 2012, 2015) in the "Ageing Report", the short-term projections are reported twice a year.

The 2006 Aging Report (European Commission 2006) projected 2.4% economic growth for the period of 2004-2010 and 2.2% for 2011-2020, 1.5% for 2021-2030 and 1.2% thereafter (longterm average of 1.7%). The 2009 Aging Report (European Commission 2009), published just before the economic and financial crisis, also projected a long-term average growth rate of 1.7%. However, the "relatively" high projections of 2-2.5% for the period up to 2020 were never reached due to the financial crisis. In the 2012 Aging Report (European Commission 2012a) growth projections were corrected downwards, to 1.4% on average for 2010-60. The 2015 Aging Report (European Commission 2015a)has projected 1.1% growth rate until 2020 and a slight "recovery" with 1.4% for the period of 2021-2060.

Growth rates before the crisis were 2.5% in 2004, 2% in 2005, 3.2% in 2006 and 3% in 2007. Hence, the Spring 2007 and 2008 short-term projections, published in the "European Economic Forecasts" [European Commission (2007)European Commission (2008)] were overly optimistic regarding 2008 and 2009 growth rates: In 2007 the estimation for 2008 was 2.7%, which turned out to be 0.9% due to the crisis. The 2008 forecast for 2009 estimated 1.8%, which turned out to be -4.2%. After the financial crisis, projections usually stated that growth rates will pick up again the year after. The Spring 2011 forecast (European Commission 2011a) estimated a growth rate of 1.9% for 2012. The Spring 2012 forecast (European Commission 2012b) estimated a growth rate of only 0% for 2012 but 1.3% for 2013. However, the actual growth rates for these years were -0.4% and 0% respectively. This shows that the economic forecasts before the start of the crisis were not realized anymore, due to the crisis. The economic recovery is much slower than expected.

Low investment levels: The slow economic recovery is partially related to the reductions in investments. When looking at current levels of gross investment in the EU (all numbers taken from (Eurostat 2015)), we can find a drop in gross investment levels by around 15% since 2007, which is equivalent to a drop of around €430bn between 2007 and 2013. Investment levels are currently at around 19.3% in the EU and are €230-370 bn below their historical average. The largest drop in investments occurred in countries such as Spain, Italy, Portugal, Greece and Ireland, and in sectors such as real estate (private and commercial) with 77% and the rest in machinery and equipment.

High unemployment rates: Another important macroeconomic indicator is the unemployment rate (all numbers taken from Eurostat 2015 [une_rt_a]), which has increased every year since the financial crisis, especially in Southern Europe. The average unemployment rate for the EU28 in 2014 was 10.2%, with the lowest rates in Germany, Iceland (both 5%) and Austria (5.6%) and highest rates in Greece and Spain (26.5% and 24.5% respectively) and Croatia with 17.5%. Southern European countries perform particularly bad, where unemployment rates have increased dramatically since 2008. Out of the Eastern European countries, Romania managed to keep unemployment rates quite stable around 7%, with the lowest rate in 2008 (below 6%) and reaching 6.8% in 2014. Bulgaria has decreased its unemployment rate between 2000 and 2008, like Romania reaching the lowest rate in 2008, from 19.5% in 2001 down to 5.6% in 2008. In the subsequent years it increased again, reaching 11.4% in 2014.

High public debt and deficit: The EU28 average debt ratio reached 86.8% in 2014, with highest rates in Greece and Italy (177.1% and 132.1% respectively) and Spain with 97.9% (all numbers taken from Eurostat 2015 [gov_10dd_edpt1]). However, the pre-crisis situation was different in these countries. Spain managed to reduce its debt ratio from 58.0% in 2000 to 35.5% 2007, Italy on the other hand has not managed to stay below the 60% ceiling, with 105.1% in 2000 and 99.7% in 2007. However, also other countries such as Germany showed increasing debt levels from 2000 (59.0%) to 2010 (80.5%), France saw an increase of its debt level from 68.1% in 2008 to 95.0% in 2014. Romania for example has constantly decreased its debt ratio from 25.7% in 2001 to 13.2% in 2008, but then increased it to 39.8% in 2014. Bulgarian has shown a remarkable decrease of its debt ratio from 2000 (70.1%) to 2008 (13.3%). The ratio also increased after the crisis, however to still relatively low level of 27.6% in 2014.

The deficit ratio (all numbers taken from Eurostat 2015 [gov_10dd_edpt1]) of the EU28 is -2.9% and therefore just below the 3% threshold after several years above the threshold, with -4.5% in 2011 and -4.2% in 2012. Greece has reached a level close to 3% in 2014 (-3.5%) after mch higher levels in 2011, 2012 and 2013 (-10.2%, -8.7% and -12.3% respectively). Spain had a deficit ratio of -5.8% after years with much higher rates (-4.4% in 2008 and -11.0% in 2009). However, Spain showed positive rates before the crisis. Germany had a deficit ratio of -3% in 2009 and -4.1% in 2010, which was then decreased in the subsequent years, turning positive in 2013 (+0.1%) and reaching +0.7%. The Romanian deficit ratio reached -1.5% in 2014 after its peak in 2009 and 2010 (with -8.9% and -6.6% respectively). The government deficit of Bulgaria was positive before the crisis, and reached -4.2% in 2009 and -3.2% in 2010.

Divergence between countries: An indicator of the convergence or divergence between European Member states is the level of GDP/capita (all numbers taken from Eurostat 2015 [nama_10_pc]). The EU28 average of GDP/capita was €27,300 in 2014. It grew by €780 on average per year before the financial crisis and €230 after the financial crisis. In 2014, countries such as Croatia, Czech Republic, Greece, Cyprus, Spain, Italy and Ireland have not yet reached their 2008 levels of GDP/capita. The decrease of GDP/capita levels was especially high in Greece, where GDP/capita declined from €21,600 in 2008 to €16,300 in 2014. GDP/capita in Spain also decreased, less dramatic however, from €24,300 in 2008 to €22,800 in 2014. GDP/capita in Germany on the other hand increased steadily over the last 15 years reaching €33,200 in 2014. Despite a drop of €1,100 in 2009, the average increase per year post-crisis is even higher than pre-crisis. France also recorded a steady increase over the last 15 years (also with a drop by €1,000 in 2009) reaching €32,400. However, the post-crisis increase of GDP/capita is half of the pre-crisis increase.

4.2 Economic Governance Framework

The European Union Economic Governance framework is the main framework for economic policies in Europe. Its three pillars are fiscal responsibility, investment and structural reforms, which are described in more detail here. In response to the crisis, several new programs and measures were introduced.

4.2.1 Fiscal responsibility

The main fiscal framework is the *Stability and Growth pact (SGP)*, implemented in 1998, which aims at establishing or maintaining a stable and sound public finance situation of the member states. The two main criteria are the deficit rule (3% deficit to GDP) and the debt rule (60% public debt to GDP). There is a preventive and a corrective component of the SGP, as well as an enforcement mechanism. The preventive part consists of the *Medium-term budgetary objective (MTO)*, which contains country-specific reference values. The reference-value should ensure that Member states reach their MTOs. EU member state report their fiscal plans once a year as part of the *Stability Programmes*, each member of the euro area has to submit a draft budgetary plan as part of the *Convergence Programmes*. The Commission then provides an assessment on each member state as well as the euro area. The corrective part consists of the implementation of an *Excessive Deficit Procedure (EDP)* when a member state does not reach its MTO. This should ensure the adoption of corrective policy responses. The enforcement mechanism is applied if countries do not respect the preventive and corrective rules of the SGP. For euro area Member states the fine can be up to 0.2% of GDP for a violation of the rules and 0.5% of GDP for repeated violation of the rules.

After the financial crisis, several additional measures and instruments have been introduced to ensure economic and financial stability. The most important ones are briefly explained here:

1. After the crisis this framework was supplemented by the *Six Pack* in 2011, consisting of 5 regulations and one Directive (proper system of accounting, fiscal planning, numerical fiscal rules, medium-term budgetary framework beyond 1 year horizon) that should

reinforce the preventive and the corrective part of the SGP. The European Semester monitors budgetary and economic policies.

2. In 2013 the *Two Pack*, consisting of two regulations (new monitoring rules and enhanced economic coordination between Member States), was put in place. It complements the preventive part of the SGP by ensuring proper integration of EU policy recommendations in the national budget planning. Euro area member states have to submit their draft budgets and the macroeconomic forecast, which the budget is based on. The Commission analyses if the budget plan is in line with the SGP and the recommendations from the European Semester. Members with difficulties will be put under enhanced surveillance.

3. Furthermore, in 2013 the *Fiscal Compact*, an intergovernmental agreement (part of the Treaty on Stability, Coordination and Governance) was signed. It requires the countries to ensure convergence towards the country-specific medium-term objective (MTO). The European Court of Justice (CoJ) can impose financial sanctions.

4. In 2015 the *Stability and Growth Pact Flexibility Mechanism* was introduced, which is a guidance on how the SGP rules will be applied to strengthen the link between structural reforms, investment and fiscal responsibility in support of jobs and growth.

4.2.2 Investment

Concerning investment and financing, an important part is the Investment Plan for Europe – the *European Fund for Strategic Investment (EFSI)*, which will be described in more detail in the next section. The Commission is working on instruments and programs that will leverage the EU-Budget to finance investments. Funds are channeled through intermediaries such as international financial institutions (mainly the EIB, EIF, EBRD and the CEB), National Promotional Banks, and public agencies of EU Member States. DG ECFIN ensures the coordination between the involved parties. There are six components:

1. Innovative Financial Instruments: Develop innovative financial instruments for participation in equity funds (risk capital), guarantees to local banks lending to SMEs or risk-sharing with FIs for large infrastructure projects.

2. Pilot Phase of the *Europe 2020 Project Bond Initiative*: Aims at financing large European infrastructure projects in transport, energy and information technology. The aim is to reduce the risk for private investments in these key areas by supporting capital market financing.

3. Venture Capital Investment: targeted at SMEs and early-stage companies through the EU Budget under programmes managed by DG ECFIN and through investments by the *European Investment Fund (EIF)*

4. Financing Programmes for SMEs, handled by major IFIs: *SME Finance Facility (SMEFF)*, *High Growth and Innovative SME Facility (GIF), SME Guarantee Facility (SMEGF) and the Capital Building Scheme (CBS)*

5. High Level Expert Group on SME and infrastructure financing: develop recommendations for better access to capital markets for SMEs and infrastructure financing

6. *Euratom Loans*: for financing investment projects

4.2.3 Structural Reforms

Structural reforms aim at competitiveness, growth potential and adjustment capacity by fostering job creation, investment and productivity in labour, goods and service markets. Policy actions include ageing and welfare state policies, labour market policies, liberalisation of service sector and policies to foster innovation.

4.2.4 Additional instruments

1. *Macroeconomic Imbalance Procedure (MIP)*

2. The *European Semester* is the annual cycle of economic policy guidance and surveillance. The European Commission analyses the fiscal and structural reform policies, monitors their implementation and provides recommendations.

3. *Financial Assistance:* in EU Member States provides financial assistance to Member states in difficult economic situations to ensure financial stability. For this purpose the *European Financial Stabilization Mechanism (EFSM)* and the *European Financial Stability Facility (EFSF)* were set up in 2010. The *European Stability Mechanisms (ESM)* was established in 2012 with subscribed capital by euro area member states. It issues bonds on the financial market to raise capital for financial assistance.

The following section will go into more detail regarding the Investment pillar of the economic governance framework, as increasing investment levels is one important aspect of the analysis in this study.

4.3 Juncker Investment Package

In reaction to the economic challenges described above – historically low investment levels and low growth rates combined with high unemployment and high public debt levels –, EC-President Jean-Claude Juncker presented an “Investment Plan for Europe” on November 26, 2014, just over three weeks after he took office (European Commission and Juncker 2014). The Investment Plan is an important component of the investment pillar within the economic governance framework of the EU (described in section 4.2).

As stated in the Political Guidelines for the Commission, Junckers priority is “to strengthen Europe’s competitiveness and to stimulate investment for the purpose of job creation" (Juncker 2014). The Investment Plan which was endorsed by the European Council on December 18, 2014 (European Council 2014a) is supposed to mobilize €315 bn additional investment over three years (2015-2017) and €450 bn until 2020 in the EU via the “European Fund for Strategic Investment”(EFSI) (European Commission and EIB 2014a). The largest part of that money is supposed to come from private sources, leveraged with a 1:15 multiplier effect [12] by a

[12] prudent estimate, based on “historical experience”

small amount of public money taken from existing EU funds (European Commission and EIB 2014d).Thus, the Commission advertises that the “Investment Plan” works without creating new public debt.

To mobilize the €315 bn, the EFSI is equipped with €21 bn – €5 bn from the European Investment Bank (EIB) and €16 bn as a guarantee under the EU budget. This EU guarantee will be backed up by €8 billion from existing funds: margins of the EU budget (€2 bn), Connecting Europe Facility (€3.3 bn) and Horizon 2020 programme (€2.7 bn) [13] (European Commission and EIB 2014a). Member States can contribute to the EFSI directly or through national promotional banks as well as indirectly by co-financing projects. It is also being discussed that Member States can use structural funds to co-finance specific projects. The Commission will not consider contributions to the EFSI when assessing Member States’ debt levels under the Stability and Growth Pact and the Convergence Program (as described in section 4.2). If countries breach the deficit threshold due to contributions to the EFSI, there will be no Excessive Deficit Procedure (EDP)(European Commission 2015c).

Commission-Vice president Jyrki Katainen described the role of the EFSI as that it supports “projects with a higher risk profile so that investment starts taking off in countries and sectors where job creation and growth are most needed”(European Commission 2015c). The fund will leverage private capital by offering more certainty to investors via risk-financing instruments. E.g. the EU guarantee in the EFSI equips the EIB with a greater “risk-bearing capacity", allowing it to provide "first loss protection" through debt financing (subordinated or senior), guarantees, equity, quasi-equity and venture capital to investors without jeopardizing its triple-A rating (European Commission 2015f).

The “Investment Plan for Europe” also includes the promise to remove barriers to private investment in Europe as part of the Capital Market Union. A first step was the adoption of the new Regulation on European Long-term Investment Funds (ELTIF) in January 2015. Furthermore, the Commission wants to revive high-quality securitisation markets and is currently working on criteria that take into account the mistakes made before the financial crisis (EuropeanCommission 2014).This is especially important for institutional investors, i.e. large insurance companies, who are looking for higher returns on investment in the current low-interest-rate-environment (Diekmann 2014).

Following President Juncker’s political guidelines, the main fields the Commission has agreed to support within the Investment Plan are development of infrastructure (transport, particularly in industrial centres; energy, particularly interconnections; broadband), education, research and innovation, expansion of renewable energy and energy efficiency; urban development as well as support for SMEs and midcap companies (European Commission and EIB 2014b). Even though no geographic or sectoral quotas are applied, the Commission admits that there will be “a bias towards those regions particularly the southern Mediterranean countries which have suffered most as a result of the financial crisis”(EurActiv. EU News & policy debates across languages 2014).

[13]The current Multiannual Financial Framework (MFF) for the period of 2014-2020 is equipped with €960 bn (commitment appropriation), of which 20% should be dedicated to climate-related activities. Approximately €70bn are dedicated to the research and innovation program “Horizon2020” and approximately €15bn into the Connecting Europe Facility “CEF”. A part of this should now be used to trigger additional private investments instead of being used as a pure subsidy.

A Steering Board decides allocation and risk profile of the fund. Currently, it is only composed of the European Commission and EIB but e.g.EU member states can be represented if they contribute to the fund. An Investment Committee, which is accountable to the Steering Board, will analyse specific projects according to the guidelines and take the investment decisions. Furthermore, a "European Investment Advisory Hub (EIAH) will be established to advice public and private project promoters as well as National Promotional Banks (NPBs). Additionally, there will be "Investing in Europe" Workshops organized locally to promote EU financial instruments among private and public project promoters.

To be funded through EFSI, projects have to fulfill certain criteria: They have to be viable, sufficiently mature so they can start until 2017 the latest, "additional"[14] and at the same time ensure "high socio-economic returns" [15]. The official documents also state the necessity for consistency with EU policy priorities such as the 2030 climate and energy framework and the Europe 2020 Strategy (European Commission and EIB 2014b). The Investment Task Force, led by the European Commission and the EIB, put forward a pipeline of more than 2000 projects worth over €1.4 trillion on the basis of Member State recommendations in December 2014 (European Commission and EIB 2014c). This list represents a first identification of potential projects, however, it is no financing commitment at this stage.

On April 22nd 2015, the EIB approved the first EFSI-projects: healthcare research in Spain, expansion of an airport in Croatia, construction of 14 new healthcare centres in Ireland and backing for industrial innovation in Italy (Europäische Kommission 2015). Germany was the first country to announce a contribution to the EFSI, promising €8 billion, followed by Spain with €1.5 billion, France with €8 billion, Italy with €8 billion, Luxemburg with €80 million and Poland with €8 billion. The countries' contributions will not go to the fund directly, but will be handled through the respective National Promotional Banks thus supplying only support for domestic projects.

Concerning the implementation process of the Investment Plan for Europe, the Council [16] adopted the regulation establishing EFSI [17] on 10 March 2015 (European Commission 2015e). After negotiations with the European Parliament, the Council announced a provisional agreement on the regulation on June 9. It will now go to Parliament for a vote and is expected to come into force at the beginning of July 2015 (European Council 2015).

[14] EFSI will only select projects that cannot get financing "from other sources on reasonable terms"

[15] this is not further specified and has no ecological or environmental dimension

[16] The EU finance ministers

[17] including the creation of the advisory hub and the project directory

5 The Modelling Challenge

In Chapter 3 and 4 the climate challenge as well as the economic challenge, which Europe is facing, has been described. These two challenges are usually considered as two different problems, even posing a contradiction in terms of finding a solution (being weighted against each other). However, we argue that they are not necessarily a contradiction but can be seen as an opportunity for Europe. But what is missing to include this possibility in the analysis are models which are able to assess the economic challenge and the climate challenge in an integrated way.

Designing a mathematical model always means that simplifications have to be made to achieve a feasible simulation tool, and some principles may be chosen without a strong empirical support. Economic modelling can probably not be done omitting all this but one has to keep in mind that the model design can already limit the set of possible outcomes significantly.

We consider it essential to point out which outcomes are inherently determined in the currently employed models, and which policy implications are beyond their means. This chapter summarizes these deliberations; after providing a brief overview of different model types, the most important model mechanisms, parameters and assumptions will be described.

5.1 State of the Art of Economic Models

When it comes to economic models for analysis and design of climate policies, curently four kinds of models pretty much define the field:

- **Optimal Growth Models** which are mainstream in climate economics since Bill Nordhaus started the DICE model family (Nordhaus/Sztorc 2013). They shape the work of many authors.
  Strengths: Optimal growth models give a sense of aggregate orders of magnitude relevant over several decades.
  Weaknesses: Climate damage assessments are quite arbitrary, win-win possibility are excluded by design.
  Critical parameters for climate policy: discount rate, technical progress.

- **Computable General Equilibrium (CGE) Models** which are the most influential models when it comes to shaping actual climate policy. They provide the framework for standard workhorses like ENVISAGE at the World Bank (van der Mensbrugghe 2010), NEMS in America (Energy Information Administration 2009) and GEM-E3 in Europe (Capros et al. 2013).
  Strengths: CGE models give a sense of sectoral orders of magnitude relevant over one or two decades.
  Weaknesses: Unemployment and finance are described very poorly. GCE models exclude win-win possibility by design.
  Critical parameters for climate policy: investment function, technical progress, labour market.

- **Partial Equilibrium Models** which are key modelling instruments for sectoral policies (energy, transport, ...). They capture the way most decision-makers – and probably most people nowadays – think: there is a single market with a single stable equilibrium defined by supply and demand. A well-known model designed from a partial equilibrium perspective is PRIMES (E3MLab/ICCS at National Technical University of Athens 2013).
  Strengths: Partial equilibrium models give a sense of challenges and opportunities over the short and medium term.
  Weaknesses: It remains unclear what happens out of equilibrium, win-win possibility are excluded by design.
  Critical parameters for climate policy: role of skills, interaction with macro-phenomena.

- **Dynamic Stochastic General Equilibrium (DSGE) Models** which are the most influential models in financial economics, widely used by central banks. They represent deterministic responses to stochastic shocks. In climate economics an important example is the use of QUEST (Ratto/Roeger/in't Veld 2008), the workhorse of the EU when it comes to financial and economic policy.
  Strengths: DSGE models give a sense of the speed at which the economy can absorb shocks.
  Weaknesses: The model does not provide any understanding of relevant shocks. Win-win possibility can not be modelled.
  Critical parameters for climate policy: expectation dynamics, determination of interest rates.

5.2 The Main Problem

The canonical models of climate economics, as described above, exclude win-win options by design. For climate policy, however, it is exactly these options that matter.

This is a two-layered problem. At the surface (which is important), the models consider a single external effect with a peculiar temporal structure: greenhouse gas emissions today cause damages in the future. The time scale of this external effect is larger than the time scale of typical economic processes. As a result, the problem at hand is how to share a global burden in the present for the sake of future generations. As there are no institutions able to allocate that burden, this becomes a task of national governments, for whom the dominant strategy is to minimize their burden.

At a deeper level, the difficulty is that these models are constructed in such a way that they exclude the possibility identified by Mario Draghi in the famous "whatever it takes" speech in September 2012: "we are in a situation now where you have large parts of the euro area in what we call a bad equilibrium, namely an equilibrium where you may have self-fulfilling expectations that feed upon themselves and generate very adverse scenarios. So, there is a case for intervening, in a sense, to break these expectations" (Draghi 2012). The possibility that is left out, is one of multiple equilibria, not all of which are Pareto optimal.

The exclusion of multiple equilibria from most economic models presently in use is quite surprising, because general equilibrium theory yields a single (let alone stable) equilibrium only under exceptional circumstances. But there is a reason for that omission: considering multiple equilibria calls for a theory of equilibrium selection, and such a theory is not available, so far. This is closely related to the question of non-equilibrium dynamics: after all, equilibrium selection has to work through such dynamics.

The problem is hard, and it needs careful scrutiny. We cannot go into detail in this report, so a few points must suffice.

Economics as it exists today is shaped by an overarching paradigm: general equilibrium theory. The new Keynesian models used, e.g., by the IMF are variants of that paradigm as are the more "orthodox" models developed by the Bundesbank (Smets/Wouters 2003) and elsewhere. Many proposals have been made to substitute that paradigm by something allegedly superior: behavioural, ecological, evolutionary, Marxist economics, neo-Ricardianism, post-Keynesianism, econophysics etc. So far, none of these has succeeded, and one reason may be that they were unable to reconstruct general equilibrium theory as a special case of their more comprehensive framework.[18] This also means that they were unable to recover the wealth of empirical knowledge and techniques of analysis that generations of economists working in the general equilibrium tradition have accumulated.[19]

The canonical exposition of general equilibrium theory is Debreu's 1959 "Theory of Value" (Debreu 1959), based on the seminal paper by Arrow and Debreu (Arrow/Debreu 1954). It is usually seen as the rigorous exposition of ideas that generations of researchers have elaborated in the wake of Adam Smith's 1776 "Wealth of Nations". Arrow and Debreu formulated general equilibrium theory as an axiomatic structure within which theorems about existence and properties of equilibria could be proved, and they showed how that structure could be interpreted in different ways to cover a wide range of economic phenomena.

As they proved, there are clearly specifiable conditions on production sets, consumption sets and preferences such that the following theorems hold[20]

- There exists at least one price system p with corresponding demands x_i and supplies y_j such that the sum of demands minus the sum of supplies is equal to the sum of endowments ω_i : $\sum_i x_i - \sum_j y_j = \sum_i \omega_i$. Such a situation is called an equilibrium. (p.83)[21]
- Any equilibrium is a Pareto optimum. (p.90)
- Given a set of endowments and a Pareto optimal allocation of commodities that can be produced from these endowments, there is a price system for which that Pareto optimum is an equilibrium. (p.90)

[18] Incidentally, Keynes tried very explicitly to present the conventional economics of his time as a special case of his more general theory, but Hicks and Samuelson succeeded in the reverse effort to integrate key Keynesian insights into a general equilibrium framework. Succeeded, that is, in terms of influence, although perhaps not of intellectual clarity.

[19] An example is the intertwined development of CGE models, the GAMS software system and the worldwide GTAP database.

[20] Page numbers refer to pages in Debreu's text (Debreu 1959)

[21] Notice that the word equilibrium here is used in the specifically economic sense of a match between supply, demand, and endowments. The word "time" is not used in the definition, and so the definition of general equilibrium does not imply that this would be a state persistent through time, and even less that it would be a state towards which an economy that is not yet in equilibrium would move.

Of course, key issues are how those clearly specifiable conditions look like and how one proves the theorems. Suffice it to say that a key proof strategy is to use a generalization of Brouwer's fixed point theorem.

This theoretical structure can be used to study an impressive amount of phenomena. International trade, e.g., can be introduced by defining a BMW in Germany and one in China as two different goods. In a similar way, corn today can be treated as different from corn tomorrow, thereby introducing time. An umbrella tomorrow if it rains can be a different good from an umbrella tomorrow if the sun shines, allowing to represent uncertainty.

