New Member States
Climate Protection and Economic Growth
Case Study Bulgaria and Romania

Final Report

Frank Meissner
Diana Mangalagiu
Leonidas Paroussos
Carlo C. Jaeger

Authors

Frank Meissner, Diana Mangalagiu,
Leonidas Paroussos, Carlo C. Jaeger

With the collaboration of:

Bulgarian partner institutions

EnEffect: Kamen Simeonov, Anton Todorov, Pavel Manchev, Stanislav Andreev, Aleksandar Stankov

Energy Institute LSC: Christo Christov, Kiril Tagarov, Violeta Hristova,
Zdravko Genchev

Julian Popov, (Adviser to the European Climate Foundation)

Romanian partner institutions

Institute for World Economy:
Manuela Unguru , Razvan Voinescu,
Cristian Moisoiu,

Aspen Institute Romania: Andrei Tarnea

Global Climate Forum: Jette Krause

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

Umwelt Bundesamt

Global Climate Forum e.V.

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1 Overview for decision-makers

Romania and Bulgaria are characterised by high energy and carbon intensities compared to the EU average. This is linked to the fact that they have low GDP per capita. To put it positively, these countries have great opportunities for catching up and need policies to realize them. Bulgaria, e.g., uses about four times as much energy per unit of GDP as the EU28 average, and has the lowest GDP per capita in the EU28. Before the financial crisis it experienced growth rates in the order of 6% without accumulating public debt and with decreasing unemployment.

The present study investigates options for these two countries to contribute to an EU-wide reduction of greenhouse gas emissions by 40% in 2030 (compared to 1990). The requirement was to combine computer simulations with individual assessments of specific policy measures.

In both countries, the period after the breakdown of the Soviet Union saw great economic losses and also reductions of greenhouse gas emissions due to the breakdown of the old industrial structure. Therefore we consider emissions reductions against a baseline of 2005 (the European numbers still refer to the baseline of 1990).

The computer simulations compare a 40% reduction scenario with a reference scenario (business as usual). The results suggest that an efficient European 40% (compared to 1990) reduction curve would imply reductions of the same magnitude for Bulgaria and Romania compared to 2005. The precise numbers in the simulation are 44.5% for Bulgaria (68% compared to 1990) and 38% for Romania (66% compared to 1990). In the reference scenario the reductions are about half that size (28% in Bulgaria and 24% in Romania, both compared to 2005). The bulk of the additional emissions reductions come from the energy sector, followed by industry. The results of the cost-efficient scenario, obtained by using the GEM-E3-NMS model, are comparable to the results of the Impact Assessment Report by the European Commission (which uses its own version of GEM-E3). Accordingly, input assumptions between the two model version are similar but not identical.

The key mechanism for emissions reduction is increasing energy efficiency. This mechanism works in the energy sector itself, in industry and in the economy as an entirety due to structural changes towards an expansion of the services sector.

According to the model simulations, wind, biomass, nuclear and CCS all contribute to emissions reductions, while the contribution of photovoltaic and additional hydro capacities are negligible.

With regard to economic consequences, in the model simulations a 40% reduction implies a slight decrease in the annual rate of economic growth (by 0.09 and 0.05 percentage points over the period 2015-2030 for Bulgaria and Romania respectively). Given the great uncertainties of economic forecasts over such time horizons, this means that the effects of such an emissions reduction on economic growth are practically undetectable.

It is essential to notice that in these simulations unemployment stays at present levels, implying that Bulgaria and Romania use their productive resources less efficiently than before the financial crisis. These countries are too small to shift to a better growth path using only their own devices. The EU, however, is large enough for such a purpose. The simulations assume that Europe as a whole suffers a permanent loss from the shock of the financial crisis, an effect known as hysteresis. This means that a short-term loss of efficiency in resource use becomes the new normal. It also means that presently there is an efficiency reserve that could be used to generate additional growth in low-carbon products and infrastructures. If the EU would realize this possibility, Bulgaria and Romania could achieve 40% reductions compared to 2005 with lower unemployment and higher GDP than in the reference scenario. Analysing such EU-wide developments, however, was not part of the present study.