In view of modelling for climate policy (and many more purposes) it is essential to realize the impact of a major theorem in general equilibrium theory, the Mantel-Sonnenschein-Debreu theorem. It shows that in the Arrow-Debreu setting, extremely complex dynamics are the norm, and that for a single set of firms, households and endowments an arbitrary number of equilibria is usually possible.[22] Among other things, this means that even if one accepts general equilibrium theory as it stands, it needs to be complemented by a theory of equilibrium selection to deliver what it promises.

Brouwer believed that in mathematics it was not really acceptable to prove the existence of something without actually constructing it, and he was unhappy that his proof for the fixed-point theorem that would later carry his name (published in 1911) was non-constructive. The existence proof by Arrow-Debreu was non-constructive, too, and this meant that in those days there was no way to implement general equilibrium theory in a computer model, as the equilibrium was not computable with the tools then available.

Already in 1928, however, Sperner had provided an important lemma that could be used to design a constructive proof of Brouwer's theorem (e.g. see Harzheim 1978 p.56), and in the following decades, constructive proofs were developed for that theorem and for generalizations of it.

On that basis, in 1967 Scarf (Scarf 1967) proposed the first algorithm that could be used to approximate an Arrow-Debreu type equilibrium on machines of those times. This opened the way for computable general equilibrium (CGE) models, soon supported by more efficient algorithms than the one by Scarf.

These models, however, were built in such a way as to simply assume away the problems of multiple equilibria, equilibrium selection and non-equilibrium dynamics. This holds for all four canonical models listed above.

5.3 Important Mechanisms

As already pointed out above, the choice of a certain modelling type already involves a lot of assumptions about the "nature" of economic processes in many respects. Some mechanisms have turned out to be key factors when it comes to evaluating the costs and benefits of climate policy. The ability of not excluding win-win-options already by design depends on the set of possible equilibria the models can describe and the existence of an out-of-equilibrium dynamics. Expectations of the economic actors have turned out to be crucial in many situations but – depending on the model type – may not be so easy to implement. The way technological progress is modelled matters significantly for the model outcome. And the ability to deal with

[22] Saari (1995) gives an excellent exposition.

(involuntary) unemployment is important, especially when it comes to modelling Europe in the context of the current crisis.

5.3.1 Equilibria and Dynamics

Today, most models derive from the framework of general equilibrium theory[23] Underlying ideas in general equilibrium economics are that rational agents optimise utilities or profits, as given by their preferences, taking prices as given, and that prices adjust to balance supply and demand, so that equilibrium is reached, i.e. all markets clear. This is formalized in the mathematical theory of general equilibrium as developed by Arrow/Debreu (1954). The theory shows that under certain conditions economic equilibria exist and that these are Pareto optimal, i.e. no agent in the system can be made better off while all others stay at least at the same level. It can be shown that equilibria are generally not unique, and none of the possible equilibria is predetermined to be the one that should prevail in a given economic system. In fact, the theory does not provide mechanisms for equilibrium selection or the dynamics of the system. A set of equations is solved simultaneously to find those prices at which equilibrium is obtained, together with the respective quantities. The commonly told story of the auctioneer who reduces prices of goods for which there is excess supply and increases those of goods with excess demand until equilibrium is reached does not actually translate into price dynamics for the formal system, that starting out from a given state would lead the system into equilibrium. For a more detailed problem analysis see Section 5.2.

All the computational models lined out in Section 5.1 are based on the ideas of general equilibrium theory without strictly being implementations of the formal system. In contrast to general equilibrium theory, they are restricted to a single equilibrium. They use representative agents, an assumption which reduces the number of possible equilibria to a single one in the general equilibrium framework (for a critique of the representative agent see Kirman 1992). The problem of equilibrium selection is thus beyond the horizon of these models.

The focus of optimal growth models is the allocation of a produced good in each time step (often considering an infinite time horizon) between consumption and investment in such a way that a representative household's lifetime utility – defined as an (infinite) sum of the discounted utilities derived from consumption at each time step – is maximized. CGE models add an optimization for the allocation of resources to different sectors using input-output tables at each time step to a similar inter-temporal optimization structure for capital. Usually a business-as-usual (BAU) scenario without climate policy measures is computed as an optimal trajectory of the system. Climate policy then enters as an additional constraint for the mitigation scenario, meaning that by definition the result can at most be as good as the BAU case, and usually comes out "worse". Within the given structure of the economy, provided by the single equilibrium that is being considered, the focus is on marginal changes induced by climate policy. In other words, the analysis focuses on climate policy redirecting economic resources (from fossil fuel based to green technologies) with the help of market based and regulatory instruments.

Models that are restricted to a single equilibrium do not provide an out-of-equilibrium dynamics but the usual assumption is that for small deviations the system will return back to

[23] While general equilibrium theory has been widely criticised, especially since the financial crisis, no other approach has as yet been able to replace this overarching paradigm in economics.

equilibrium immediately. While there is same empirical evidence for the state of the economy being quite stable over time (sudden price jumps are not usually observed), however, there is no theoretical foundations why equilibria obtained by these modelling approaches have to be stable and for how large a deviation from the original state the system may not come back to it (see Saari 1995).

The approach of agent-based modelling (ABM) is very different from the idea of general equilibrium theory. In ABM, the model is based on different agents that are implemented with certain rules for (inter)action, and the economic system's development results from actions and interactions of the agents computed in model runs. There are various advantages of this approach: unrealistic assumptions like completely rational behaviour of all agents and complete information can be dropped, and theoretical difficulties arising e.g. by using aggregate agents and by assuming the existence of only one (stable) equilibrium are circumvented. As has been pointed out earlier, especially the latter is important if an economic transition is the object of the investigation. Important economic mechanisms like the role of expectations and coordination of the actors (see below) can be implemented much more straightforward.

However, these advantages come at a price. Given this dynamics based on the agents' decision rules the system may probably reach some kind of stable state which can be (but is not necessarily) an economic equilibrium, there can be a variety of this stable states, and the system dynamics based on agents actions can be quite complex and even chaotic. Therefore, these kind on "non-mainstream" models still fight reasonable problems when it comes to calibrating then to real-word data.

5.3.2 Expectations and Coordination

Different growth patterns in the past have shown that investment dynamics can be considered as a case of convention dynamics[24] with several focal points for investors' growth expectations. In a setting of low growth, agents expect further low growth and invest little, while in periods of higher growth, expectations improve and hence investments increase. In both cases the dynamics is self-perpetuating, that is, the focal point of investors' expectations is likely to stay in place. However, looking at the history of economic growth, there have been shifts from one focal point to the other and back, that is, transitions from one convention to another are possible. Relating back to the challenge of equilibrium selection as mentioned in the previous section, the problem that expectations can become self-fulfilling has also been pointed out in a description of Europe's situation by the president of the European Central Bank, Mario Draghi: "we are in a situation now where you have large parts of the euro area in what we call a 'bad equilibrium', namely an equilibrium where you may have self-fulfilling expectations that feed upon themselves and generate very adverse scenarios" (Draghi 2012).

Expectations play a fundamentally different role in different model types. A CGE-model assumes perfect information. That means that the representative agents base their decisions

[24] Conventions arise in cases where groups of people can choose between several alternatives, but benefit from coordinating on the same choice. A standard example is driving on the right or left side of the road. Convention dynamics show long stretches of time where one of the alternatives is chosen – it becomes the conventional way of doing things – but sometimes, a transition to another alternative may occur. Such transitions usually take place rather quickly, by a critical mass of group members switching to the new convention, since times where several alternatives are used within the same group of people are usually problematic.

(production, consumption) on their insight into the equilibrium state of the economy. In agent-based models, agents do not have perfect information. Thus, the agents' expectations are an important factor in their decision making. Especially for investment decisions, expectations can be crucial. Investments depend on returns on investment, but also on expectations about future development of related sectors, (energy) prices, and future policies. While investors may be interested in rates of return and the like, they need to take their investment decisions under uncertainty so that the decisions are necessarily based on expectations. To analyse how climate policy might influence such expectations for triggering a sustainability transition, modelling expectation dynamics is of major interest.

The role of expectations in selecting an economic equilibrium out of several viable alternatives needs to be analysed and incorporated into simulations. The design of the economic model determines whether (and if so to which degree) feed-backs between agents' expectations can be described and if this can lead to self-fulfilling dynamics. Another crucial point is, to which degree agents coordinate their expectations.

Jaeger 2012 analyses climate policy as an example of problems of the global commons and points out that equilibrium selection is a coordination problem. He summarizes that markets are multi-stable systems with a major difference between marginal changes, for which price movements operate as scarcity signals, and regime changes, for which prices are conventions that solve a coordination problem, and highlights that regime changes in which these conventions are modified need to be investigated in a perspective of sustainable development [see p. 97].

Considering climate change a market failure "whereby the uncoordinated actions of individuals pursuing their own self-interest collectively deliver a worse outcome for society as a whole" [p. 9] as Zenghelis 2011 puts it, suggests that framing the question under study as "how can climate policy facilitate a re-coordination of investors' expectations for a sustainability transition?" is helpful for modelling and analysing costs and benefits of climate policy.

Profits of individual investors depend on whether they correctly estimate growth perspectives of the economy. These perspectives in turn depend on the expectations of the individual investors in the economic system. This means that no agent in the economy can make a transition from one to another growth path alone but all could benefit from a coordinated shift to it. Game theoretical aspects like this are usually omitted in the model design.

5.3.3 Technological Progress

An important model feature is the implementation of technical progress. It can be modelled in different ways, e.g. it can be represented exogenously in the production function. However, one source of technical progress is learning-by-doing, i.e. technical progress is regarded as a function of cumulative experience, which can be represented as the cumulative investment. For investment decisions that means that agents have to be aware of the learning-by-doing effect prior to their decision to select the optimal production factor mix. It also means that assuming higher (global) demand and therefore increasing production levels, prices for clean technologies will decrease more rapidly and this will trigger technological progress in other sectors (upstream and downstream industries) as well. This important effect is often underestimated.

The most popular analysis of sectoral technical progress nowadays is based on learning rates.[25] The canonical formulation considers a power law linking two time-dependent variables: cumulative productive capacity $X(t)$ and unit cost $Z(t)$. The power law then is $Z(t) = C \cdot X(t)^B$, with constants C and B.[26] It follows that

$$\frac{Z(t+1)}{Z(t)} = \left(\frac{X(t+1)}{X(t)}\right)^B \quad (1)$$

Nagy et al. (2010) find that sectoral technical progress depends on the growth of the sector plus a random component. The random component then captures the multitude of factors that influence technical progress in ways not represented by the learning curve, see (Nemet 2006).

Technical progress of the economy as a whole is a mixture of stochastic processes for the learning exponent B at the sectoral and national levels. The unconditional probability distribution and expectation of B is the same in all these processes, and so in the economy as a whole.

As Nagy et al. (2010) show, instead of cumulative capacity, other variables can be used, and as long as one is interested in current trends it does not really matter whether one takes cumulative capacity, current output or even time (Moore's model).[27] The last case is an instance of exogenous technological progress: taking time as the independent variable means that if a policy affects patterns of economic growth, technological progress stays the same. Treating technical change as exogenous does no harm as long as one analyses either a given past or policies that can reasonably be assumed not to influence growth. But when studying things like future climate policy, assuming exogenous technological progress would be hard to justify: the evidence pointing to an effect of economic growth on the drift of technological progress is too strong.

For empirical purposes, cumulative capacity can be approximated by cumulative production as long as the period considered is not restricted to something like the global financial crisis of 2007. The growth of cumulative capacity is in the same order as output growth. For industrialised countries, this leads to an order of magnitude of 1.025. Moreover, in simulation work one can estimate increases of cumulative productive capacity from the base run. As for the dependent variable, $Z(t)$, typical studies on learning curves interpret it as unit cost. When considering technical progress of the economy as a whole, the relevant variable is the inverse of total factor productivity, $Z = 1/\mathrm{TFP}$.

Given the long-run tendency of the capital-output ratio to be constant in industrialised countries, recently re-enforced by D'Adda/Scorcu (2003), one can estimate TFP by considering unit costs in terms of the labour a unit of output can buy. Again for industrialised countries, this

[25] See http://ampere-project.eu/web/images/Tech_Workshop/rubin__uncertainties_in_experience_curves__20130527.pdf for an exposition by a leader in the field, albeit with a mistaken minus sign on p.7.

[26] The learning rate LR is defined as $LR = 1 - 2^B$ and gives a measure of the cost reduction achieved when cumulative productive capacity is doubled.

[27] It is useful to notice that cumulative capacity cannot decrease, so this takes care of the problem that even shrinking sectors are unlikely to simply forget how to do things.

leads to an order of magnitude of 1.015. Therefore, B is in the order of $\log(1.015)/\log(1.025)$, i.e. the logarithm of the increase in TFP to the base given by the increase in cumulative capacity. This yields a B in the order of 1.

5.3.4 Inefficient Labour Market

Taking into account the economic challenges that Europe is currently facing (as described in Chapter 4) is not trivial in economic models in general, and in CGE models in particular. One important aspect here is the existence of involuntary unemployment. The labour market is usually modelled in analogy to goods markets, in particular, labour supply and labour demand are balanced by the equilibrium price of labour, the wage. This setup excludes involuntary unemployment in equilibrium. However, involuntary unemployment is certainly present in the European economy at the moment.

Search models are an approach for taking this into account. They explicitly consider a matching problem in the labour market: not all jobs are suitable for all households looking for jobs and vice versa, meaning that recruiting and job search activities are essential on the parts of firms and households, respectively. “Match-making” between employers and employees could be considered a necessary input good for production, however, there is no market, and hence no price for this good. In other words, there is a labour market externality to be taken into consideration. An overview of works on labour search models is given for example by Rogerson/Shimer/Wright 2005. In the following, we sketch an example model by Farmer 2011 which shows that there may be a continuum of equilibria in economies with search.

Farmer 2011 introduces a labour market with search into a discrete-time infinite-horizon neoclassical model. That is, in this model, a representative household maximizes expected utility (an infinite sum of discounted “felicity” for each time step that depends on consumption) subject to a budget constraint for each time step in terms of income and financial assets. Consumption goods (C) are produced using capital (K) and labour (L), and there is a stochastic input (S_t) in the production technology which represents productivity shocks:

$$C_t = S_t K_t^a L_t^b, \tag{2}$$

with $a + b = 1$. This far, prices and quantities that occur in a competitive equilibrium can be computed by solving a set of equations. Search is introduced as follows: labour employed by firms, L_t is a sum of productive labour (as in standard models) and search, or recruiting labour $L_t = X_t + V_t$. This means that the production function is modified to

$$C_t = S_t K_t^a X_t^b \tag{3}$$

A search function provides the relation between L, V, and the amount of work households search for H (which is here assumed to be equal to 1).

$$L_t = (\Gamma V_t)^{\frac{1}{2}} (H_t)^{\frac{1}{2}} \tag{4}$$

where Γ is a parameter for the efficiency of recruiting. The model considered here assumes, for simplicity, that all work contracts last only for one period of time. The so-called Beveridge curve, also known as “UV-curve”, considers the corresponding relation between unemployment and the job vacancy rate. This curve, of hyperbolic shape as in (4), downward sloping, can be found in empirical data, where a higher rate of unemployment normally occurs with a lower rate of vacancies. For this model, there is a solution to the social planning problem. It provides an optimal L_t that depends on the parameter Γ. However, in the decentralized model of optimizing firms and households, these agents take the efficiency of recruiting, respectively of job search, as given, while the recruiting efficiency parameter is endogenously determined by aggregate economic activity. This constitutes an externality on the labour market, as firms cannot take into account the contribution their recruiting activity makes to overall recruiting efficiency. The externality leads to a continuum of equilibria: When unemployment is high, the real wage and the productivity of a recruiter are high because all firms allocate a small fraction of employed workers to recruiting and congestion effects are small. Vice versa, when unemployment is low, the real wage and the productivity of a recruiter are low because all firms allocate a large fraction of employed workers to recruiting and congestion effects are large (see Farmer 2011 p.10). The model can be “closed” by a further equation, that selects one of the possible equilibria. In search models, this is often done via a bargaining equation: it is assumed that firms and workers bargain over the wage to be paid. The bargaining weights of firms and households then determine employment. Farmer 2011 closes the model with beliefs of agents about asset prices, thus introducing Keynes’ idea of “animal spirits” into the model. Then, employment, which is constant in the bargaining model in equilibrium, can vary in response to both productivity shocks and belief shocks. Depending on how these beliefs are modelled, the model can reproduce results of the bargaining model and other models. In particular, it is possible to model rational beliefs of agents which are self-fulfilling, that is, the agents’ beliefs select the equilibrium that agents believed in.

5.4 Data and Policy Assumptions

In Section 5.3 was discussed that the model design influences the possible outcomes of the simulations. Besides these assumptions for the existence of and relations between variables, also other inputs are crucial for the output of any model. Here assumptions have to be made as well, which are mainly assumptions concerning policies (e.g. renewable targets) and assumptions concerning unavailable data (e.g. future population). A combination of certain data and policy assumptions then determines a “scenario”.

5.4.1 Data Assumptions

A lot of data is fed into the relevant models for calibration and initialization. Other important values arise endogenously. Here, crucial points are highlighted.

- *Interest rates* – Future interest rates have to be estimated, e.g. using the ECB inflation forecasts. They will largely depend on monetary policy choices.
- *Discount factors* – Different discount factors used depend on the interest rates for debt and equity and the mix of debt and equity. The discount factor and the depreciation rate assumed for a capital good determine the net present value of an investment and therefore the price for the good (e.g. electricity generation prices).

- *Fuel and energy prices* – In general, prices are computed endogenously but for fossil fuel prices exogenous assumptions on resource depletion or the level of taxes play an important role. It will be investigated whether it is possible to apply different tax levels (and therefore prices) for households and firms, and which effect this might have.
- *Energy mix* – Parameters for technological substitution have to be chosen, e.g. on Weibull functions or other. Exogenous constraints may be given by capacity availability, site availability or specific policies. Endogenous factors are fuel resources/prices. Generation costs are (endogenously) influenced by technical progress and learning-by-doing.
- *Carbon intensities* – The degree of effectiveness in primary energy use is supposed to increase over time as technology advances.
- *Abatement costs* – Abatement costs for energy-related CO_2 emissions depend on the substitution possibilities among fuels and between fuels and other inputs. Otherwise marginal abatement cost curves may be obtained from empirical data or have to be estimated. It is important – and not always straightforward – to distinguish between fuel switching or other refurbishment costs and investments into new capital stock. Abatement can also be done by buying carbon certificates (offsets) from outside the EU, usually at a lower price per ton of CO_2.
- *Energy demand* – In general, energy demand is endogenous. Energy requirements per unit of production or consumption (energy intensities) can change both endogenously through substitution or/and through exogenously defined autonomous energy efficiency improvements.
- *Population* – Population growth is an exogenous model input. We will investigate different scenarios of population development. An important factor and uncertainty here is the level of migration into and across Europe.
- *Skilled vs. unskilled labor* – Regarding the quality of labor, it is to be investigated whether there is a mechanism for human capital formation (through investments into education and training) or a migration function between skilled and unskilled labor (e.g. of the Harris-Todaro type).

5.4.2 Policy Assumptions

With respect to policies, the following assumptions will be considered in the present project.

- *Emission reduction targets* – At least three different targets are investigated, a -30%, a -40%, and a -50% target for 2030, assuming a more or less linear reduction path. If considered useful an additional target of -45% can be added.
- *Renewable or energy efficiency targets* – Additionally, further targets regarding the share of renewable energies or the energy efficiency will be considered. As the European Commission has just proposed a target of 27% for renewables by 2030, this would be an obvious choice to investigate and compare with a more ambitions target.

- *Technology choices* – There may be political reasons for decisions on the use of certain technologies (CCS, nuclear energy), which have to be taken into account.
- *Cost of carbon emissions* – The cost of carbon emissions can be represented via a trading system for emission certificates or via a carbon tax. One important question for the European trading system (EU-ETS) is how many carbon certificates will be allowed to be imported into the EU-ETS, via for example the Clean Development Mechanism (CDM) and Joint Implementation (JI). Furthermore, the excess amount of carbon credits that have accumulated in the system have to be taken into account. Both questions will influence the amount and price of carbon certificates and therefore the price of energy.
- *Taxes and subsidies* – Besides a potential tax on carbon emissions additional environmental taxes may be employed. Subsidies (e.g. for renewable energy or energy-related refurbishment) are possible policy measures to encourage faster abatement.
- *European burden sharing* – A European climate policy has to take into account the very different situations and possibilities in the member states. Thus, an emission reduction target possibly consists of specified targets for different member states and considers a fair distribution of burdens.
- *Climate policy of the rest of the world* – The emission reduction scenarios investigated within this work are scenarios regarding the EU, but since Europe is economically connected with the rest of the world, choices have to be made for possible climate policies outside the EU. Weak climate targets elsewhere will lead to a steeper increase of fossil fuel prices than in the case of strong climate policy outside the EU (possibly a new international climate agreement or bilateral agreements, e.g. between the EU and China) due to a higher demand for fossil fuel resources. In the case of strong climate policies elsewhere, there are more possibilities for technological progress in the cleantech industry and more opportunities for exporting mitigation technologies from the EU to the rest of the world. Different versions of the international climate policy landscape will be investigated in the scenarios.
- *Monetary and fiscal policy* – Especially for the -50% scenario it is necessary to identify ways to finance the additional investments needed. As far as possible within the model framework, we will investigate options for a looser monetary policy (e.g. the ECB buying green project bonds on the secondary market) and changes in fiscal policy, fostering public investments in education, training initiatives and energy efficiency.

6

The Policy Challenge

As for the modelling challenge a similar challenge arises in policy making, where the integration of climate and economic policies is key. One aspect of this will be to deal with the trade-off between increasing investments and high levels of public debt in the EU.

For this purpose, this Chapter offers a critical review of the policies implemented in climate as well as economic policy, as already described in Chapters 3 and 4 respectively. This section argues why current policies are not sufficient for a transition to a low-carbon economy and outlines first suggestions on how climate and economic policy measures can be better aligned and integrated to trigger a shift to a low-carbon economy.

6.1 Policy Implications

There are strongly contrasting views on climate change.[28] Natural scientists often tend to present anthropogenic climate change as an utterly catastrophic danger to be avoided at all cost. While this apocalyptic narrative still captures large parts of public imagination, policy making is much more geared to the idea of balancing the costs and benefits of various policy options. The fundamental structure of the problem is seen as comparing costs incurred in the present against benefits – namely the avoidance of climate damages – occurring in the future.

The experience of global climate policy so far strongly suggests that the present framing – be it in the apocalyptic or in the cost-benefit version – does not offer a viable approach to tackle the climate challenge.

If climate policy is solely oriented towards avoiding climate damages, it faces the problem that most of these damages are decades and even centuries away. This does not make them less serious in an abstract sense, but for policy purposes it has a devastating effect. It is very difficult to create and mobilize powerful advocacy coalitions for goals that lie far beyond the horizon of political accountability. The uneven geographical distribution of potential future damages furthermore adds to the complexity of the issue. Moreover, attempts to estimate those damages are clouded by large uncertainties, for example, about the proper discount rate to be used for intertemporal comparisons. Given the complexities of global policy-making, this has led to overall paralysis regarding the key challenge of reducing emissions.

What is required is a climate policy narrative about opportunity creation, instead of burden-sharing. This is by no means a trivial task, and it will not be settled by a few shining examples of successful businesses with small carbon footprints. For a start, it is useful to assemble some important building blocks.

The openness of the future. The world economy is one of the most complex systems we know of, and it is far from having one optimal trajectory. By reasonable standards, however, some trajectories are better than others. E.g., the trajectory along which in the past decades billions of people have been able to escape poverty is preferable to the trajectory of

[28] This section is based on the contribution to the Global Climate Policy Conference, London, 7-8 May, 2014, by Carlo Jaeger, Ken Abbott, Dan Bodansky, Gary Dirks, Sonja Klinsky, Michael Hanemann, Sander van der Leeuw and Yongsheng Zhang. Responsibility for errors stays with Carlo Jaeger.

the preceding centuries where poverty was overcome only for a small part of human population. Climate policy needs to foster trajectories where poverty alleviation goes along with emissions reduction.

Turning obstacles into resources. At the beginning of the modern era, the Dutch economy was clearly at a disadvantage compared with, say, Denmark, because it had to incur additional efforts to develop an economy below sea-level. However, as a side-effect these efforts produced a remarkably effective culture of collective action, turning the challenge into a new resource as well as new industries. Similarly, a community that decides to tackle the climate challenge may gain new resources by doing so, be it at the local or global level. On the other hand, a schematic reliance on price signals as sufficient policy instruments risks missing the learning capabilities present in the real economy.

Options at the technological frontier. Highly industrialized countries can grow in different directions. Typewriters did not disappear from offices because of a shortage of paper, but because new branches of professional specialization – computer scientists etc. – emerged in the social division of labour. Advances in the technological frontier of the world economy usually go along with greater sophistication in the division of labour. Green growth offers major opportunities in this regard, not only in the energy sector, but also in many other fields, in particular at the interface of urban systems and information technology.

6.2 Climate Policy - Climate Package

Since the prevalent framing of the climate challenge is a trade-off between economic growth today and costs of climate change tomorrow, the costs of climate change mitigation today will bring benefits in terms of reduced costs of climate change in the future. Subsequently, most of the discussion focuses on optimizing the cost-benefit calculation for this trade-off as well as on sharing this global effort in a fair manner.

While the standard approach to climate policy presents financing emission reductions as a cost to the economy (called the cost-approach in Chapter 3.3), Romani/Stern/Zenghelis 2011 claim that “the expenditure involved in making the transition to a low-carbon economy must be analysed as an investment, rather than being seen simply a net cost or solely as a direct cost to the public purse.” [p. 3].

Hence, investment is a key element of the benefit approach to climate policy: rather than considering a redirection of the existing investment volume towards green technologies and products through market based and regulatory instruments, the benefit approach focuses on additional investments. These can be viewed from a “green” perspective – as a means to the end of decarbonizing the economy – or from a “growth” perspective, where investment is closer to being an end in itself: generating growth, it can be considered as an exit strategy from the economic crisis in the European Union. Sections 3.1 and 3.2 have shown that investments will be needed across all sectors and especially investments into energy efficiency across the board need to be increased. Concerning geographical aspects, investment needs will be particularly high in Eastern European countries, as these have much higher levels of energy intensity (per capita and per GDP) and an older structure of its capital stock, but with fewer measures in place than the other Member states (see Section 3.4.

Proposals such as the Green New Deal have focused on a public investment program, which might even lead to lower financing costs, considering the low interest rates. However, with the existence of high levels of public debt and most Members of the European Union already violating the Stability and Growth Pact, as described in Section 4.1, the implementation of a large scale “green" public investment program is rather unlikely. Therefore, a part of the climate challenge is how to finance the additional required investments and how to trigger a large-scale investment impulse.

The current situation in Europe has variously been characterised by the term “savings mismatch”, for example by Diekmann 2014, who observes “a large pool of savings that seems to have nowhere to go, [. . .] huge challenges [including] climate change [. . .] but an endless struggle to find investment opportunities”[p. 1]. He proposes infrastructure-backed bonds as a new class of safe investments, in particular for institutional investors. Therefore, climate policy needs to become more integrated with economic and financial policy.

6.3 Economic Policy - Investment Package

As described in Chapter 4 the European economic governance framework is very much focused on the fiscal and structural reform policies (via the European Semester and its “fiscal responsibility” pillar). The “Investment” pillar is promoting SMEs with several financing programmes. The “structural reform” pillar of the economic governance system does not make a specific reference to issues regarding a transformation to a low-carbon economy and the related structural challenges.

The Investment Plan for Europe (for description see section 4.3) that is supposed to address low investment levels while at the same time stimulating growth and employment has been subject to criticism from think tanks, NGOs, scientists and journalists. The shortcomings summarized in this report range from the design of the EFSI over the focus on private investment to coherence issues with other EU policies. It was argued that the plan misunderstands the problem behind the economic situation of the Euro zone as it ignores the role of austerity policies for the decline of investment and the lack of recovery (Sander 2015). Other critics disapproved of the strong focus on private investors since the areas of investment that the plan is set out to promote are traditionally public (Coulter 2014). Numerous critics have found the fund to be inadequate in scale (EurActive/Vincenti 2015). Others complain that the plan might come at the expense of other important EU programmes. Research institutions like the League of European Research Universities, Euroscience or European University Association as well as the European Parliament have taken a stand on not using Horizon 2020 funds for the EFSI (Hedda 2015; Adjacent. Digital politics Limited 2015). Others have voiced their concerns that the Youth Guarantee might become underfunded (EurActive/Negrescu 2015). Adding to this, the leverage ratio has been doubted, as the plan expects to use €21 bn to mobilize an overall €315 bn (1:15) (Claeys/Sapir/Wolff 2014). A study from Societe generale (2014) reckons that the expected leverage ratio of 1:15 is too high, given that the multiplier effect in a similar initiative (the Project Bonds Initiative) was only 1:5 to 1:7.

As this report focuses on the integration of climate and economic policy, it takes a closer look at the coherence of the Investment plan with the “2030 climate and energy framework” and the Energy Union.[29] Most fields of investment that the official document names touch sustainability: infrastructure, notably broadband and energy networks[30], as well as transport infrastructure in industrial centres; research and innovation, renewable energy and energy efficiency. The plan refers to energy and climate in its examples of "typical projects": construction and rehabilitation of public buildings to improve their energy efficiency, greening projects for maritime transport, alternative fuel infrastructure along major roads and third generation biorefineries. At the same time, high-carbon infrastructures like the expansion of airports or roads are named by the joint Investment Task Force (European Commission and EIB 2014b). In his vision of where the money should go, presented in his speech on November 26, 2014, Juncker referred to an electric car charging infrastructure, better waste, recycling and water treatment facilities, energy efficiency for households and firms, interconnecting networks and markets, integrating renewable energy and diversifying sources of supply as being important investment areas within the package (European Commission and Juncker 2014).

To ensure that the Investment Plan does not only focus on jobs and growth but also on climate and energy security, the environmental organization E3G suggested additional project selection criteria.[31] Their briefing paper favors e.g. applying tight Emissions Performance Standards (EPS)[32] as well as a shadow carbon price to all projects to exclude high-carbon investments, prioritising projects that enhance the Energy Union and Europe's climate targets, evaluating projects against short-, mid-, and long-term demand scenarios in line with the EU targets (GHG, RES, energy, efficiency and interconnection) and setting up special purpose investment platforms[33] e.g. for energy efficiency in buildings and smart cities (E3G 2015). Concerning the latter, MEP Kathleen Van Brempt is negotiating a dedicated efficiency fund of €5 bn in risk guarantees with the Council of Ministers (EurActive/Crisp 2015).

A group of non-governmental organisations – Bankwatch, Counter Balance, Friends of the Earth Europe and WWF – have voiced similar suggestions for criteria, calling on the fund to ensure long-term sustainability of investments. Thus, project selection and performance criteria should be consistent with EU 2050 climate, resource efficiency and biodiversity goals. To achieve this, EFSI should concentrate on energy and resource efficiency investments that the organisations see as "cost effective, job intensive, improving EU energy and resource security and reducing EU vulnerability to external shocks" (Bankwatch Network 2015). Examples given are renewable energy generation, smart grids, [34] electricity storage, railway transport and urban mobility, infrastructure for electric cars and "green infrastructures" that reduce the impact of climate change. At the same time, these NGOs want to exclude carbon and resource inten-

[29]The official communication on the Energy Union (European Commission 2015d) names the investment plan several times: It states that for the investment in sustainable alternative fuels (e.g. biofuel production processes and the bio-economy) the EU Investment Plan "could help to ensure the necessary financing". Also, the Commission wants to "make use of all available Community funding instruments in particular the future European Fund for Strategic Investments (EFSI)" for the construction of gas infrastructure for diversification of supply.

[30]The official communication of the Commission states that the investment in "strategic infrastructure" (digital and energy investments) should be "in line with EU policies".

[31]The key criteria at the moment are: EU value added, economic viability and value and reasonable expectations for capital expenditure in the 2015-17 period.

[32]At least 350 gCO2/kWh and thus tighter than the EPS currently used by the EIB.

[33]also suggested by ECOFIN

[34]The Commission estimates the investment need for grids at €142 billion by 2020

sive investments such as airports as well as excess gas infrastructure that does not take into account the possibility of shrinking demand. Bankwatch also demands a “fair risk balance” between private investors and public institutions as well as stakeholder involvement in the EFSI governance (Bankwatch Network 2015).

An assessment by E3G et al. (2015) of the €1,409 bn project pipeline that Member States have proposed for EFSI has identified low-carbon investment projects (excluding nuclear) worth €624 bn (44% of the whole pipeline). These are mostly transport (€269 bn) and RES projects (€137 bn), leaving energy efficiency and grid infrastructure at €114 bn (8% of the pipeline). At the same time, “high”-carbon transport and energy projects make up €278 bn and thus 20% of the project pipeline, another 6% are nuclear projects (E3G et al. 2015). The recently approved first four EFSI-projects also contain a high-carbon-transport investment with the expansion of an airport in Croatia (Europäische Kommission 2015).

Integration of climate and economic policies has not been a high priority so far, partially because these are two separate fields of policy which are mostly regarded as posing a contradiction and partially because it lacks the models that are able to analyse such policies in a satisfactory way. Part II aims at contributing new approaches to address the four challenges.

Part II

Analysis

After having described the four challenges, the following chapters will address how such integrated policies can be analysed and which problems can arise when implementing such policies, especially in countries with high energy intensity and low GDP/capita. Section 7 will show simulations using a version of the model GEM-E3, that was adjusted to account for economic and environmental win-win possibilities. Section 8 applies a different CGE model, IMACLIM and section 9 shows newer agent-based modelling approaches to climate and economic policy analysis. Chapter 10 contains a qualitative analysis of the difficulties arising when substantially increasing investments in energy efficiency in Eastern Europe.

7

Green Growth in a Computable General Equilibrium Model

7.1 Problem Description

The majority of studies that investigate the reduction of global GHG emissions (Intergovernmental Panel on Climate Change 2015, van Vuuren et al. 2007, OECD 2008) suggest that the cost required to mitigate GHG emissions to safe concentration levels (450 ppmv) ranges from 0.2% to 2% of GDP by 2050. Timely and globally concerted action would reduce the costs of GHG abatement (Kriegler et al. 2013). This cost is usually measured when the counterfactual scenario is compared to a reference scenario where the externality of GHG emissions is not included. The calculation of the cost of reducing GHG emissions does not usually include the benefits from avoiding climate damages and from pollutants reduction.

The EU28 has long been a leader in pursuing a global climate deal, and has early outlined a robust set of targets for drastically reducing its GHG emissions by 2030, as described in Section 3. According to the EU contribution submitted in March 2015 in the UNFCCC: "The EU and its Member States are committed to a binding target of at least 40% domestic reduction in greenhouse gas emissions by 2030 compared to 1990, to be fulfilled jointly, as set out in the conclusions by the European Council of October 2014". This GHG emissions reduction target proposed by the European contribution to COP-21 is in line with the objective included in the recently adopted 2030 framework for energy and climate policies.

A key question to address is whether GHG mitigation can be a welfare improving action, when climate change effects are not taken into account. That is whether GHG emission reduction can lead to a higher growth path as compared to a scenario that does not involve GHG mitigation action. A critical issue then is to identify any market imperfections that can be removed when implementing GHG mitigation policies.

7.2 Methodology

CGE models by representing a closed economic system and by being founded on rigorous microeconomic theory are able to evaluate resource reallocation problems and trace the contribution to the adjustment process of the economic system of all factors involved. The reference scenario in these models (i.e the initial equilibrium point) represents an optimal allocation of resources when no frictions or market imperfections are taken into account (it represents a long run equilibrium where the economy grows at steady state), hence all counterfactual scenarios need to lead to sub-optimal solutions by definition.

Since market imperfections failures exist and are important in determining market performance many extensions to the classic Arrow-Debreu general equilibrium model have been made so as to increase the realism and accuracy of computable general equilibrium models. Important extensions are considered to be the representation of involuntary unemployment in the labour market (Boeters/Savard 2011), oligopolistic competition and monopolies (Balistreri/Rutherford 2013) and Foreign Direct Investment (FDI) and endogenous productivity (Tarr 2013). Our objective in this study is to discuss the mechanisms that are important in driving the results of GHG mitigation policies in a CGE setting in order to set the stage for model improvements that will increase the realism and computational accuracy of CGE models.

The key features of a CGE model that drives its results are summarised below:

- **Expectations**: CGE models representation of expectations fall under three main categories: i) myopic (static or recursive dynamic CGE models), ii) Adaptive (recursive dynamic models) and iii) Perfect foresight (inter-temporal/dynamic CGE models). They differ regarding their ability to represent expectation dynamics and are important when considering an economic impulse that can change the expectations of the sum of all investors and producers.

- **Learning by doing**: CGE models apart from few exceptions exogenously represent technical progress. Few represent two factor learning curves (learning by doing and learning by research). However, the technological development of clean technologies is key for a transition to a low-carbon economy. The higher the production level of these new technologies, the higher will be the technological progress for these products. An exogenous rate of technological progress does not take this effect into account when higher levels of investments are applied.

- **Labour Market**: The default representation of the labour market in CGE models is via a market clearing wage. Unemployment is considered to be voluntary through households endogenous optimal choice between labour supply and leisure. In a CGE framework with perfect labour markets, policies that would promote employment or imply the transition towards a more labour intensive economic structure would tend to increase wages.

- **Suboptimal use of capital**: A core assumption of CGE models is full employment of resources. As capital is assumed to be fully employed any new investment project needs to draw resources from other investment projects. Crowding out remains a key distinction between CGE models and macro-econometric models. In the current European situation, there is evidence for a suboptimal use of capital, making this an important point of investigation.

- **Elasticity of substitution**: The regional and sectoral dimensions of a CGE model largely depends on the purpose for which the model is designed and the data availability. While elasticities of substitutions between capital and labour are key in driving the model results, they are rarely estimated on the dimensions of the model.

In order to investigate the potential for welfare improving of GHG mitigation action we take the following steps:

1. First we use a standard CGE model in order to quantify a GHG emission reduction scenario using the default features of the modelling framework.

2. Then we identify the key model mechanisms involved in GHG abatement that are important in determining the overall adjustment costs.

3. Then we try to improve the modelling representation of these mechanisms in order to capture features that are considered to be crucial in determining the overall economic impact from GHG mitigation.

4. We compare the extended version of the model both with the reference and the standard M50 scenario so as to draw conclusion regarding the properties of the new model

7.2.1 Overview of the CGE model

The CGE model used in this study is described in detail in Capros et. al. In this section we present the main features of the model in a non technical way. Annex B provides a technical description of GEM-E3. The GEM-E3-M50 model is a multi-regional, multi-sectoral, recursive dynamic computable general equilibrium (CGE) model which provides details on the macroeconomy and its interaction with the environment and the energy system. It is an empirical, large scale model, written entirely in a structural form. GEM-E3-M50 allows for a consistent comparative analysis of policy scenarios since it ensures that in all scenarios, the economic system remains in general equilibrium. In addition it incorporates micro-economic mechanisms and institutional features within a consistent macro-economic framework and avoids the representation of behaviour in reduced form. The world version of the GEM-E3-M50 model simultaneously represents 38 regions and 31 sectors linked through endogenous bilateral trade flows. The model features perfect competition market regimes, discrete representation of power producing technologies, option to introduce energy efficiency standards, formulates emission permits for GHG and atmospheric pollutants.

The environmental module includes flexibility instruments allowing for a variety of options when simulating emission abatement policies, including: different allocation schemes for emissions (grandfathering, auctioning, etc.), user-defined bubbles for traders, various systems of exemptions, various systems for revenue recycling, etc.

It formulates separately the supply or demand behaviour of the economic agents which are considered to optimise individually their objective while market derived prices guarantee global equilibrium, allowing the consistent evaluation of distributional effects of policies.

It considers explicitly the market clearing mechanism and the related price formation in the energy, environment and economy markets: prices are computed by the model as a result of supply and demand interactions in the markets and different market clearing mechanisms, in addition to perfect competition, are allowed.

The model formulates production technologies in an endogenous manner allowing for price-driven derivation of all intermediate consumption and the services from capital and labour. In the electricity sector a bottom-up approach is adopted for the representation of the different power producing technologies. For the demand-side the model formulates consumer behaviour and distinguishes between durable (equipment) and consumable goods and services.

Total demand (final and intermediate) in each country is optimally allocated between domestic and imported goods, under the hypothesis that these are considered as imperfect substitutes (the "Armington" assumption). Institutional regimes, that affect agent behaviour and market clearing, are explicitly represented, including public finance, taxation and social policy. The model represents goods that are external to the economy as for example damages to the environment.

The internalisation of environmental externalities is achieved either through taxation or global system constraints, the shadow costs of which affect the decision of the economic agents. In the GEM-E3-M50 model global/regional/sectoral constraints are linked to environmental emissions, changes in consumption or production patterns, external costs/benefits, taxation, pollution abatement investments and pollution permits.

Firms maximize their profits using a Constant Elasticity of Substitution (CES) production function and they operate within a perfect competition market regime. Capital is assumed to be perfectly mobile across sectors but not across countries.

Households maximize their utility using a Lineal Expenditure System (LES) function. Labour supply is derived from a Philips curve that inversely relates unemployment rate and wages.

The model is recursive dynamic over time with endogenously specified investments that are determined using the Tobins'Q (i.e. by comparing the market price of capital with its replacement cost). Moreover it is based on the myopic expectations of the participant agents. The model covers all government fiscal policy and consumption is exogenous in the model. Technology progress is exogenously represented in the production function.

The model is calibrated to a base year data set that comprises a full Social Accounting Matrices for each country/region represented in the model. Bilateral trade flows are also calibrated for each sector represented in the model, taking into account trade margins and transport costs. Consumption and investment is built around transition matrices linking consumption by purpose to demand for goods and investment by origin to investment by destination. The initial starting point of the model therefore, includes a very detailed treatment of taxation and trade.

Once the model is calibrated, the next step is to define a reference case scenario. The reference case scenario includes all already decided policies. The key drivers of economic growth in the model are labour force, total factor productivity and the expectations on sectoral growth.

The "counterfactual" equilibrium can be computed by running the model under assumptions that diverge from those of the reference scenario. This corresponds to scenario building. In this case, a scenario is defined as a set of changes of exogenous variables, for example a change in the tax rates. Changes of institutional regimes, that are expected to occur in the future, may be reflected by changing values of the appropriate elasticities and other model parameters that allow structural shifts (e.g. market regime). These changes are imposed on top of the assumptions of the reference scenario thereby modifying it. To perform a counterfactual simulation it is not necessary to re-calibrate the model.

A counterfactual simulation is characterised by its impact on consumer's welfare or through the equivalent variation of his welfare function. The equivalent variation can be, under reasonable assumptions, directly mapped to some of the endogenous variables of the model such as consumption, employment and price levels. The sign of the change of the equivalent variation gives then a measure of the policy's impact and burden sharing implications.

7.3 Areas for Model Improvement

We have identified the following mechanisms as key in driving the results of CGE models when are used to quantify GHG policies:

1. Expectations and dynamic properties (dealing with myopic expectations)
2. Learning by doing (incorporating the accumulation of knowledge)
3. Labour Market (addressing involuntary unemployment)
4. Investment financing schemes (addressing the suboptimal use of capital)

The first three items are implemented as changes to the model and the fourth was implemented as a policy scenario. Other important aspects such as performing sensitivity runs on a wide plausible range of elasticities of substitution was not performed as it was beyond the scope of this study. The formalisation of a method that would ensure the robustness of model results across a range of elasticities of substitution is an interesting aspect that can be further investigated in the future.

Relevant notational details are specified in Box 7.

Box 7: Notation

Superscripts

"*Ref*" denotes the reference.
"*M50only*" denotes the 50% GHG reduction
"*Cf*" denotes the M50only scenario with additional model changes.

Subscripts

"i" is the sectoral index.
"j" is the regional index.
"t" is the time index.

7.3.1 Expectations

There are two main approaches in modelling time in CGE models: i) The recursive dynamic approach where multiple static equilibria are linked with a stock flow relationship of capital and investment and ii) an inter-temporal or completely dynamic approach where agents optimize their objective functions over the entire simulation period.

Both approaches are mainly characterised by the way agents form their expectations. Expectations can be myopic (i.e. set of decision parameters is constant over time), adaptive (past and current level of decision parameters are used in agents optimization problem) and rational expectations (access to the complete information set, both present and the future).

In the GEM-E3-M50 model agents have myopic expectations with respect to prices. Investment is formulated by:

$$INVV_{i,t} = A1_{i,t} \cdot K_{i,t} \cdot \left(\left(\frac{PK_{i,t}}{PINV_{i,t} \cdot (r_t + d_{i,t})} \right)^A + STGR_{i,t} + d_{i,t} \right). \quad (5)$$

where $A1$ is a calibrated scale parameter; K is the optimal demand for capital; $PINV$ is the unit cost of investment; d is the depreciation rate; r is the national interest rate and $STGR$ is the exogenous agents expectations on sectoral growth.

The update of the capital stock is given by the following motion equation:

$$K_{i,t} = K_{i,t-1} \cdot \left(1 - d_{i,t}\right) + INVV_{i,t-1}. \quad (6)$$

The STGR parameter is used to adapt the expectations of the agents regarding the future rate of return on capital so as to implement investment plans consistent with the realized.

For the purpose of better representing expectation dynamics, the adjustment of STGR was implemented in the following way:

$$STGR^{Cf}_{i,j,t} = STGR^{Ref}_{i,j,t} \cdot \left(\frac{Q^{Cf}_{i,j,t-1}}{Q^{Ref}_{i,j,t-1}} \right)^2. \quad (7)$$

The calculations are done recursively since STGR parameters are needed to compute current output. Output values per country and per sector, $Q_{i,j,t-1}$, are used. In sectors where the output in the reference is small (e.g. Biomass), an increased output in a counterfactual scenario lead to a high adjustment of the STGR parameter. To keep the correction within a reasonable range, the correction factor is limited to a range from 0.5 to 3, i.e.

$$0.5 \cdot STGR^{Ref}_{i,j,t} \leq STGR^{Cf}_{i,j,t} \leq 3 \cdot STGR^{Ref}_{i,j,t}. \quad (8)$$

7.3.2 Learning by doing

In GEM-E3-M50, the values for the total factor productivity $TFP_{i,j,t}$ are given exogenously as a result of a dynamic calibration of the model to exogenously given GDP growth rates. An endogenous growth model would require the link of TFP with endogenous decision on R&D and innovation. In our approach we have semi-endogenised TFP in order to reflect learning by doing effects from higher production. The equation below provides the computation of TFP by taking into account the changes in production.

$$TFP^{Cf}_{i,j,t} = TFP^{Ref}_{i,j,t} \cdot \frac{Q^{Cf}_{i,t-1}}{Q^{Ref}_{i,t-1}} \tag{9}$$

Here $Q_{i,t-1}$ is the sum of the sectoral outputs over all regions j, i.e. $Q_{i,t-1} = \sum_j Q_{i,j,t-1}$ because for technological progress spill-over effects between different regions are important. The correction factor $Q^{Cf}_{i,t-1}/Q^{Ref}_{i,t-1}$ represents the fact that technical progress in a given sector depends on the investment in the sector: the more is being invested, the faster is the technical progress. Nagy et al. 2010 provide the best statistical analysis so far of the main hypothesis about endogenous technical progress.

To keep the correction within a reasonable range and to make sure that shrinking sectors do not ”unlearn”, the correction factor is limited to a range from 1 to 3, i.e.

$$TFP^{Ref}_{i,j,t} \leq TFP^{Cf}_{i,j,t} \leq 3 \cdot TFP^{Ref}_{i,j,t}. \tag{10}$$

7.3.3 Labour Market

A critical feature of the labour market representation in CGE models is the dynamic calibration of the labour supply elasticity. In cases with high unemployment rates it is important that the additional demand for labour is met by the pool of unemployed without any impact on the wage level. As unemployment is reduced it is expected that additional demand for labour will gradually exert an upward pressure on the labour market.

In the current study the model changes focused on the dynamic calibration of the labour supply elasticity.The idea is that the elasticity of labour supply is not independent from the level of unemployment, meaning that with a high unemployment level, increasing employment will lead to less steep increases in wages. For the reference case the relation between wage $w_{j,t}$ and unemployment rate $U_{j,t}$ is

$$w_{j,t}(U_{j,t}) = a_{j,t} + \frac{b_{j,t}}{U_{j,t}^{\eta^{Ref}_{j,t}}}. \tag{11}$$

This has been modified, and the elasticity for the counterfactual $\eta^{Cf}_{j,t} = \eta^{Ref}_{j,t}(1 + 2(U^{Ref}_{j,t} - U_{j,t}))$ now depends on the unemployment rate. That means, the formula for the relation between wage and unemployment then is

$$w_{j,t}(U_{j,t}) = a_{j,t} + \frac{b_{j,t}}{U_{i,j,t}^{\eta^{Ref}_{j,t}(1+2(U^{Ref}_{j,t} - U_{j,t}))}}. \tag{12}$$

In the case of a difference in unemployment rates with respect to the reference case, wage adjustments depend on the unemployment rate. For the unemployment rate of the reference, this yields the elasticity of the reference, for larger unemployment rates the elasticity becomes smaller than in the reference, and for smaller rates the elasticity becomes larger.

7.3.4 Investment financing schemes

As described before, the current situation in Europe is characterized by a suboptimal use of capital (low levels of investments etc.). Something to be aware of is that new investments do not necessarily crowd out other investments but are additional investments. In this case, increasing investment levels can actually improve the economic situation. Implementing this as a model change was beyond the scope of this study. But an increased investment level can also be implemented as a change in policy, meaning that the government implements a specific policy which triggers additional investments.

For the present study, a public investment impulse was modelled in the following way: an increase of the VAT is assumed, the revenues of which are used to subsidise investment. It needs to be pointed out that the important part mechanism we want to show is the effect of the investment impulse and not how the additional investment is funded. Considering the high levels of public debt in the European Union, the aim should be to trigger as much private investment as possible. This issue has been discussed in the policy challenge.