In the study, the modelling results for Bulgaria and Romania were combined with an assessment of individual policy measures. With both methods, improving energy efficiency turns out to be a particularly promising approach for emissions reductions in these countries. Among the measures considered, the greatest economic advantage per emission reduction is to be expected from better use of excess heat in industry (including improvements of industrial buildings). Next come measures for retrofitting buildings: public ones, multi-family residences, and single-family residences. Another interesting measure to be implemented is the introduction of LED street lighting.

The assessments performed here also suggest that a more comprehensive analysis would require a larger study looking into the following issues:

First, the delicate question of energy prices would have to be tackled. One should not forget the toppling of the Bulgarian government by protests over increasing energy prices in 2013. While subsidies and regulations enforce economically inefficient energy prices, a politically reasonable way to correct this situation is by increasing growth, and thereby incomes, first and adjusting those prices in a second step. An understanding of this situation by other member states and the Commission is a precondition for an economically efficient climate policy in Bulgaria and Romania.

Second, the role of education needs to be reconsidered. Our analysis suggests that there are no bottlenecks on the labour market that would make the climate policy measures considered unfeasible. But there is no doubt that the catch-up options available to Bulgaria and Romania would be greatly enhanced by improved opportunities for high-class education, especially in preparing skilled workers, technicians, engineers, etc. This would be beneficial to both countries particularly considering the brain drain they faced over the last two decades. Such an improvement cannot happen overnight, but considering the time horizon up to 2030 it can make a decisive difference.

Third, two different ways of performing the investments required to achieve 40% emissions reduction need to be considered. Presently, there is a danger that such investments will crowd out the already reduced investments for other purposes, simply because the owners of financial capital prefer to keep it idle rather than running the risk of investments stranded due to lacking demand. On the other hand, there is an opportunity to use climate investments to mobilize some of that idle financial capital. This requires the design of incentives for financial investors, and such incentives would need to be implemented at a European scale.

In the course of this project, a new effort sharing decision (ESD Decision No. 406/2009/EC)[1] for the fair distribution of non-ETS emission reduction efforts was decided and implemented in October 2009. Therefore, the BMUB commissioned a supplementary study, investigating the changes in economic effects, taking into account the new effort sharing decision. The results can be found in the Report "New Member States Climate Protection and Economic Growth - Macroeconomic implications of a burden sharing non-ETS GHG target in Bulgaria and Romania" which can be downloaded on www.globalclimateforum.org.

2 Project design

2.1 Objective

The objective of the research project "New Member States: Climate Protection and Economic Growth" is to analyse economically feasible and implementable climate protection measures in Bulgaria and Romania. The question we attempt to answer is "How both countries can reduce emissions significantly and permanently while simultaneously achieve pre-2008/9 crisis sustainable growth?"

The project has been articulated around two main approaches. With a **Bottom-Up** approach we focus on single mitigation measures and their potential impacts, barriers and implementation. We use a **Top-Down** approach for a macroeconomic analysis of potential investments into renewable energies and energy efficiency activities.

2.2 Methodological framework of the top down approach

We study the adjustment of the Romania and Bulgaria economic and energy system when the EU28 wide GHG emissions in 2030 are reduced by 40% compared to 1990 levels. Our analysis is based on the results of the computable general equilibrium model GEM-E3-NMS[2]. In order to facilitate the understanding of the model results we provide here an overview of the main features of the model.

GEM-E3–NMS is a recursive dynamic computable general equilibrium model that covers the whole world aggregated to 46 countries/regions, 32 economic activities and 4 types of economic agents. The model represents, within a rigorous microeconomic framework, the multiple interactions between all agents and markets of the economic system and simulates the mechanisms that define the distribution of resources and economic activity. The model calculates how the finite resources of the economic system are redistributed when a departure from their initial equilibrium point occurs. The key factors determining the adjustment process towards the new equilibrium point are identified providing useful insights for the properties of the economic system under study.