In the implementation, the required additional VAT rate is calculated such that the government revenues are increased by 10% compared to the M50only case. That means that the required VAT rate is determined through:

$$\text{VATrevenues}^{Cf} = \text{VATrevenues}^{M50only} \cdot 1.1 \quad \perp \quad \text{VATadditionalRate}^{Cf} \tag{13}$$

The subsidy per unit of investment, P^{INV}_{Sub}, is calculated in a way that the new investment is equal to the M50only investment plus the additional VAT revenues:

$$INV^{Cf} = INV^{M50only} + \text{VATadditionalRevenues}^{Cf} \quad \perp \quad (P^{INV}_{Sub})^{Cf} \quad \text{and} \tag{14}$$

$$P^{Cf}_{INV} = P^{M50only}_{INV} \left(1 + (P^{INV}_{Sub})^{Cf}\right), \tag{15}$$

with P^{INV}_{Sub} being a negative value here.

7.4 Scenario Definition

7.4.1 Reference Scenario

The reference scenario is the benchmark against which all policy/counterfactual scenarios are evaluated. The development of a reference scenario can be performed:

- Either by the dynamic calibration of the model to a predefined outlook
- Or by mere use of projections for the key drivers of growth: Technical progress and population

A reference scenario when used for applied modelling purposes should include all policies already decided and in place. As mentioned in the previous section a reference scenario represents the optimum path in the absence of any frictions and imperfections. The main underlying assumption in building a reference scenario with the GEM-E3-M50 model is to model a sustainable output growth rate for all countries where for example excessive current account deficits or surpluses are gradually eliminated. This is in line with a zero output gap.

The output gap suggests that the economy operates in an inefficient non sustainable manner (either through overworking or underworking).

In the GEM-E3-M50 model the macro-economic projections of the reference case are consistent with the 2013 Ageing Report prepared by DG ECFIN (DG ECFIN, 2012). EU28 has an almost constant growth rate of 1.5% over the period 2015-2050. In the same period working age population is decreasing which means that labour productivity needs to increase so as to sustain the GDP growth rate.

7.4.2 Central Scenario M-50 (M50 only)

In this scenario EU28 undertakes to unilaterally decrease its GHG emissions by 50% compared to 1990 (46% reduction from 2005). Non-EU countries continue their reference GHG policies (i.e. pledges until 2020 and no intensification of GHG policies thereafter). In this scenario it is assumed that emission reductions are done in a cost-efficient manner, which means emission reductions with the lowest abatement costs will be realized first [35] In the central case scenario it is assumed that carbon tax revenues are not recycled back to the economy but they are used instead to improve the public budget (increase public surplus or decrease public deficit).

7.4.3 Variants of the M50 Scenario

In order to evaluate the performance of the different mechanisms described above, a series of scenarios was quantified with the model. These scenarios involve the activation of one or more of these respective mechanisms. The scenarios quantified are described in Table 3. The mechanisms take effect in 2015 and are applied for the entire period up to 2030 in all scenarios.

The parameterization of tfp for Germany for scenario “M50all” can be found in Annex A as an example. This serves to illustrate the magnitude of the effect on tfp.

The focus of this study was to evaluate different mechanisms based on an ambitious climate target, in order to see which mechanisms can trigger a shift from negative to positive economic effects. It is not easily possible to compare the effects of the mechanisms based on a climate target with the mechanisms based on the reference scenario, as this raises new questions about the size of the investment impulse and therefore comparability issues. This was beyond the scope of this study but would be an interesting next step.

7.5 Results

7.5.1 Macroeconomic aggregates

Table 4 shows annual growth rates and Table 5 the labour market outcomes from 2015 to 2030 for the reference scenario. We can see that the population as well as the labour force are slightly decreasing and the employment level is increasing.

Table 3: Definition of Scenarios

Abbreviation	Scenario	Description
M50 only	M-50	-50% reduction of ETS GHG emissions compared to 1990
M50 tl	M-50 with technology learning	Learning by doing effects are introduced in the sectors producing both clean energy technologies and other equipment goods
M50 exp	M-50 with adaptive expectations	The investment decision of firms is adjusted so as to reflect rational expectations rather than myopic expectations
M50 lm	M-50 with flexible labour market	Labour supply elasticity is dynamically calibrated
M50 inv	M-50 with alternative financing	Part of the investment required to decarbonise the EU economy is financed by increasing consumption taxes
Scenario Combinations		
M50 tl+inv	M-50 with technology learning and alternative financing	
M50 tl+exp+inv	M-50 with technology learning, adaptive expectations and alternative financing	
M50 all	M-50 with all mechansims together	
With energy efficiency improvment goals		
EE40	M-50 only in combination with 40% energy efficiency improvments	
EE40 all	M-50 with all mechansims in combination with 40% energy efficiency improvments	

Table 4: Macroeconomic Annual Growth Rates of the Reference Scenario

EU-28	2015-20	2020-25	2025-30
Gross Domestic Product	1.5%	1.6%	1.5%
Investment	1.4%	1.6%	1.5%
Public Consumption	1.6%	1.6%	1.5%
Private Consumption	1.6%	1.7%	1.6%
Exports	2.0%	2.0%	2.1%
Imports	2.3%	2.3%	2.3%
Labour productivity	1.2%	1.6%	1.7%

Source: Own calculations using GEM-E3.

Table 5: Labour Market Outcomes of the Reference Scenario

EU-28	2015	2020	2025	2030
Employment (in m. persons)	224	227	227	225
Population (in m. persons)	434	436	432	425
Labour Force (in m. persons)	101	102	101	99
Unemployment rate	11%	10%	9%	9%

Source: Own calculations using GEM-E3.

This sections shows the main finding of the simulations using a CGE model that partly endogenizes learning-by-doing effects and adaptive expectations, and takes into account the effects of involuntary unemployment on the labour market.

The macroeconomic aggregates for all scenarios in 2030 compared to the Reference are shown in Table 6. For GDP and employment, the results for 2030 are also depicted in Figures 12 and 13. Additionally, for GDP the time series is also shown in Figure 11.

Table 6: Results for the EU28 in 2030 compared to Reference

	M50 only	M50 ln	M50 exp	M50 lm	M50 inv	M50 all	EE40	EE40 all
GDP	−0.56%	−0.22%	−1.04%	−0.51%	−0.24%	9.73%	−0.57%	9.97%
Investments	−0.40%	−0.01%	−0.49%	−0.34%	2.49%	18.37%	−0.53%	19.85%
Consumption	−0.71%	−0.26%	−1.52%	−0.65%	−1.12%	5.54%	−0.73%	5.61%
Exports	−0.56%	−0.39%	−0.93%	−0.53%	−0.33%	25.28%	−0.24%	24.50%
Imports	−0.12%	0.00%	−0.58%	−0.09%	0.06%	7.09%	0.09%	6.72%
Employment	−0.76%	−0.46%	−1.41%	−0.66%	−1.21%	1.18%	0.66%	2.21%
Energy Use	−4.91%	−3.83%	−5.57%	−4.87%	−4.87%	−2.73%	−19.06%	−16.62%

Source: Own calculations using GEM-E3-M50.

We can see that the two policy scenarios, M50only and the EE40only (no model changes applied), show a decrease in GDP compared to the reference scenario (-0.56% and -0.57% lower GDP in 2030 compared to reference). This is in line with the outcomes of the European Commission Impact Assessment Report on the 2030 climate and energy framework, where a 40% GHG target lead to a decrease of GDP between -0.1% and -0.45% in 2030 compared to reference (see Section 3).

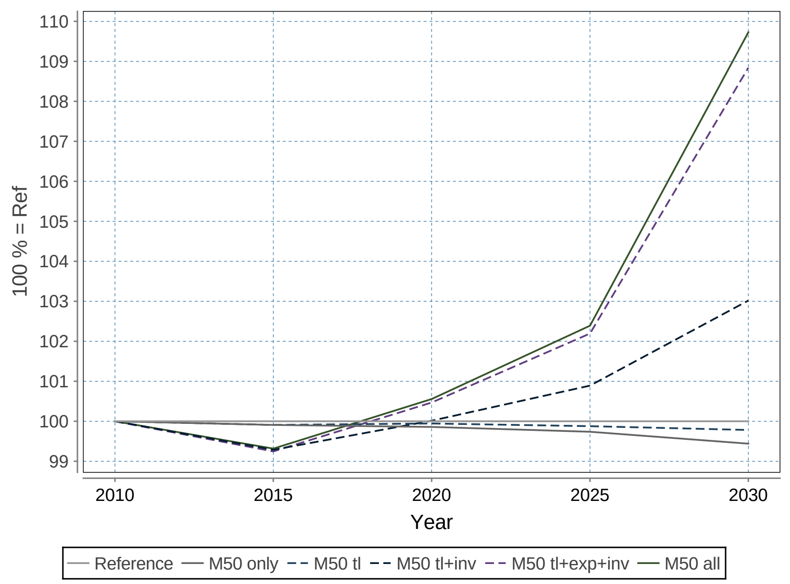
Negative outcomes can also be seen in the scenarios where M50 scenario is combined with only one of the model changes (tl, inv, lm), however the negative effect becomes smaller. The introduction of myopic expectations (exp) however, is causing a decrease in GDP compared the M50 only scenario, because it amplifies positive as well as negative effects. This is caused by the way the expectations dynamics where introduced in Equation (7).

However, the combinations of the individual changes (tl, exp, lm) with the investment impulse have positive effects, which indicates that an investment impulse may have a critical role in alleviating the negative crowding out effects. The investment impulse triggers endogenous technological learning due to the higher production levels, and therefore show positive GDP effects compared to the reference scenario. The change of the expectation dynamics in the model amplifies this growth effects as shown in the M50 tl+exp+inv scenario (see Figures 12). For the combination of all supposed model changes, the scenario with an ambitious climate policy target results in a state of the economy with a higher GDP compared to the reference case in 2030. When looking at the time series (see Figures 11) from 2015 to 2030, one can see that there is a dip in GDP at first which is due to the fact that the GDP effects from the additional investments are realized with a time lag of 5 years in the model. Investments are 2.5%

[35] This means that no effort-sharing options are taken into account here. Effort-sharing between countries would lead to a less optimal outcome, hence larger economic costs.

higher in 2015, 5.5% in 2020, 8.6% in 2025 and 19.9% in 2030. Respectively GDP growth is 0.7% lower in 2015, but 0.56% higher in 2020, 2.24% in 2025 and roughly 10% higher in 2030.

Figure 11: GDP EU28 compared to Reference



Source: Own calculations using GEM-E3-M50.

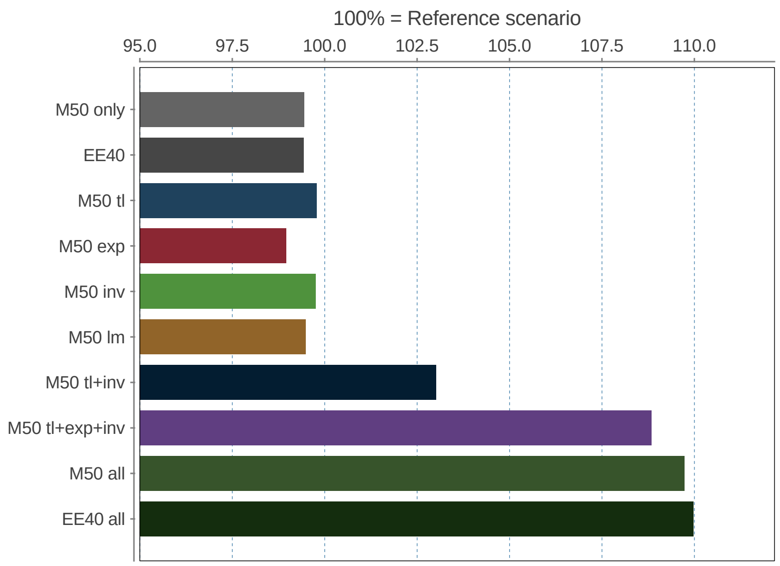
For employment, the effects are similar, M50 and combinations of M50 plus one model change show negative effects on employment. EE40only shows a positive effect on employment (0.66%), even without the model changes. This is again in line with the European Commission Impact Assessment Report on the 2030 climate and energy framework, where additional Energy Efficiency targets showed positive employment effect between 0.3% and 0.5% in 2030 compared to reference. Hence, the 40% energy efficiency goal has a stronger positive impact on employment than on GDP. For the combined scenario (EE40 all) the employment effect is above 2% in 2030 as compared to reference.

Figure 14 shows the energy intensity in 2030 for all the scenarios. The strongest decrease is obtained in the scenarios with a 40% energy efficiency goal.

Hence, a 50% GHG emission target and a 40% energy efficiency target combined with an investment impulse reduces energy consumption and GHG emissions substantially, with a positive impact on GDP and employment.

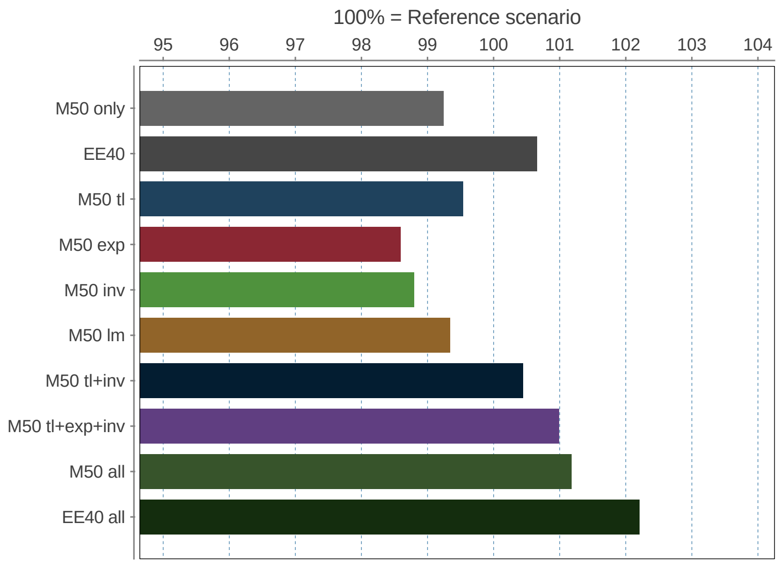
Overall, the macroeconomic results show that a green investment impulse may have a positive impact on the economy, as compared to the reference scenario. The single model changes did not have a large impact on the results because mechanisms such as technical progress and expectation dynamics need a trigger. This trigger is provided by the investment impulse, which in combination lead to significantly better results.

Figure 12: GDP (EU28 2030) compared to Reference



Source: Own calculations using GEM-E3-M50.

Figure 13: Employment (EU28 2030) compared to Reference

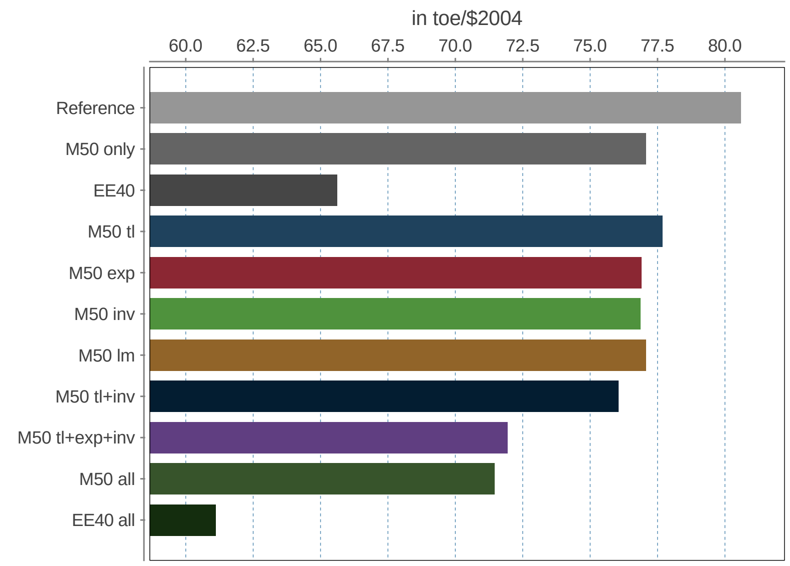


Source: Own calculations using GEM-E3-M50.

7.5.2 Sectoral impacts

At a sectoral level it is the energy sector and energy-intensive sectors that contribute most to the abatement process. Whereas sectors contributing to the transition to the low carbon econ-

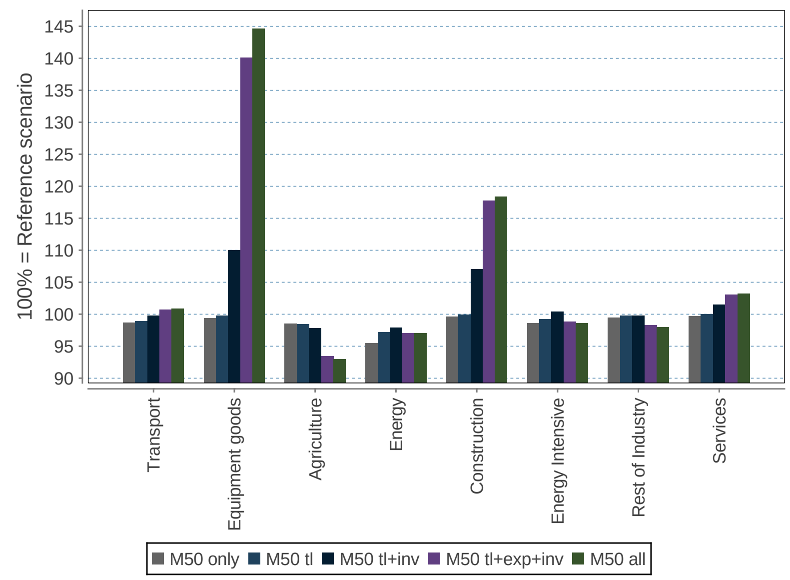
Figure 14: Energy Intensity (EU28 2030)



Source: Own calculations using GEM-E3-M50.

omy like construction and equipment goods will benefit most in terms of increased production. The production levels of the different sectors are presented in Figure 15.

Figure 15: Sectoral results (EU28 2030)



Source: Own calculations using GEM-E3-M50.

7.5.3 Regional impacts

The results of the different scenarios are presented in 4 EU regional groups. Each member state has been allocated to each group according to their 2010 ranking on a composite index that is composed of GDP/capita and energy intensity (applying a 50-50 weight). The composite index is calculated as follows:

$$Index = 0.5 \cdot percentile\left(\frac{1}{EnergyIntensity}\right) + 0.5 \cdot percentile\left(\frac{GDP}{population}\right) \tag{16}$$

The four groups are defined as the quantiles of the composite index. Quantile 1 represents countries with low GDP/Capita and high energy intensities while Quantile 4 represents the group of countries with high GDP/Capita and low energy intensities. The groupings of the respective countries are described in detail in the table below:

Box 8: Country Groups

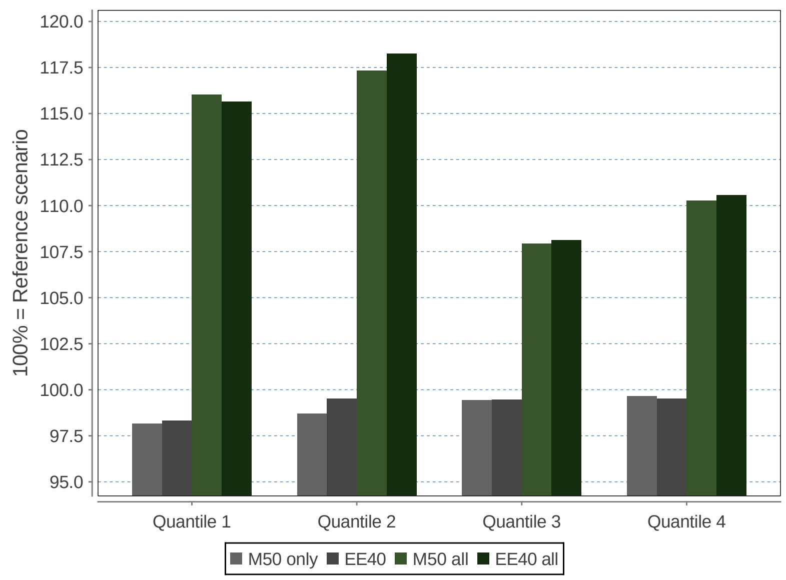
Quantile 1: Bulgaria, Romania, Latvia, Lithuania, Estonia, Poland, Hungary
Quantile 2: Croatia, Czech, Slovakia, Malta, Slovenia, Greece, Cyprus
Quantile 3: Portugal, Spain, Italy, Belgium, Germany, Finland, Austria
Quantile 4: France, Netherlands, UK, Sweden, Denmark, Ireland, Luxembourg

The effect on GDP (see Figure 16) is largest for the countries in quantile 1 and 2, which are mostly Eastern European countries and some Southern European countries. The effect on employment (see Figure 17) turns positive due to the additional energy efficiency target in all regions. Increases of employment are highest in quantile 3. The effect on GHG emissions (see Figure 18) is highest for countries in quantile 1, as these are the countries that had the highest energy intensity in the beginning and they are catching up over time.

7.6 Concluding Remarks

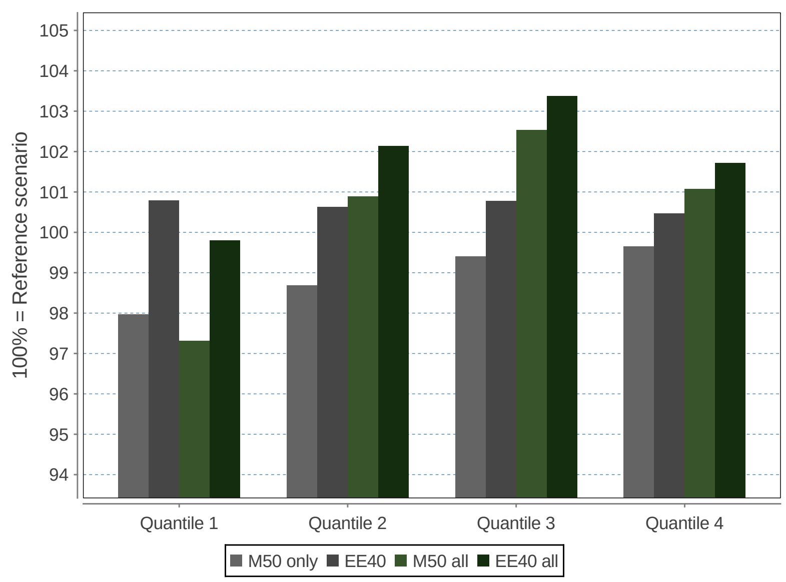
CGE models are powerful tools in addressing resource reallocation problems and probably the most widely used tools utilised for development and planning. Grounded on rigorous microeconomic theory foundations and by using mainly publicly available data sets they provide a transparent and consistent approach in comparing competing policies. However there is still room for improvement mainly regarding the modelling of market imperfections. Several CGE model development efforts exist that depart from the classical perfect market general equilibrium paradigm (see Willenbockel for incorporating imperfect competition and Boeters for modelling involuntary unemployment). Our current research identified key mechanisms that are important in determining the overall results of a typical CGE model in mitigating GHG emissions. These mechanisms relate to the crowding out effect (full employment of resources), learning rates, the dynamic properties of the model and the flexibility of the labour market. We

Figure 16: GDP effects by region in 2030



Source: Own calculations using GEM-E3-M50.

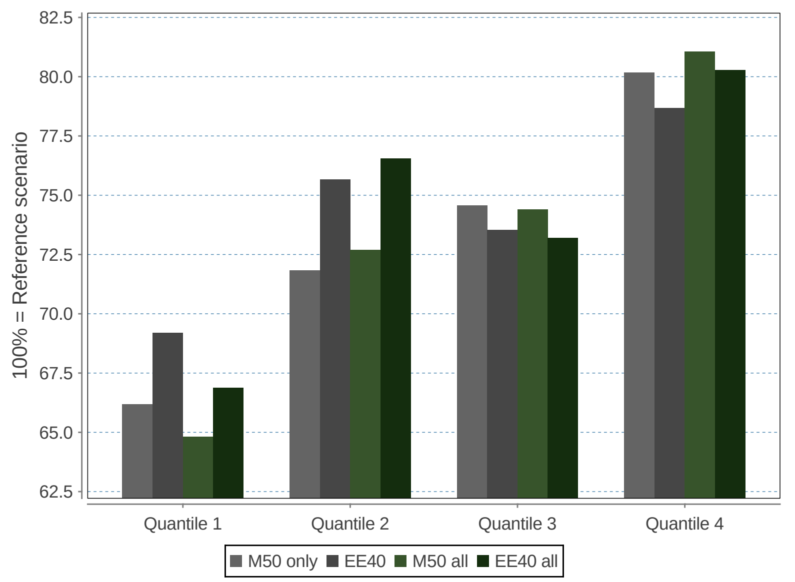
Figure 17: Employment effects by region in 2030



Source: Own calculations using GEM-E3-M50.

have highlighted the importance of these mechanisms by employing simple adjustments to the model. It should be noted that these suggested modelling improvements only show the mechanism at place but they lack empirical validation regarding their parameterization and hence the magnitude of the impact.

Figure 18: GHG emissions by region in 2030



Source: Own calculations using GEM-E3-M50.

8 Green Growth in IMACLIM

Similar results as the GEM-E3 simulations shown in Chapter 7 have also been obtained with IMACLIM-R (Cassen et al. 2010), developed at CIRED, Paris, which is well established in the literature. For the present runs it has been combined with the energy sector model WEM of the International Energy Agency.

IMACLIM is a general computable equilibrium (CGE) model for Europe that exhibits some special features, of which for this study the most important ones are generally speaking:

1. IMACLIM incorporates frictions, i.e. although a general equilibrium point determines the direction of the system's dynamics, equilibrium is not obtained immediately after a deviation but some adjustment time is needed.

2. IMACLIM takes into account learning-by-doing in all sectors and regions.

8.1 Scenario Description

GDP is depicted for a reference scenario (R), three intermediate scenarios (V0-V2), and a green growth scenario (V3) where the overall investment level is increased. The five scenario are:

- *Reference (R)*: The reference scenario (R) is characterized by a (Japanese-like) stagnation. Regarding exogenous parameters, no US monetary policy for controlling the exchange rate between the dollar and the euro and no geo-political shock changing the dynamics of the oil prices were assumed. Furthermore, the absence of an integrated policy in the EU, which would result in a fast catch-up to before-crisis labor productivity trends, is assumed. This before-crisis natural labor productivity trend was expected to catch up with US labor productivity level around the year 2040 and then follow an historically observed 1.7% per year growth rate. Instead, the assumption is that Europe follows a Japanese stagnation profile with the catch-up taking place only in 2060.

- *Decarbonisation measures and a unique price for carbon throughout the economy (V0)*: A unique carbon price is introduced that signals the overall efficiency of reaching a given decarbonisation target and comes to consider that climate policies have to be conducted for pure climate objectives independently from other sustainable development objectives.

- *V0 + Structural policies (V1)*: Climate policies are adopted together with other structural policies aiming at a more sustainable development in Europe. These are twofold: 1. Capacity building and industrial policies: the low carbon transition mobilizes activities which are mostly sedentary in the sense that they are local-specific (a railway system, a windfarm). They are thus promoting a more inward oriented industrialization with domestic markets less exposed to direct international competition like automobile or steel industry. However, to maximize their positive effect on growth and employment it matters a) to secure the availability of appropriate skilled manpower and b) to conduct consistent industrial policies securing that most of the segments of the value chain are produced domestically. 2. Redirection of investment in the transportation sector and in urban planning to reduce constrained mobility needs, improve traffic regulation and increase the share of non-gasoline based transportation modes.

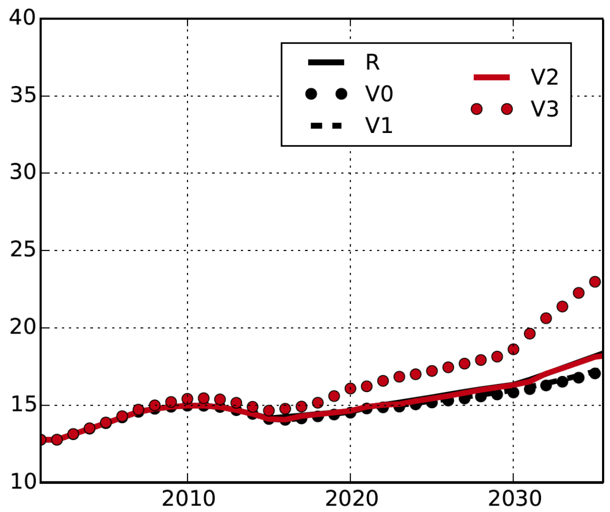
- *V1 + Recycled carbon taxes (V2)*: The major reason why the two previews policy packages, despite optimistic assumptions about the penetration of energy efficiency and about the deployment of structural policies still result in a negative impact on growth by comparison with the Japanese-like baseline is the adverse mechanisms resulting from higher production costs. The only way to prevent this propagation mechanism is to raise a carbon tax and to recycle its revenues into the economy so as to decrease the tax burden on production proportionally, which is done in this scenario. The optimal recycling is country specific and carrying out a precise study for each country was beyond the scope of this study.

- *V2 + Investment Stimulus (V3)*: The final policy package incorporates a financial device which both lowers investment risks in low carbon projects and redirects savings towards the low carbon transition. It does so by upgrading the efficiency of financial intermediation which allows for offsetting the crowding-out effect on other productive sectors by increasing the share of the savings dedicated to long-term investments instead of speculative short-term investments.

8.2 Results

In Figure 19 preliminary simulation results until 2035 can be seen.

Figure 19: GDP - EU until 2035



Source: Own computations using IMACLIM-R. June 1st, 2015.

Figure 19 shows annual GDP growth rates for all scenarios, unemployment compared to the reference is given in Figure 19. The results of V0 (introduction of a carbon price) are very similar to other assessments of climate policy, where climate policy is introduced as an additional constraint which leads to lower rates of GDP and employment. Comparing scenario climate-only (V0) to the reference scenario (R) shows, unsurprisingly, a GDP loss which is negligible up to 2020 given the low level of the carbon price but increases steadily as these carbon price increases. The economic growth rate of this policy variant is 19.2% lower than the growth rate of the baseline scenario in 2020-2025 and still 16.4% lower in 2030-2035, which demonstrates that the deployment of endogenous technical change is not fast enough to compensate the rise of the carbon price which culminates around €400 in 2030-2035. This result is unsurprising because, in the absence of companion fiscal policy to offset its impact by lowering the fiscal charge which falls ultimately on production, higher energy costs propagate throughout all the sectors and results in higher production costs. The results of V2 show that recycling the revenues from the carbon tax will almost offset the negative impact of the carbon price on GDP and employment. Scenario V3 is the only one showing a substantial increase in investments.

The main result for the green growth scenario (V3) is that GDP growth is significantly higher than in the baseline scenario at all time periods including the short-term. The important difference is that in this scenario, additional investments are realized, therefore “green” investments do not only crowd-out other investments. The results show that a higher GDP growth rate as well as a significant decrease of unemployment can be obtained. At the end of the simulation period the GDP growth rate in Europe exceeds 4% per year.

Table 7: Annual Growth Rates of GDP in %

Scenario	2010-2035	2015-2020	2020-2035	2030-2035
R	0.78	0.65	1.46	2.16
V0	0.52	0.57	1.08	1.51
V1	0.56	0.64	1.11	1.49
V2	0.77	0.73	1.43	2.13
V3	1.61	1.89	2.41	4.3

Source: Own computations using IMACLIM-R. June 1st, 2015.

Table 8: Unemployment rate indexed to Reference

Scenario	2015	2020	2025	2030	2035
R	1	1	1	1	1
V0	1.02	1.04	1.11	1.15	1.31
V1	1.02	1.02	1.08	1.11	1.28
V2	1.02	1	1.03	1.01	1.02
V3	0.9	0.75	0.78	0.79	0.93

Source: Own computations using IMACLIM-R. June 1st, 2015.

The major sources of growth activated by the green growth scenario are:

- the recycling of the revenues of carbon prices which can turn the negative impact of higher energy prices into a (very slight) gain after two to three years,
- the short-term impact of lowering the risk for investments in the energy sector and energy-related investments in other sectors,
- the short-term impact of increasing, at the margin, the share of the savings of households that is invested in energy efficiency (in the real world this is less savings trapped in the financial intermediation; in IMACLIM, this is more investment with a larger share directed to domestic economies (instead of going into the world pool of capital),
- a short and medium-term impact of a more inward-oriented economic strategy with a higher demand for non-exposed activities or, what PN Giraud calls sedentary activities; in modelling terms this translates into a lower income and price elasticity of imported goods in domestic markets,
- the medium and long-term productivity effect of a) higher productivity of energy as a production factor and b) gains from learning by doing on the production of equipments due to higher investments in all sectors triggered by higher growth and cuts of investment risks in the energy-related sectors. The impact is low in the short-term but high in the long-run, accelerating the catching-up of the EU economy,
- the short, medium and long-term positive feedback due to higher employment rates triggered by a) lower labor costs for the same level of public expenditures b) enhanced activity due to higher investments c) higher domestic demand addressed to domestic labour.

9 Green Growth in Agent-based Models

To complement the results from the previous sections, this section presents agent-based approaches to analysing investment-oriented climate policy in view of a sustainability transition. Computational agent-based models (ABMs) work by implementing agents on a computer, equipping them with rules for decisions and interaction, and observing the macro-level behaviour of the modelled system from simulation runs that compute the outcomes of repeated interactions between agents. Agent-based modelling thus provides a way of considering out-of-equilibrium dynamics in economic systems. As there is a large freedom in how to represent agents, some of the mechanisms identified in Section 5.3 are easy to implement in ABMs. For example, agents can have limited information and be endowed with expectations about variables they do not have full knowledge about.

At the same time, and partly due to the large freedom of what to represent and how, ABMs quickly become complex. It may therefore be difficult to relate an ABM to real-world data in a meaningful way. This is, however, a prerequisite for producing simulations that are relevant for policy analysis. Applied ABMs that have produced policy relevant outputs are still rare. This section presents work in progress from two promising approaches towards policy analysis of a sustainability transition with the help of ABMs: Section 9.1 presents preliminary results from STOEMSys – Sustainability Transition Open Economic Modelling System. Section 9.2 describes how sustainability concerns are currently being included in the EURACE model.

9.1 Analysis Using STOEMSys

The Sustainability Transition Open Economic Modelling System (STOEMSys) is a modelling system that is being developed at GCF. This work has been funded by the German Federal Ministry for the Environment, Nature Conservation, Building, and Nuclear Safety through Project 03KSE041 (Bewertungsmodul Klimapolitik). A detailed description can be found in (Jaeger et al. 2015).

9.1.1 STOEMSys Overview

STOEMSys' focus is to provide a tool for simulating a *sustainability transition*, technically speaking this means that the implemented models are able to deal with multiple equilibria and provide a dynamic for transitions between them.

It is an *open* system in two respects: It is designed to be extended by additional components. Its modular architecture is geared towards complementing a macroeconomic module with information from detailed models of specific climate-relevant sectors, in order to strike the right balance between sectoral considerations and the macroeconomic "big picture" for assessing effects of climate policy. Secondly, all STOEMSys computer code is open source and is freely available upon request.

It is an *economic* modelling system aimed at evaluating costs and benefits of climate policies. The system is designed in a way that these can not only be reported in monetary terms but also in non-monetary terms with explicit reference to particular agents (e.g. unemployment, GHG emissions, etc.).

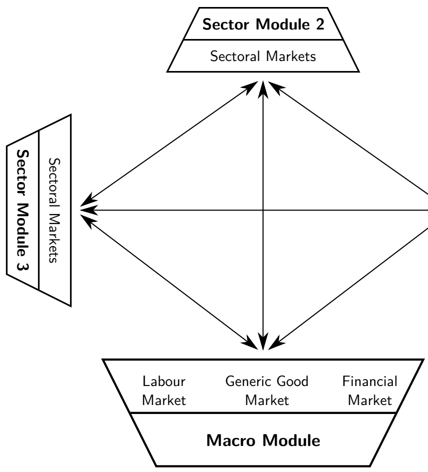
STOEMSys is a *modelling system* in the sense that it provides a variety of different tools for tackling the task of producing economic simulations of a sustainability transition. It thus is a framework of elements necessary for producing such models, that shall – in contrast to standard climate policy analysis models and via the representation of multiple equilibria which these do not provide – be able to identify win-win strategies for climate policy. This requirement made it necessary to think out of the (usual climate policy simulation) box; especially the need for non-equilibrium dynamics means that trodden paths are being left.

9.1.2 Implementational Characteristics

Characteristic features of the modelling building block are:

- *Aggregate agents*: The economic agents (firms, households, . . .) are implemented in an aggregate manner. Currently every good is produced by only one firm, and a firm produces only one good. Agents have decision functions that determine their behaviour, e.g. a firm's production planning or investment decision.
- *Modular architecture*: For climate-economic cost-benefit analysis emissions play a crucial role. They are distributed unevenly throughout the economy (see Section 3, and potential measures for reducing emissions differ substantially between sectors. Any analysis of measures taken to reduce emissions needs to take into account a "bottom-up" analyses of the climate-relevant sectors. However, policies targeted at a specific sector will also have cross-sectoral, labour market or other macroeconomic effects. A macroeconomic view is thus necessary, which concerns the whole economic system. In order to strike the right balance between sector-specific considerations and macro-economic effects, STOEMSys uses a modular approach: it supplies a model architecture in which a macro-economic module and detailed sector-specific modules can complement each other for the assessment of costs and benefits of climate and energy policy measures. Here, the macro-module depicts the rest of the economy that is not modelled in detail using a specific sectoral module. Figure 20 gives an overview of the modular structure. Each module also contains one or more markets. For sectoral modules these are the markets for the goods produced within this sector. The macro-module contains labour and financial markets as well as a market for the "generic good" which represents all the goods not produced in a sectoral module.
- *Price dynamics through expectations and learning*: One central question in non-equilibrium economic modelling is how prices are set and how they adjust over time. In STOEMSys, there is a possibility to choose a price-dynamics mechanisms which is based on firms' expectations and learning. It is assumed that the main objective of every firm is to maximize its profit, but in the situation of perfect competition, for an aggregate firm this means that the optimal aggregate extra-profit (i.e. the difference of revenues and labour and capital costs) is zero (e.g. see von Neumann 1945). The outcome of this optimization in combination with the firm's demand expectations determines the price of

Figure 20: Modular Architecture



the good. Price development depends on different assumptions of the (aggregate) firm concerning the demand for its good, on assumptions about the costs, as well as on the adjustment process for the expected demand.

For the simulations shown in the next section, a model was used which is a combination of a macro-module with a simple sectoral buildings module. For a complete documentation of the model see Chapter 10 of Jaeger et al. (2015).

Below, outcomes of two different simulations (Case 1 and Case 2) are shown. In both simulations there are two scenarios, one Business-as-usual scenario (BAU) and one Green Growth scenario (GG). The difference is that in the Green Growth scenario the rate at which buildings are renovated (retrofit rate) is increased. This assumes that the retrofit rate can be increased with policy measures.

9.1.3 Scenarios and Simulation Results

The model used for simulations couples a sectoral STOEMSys-module representing the building sector (BS) with a STOEMSys macro-module (MM) representing the rest of the economy. The model and modelling results have been described in much more detail in Jaeger et al. (2015).

In total there are four agents, two in the macro-module (household, generic firm) and two in the sectoral module (retrofit firm, construction firm) and three goods (generic good, retrofitting, construction of green buildings), each of which is provided by the respective firm. Table 9 gives an overview. All agents own a part of the building stock, which consists of "brown" and "green" buildings. Retrofitting turns brown buildings into green buildings, and newly constructed buildings are always green.

Table 9: Agents

Agent	module	supplies	demands
Household	MM	labour	generic good, retrofitting, construction
Generic firm	MM	generic good	labour, generic good, retrofitting, construction
Retrofit firm	BS	retrofitting	labour, generic good, retrofitting, construction
Construction firm	BS	construction	labour, generic good, retrofitting, construction

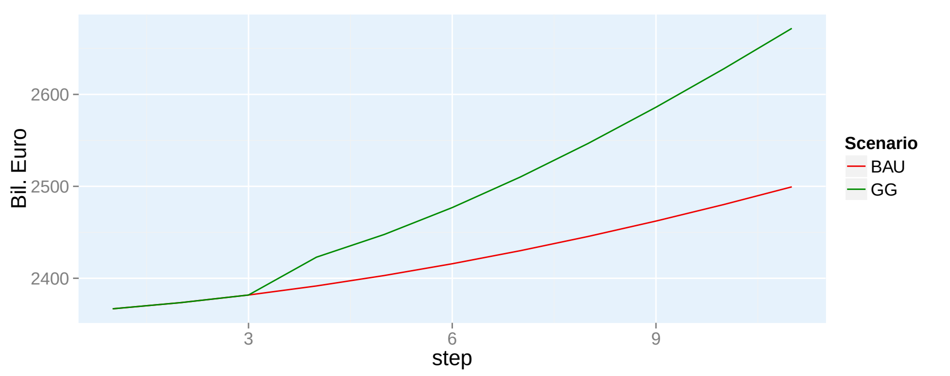
The model was initialized with aggregate German economic data of the year 2010, and run for 10 steps, representing the years up to 2020. The level of GDP in the simulation results is stated in billion Euro, the same as for the input data used.

In a first simulation (Case 1), all agents use very simple decision rules without the expectation-based price dynamics mentioned in Section 9.1.2.

Here, the relevant mechanism is a policy that increases the retrofit rate from 0% of brown buildings in the BAU scenario to 3% in the GG scenario starting in time step 3. Because the built environment is the largest fraction of fixed capital, climate policies aiming at increasing its energy efficiency can be designed so as to trigger a significant increase in total investment, which in turn spurs additional growth. If more sectors were added (e.g. a power sector), emissions could be reduced much more while preserving the higher growth path.

Figures 21 and 22 display simulation results for GDP and emissions.

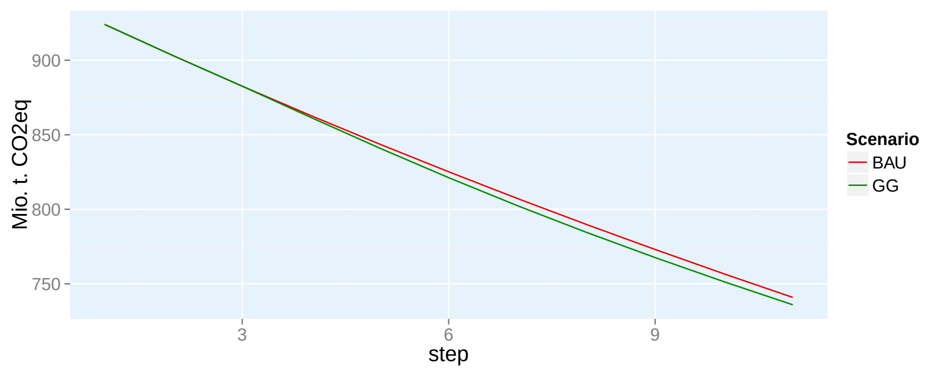
Figure 21: GDP for Germany in Case 1



Source: Jaeger et al. 2015.

In a second simulation (Case 2), we again compare a BAU with a GG scenario, using a model with the same multi-agent structure as in the previous section but much more sophisticated decision rules based on expectations and learning, leading to a more complex price dynamics (see Chapter 8 of Jaeger et al. 2015). The reason for this lies in the fact that in transitions from one equilibrium to another prices cannot be in equilibrium all the time. Of course, in reality out-of-equilibrium prices are quite normal but it is remarkably difficult to model the

Figure 22: Emissions for Germany in Case 1

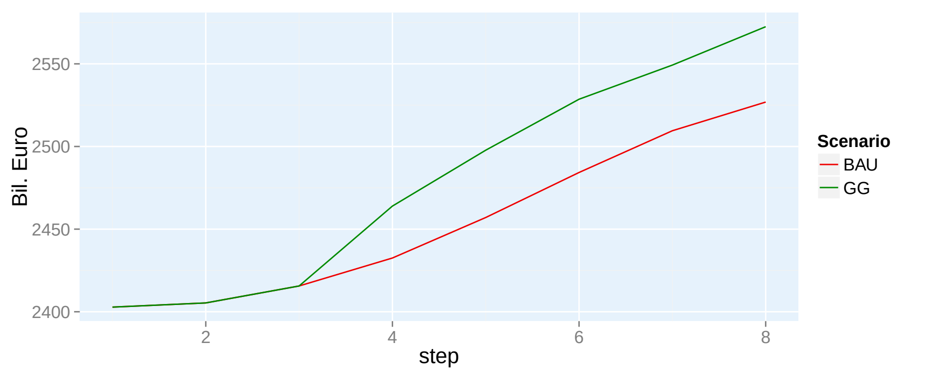


Source: Jaeger et al. 2015.

dynamics of relative prices out of equilibrium (which is a main reason for the fact that most economic models do not model such dynamics at all).

Therefore, here we combine a macro-module and a buildings module with the same agents as above, but their decision rules have been refined: price dynamics driven by expectations that are updated with a learning algorithm have been introduced. More precisely, the generic firm in this version has expectations about the demand from the other agents at the prices it may set. By optimizing its expected profit it decides how much to produce and sets the price accordingly. When the market transactions have taken place, the firm uses the new information to update its expectations. A policy is introduced in time step 3, that increases the retrofit rate of brown buildings from 0% to 2% for households, which means that they make additional investments.

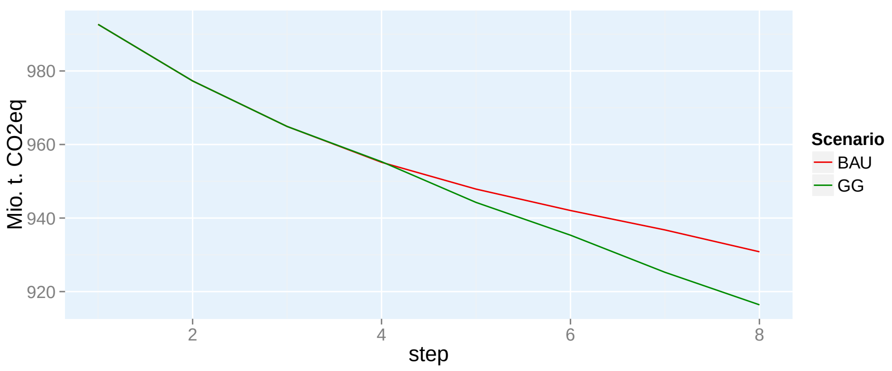
Figure 23: GDP for Germany in Case 2



Source: Jaeger et al. 2015, preliminary.

Figures 23 and 24 display the preliminary results. They are preliminary in the sense that the model is still very sensitive to calibration changes and the observed dynamics show some

Figure 24: Emissions for Germany in Case 2



Source: Jaeger et al. 2015, preliminary.

problems after about a decade in the simulation (see Chapter 9 of Jaeger et al. 2015 for discussion). Also, with the price dynamics the model needs a tuning phase at the beginning, not displayed in the figures, as the learning algorithm draws on results from previous time steps that have to be supplied artificially at initialisation.

These first preliminary results from an agent-based model using STOEMSys show that the general pattern of the results obtained with an enhanced CGE model can also be confirmed by using a very different non-equilibrium modelling approach.

9.2 Modelling a Sustainability Transition with the SYMPHONY Model

The EURACE model is a large scale macroeconomic agent-based model (ABM) and simulator under continuous development (Cincotti/Raberto/Teglio 2011, Raberto/Teglio/Cincotti 2012). The model is now being developed further under the research project SYMPHONY, funded by the European Commission. It represents the real economy, the financial sphere, and the public sector. Its agents are firms and households, banks, a central bank and a government. Agents interact pairwise in different markets (e.g., a capital good, a consumption good, housing, credit, and labour markets), and are characterized by bounded rationality, adaptive behaviour and a balance-sheet approach. Current model development includes, among other things, an analysis of the effects of a bias resulting from adaptive expectations of agents.

The goal of the work done within the project SYMPHONY, where GCF is playing a key role, is to be able to analyse a transition to a sustainable economy using the Agent-based Model EURACE. For analysing a sustainability transition, the most important policy questions have been analysed and translated into modelling requirements. The policy topic under focus is the 2030 framework for energy and climate policy, with its three targets: a GHG emission target, an energy efficiency target and a renewable energy target. This topic was chosen because the three elements are the most important from a political point of view and the most straight-forward from a model implementation point of view, as they can be implemented in a step-by-step manner.

Related tasks identified are to introduce greenhouse gas emissions, renewable energy, and energy efficiency within the model. As a large part of emissions arise from energy generation and use, the representation of energy as a good in the model is important. It is used by firms in their production processes, and by households, for example via buildings. As both these types of agents are already present in the model, including energy use is a matter of refining existing agents. GHG emissions can then be attributed to the energy produced and used in te system. A tax on energy use has already been implemented in the model. Once GHG emissions are introduced in the model, a tax on GHG emissions, a carbon tax, can be introduced as well. Energy efficiency then is a characteristic of the energy use of these agents. Investments into energy efficiency improve this characteristic. This may also mean the introduction of new firms or technologies into the model, for example, construction firms that retrofit buildings to increase energy efficiency. So far this part has not been addressed in detail. In order to show the transition of the electricity production towards more renewable energy, new agents had to be introduced. Refinements can account for the emission intensity of the energy used. Policy options for increasing the share of renewable energy include government regulation, a carbon tax, and a feed-in-tariff.

Out of these modelling requirements, so far renewable energy was the focus of what has been already implemented in the current, early version of the model. Fossil fuel based and renewable electricity need to be modelled as (at least) two types of the electricity good, in order to analyse a transition from one good to another and to track the different amounts of emissions produced. For this purpose the following agents have been added to the model: a fossil electricity producer, a renewable electricity producer and a foreign economy. These agents interact with others through the (also newly introduced) electricity market. A feed-in-tariff mechanism is modelled in a way that is very similar to the feed-in-tariff systems in place in Germany and many other countries. There are long-term contracts for renewable energy producers who receive a guaranteed electricity price (set externally, so by policy). Renewable energy has priority in the grid. The level of production of renewable electricity is dependent on the investment decision of the renewable electricity producer. In SYMPHONY the investment decision is based on a Net Present Value (NPV) calculation, calculating if the (discounted) expected future cash flows are larger than the initial investment. If the NPV is positive, which depends on the expected revenues from selling the electricity (with the feed-in-tariff system in place, the level of the guaranteed price becomes important here), the investment will be made. The investment behavior of the electricity company is constrained by the funds available. In a second step, the ability of renewable energy producers to take on debt, was introduced. Depending on the allowed leverage ratio (debt-to-equity ratio), he can take on debt to invest into new renewable power capacity which increases the investment level. The way this subsidy is financed can differ as well. One possibility that is implemented is that the difference between the feed-in-tariff price and the market electricity price is covered from a reallocation charge that is charged from electricity consumers (as currently done in most countries using a feed-in-tariff). Another possibility is that it is financed via the government budget, through an increased of the overall consumption tax rate (VAT).