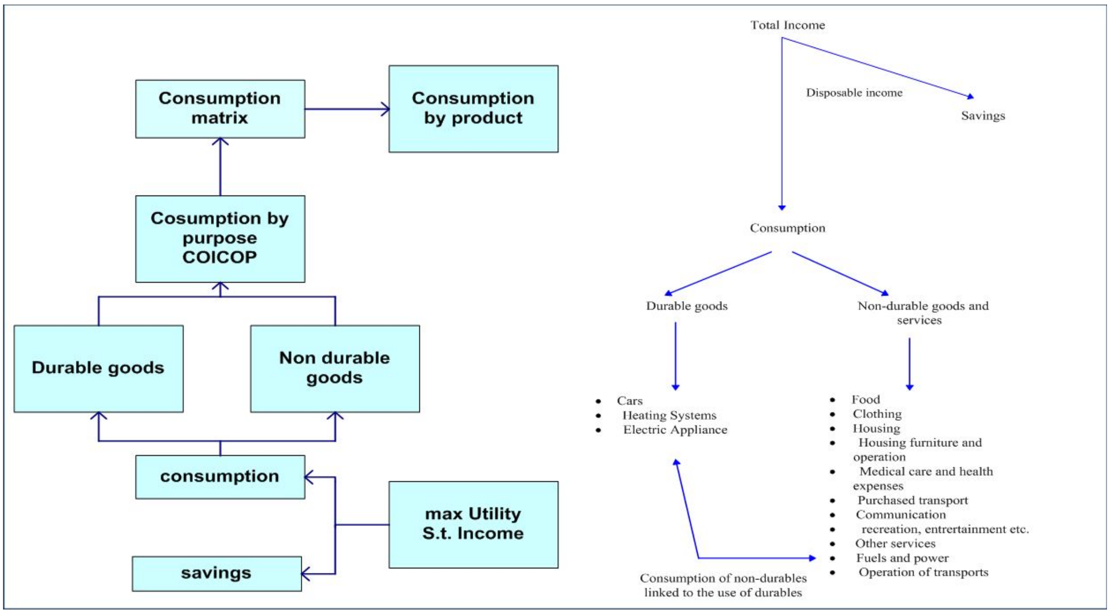
Firms operate in a perfect competition environment and maximize their profits subject to their production function. The solution of the firms' optimization problem consists of the optimal demands for each production factor. The derived demand and

[1] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009D0406
[2] The NMS version of GEM-E3 has been developed for the purposes of the current study.

the unit cost functions determine the firms demand for production factors and its product supply. Domestic production is defined by economic sectors and it is assumed that each sector produces a single product, which is different from any other product in the economy. Production functions are of the constant elasticity of substitution (CES) type and exhibit a nested separability scheme, involving capital (K), labour (L), energy (E) and materials (M). The CES nesting levels depend on the factor substitution possibilities determined by the distinctive features of each activity/sector.

Households purchase goods and services from which they derive utility. The behaviour of the representative household in each country is derived through maximizing a LES[3] utility function subject to its disposable income. The consumption system in GEM-E3-NMS is detailed as it decomposes consumption purposes to demand for specific consumption products through the use of consumption matrices. Following Conrad and Schroder (1991) the consumption of durable goods requires the use of linked non-durable goods. The GEM-E3-NMS model distinguishes between durable and non-durable goods and links the consumption of goods and services to the use of durable goods. The stock of durable goods changes dynamically over time as a result of investments by households in new durable goods (which are determined endogenously).

Figure 1: Household consumption circuit in GEM-E3-NMS



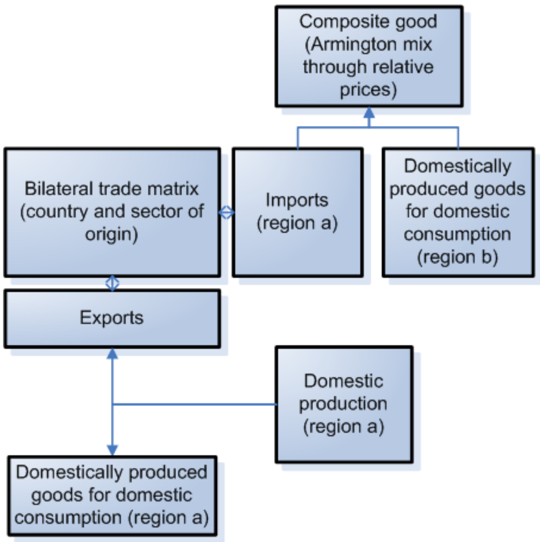
Source: Capros; Van Regemorter; Paroussos et al. (2013)

All countries in the model are linked through endogenous bilateral trade transactions. The Armington (Armington, 1969) specification is adopted according to which the demand for products (final or intermediate) is allocated between domestically produced products and imported products. In this specification, consumers (intermediate or final) demand a composite commodity which combines domestically produced and imported goods, which are considered as imperfect

[3] Linear Expenditure System.

substitutes. Demand for imports is allocated across imported goods by country of origin.