An advantage of using this kind of model for climate policy evaluation in the future is that they are more detailed with respect to financial markets. Since the second policy case for the SYMPHONY project is financial stability, the goal is to be able to demonstrate the current economic situation and to analyze economic policies that are discussed at EU level, as described in Chapter 4. This means that the financial sector is represented in a rather detailed fashion in the model. This allows for synergies, for example, economic policies can be combined with emission reduction targets or other climate policies, as described in 6. What is particularly interesting to analyze within the SYMPHONY project, is the combination of climate and economic policies, such as a "green" fiscal stimulus program and a "green" quantitative easing program. Furthermore, new climate finance instruments such as green bonds could be analysed using this model.

Addressing both the topic of sustainability and of financial stability, is an innovative endeavour, as these two policy cases are usually not analyzed in an integrated way. Often, models focusing on finance do not represent sustainability issues, while climate policy analysis models do not provide a sufficient representation of financial markets. The integration of the two issues is the main modelling and policy challenge. The SYMPHONY project shows that an agent-based approach is able to combine these topics. The work on this model is still ongoing. Next steps will be to introduce GHG emissions as well as energy efficiency investments and an investment impulse.

Part III

Beyond the models

10

Energy Efficiency Investments in Central and Eastern Europe

10.1 Introduction

The simulation results in Section 7.5 show higher emission reductions (and therefore higher investment needs) in Central and Eastern European countries (quantile 1 and 2) as compared to the rest of the EU, due to their low energy efficiency and because emission reductions are implemented in a cost-efficient manner. In terms of policy, this would mean that an investment-oriented climate policy should target especially these countries and adapt to their needs.

The results in Section 7.5 also highlight an economic opportunity for countries with low energy efficiency and low income/capita (see results for countries in quantile 1 and 2), as GDP increases are much higher than for countries in quantile 3 and 4. Furthermore, additional energy efficiency targets show the largest positive effects for employment. Hence, the question is how this opportunity can be realized.

Therefore, this chapter addresses the question of how to effectively implement an investment-oriented climate policy in Central and Eastern Europe and how to mobilize the necessary investments for such large emission reductions in reality. We analyse the conditions needed to increase overall investments and to direct a large share of these investments into energy efficiency measures in these countries. Since investment needs are much higher in countries characterized by lower income and low energy efficiency, we look into financing schemes which need to be designed to attract additional private investments. We used three countries as examples: Bulgaria, the Czech Republic and Romania.

As already discussed in Chapter 3, the three countries under study are characterised – compared to the other EU member states – by high energy and GHG intensities (Bulgaria, the Czech Republic and Romania rank 1st, 3rd and 5th, respectively, among all EU member states in terms of energy and GHG intensities).

This poses a challenge to these countries because at the same time, two of them – Bulgaria and Romania – are the economically weakest countries within the EU in terms of GDP/-capita (€5.500 for Bulgaria and €7.100 for Romania (Eurostat 2015[nama_gdp_c])), also see the discussion in Chapter 4. The Czech Republic's GDP/capita is, with 14.200 Euro, closer to the EU28 average of 25.700 €/capita but also on the low side. While restructuring towards a low carbon economy may be a challenge for these three countries, their high energy intensity also represents important opportunities. For more than two decades, after the collapse of their communist regimes, the three countries went through major economic restructuring and downturns (1996/1997 and 2009) that reshaped social and demographic conditions. They faced substantial changes in GDP/capita during these two restructuring periods. However, as compared to other European countries, especially Southern European countries, unemployment rates as well as government debt and government deficit levels have remained relatively low and stable, as described in Chapter 4.

While the energy intensity of the Bulgarian economy followed a clear downward trend over the past decade (with reductions of about 3.4% annually since 2002), Bulgarian energy intensity (610 kg oe/€1,000) is still twice as high as the average of the new member states. In Romania, energy intensity has also decreased at a high rate throughout the past decade (3.8% annually since 2002) to 335 kg oe/ €1,000 (Eurostat 2015[tsdec360]). The Czech Republic has the third highest energy intensity among the EU member states at 355 kg oe/ €1,000, with moderate improvements since 2002 at 2.3% annually.

This chapter combines an analysis of relevant scientific literature, sectoral and policy reports with interviewing experts in the field of energy efficiency from Bulgaria, the Czech Republic and Romania and an in-depth case study analysis. The main objective in the interviews was to find out experts' assessment on what the main barriers and drivers for energy efficiency projects implementation are in their countries and which measures and instruments they propose to overcome or support the particular situations. We interviewed eleven experts, five in Bulgaria, four in Romania and two in the Czech Republic. The in-depth case study analyses how the main barriers for energy efficiency projects investment and implementation were overcome in a specific project of an important size.

This chapter is structured as follows: Section 10.2 presents an assessment of the retrofitting needs in the residential buildings sector and industrial sectors in the three countries, then Section 10.3 analyses the barriers and drivers for energy efficiency investments and implementation in the two sectors above and Section 10.4 presents the case study focusing on an investment success story: buildings retrofitting in Romania with EEEF/Banca Transilvania funding before Section 10.5 concludes.

10.2 Assessment of Energy Efficiency Potential

Energy retrofitting needs to take place in nearly every sector in the three countries considered. Different retrofitting options and measures exist and they differ in terms of their potential energy savings, costs and economic efficiencies. Besides the energy sector, two other relevant sectors in terms of energy efficiency are "buildings" and "industry". These two sectors were largely highlighted by the experts in the interviews as very important to focus on, for details see Box 9. In the following, we present the findings from the experts' interviews and an in-depth analysis of the current situation in these two sectors in Bulgaria, the Czech Republic and Romania.

10.2.1 Residential Building Sector

Depending on the climate zone and the energy efficiency status of buildings, heating consumption in residential buildings differs among the EU28 member states. Malta has the lowest heat consumption per m^2 living area with 19 kwh/m^{2}a, Luxembourg the highest with 219 kwh/m^{2}a (Enerdata 2012 pg.15). Figure 25 shows the range of total energy consumption (including

Box 9: Energy efficiency needs – Insights from Experts

For **Bulgaria** the interviewed experts stated that while retrofitting the building stock is of significant interest, all sectors of the Bulgarian economy need investments into energy efficiency. Energy efficiency in buildings includes retrofitting the existing building stock as well as the construction of new residential and public buildings. The existing building stock needs to be modernised not only due to its bad thermal conditions but also due to its overall condition. One expert mentioned that the new building code should be based on Passive House Standard and Nearly Zero-Energy Standard, but from our point of view this is a highly ambitious goal for the moment in Bulgaria. Based on population income, climatic needs and existing energy prices, such investments are hardly economically efficient. The experts also pointed out the importance of energy efficiency measures to be taken in heavy industries, which represent a significant consumer of energy in Bulgaria. One expert further pointed out that in the recent years the production of metals (especially the production of parts for the automotive industry) was an "engine" for the Bulgarian economy – a sector that traditionally has high energy consumption. Further sectors that need investment (but not only in energy efficiency) are metallurgy, chemical industry and transport.

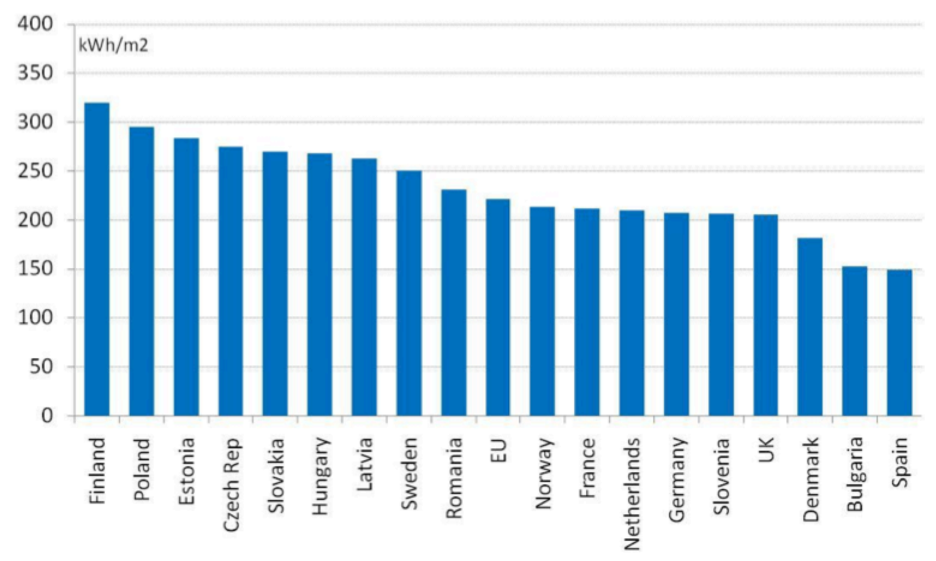
For **the Czech Republic** and **Romania** the interviewed experts referred to similar needs in their respective countries. A Romanian expert pointed out that while over the past ten years important efforts have been made to increase the energy performance of multi-family residential buildings with financial support from national programs, EU structural funds, local funds as well as EIB and EBRD funds, the remaining part of the residential building stock including individual housing is very high and needs to be retrofitted. Another expert emphasised the importance of the development of the domestic construction materials sector (e.g. insulation materials, energy efficient windows etc.) for energy retrofitting. Similarly to Bulgaria, one expert emphasised that the **Romanian** economy is highly dependent on energy intensive sectors that include metallurgy, cement and petrochemicals. In addition, in the energy sector many old units need replacement and/or retrofitting.

electricity and hot water generation) per m^2 in the building stock of the European Union in 2009 (residential and non-residential buildings).

The three countries under study, Bulgaria, the Czech Republic and Romania, are located in different climate zones. According to iNSPiRe, Bulgaria, located together with France and Slovenia in the southern continental zone, has a relatively low average energy consumption for heating purposes of 91 kwh/m^2a, while the values for the Czech Republic and Romania are 168 and 170 kwh/m^2a respectively (iNSPiRe 2014 pg. 27).

The thermal efficiency of buildings is mainly determined by the amount of thermal losses of their constructional elements. Thermal losses are measured by the U-Value ($W/m^2/K$). This value shows the amount of energy (in Watts) that the surface of a constructional element (window or wall) loses per 1K temperature difference. The evaluation of energy quality of buildings can be done by comparing the U-Values with either best practice examples and/or with similar buildings in other countries located in the same climate zone. Figures 26 and 27 show the different U-Values for the residential building stock in Bulgaria, the Czech Republic and Romania depending on the building age and compared to the weighted average of the individual climate zone. Obviously, more recent buildings have better energy quality. When comparing the existing building stock in the three countries considered (here we focus on the

Figure 25: Energy consumption in buildings (2009)



Source: Enerdata 2012 pg. 15.

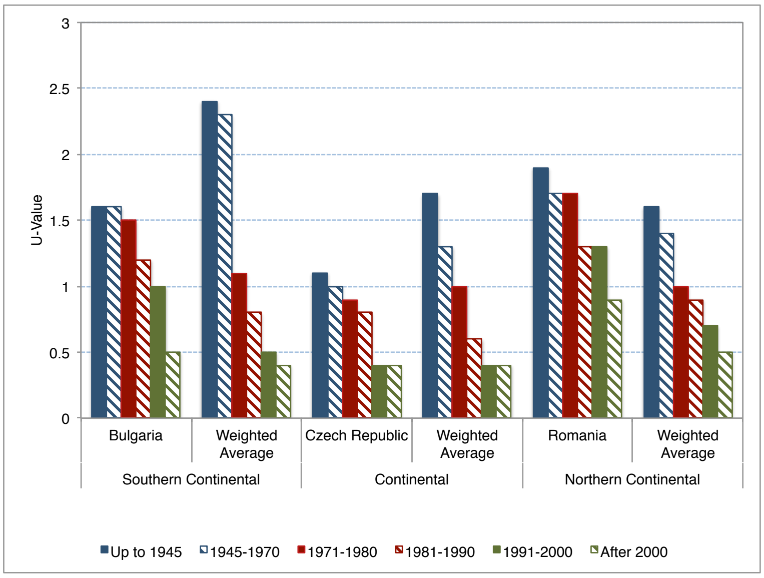
wall thermic properties) with that in other countries in the same climate zones, the following observations can be made (iNSPiRe 2014 pg. 22):

- In Bulgaria, buildings constructed before 1970 have a better thermal quality than the average in the same climate zone and buildings constructed after 1970 are significantly worse.
- In the Czech Republic, old residential buildings have up to 40% better thermal quality than the average in the same climate zone. However, after 1980 no difference exists anymore.
- In Romania, the whole residential building stock has up to 30% lower thermal quality than any other country in the same climate zone.

To estimate a range of the overall energy saving potential in the residential building stock for the three countries, we need to analyse its age structure. Taking into account that the major share of the building stock was constructed before 1970, energy saving potential seems to be important for this type of buildings. Among the three countries studied, Bulgaria has most buildings that were constructed before 1970 (60%) followed by the Czech Republic (58%) and Romania (52%), as shown in Figure 28.

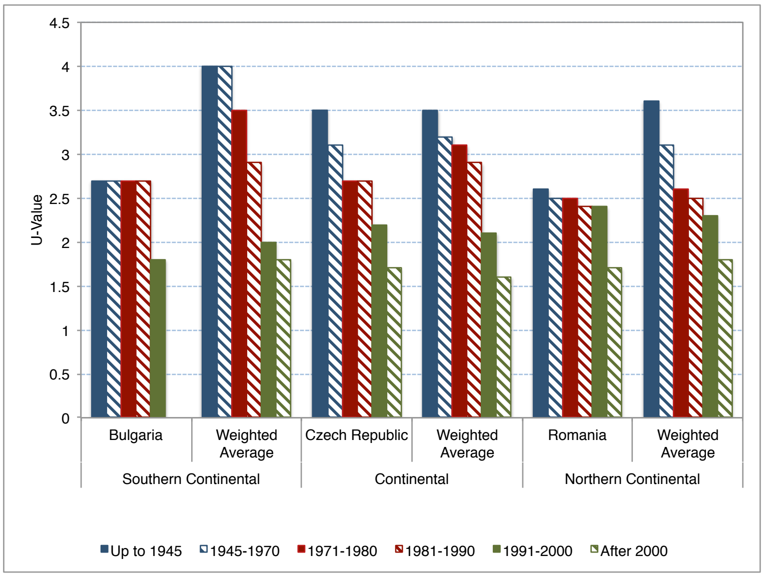
Regarding heating, only a share of the buildings uses fossil fuels. In Bulgaria and Romania wood is the main source used for heating in residential buildings with 40% and 60%

Figure 26: U-Values "Walls" depending on the year of construction and compared to climate zone weighted averages



Source: iNSPiRe 2014 pg. 22.

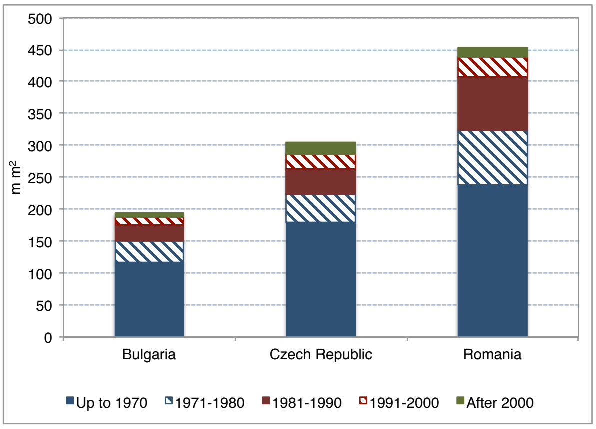
Figure 27: U-Values "Windows" depending on the year of construction and compared to climate zone weighted averages



Source: iNSPiRe 2014 pg. 22.

respectively, while in the Czech Republic, natural gas accounts for 40% of the fuel consump-

Figure 28: Age structure of the residential building stock



Source: iNSPiRe 2014 pg. 17.

tion (iNSPiRe 2014 pg. 31).

We estimate the possible average energy saving potential of dwellings based on:

- the heating index depending on the location (Werner 2006) – we base our calculations on the location of the capital cities,
- the average U-Values for windows and walls of building constructed before 1970,
- potential U-Values after retrofitting based on iNSPiRe (2014, pg. 22),
- and average dwelling surfaces based on our own assumptions.
- We do not consider the efficiency of conversion of fuels into heat and/or the efficiency of district heating systems.

The average saving potential for residential buildings older than 40 years is approx. 80 kwh/m^2a in Bulgaria, 100 kwh/m^2a in the Czech Republic and 130 kwh/m^2a in Romania. Additional savings of approx. 10-15% per dwelling are possible if heating systems are also retrofitted and/or fuel type is changed. Based on the overall surface of dwellings and a share of around 50-70% of fossil fuel heated dwellings, estimates for the national annual energy saving potential and the overall investment needs for Bulgaria, the Czech Republic and Romania are shown in Table 10 (based on retrofitting costs of up to 100 - 150 Euro per m² living area[36]).

10.2.2 Industrial Sectors

As already discussed in 3.1, Bulgaria and Romania still show high energy intensities of their economies, with Bulgaria being the highest in the European Union.

[36] We follow Petersdorff et al. 2004 pg 53. and take inflation into account.

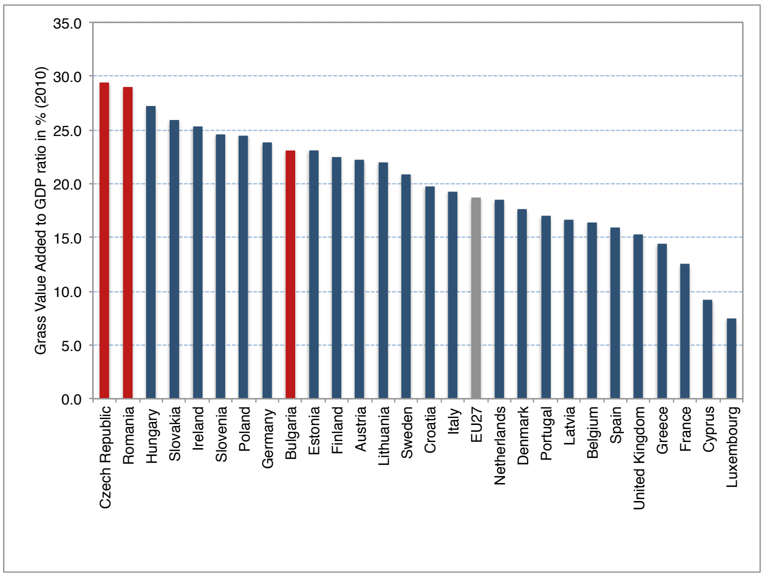
Table 10: Annual energy saving potential

	Energy saving potential per year	Percent of national energy consumption	Investment needs
Bulgaria	5 TWh/a	3	Euro 12 - 17 bn
Czech Republic	9 TWh/a	3	Euro 18 - 26 bn
Romania	15 TWh/a	7	Euro 24 - 36 bn

Two main reasons are responsible for the low energy efficiency in the economies of Bulgaria and Romania. On the one hand, the replacement of out-dated equipment is still in progress and on the other hand, industrial production has a proportionally higher share in the national GDP than in the EU average.

The high energy intensity in the three countries is both due to a lack of efficiency of transmission, distribution and use of energy as well as due to the production structure of their economies: the energy intensive industries such as mining and quarrying, manufacturing, steel production, chemicals and power generation represent a large share in total value added, particularly in Bulgaria and Romania. As shown in Figure 29, the industrial sector of the three countries under study has a relatively large share in the national GDPs. While economically strong countries with high GDPs like France, UK and Italy generate less than 20% of their GDPs in the industry, the value in the Czech Republic and Romania is nearly 30% and in Bulgaria 23%. Among the 10 countries with the highest share of industry, only Germany and Ireland are not former "new member states" of the EU.

Figure 29: Gross Value Added to GDP ratio of the industry sector (2010)

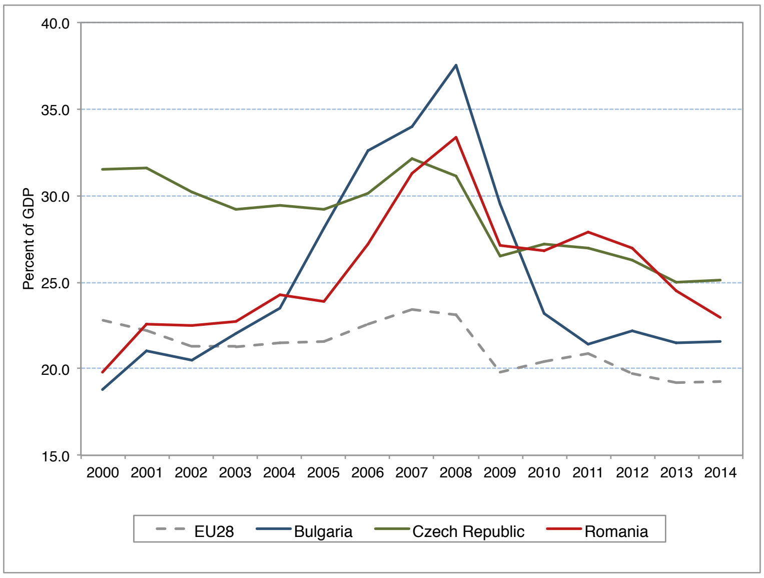


Source: Eurostat 2015[nama_nace06_c].

As shown in Figure 30 the gross investments related to GDP in Bulgaria and Romania changed significantly over the past 14 years. Starting with levels below the EU28 average in the 1990s the investments have been increased significantly until 2007/08. As one result of the financial crisis the investment to GDP ratio have been decreasing since 2008. The investment to GDP ratio in the Czech Republic have been higher than that of the EU 28 since 2000 by ca 6%.

All three former New Member States have lower levels of gross investments per capita than the EU28 average. While the gross investment per capita in the Czech Republic reaches 70% of the EU28 average in 2014, Bulgaria and Romania lag behind significantly with 23% and 32% of EU28 average.

Figure 30: Gross investment to GDP ratio (2000-2015)

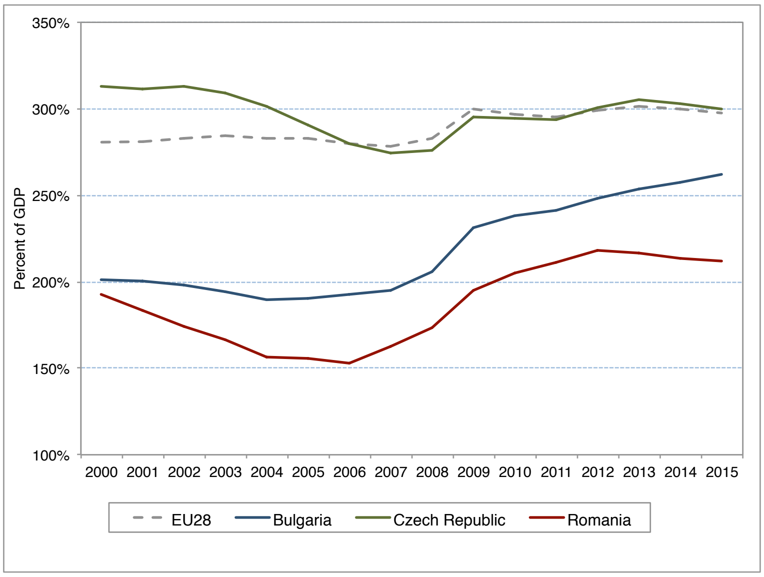


Source: Eurostat 2015[nama_10_gdp].

These lower investment activities are reflected in the net fixed capital formation. Figure 31 shows the development of the aggregated net capital stock as ratio of the annual GDP of the EU28 and the three countries under study. The net capital stock defines the amount of the national capital stock that is not depreciated and in this sense is "new". New assets – machinery, buildings, vehicles etc. – have in general a lower energy intensity so that longer use of depreciated capitals led to higher energy consumption.

The aggregated saving potential in Bulgaria and the Czech Republic is low in relative terms and in Bulgaria also in absolute terms among the three countries. In Bulgaria, the saving potential per dwelling is lowest too, which has an impact on the economic efficiency of retrofitting measures. One of the reasons for the low saving potential in the Czech Republic is the progress in retrofitting already made over the past years. On the other hand, Romania

Figure 31: Net fixed capital stock to GDP ratio (2000 - 2015)



Source: European Commission 2015b.

has a significant saving potential based on a low average thermal standard of the existing residential building stock.

Nevertheless, the present living conditions in old buildings are poor, therefore modernisation has to take place anyway. A combination of building modernisation and energy retrofitting leads to a relative cost reduction of such investments and positive scale effects. From a macroeconomic point of view, the retrofitting of residential buildings has a positive impact on national added value and employment, as could be seen in Section 7.5. Coupling building modernisation with energy retrofitting leads to increasing living standards additionally.

Modernisation of industrial production capacities has a direct influence on competitiveness and therefore on potential exports. As shown above, Bulgaria and Romania lag behind in terms of net investments. Such investments have direct positive impacts on GDP, income and as a result on living conditions. Moreover, retrofitting activities create jobs and can help reduce national unemployment.

In addition, lower consumption of fossil fuels – in the building sector and in industries – helps to reduce imports of natural gas in Bulgaria and the Czech Republic and to a lower extent in Romania.

10.3 Barriers and Drivers for Energy Efficiency Investments

The socio-economic and political environment of a country as well as the value of economic parameters determine the economic efficiency of investments and therefore investment decisions and the amount of investment activities of private investors, households and companies. Therefore, in addition to overall macroeconomic indicators such as GDP growth, employment and tax schemes, we need to look into sector specific and investor group related parameters such as loan interest rates, consumer specific energy prices, subsidies etc. See Box 10 for expert views on barriers and drivers for energy efficiency investments.

In the following two sections, we highlight two relevant parameters, their specificity and impact on investors' behaviour in Bulgaria, Romania and the Czech Republic.

10.3.1 Interest Rates and loan analysis

External finance - mainly bank loans - is the key element for financing energy efficiency investments. The demand for loans depends mainly on the interest rates, which define ceteris paribus - the economic efficiency of an investment. According to our calculations, an interest rate increase by 1 percentage point increases loan payments and reduces discounted cash flows respectively by 4-5% (for 10 years lending term).

Based on the latest available data, Figure 32 presents the interest rate differences between the EU28, Bulgaria, the Czech Republic and Romania[37]. The interest rates for households as well as for companies in Bulgaria and Romania are more than three times higher than the EU28 average values, while the values for the Czech Republic are about twice as high.

Higher interest rates in Bulgaria and Romania reflect higher macro economic, financial and micro economic risks. On the micro economic level, the most important parameter is the risk that investors are unable to payback their loans. Since 2007 the **credit default risk** increased in the EU28 as result of the economic and financial crisis. Therefore the national situations differ significantly within the European Union. While economically well performing countries denote a moderate increase of up to 100 %, the countries that where hit significantly by the crisis in 2007/2008 had to cope with increases of up to 1.600%. Figure 33 presents the figures in 2007 and 2011. Among the three countries under study, the Czech Republic had the lowest credit default risk ratio (non-performing loan ratio – NPLR) with approx. 5.5% while the values for Romania (14%) and Bulgaria (15%) reflect higher risk for banks to provide capital for households and companies.

To some extent, large differences in risk across industries and firm sizes exist. The Czech National Bank indicates e.g. that in the construction sector the NPLR is above 22% while in other sectors the value is below 10% and the average is around 5% (Czech National Bank 2014 pg 29). A similar picture exists in Romania. According to the National Bank of Romania the credit default risk ratio (NPLR) for corporate loans of small and medium size enterprises (SME) increased from about 15% in 2011 up to 25-30% (higher value for mortgage-backed loans) (National Bank of Romania 2015a pg. 142). In contrast, the NPLR for large companies is lower than 10%. High default risks result in either a shrinking supply of loans to households and investors and/or in risk premiums that increase the interest rates.

Higher risks, higher interest rates and different macro economic growth over the past years resulted in a change of the developments of loan demands and supplies in the three countries.

[37] Interest rates differ depending on the lending term and the currency in which the loan is provided. For simplicity reasons, interest rates are given only for national currencies and not for credits in Euro and for volumes lower than 1m Euro. For households, we present only interest rates for credits for durable goods and real estate, not for consumption.

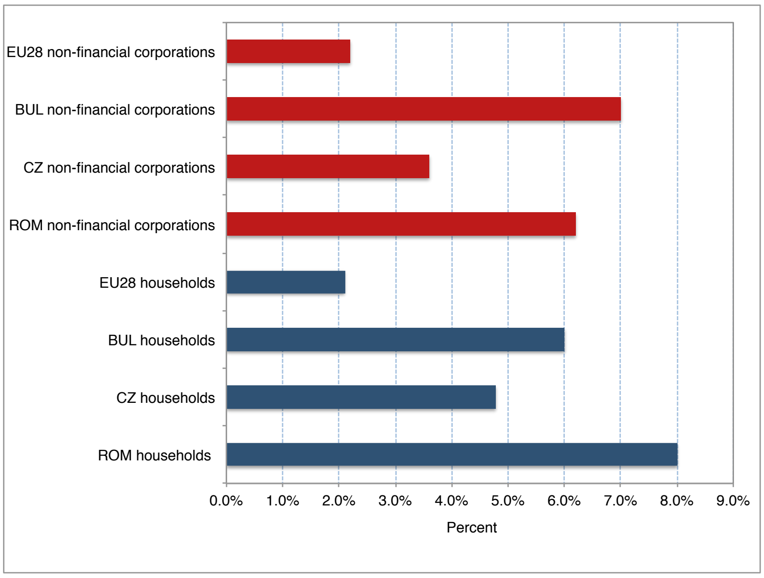
Box 10: Barriers & drivers for energy efficiency investments – Insights from Experts

The experts were asked to assess the relevance of a number of socio-economic, political and technical parameters determining the implementation and success (or lack) of energy efficiency investment in their countries. All **Bulgarian experts** interviewed identified financial barriers as the most important barriers for the implementation of energy efficiency projects. They mentioned that the lack of appropriate and easy to access financial schemes is critical for investors. The reason for that is not the scarcity of supply but the fact that the majority of people are poor and any investment is far from their priorities in life. One expert mentioned that there are available funds in Bulgaria which are not used due to a lack of interest (investment ability respectively) from people, even if over the past two years, Bulgarian banks have been characterised by very high liquidity levels and historically low interest rates (see Section 10.3.1). Further barriers that are identified by experts as relevant are inadequate energy prices, public awareness and acceptance, however one expert pointed out that energy prices are low but not inadequate (see Section 10.3.2. Technical barriers (lack of adequate numbers of contractors and service companies, complexity of technical solutions, insufficient information on suitable technologies) weren't considered by experts as responsible for the actual situation of energy retrofitting activities in the country. Further barriers mentioned in Bulgaria were: - Unclear and frequent changes in regulatory framework, - Lack of appropriate building (asset) management and - Lack of powerful owners associations with traditions and capacity.

According to the **Czech experts** and in contrast with the situation in Bulgaria, financial difficulties and complexity of raising funds are not an important barrier to the implementation of energy efficiency projects. A much more critical point – that is important for Bulgaria and Romania too – is the lack of information on the possible return on investment (ROI). While this general statement has to be evaluated for specific sectors and energy efficiency measures, altogether the lack of information and knowledge in the Czech population about energy efficiency seems to result in low public awareness and acceptance and low support for investments in the Czech Republic. Several experts suggest that financial incentives for investment (e.g. low interest rate loans, grants, tax exemptions) and clear information about the ROI of the projects should be used to support investors decisions. Regarding institutional and administrative barriers, none was considered particularly impeding private investment into energy efficiency projects. Experts emphasised the importance of clear energy intensity and energy efficiency indicators and tools (e.g. energy audits) as well as the enforcement of energy efficiency legislation (e.g. energy efficiency standards for housing, equipment, vehicles) for increasing investors' activities.

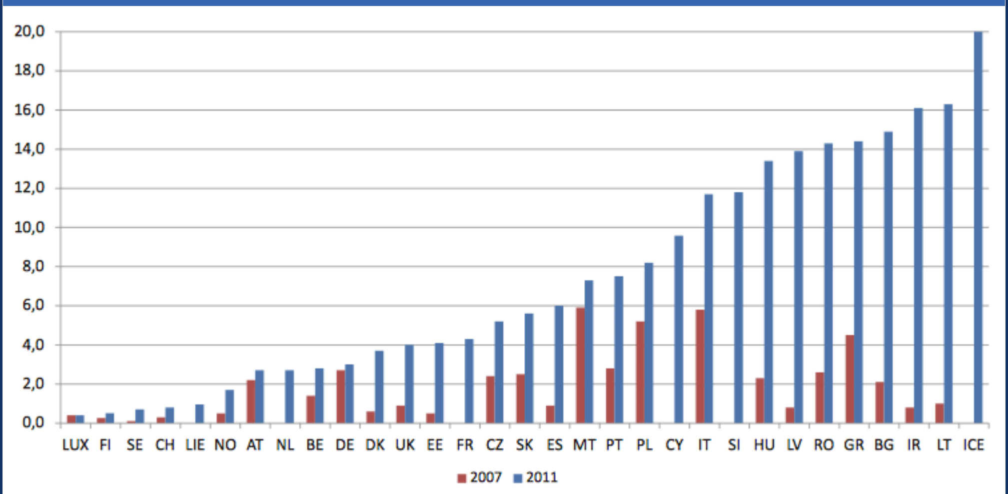
In contrast to the situation in the Czech Republic – but similarly to Bulgaria – **Romanian experts** assessed financial difficulties as an important barrier for investments in particular for the residential building sector. One expert mentioned that currently the main difficulty is the definition of lending mechanisms without property guarantee / mortgage for home owners. The lack of appropriate financing relates to the overall situation of inadequate return of investment of energy efficiency investments. In the current conditions in Romania, building energy retrofitting is not always economically feasible. Another expert highlighted that the legal framework and the structure / operation of the authorities for drafting and implementing of energy efficiency legislation are important barriers to energy efficiency in Romania. Similarly to Bulgaria, technical barriers in Romania do not seem to hinder investments. The technology needed is available at market price. A more general problem is that the government does not incentivise companies to increase their energy efficiency.

Figure 32: Interest rate for households and companies in the EU28, the Czech Republic, Bulgaria and Romania in 2015 (in %)



Source: European Central Bank 2015a,National Bank of Romania 2015b, Czech National Bank, Bulgarian National Bank 2015.

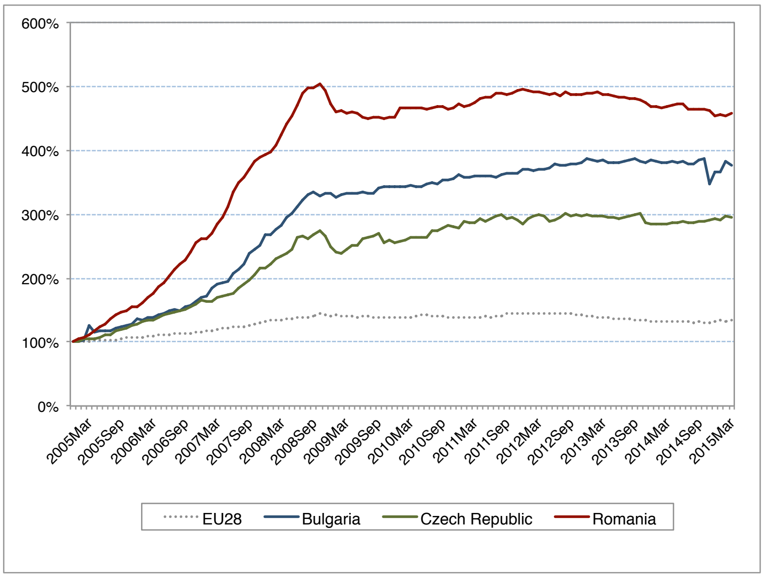
Figure 33: Non-performing loan ratio (in %)



Source: European Banking Federation 2012 pg. 10.

The total amount of outstanding loans increased from 2005 to 2008 significantly in Bulgaria, the Czech Republic and Romania compared to the EU28 (see Figure 34). After the crisis

Figure 34: Loan statistics Percentage compared to December 2004



Source: European Central Bank 2015b.

however, Bulgaria and the Czech Republic show only small increases of the overall amount of outstanding loans since 2008, and Romania even decreased the amount of loans outstanding.

Despite the relatively high differences to the EU average, the figures in the three countries under study show a moderate interest rate level. Current values are similar to the ones the European Union had 15 years ago. In addition to the current value, it is important to notice that interest rates decreased since the peak of the financial crisis by up to 50%.

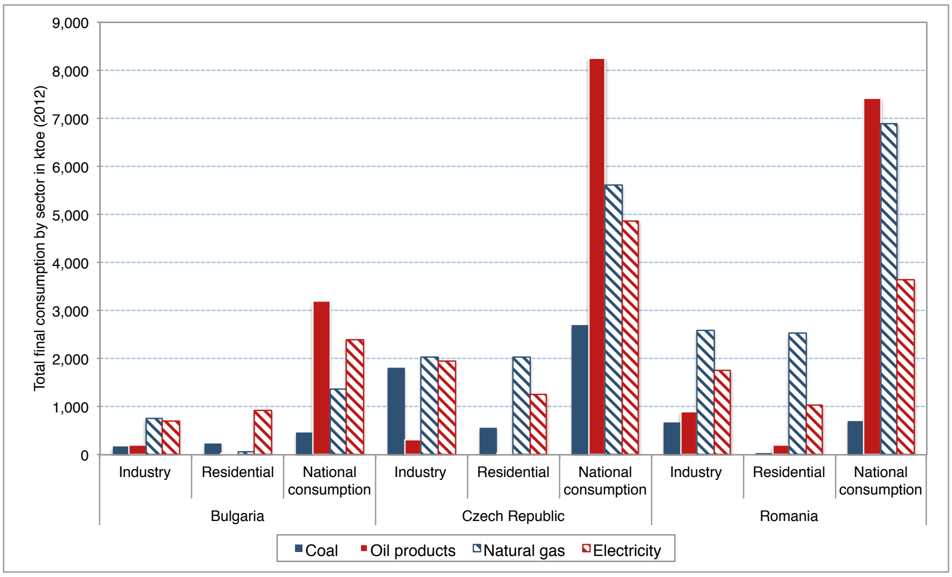
10.3.2 Energy Consumption

Fuel prices have a significant impact on the economic efficiency of retrofitting measures. Obviously, high prices per energy unit lead to potentially higher monetary savings than low and/or subsidised prices. Fuel types differ in their importance for the various economic sectors as well between the three countries. Figure 35 shows the final energy consumption for coal, oil products, natural gas and electricity for the three countries in 2012.

The primary energy source for electricity generation in all of the three countries considered is coal: Bulgaria – approx. 50%, Czech Republic – approx. 55% and Romania – approx. 40%, followed by nuclear (30 - 35% in Bulgaria and Romania) and hydro in Romania (approx. 20%) (Figures for 2012 – International Energy Agency 2015). The use of natural gas plays a role only in Romania (approx. 15% of total electricity production).

To assess the importance of each fuel type in the two sectors (industry and residential) for the three countries, we show in Figure 36 the shares for each fuel type of the final national energy consumption.

Figure 35: Final energy consumptions by fuel and sector



Source: International Energy Agency 2015.

10.3.2.1 Coal

Coal is relatively unimportant in Bulgaria and Romania for the residential and industry sectors while it plays a significant role in the Czech Republic where approx. 25% of the energy demand in the industry is covered by coal.

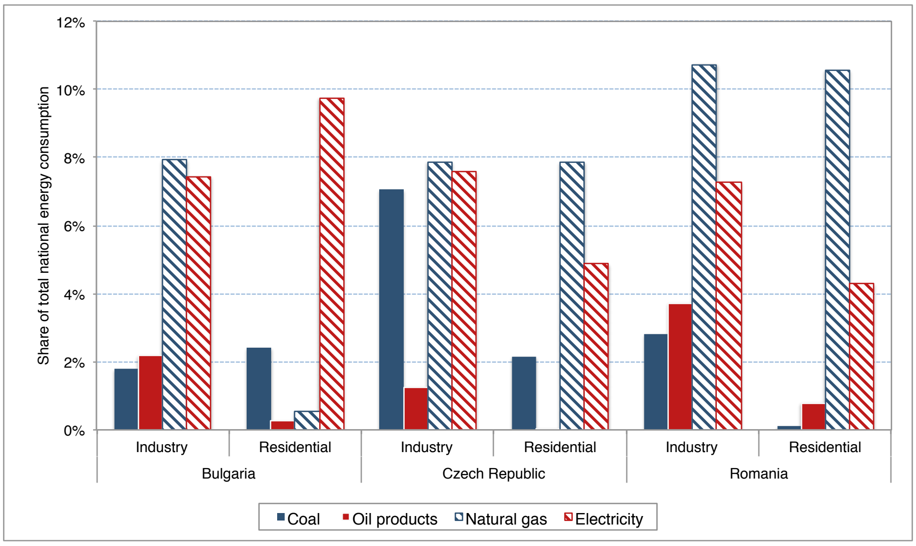
The consumption of natural gas for heating purposes plays a minor role for the residential sector in Bulgaria, so that natural gas prices are mostly irrelevant for the population. In contrast, in the Czech Republic more than 40% of the population uses natural gas for residential heating and additionally approx. 15% use heat provided by district heating systems – which is also based on natural gas to some extent. In Romania natural gas is one of the main fuel types that is used – in industry 40% and households 31% of the overall energy consumption.

Electricity has a high share (approx. 40%) in the energy consumption of Bulgarian households because it is used for about 60% of the water heating in residential buildings – compared to 30% in the Czech Republic and only a minor amount in Romania (see iNSPiRe 2014 pg. 32).

The present level of interest rates for households and investors in Bulgaria and Romania does not hinder investments by itself but it influences the internal rate of return of investments. Therefore the level of interest rates has to be assessed in combination with other determinants of profitability of investments. One of these is the energy price that determines the amount of avoided energy spendings for households and companies. In the following section, we analyse prices of natural gas and electricity for households and industrial consumers in Bulgaria, the

Czech Republic and Romania and assess how their value influences the demand for retrofitting activities.

Figure 36: Share of total energy consumptions



Source: International Energy Agency 2015.

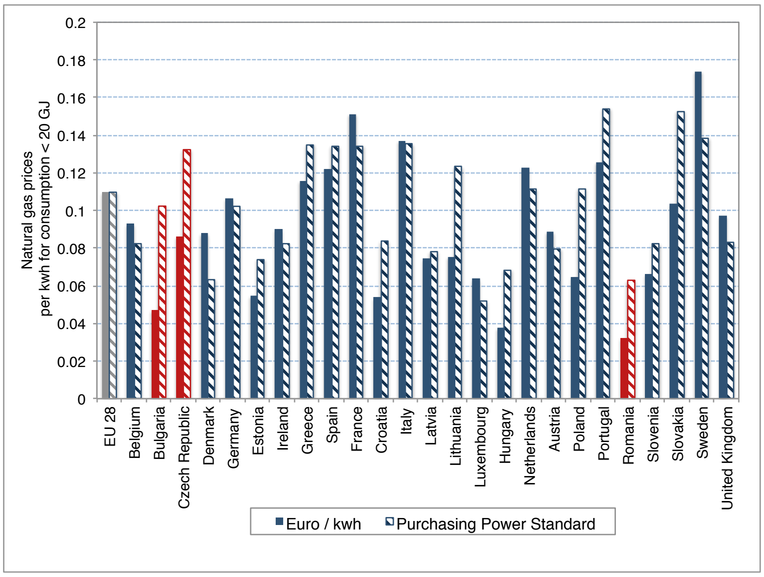
10.3.2.2 Energy Prices

As presented in Figure 37, the natural gas price in the Czech Republic is 0.086 Euro/kWh. This value is 20% below the EU28 average price of 0.11 Euro/kWh in 2014. However if we compare prices in purchasing power standards (PPS), the price for natural gas in the Czech Republic is 20% higher than the European average and higher than for example in Germany. From this point of view, for households in the Czech Republic – ceteris paribus – the level of natural gas prices support investments into retrofitting of buildings.

Romanian natural gas prices for households are (one of) the lowest among the EU member states. Prices are approx. 70% lower than the EU average in Euro and 43% in purchasing power standard respectively. Romania owns significant reserves of natural gas. The annual production is approx. 400,000 TJ (International Energy Agency 2015) and covers 80% of the domestic consumption. The gas market in Romania is still regulated for household consumption and its liberalisation is planned to start mid 2015 (Visegard (2015)).

Natural gas prices (see Figure 38) for industrial consumers in Bulgaria and in the Czech Republic are approx. 10% and 20% respectively, lower than the EU28 average measured in Euro. Taking the purchasing power standard into account, this situation changes substantially. The resulting natural gas price for industries in Bulgaria is 100% higher than in the EU. Since 2010 the price increased by 40% compared to a slow increase of 10% in the Czech Republic over the same period. Romanian natural gas prices for industrial consumers increased by 45%

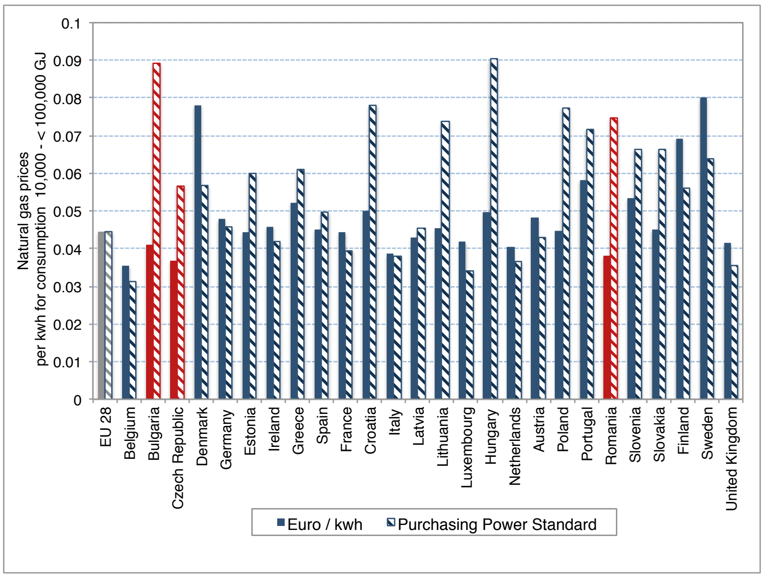
Figure 37: Household natural gas prices 2014 in Euro/kwh and Purchasing Power Standard



Source: Eurostat 2015 nrg_pcs_202.

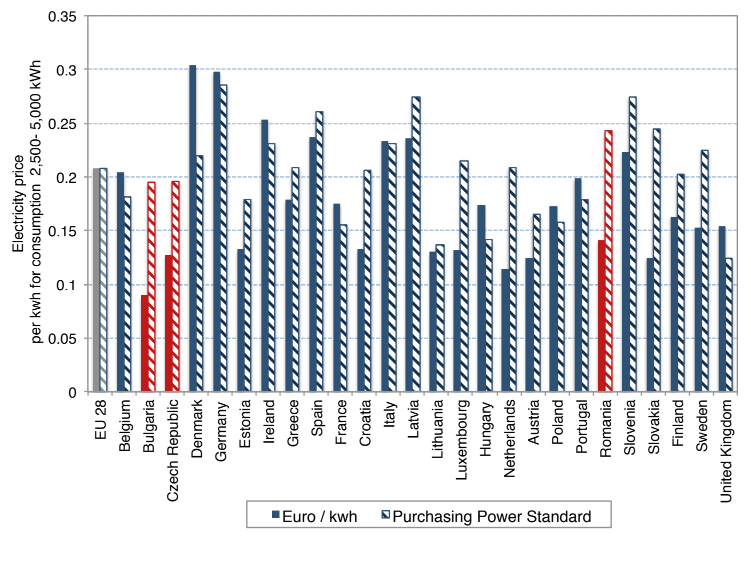
in the same period as one result of the market liberalisation in this segment. End 2014 the natural gas price in purchasing power standard was 70% higher than the EU28 average.

Figure 38: Industry natural gas prices 2014 in Euro/kwh and Purchasing Power Standard



Source: Eurostat 2015 nrg_pcs_203.

Figure 39: Household electricity prices 2014 in Euro/kwh and Purchasing Power Standard



Source: Eurostat 2015 nrg_pcs_204.

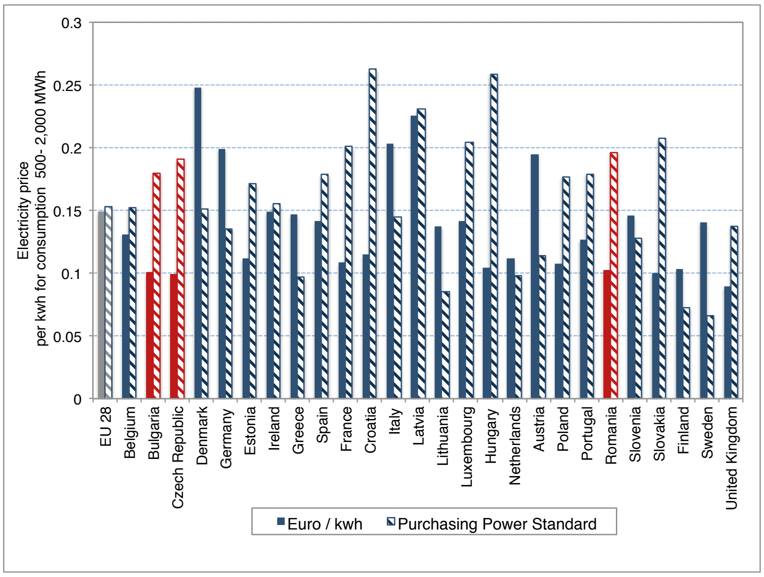
The price for electricity for households (including all taxes) has increased since 2010 in the EU28 by 25%. In purchasing power standard the price increase in Bulgaria and the Czech Republic was moderate at 7% and 5% respectively – in Euro the price in Bulgaria has fallen by 5%. Romania has faced a different situation – the household price for electricity increased by 22% (in PPS) (Eurostat 2015 nrg_pc_204). While the electricity price for households in Bulgaria and the Czech Republic is at the same level as the EU28 average (in PPS), the price in Romania is 17% higher (see Figure 39). The price for industrial consumers in all three countries is higher than the EU average in PPS: +17% in Bulgaria, +25% in the Czech Republic and +28% in Romania (see Figure 40).

As described above, fuel prices are relatively low in Euro but not in purchasing power standard units. Therefore the following problem arises: for energy consumers the perceived prices (in relation to income and living conditions) are high but in real terms they are not. This leads to the situation that – compared with investments in other European countries – the discounted cash flows of retrofitting are low in the three countries (high interest and low energy prices).

In addition to these two main parameters (interest rates and energy prices), several other factors influence the profitability of investments and so investment decisions. These are e.g. household incomes, equipment costs (in Euro per unit of energy saving), loan subsidies (e.g. grant component or interest rate subsidies), administrative and institutional factors etc.

In Box 11, we present our analysis of the experts' interviews which highlight drivers that can change relevant parameters and help to overcome existing barriers.

Figure 40: Industry electricity price 2014 in Euro/kwh and Purchasing Power Standard



Source: Eurostat 2015 nrg_pcs_205.

10.4 Investment success story: buildings retrofitting in Romania with EEEF/Banca Transilvania funding

10.4.1 Context

A specific case study has been investigated in order to show a positive example of how energy efficiency projects can be implemented in practise.

There is an important need to retrofit residential and non-residential buildings in Romania – most of the existing stock of buildings are older than 50 years and their energy consumption is substantial. Residential buildings dominate the market, accounting for 86% of the built floor area. Romania also has a high level of private ownership of residential buildings, at 84%. Due to the low income of much of the population and therefore scarcity of funds, energy efficiency investments are low on the public agenda and the process of building retrofitting is at the very beginning. It is estimated that at the national level the percentage of the buildings that have been already retrofitted is below 15%.

According to the EU 20/20/20 strategy, Romania has to ensure that its building stock is retrofitted. In 2014, the Romanian government published its national building renovation strategy which recognises the progressive, long-term nature of the renovation challenge, by setting out a 3-phase stepwise approach:

- Phase 1 - Establish conditions that major renovations can become a target within five years;

Box 11: Drivers to overcome barriers for energy efficiency investments – Insight from Experts

Experts were asked to make a proposals on how to overcome the existing barriers for energy efficiency investment. Several **Bulgarian experts** stated that strong and clear political will as well as appropriate legislation including norms, regulations, national programmes and individual, consumer specific goals for energy savings combined with "White Certificates" schemes is needed. To raise the acceptance and awareness as well as to overcome existing information deficits, an active and effective communication by government supported campaigns is suggested. Considering that Bulgarian households have a low income compared to all other member states, retrofitting existing residential building stock needs clear government policy and incentives. Decreasing the level of corruption in the country is also mentioned as a possible driver.

The **Czech experts** also emphasised clear and stable energy efficiency legislation, which should encourage energy utilities and industry sectors into energy efficiency project implementation as a relevant driver to overcome existing barriers. They suggest voluntary agreements between energy utilities and industry sectors and the government. In addition to this regulatory approach, a stronger awareness of the population and the visibility of opportunities is needed, so that marketing campaigns would be helpful. Moreover, an increase of supplies of energy efficiency technologies by the private sector is suggested.

For the **Romanian experts**, the development of policy instruments and of a coherent legal framework is an important driver, which should include regulating the set-up and operation of energy efficiency projects. Suggested policy measures are: "well designed" subsidies, regulation of access to the market for e.g. small and medium size high efficiency cogeneration projects. Improvements of the legal framework have to include a faster and better implementation of EU legislation. As long as the financial conditions for private investments into energy efficiency projects lag behind the needs, the number and quality of ESCO companies becomes relevant. One Romanian expert – but this holds for Bulgaria and the Czech Republic too – suggested to implement fiscal facilities for ESCO companies so that they become able to invest in large scale projects. A very important – and from our perspective widely overseen point – relates to the qualification requirements for construction works. One expert suggested to set up a rating system in public procurements specification for construction works (in order to support the construction companies which are investing in quality) and to impose minimum qualification requirements for relevant professions in the tendering process. Other drivers mentioned to help overcoming existing barriers are: the involvement of local entities for energy efficiency presently under the ANRE (national energy regulatory agency), a government and international financial institutions coordinated effort with voluntary participation of local banks for low cost finance of projects, better monitoring and simplification of the bureaucracy needed for the projects and a well defined framework and procedures for the performance of newly built and renovated buildings.

- Phase 2 - Developing technology for renovation of buildings that can provide the means to achieve a substantial reduction in energy consumption and nearly zero energy consumption in buildings, within about 15 years;
- Phase 3 - Deep renovation of all buildings as the norm thereafter.

In this context, Romania implemented several support programmes that provide consultancy, grants and interest rate subsidies for investors. These programmes have been changing over the years, have been updated depending on changing needs and are specific to different investor groups and building types. Energy efficiency investments in several sectors in Romania are supported by funds from the European Investment Bank (EIB), from the European Bank for Reconstruction and Development (EBRD) and from the European Energy Efficiency Fund (EEEF).

10.4.2 Bucharest Project

The city of Bucharest has been more active in energy efficiency. An interesting case study is an project initiated by the Bucharest City Hall with the aim of retrofitting 273 buildings in District 6. The project is divided in 3 stages, comprising 110, 103 and 60 buildings respectively. The whole project is supported by energy auditors. For each building an energy audit was performed and an energy certificate was issued measuring the consumption before and after the implementation of the retrofitting measures. The measures included are wall insulation, replacing of boilers and modernisation of doors and windows. The majority of the retrofitted buildings still use district heating, while in some buildings owners have installed individual gas heating. Most of the beneficiaries (flat owners) have low or medium incomes. In addition to the potential energy savings, a further trigger for engaging in such investments was the age of technical equipment of buildings. In some cases the equipments used (boilers, individual heating systems) were so old, that it put in danger the people using them, so their replacement was very much needed.

It started in 2012 and the three stages are planned to be completed by the end of 2015. At the start of the project, the City Hall made a first phase of replacements free of charge as a "show case". The City Hall having a good financial standing and rating, was able to get for the first stage of the project a loan from the European Investment Bank under good financial conditions.

The investment volume for the three stages is approx. €150 million. For the second stage, 50% of the finance needed is provided by the Bucharest City Hall from national and local budgets. The other 50% is funded by the flat owners (from saved energy costs). For social housing, the City Hall covers the full cost which is then repaid via the saved energy costs of the tenants. The part of the funding to be recovered over time from saved energy costs is initially covered by the City Hall through loans from international and Romanian financial institutions.

It was important that the City Hall choose a consortium of construction companies that were able to perform the required works in due time. The works affected the home owners as they implied noise and scaffolding mounted near the windows of the apartments. It was important as a consequence for the construction companies to have high standards of professional level and practices and try to disturb flat owners as little as possible.

10.4.3 Role of Banca Transilvania & EEEF

The consortium of construction companies had to accept deferred payments of 18 months after the start of the retrofitting to win the City Hall tender. Therefore the consortium asked Banca Transilvania for bridge finance in the second stage of the project.

Banca Transilvania – the third largest bank in Romania founded in 1993 – has been involved in the financing of the project by provide bridge finance for the consortium of construction companies performing the work. Banca Transsilvania financed the second phase of the project via the European Energy Efficiency Fund (EEEF), and takes part also in the third stage of the project.

The bid for the first stage of the project happened before Banca Transilvavia and EEEF signed their agreement in 2013. EEEF provided Banca Transilvavia with a refinancing facility of €25 million over 10 years. The bank can select potential projects at its own discretion as long as it is in compliance with the EEEF investment eligibility criteria. EEEF has chosen Banca Transilvania based on their standing and expertise, which the bank proved in a previous experience with EBRD.

After the signature and when the second bid by the Bucharest City Hall went out, Banca Transilvavia and the consortium of construction companies which won the bid to perform the work decided to work together via bridge finance. Only one of the companies in the consortium was already a client of Banca Transilvania before the project.

Regarding the third stage still outstanding, Banca Transilvania has only issued an advance payment guarantee so that the construction company receives a down payment from the Bucharest City Hall and is able to start working for this third stage. Banca Transilvania has also issued a commercial binding limit so as to finance the third stage of the project, which has not been yet disbursed by the company.

10.4.4 Challenges

The organisations and institutions involved in the project had to overcome several challenges and barriers:

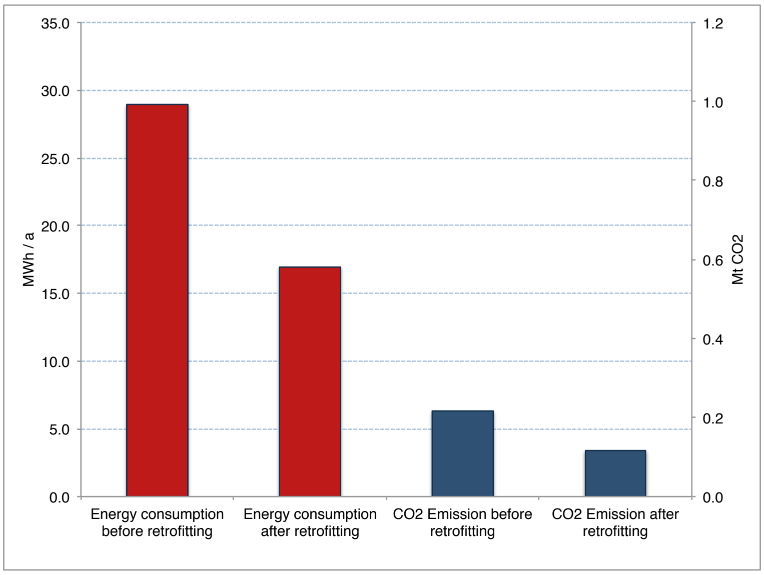
- A feasibility study was needed to demonstrate the soundness of the investment in terms of economic and social benefits. Therefore potential energy savings evaluations per dwelling depending on its size and the building age as well as its structure had to be performed. Based on the available data on retrofitting costs for different retrofitting options, the economic efficiencies needed to be determined.
- No coherent national policy for retrofitting schemes was available when the project was designed.
- Financial contribution of dwelling owners has an impact on the efficiency of a single investment. Therefore discussions with the flat owners and flat owners' associations concerning their financial contribution to the project took place. Some flat owners weren't able to cover even a small percentage of the investment, therefore the City Hall decided to finance the investment entirely by its own resources. This process has delayed the decision to implement the project.
- Deciding on the financing scheme so as to cover the 50% part that was the responsibility of the City Hall. The City Hall had to take into account its maximum indebtedness level (30% of its own revenues) so to get the approval from the City Council for the project.
- For the City Hall it was important that the consortium of construction companies accepts deferred payment. Therefore they launched the bid asking for a 18 months-term of payment.

- Considering that no non-reimbursable financial resources were available for the City Hall for this project, it was difficult to justify choosing this investment over other types of investments.

10.4.5 Results and Outcomes

An improvement of at least one level of the energy class was achieved, mostly from D/C to B. While a minimum of 20% of energy saving is a condition for the eligibility for EEEF funding, the project achieved over 40% of energy saving on average. Regarding the social outcomes, the project has brought considerable positive impact in energy efficiency and associated decrease in the energy bill of the flat owners. The reduction of the energy bill by 40-50% as a result of implementing energy efficiency measures on thermal insulation of their residential building improves households financial resources considerably. The whole project leads to a reduction of energy consumption of ca. 16.9 MWh per year and emissions reduction of 2.9 Mt CO_2 (see Figure 41). Until now there do not seem to be any quality issues, the retrofit works which have been performed have respected the quality requirements agreed with the Bucharest City Hall.

Figure 41: Effects on energy consumption and CO_2-Emission



Source: Figures provided by Banca Transilvania.

A positive side effect results from the renovation of the facade of the blocks. Some flat owners started themselves working on the buildings before the project and they used different materials, colours and standards. Such colour differences very much affected the image of the city, so that the comprehensive retrofitting activity results in a improving shape of the buildings and also image of the city.

From the EEEF point of view, this project is a very successful approach for the fund to enter the Eastern European market. With Banca Transilvania, the EEEF partnered with a well positioned local bank with good expertise and standing in the market. Especially as a typical SME bank, Banca Transilvania has client relationships to construction companies, ESCOs and other enterprises which provide valuable opportunities to support also smaller projects via bundling models.

One can expect that many other town halls will start developing projects in building retrofitting. However, most municipalities cannot afford the same kind of scheme as the one used by the Bucharest City Hall District 6 due to their low local budget and low financial standing. More projects are to be expected considering that non-reimbursable funding will be available for energy efficiency projects starting mid 2015. Financing lines for town halls will come into existence as non-reimbursable funds from the EU over 2015-2020 for a total amount of €2 bn for Romania for energy efficiency projects, most of which will be available for building retrofitting. Today EU structural funds cannot be combined with facilities such as EEEF in the same phase. However, there are working groups at the European Commission level that look into how to better use and combine such financial schemes.

10.5 Lessons learnt

The simulation results in Section 7.5 showed that investment needs for emission reductions are much higher in lower income/low energy efficiency countries. However, over the last decade, investments into energy retrofitting of residential buildings and industrial facilities in Central and Eastern European countries have been small scale, mainly demonstration and pilot projects. Compared with the overall needs in these sectors, the progress is relatively slow. Hence, in this chapter we analysed the conditions needed to increase overall investments and direct a large share of these investments into energy efficiency measures in Bulgaria, Romania and the Czech Republic.

By combining analysis of relevant scientific literature, sectoral and policy reports with interviewing experts in the field of energy efficiency in the three countries and a case study, we assessed the main barriers and drivers for energy efficiency projects implementation. Presently, the investment conditions do not support considerable investments in these countries. Low incomes, low energy prices and high interest rates hinder private investments into residential retrofitting due to low economic efficiency (low NPVs) of such investments. Additionally, the low investment capacity of households (due to low incomes), the lack of appropriate financing schemes, a lack of public awareness and acceptance and a missing or frequently changing regulatory framework are the main barriers.

Possible drivers for investment, mentioned by experts were a stable regulatory framework, the introduction of “White Certificates” for energy efficiency, effective communication campaigns, effective financing schemes for ESCOs as well as minimum qualification requirements in the tendering process for the relevant professions.

We provided an example of successful investment projects in Romania which shows that relevant retrofitting activities require multiple support and a socio-economic environment that foster such investments. Based on this case study, we would like to emphasise the following lessons to be learnt:

- **Institutional requirements:** Good coordination of all stakeholders involved in the project helps to reduce friction losses. This coordination task was fulfilled in this case by the

Bucharest City Hall. A main task of the City Hall was the coordination of the investors. Dwellings are owned by individuals, who have to coordinate their investment decisions if a complete building block has to be retrofitted. This comprises, on the one hand, the joint decision by owners associations (balance of interests) and, on the other hand, the coordination of finance and the process of retrofitting.

Standardisation of the retrofitting activities – in this case also administrated by the City Hall – leads to better coordination of retrofitting procedures, allocation of construction materials, positive scale effects and costs reduction.

Furthermore *local banks* are needed for the coordination of international funds and the lending schemes.

- **Financial conditions:** Over the last years, interest rates in the three countries are relatively low and energy prices for households have been increasing. This leads to an increase of the efficiency of retrofitting projects, which has not been the case before.

  Financing from European institutions and facilities (e.g. EEEF, EIB, EBRD) provides support and technical assistance for the implementation of projects. The allocation of funds that are used for loans reduce financing costs.

  Even if *subsidies* contradict market economic theory, only such support allows most families with low incomes to join in retrofitting projects. However, they cannot easily be combined with private sources of financing due to regulations, which in some cases however would be useful. The large availability of grants also hinders the establishment of a market for energy efficiency financing (ESCOs).

11 Conclusion

Four major challenges have been described and analysed in this study: the climate challenge, the economic challenge, the modelling challenge and the policy challenge. The contribution of the study consists in tackling the modellig challenge so as to integrate the other three challenges. The policy solution proposed on that basis is an investment-oriented climate policy.

As opposed to other model results, the results of the simulations show that even with a 50% reduction of emissions, an investment-oriented climate policy can lead to an increase in economic growth and employment. The key mechanisms identified were an investment program, resulting learning-by-doing effects and expectation dynamics. These results show that the models used for climate policy evaluation so far unnecessarily exclude the possibility of positive economic effects by design. The purpose of this study is to open the debate in climate and economic policy towards the possibility of true win-win options.

Concerning the policy debate in Europe, the results highlight the lack of integrated strategies for climate and economic policy. Putting a stronger emphasis on investments can be beneficial in economic as well as environmental terms. The current unsatisfactory economic situation could be overcome by closing the investment gap through an investment impulse, acting as a driver of innovation and positive expectations. For the policy framework in the area of climate and economic policy this means that the 2030 climate and energy framework will need to incorporate an impulse of “green” investments. The economic governance framework can then incorporate the transition to a low-carbon economy as an overarching goal.

Especially for Central and Eastern Europe we found a mismatch between model results and reality. An investment-oriented climate policy would have to take account for the economic situation and the resulting needs of these countries.

The Synthesis Report, included at the beginning of this document, provides a more comprehensive summary of all chapters, including the described challenges, the analysis and the main conclusion from the report.

Annex

A

TFP Correction Factors

As an example for the TFP-correction factor (see Equation 9) in the M50all, the values for Germany are given in Table 11.

Table 11: TFP Correction Factors For Germany

Sector	2003	2004	2005	2010	2015	2020	2025	2030
Agriculture	1	1	1	1	1	1	1	1
Coal	1	1	1	1	1	1	1	1
Crude Oil	1	1	1	1	1	1	1	1
Oil	1	1	1	1	1	1	1	1
Gas	1	1	1	1	1	1	1	1
Electricity supply	1	1	1	1	1	1	1	1
Ferous metals	1	1	1	1	1	1	1	1.0384845
Non-ferrous metals	1	1	1	1	1	1	1.0028413	1.0232062
Chemical products	1	1	1	1	1	1	1	1.0163596
Paper products	1	1	1	1	1	1	1	1.0055081
Non-metallic minerals	1	1	1	1	1	1.0160084	1.0289584	1.0693232
Electric goods	1	1	1	1	1	1.011939	1.0836786	1.4807742
Transport equipment	1	1	1	1	1	1	1.0087505	1.0261409
Other equipment goods	1	1	1	1	1	1	1.0030572	1.0117295
Consumer goods industries	1	1	1	1	1	1	1	1
Construction	1	1	1	1	1	1.0403747	1.0697556	1.1233369
Transport (air)	1	1	1	1	1	1	1	1
Transport (land)	1	1	1	1	1	1	1	1.0079859
Transport (water)	1	1	1	1	1	1	1	1
Market services	1	1	1	1	1	1	1	1.0113115
Non-market services	1	1	1	1	1	1	1	1.0015086
Coal fired	1	1	1	1	1	1	1	1
Oil fired	1	1	1	1	1	1	1	1
Gas fired	1	1	1	1	1	1	1	1
Nuclear	1	1	1	1	1	1	1	1
Biomass	1	1	1	1	1	1.3172748	1.2954495	1.3365444
Hydro electric	1	1	1	1	1	1.0333896	1.0457575	1.0496914
Wind	1	1	1	1	1	1.0401805	1.1079812	1.1269489
PV	1	1	1	1	1	1	1.0112414	1.0046902
CCS coal	1	1	1	1	1	1	1.0729635	1.2089481
CCS gas	1	1	1	1	1	1	1	2

B

Short Technical Description of the GEM-E3-M50 Model

This section provides a short technical overview of the GEM-E3-M50 model. The purpose of this section is not to present the model in detail but to provide a sketch of the general structure of the model in order to support the illustration of the modelling mechanisms described in the section above.

B.1 Firms

Firms maximise their profits subject to technology constraints.

$$MaxP \cdot Q - Costs.t.Q = CES(K, L, E, M) \tag{17}$$

The production function used is the Constant Elasticity of Substitution (CES) in calibrated share form as presented in Rutherford (2002). Firms production is modelled via a nested tree of production functions so as to explicitly reflect different substitution elasticities among different inputs:

$$Q_i = TFP_i \cdot \bar{Q}_i \cdot \left(theta_i \cdot \left(\frac{KLEi}{K\bar{L}E_i} \right)^r \cdot (1 - theta_i) \cdot \left(\frac{MAi}{\bar{MA}_i} \right)^r \right)^{\frac{1}{r}} \tag{18}$$

$$KLE_i = K\bar{L}E_i \cdot \left(theta1_i \cdot \left(\frac{KLi}{\bar{KL}_i} \right)^{r1} \cdot (1 - theta1_i) \cdot \left(\frac{ENi}{\bar{EN}_i} \right)^{r1} \right)^{\frac{1}{r1}} \tag{19}$$

$$KL_i = K\bar{L}_i \cdot \left(theta2_i \cdot \left(\frac{Ki}{\bar{K}_i} \right)^{r2} \cdot (1 - theta2_i) \cdot \left(\frac{Li}{\bar{L}_i} \right)^{r2} \right)^{\frac{1}{r2}} \tag{20}$$

$$MA_i = \left(\sum_{j=1}^{n} theta3 \cdot \left(\frac{IOj, i}{I\bar{O}_{j,i}} \right)^{r3} \right)^{\frac{1}{r3}} \tag{21}$$

where Q: total output, TFP: Total factor Productivity, KLE: Capital-Labour-Energy bundle, MA: Material bundle, theta: distributional parameter between KLE and MA, r: parameter related to elasticity of substitution, KL: Capital - Labour bundle, EN: Energy bundle, theta2: distributional parameter between KL and EN, r2: parameter related to elasticity of substitution, IO: intermediate inputs, theta3: distributional parameter among intermediate inputs, r3: parameter related to elasticity of substitution.

B.2 Households

Households maximise their utility subject to their income constraint.

$$MaxU = LES(C, LJV)s.t.M = w \cdot L + r \cdot K + foreignTransfers \tag{22}$$

where U: Utility represented by a Linear Expenditure System function, C: Consumption, LJV: Leisure Households follow a two step decision process. At first they allocate their resources among consumption/labour supply and savings and then they allocate aggregate consumption over different consumption purposes.

$$C = ch \cdot \frac{bh}{P} \cdot (M - P \cdot ch - Savings) \tag{23}$$

where ch: subsistence minima, bh: consumption share parameter

B.3 Trade

All regions of the model are linked via endogenous trade transactions. Consumers (both firms and households) consider domestically produced goods and imported goods as imperfect substitutes (Armington assumption). The decision for imports is a two level decision: At the first level the choice between total demand for domestically produced goods and imported goods is made and at the second level the choice among different trading partners is made. Cost minimisation drives the decision for the optimal mix of the composite good [domestic and imported]:

$$Y_i = \cdot \bar{Y}_i \cdot \left(domestic_i \cdot \left(\frac{DPi}{\bar{DP}_i} \right)^{r4} \cdot (imported_i) \cdot \left(\frac{IPi}{\bar{IP}_i} \right)^{r4} \right)^{\frac{1}{r4}} \tag{24}$$

$$IP_s = \left(\sum_{r=1}^{m} theta4 \cdot \left(\frac{TRADEr,s}{\bar{TRADE}_{r,s}} \right)^{r4} \right)^{\frac{1}{r4}} \tag{25}$$

where Y: composite good, DP: Domestic Product, IP: Imported Product, domestic/imported: distributional parameters between domestically produced goods and imported goods, r4: parameter related to elasticity of substitution, TRADE: Bilateral trade transactions

B.4 Government Consumption

Government consumption (GC) is set exogenously (gcexo), GC=gcexo.

B.5 Investment

The model is recursive dynamic over time with endogenously specified investments that are determined using the Tobins'Q (i.e. by comparing the market price of capital with its replacement cost). The motion equation of the capital stock is:

$$K_t = (1 - d) \cdot K_{t-1} + INVV_t \tag{26}$$

Firms in the current year decide on their optimal capital stock by comparing the rate of return on capital to its replacement cost.

$$INVV_{i,t} = A1_{i,t} \cdot K_{i,t} \cdot \left(\left(\frac{PK_{i,t}}{PINV_{i,t} \cdot (r_t + d_{i,t})} \right)^{A} + STGR_{i,t} + d_{i,t} \right). \tag{27}$$

where $A1$ is a calibrated scale parameter; K is the optimal demand for capital; $PINV$ is the unit cost of investment; d is the depreciation rate; r is the national interest rate and $STGR$ is the exogenous agents expectations on sectoral growth.

B.6 Labour Supply

The model does not assume full employment of labour. It incorporates the following labour supply curve that inversely relates wages[w] with unemployment rate [unrt]:

$$w_{j,t}(Unrt_{j,t}) = a_{j,t} + \frac{b_{j,t}}{Unrt_{j,t}^{\eta_{j,t}^{Ref}}}. \tag{28}$$

B.7 GHG Emissions

Energy related CO2 emissions are calculated by applying the appropriate emission factors to fossil fuel burning.

$$EMCO2_{ff,i} = efCO2ff \cdot AER_{ff,i} \cdot EN_{ff,i} \tag{29}$$

Process related GHG emissions are linked with the volume of production

$$EMGHG_i = efCO2ff \cdot Q_i \tag{30}$$

The imposition of GHG emission reduction target generates a dual value that increases the user cost of the emitting activity.

$$GHGTARGET \geq EMCO2 + EMGHG \perp CTAX \tag{31}$$

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