Figure 2: Trade flows in the GEM-E3-NMS model.



Source: Capros et al. (2013)

The model is calibrated to the GTAP[4] v8 database that identifies separately skilled and unskilled labour. The labour market does not follow the standard CGE[5] approach where wages are fully flexible and adjust until supply equals demand. Instead a wage supply curve that represents an inverse relationship between wages and unemployment has been included. The labour supply elasticity[6] of this curve for Bulgaria and Romania has been calibrated to 0.1.

The model represents all sources of GHG emissions: CO_2 emissions from energy combustion, process related carbon emissions and non-CO_2 GHGs (CH_4, N_2O, F-gases). Abatement of energy related CO_2 emissions is performed by energy efficiency improvements, fuel and technology switching and economic activity adjustments whereas for process related emissions sectorial marginal abatement cost curves are included in the model.

A bottom-up approach has been adopted to represent the structure of the power generation system. The aggregate electricity supply sector found in the statistical input – output tables has been split to ten different power generation technologies and to the electricity transmission and distribution sector. The power generation technologies included in the model are presented in Table 1.

[4] Global Trade Analysis Project, https://www.gtap.agecon.purdue.edu/.
[5] Computable General Equilibrium.
[6] In the GEM-E3-NMS model the labour supply function is calibrated to a wage elasticity of 0.1 documented in several empirical studies (see Ballard, 2000; Sorensen, 1999; Juhn et al, 2002 and Heim 2009 among others).

Table 1: GEM-E3-NMS power generation technologies

No	Technology	No	Technology
1	Coal fired	6	Hydro electric
2	Oil fired	7	Wind
3	Gas fired	8	Solar
4	Nuclear	9	CCS coal fired
5	Biomass	10	CCS Gas fired

Source: GEM-E3-NMS

The production function of each power generation technology is based on the TECHPOL database (TECHPOL, without year). The cost structure of each electricity production technology can be different across countries depending on fuel prices, capital costs and wages. A representative production structure for each technology is presented in the table below.

Table 2: Power technology costs breakdown

	Coal fired	Oil fired	Gas fired	Nuclear	Bio-mass	Hydro elec-tric	Wind	Solar
Agricultural feedstock					66.4%			
Coal	32.3%							
Oil		70.6%						
Gas			78.5%					
Capital	50.6%	22.3%	15.5%	79.6%	27.2%	80.3%	84.4%	95.2%
Labour	17.1%	7.2%	6.0%	20.4%	6.4%	19.7%	15.6%	4.8%

Source: TECHPOL

The capital costs of power generation technologies are formulated by an investment matrix that translates the investment demand of each power generation technology to specific demand for investment products. This matrix is based on a literature survey of the specific technologies EWEA (2009) and JEDI Models (2014). A representative investment matrix for the different power generation technologies is presented in Table 3:

Table 3: Power technologies investment matrix

	Coal fired	Oil fired	Gas fired	Nuclear	Biomass	Hydro electric	Wind	Solar
Agriculture	0.0%	0.2%	0.0%	0.0%	13.8%	0.2%	0.0%	0.0%
Ferrous & non-ferrous metals	0.0%	0.9%	0.0%	2.4%	0.0%	1.2%	11.0%	0.0%
Chemical Products	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	6.3%	0.0%
Electric Goods	13.5%	5.5%	18.7%	4.8%	0.0%	4.7%	6.5%	6.8%
Other Equipment Goods	31.1%	17.7%	19.9%	10.7%	0.0%	13.1%	39.9%	19.9%
Construction	40.7%	60.6%	45.9%	69.5%	68.0%	64.5%	28.6%	50.4%
Market Services	14.5%	14.8%	15.4%	12.8%	17.0%	16.1%	7.7%	22.9%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Source: GEM-E3-NMS

In the model unit production costs of power generation technologies are endogenously computed and are subject to the technology specific production function and the country specific labour, capital and fuel costs. The production structure of each technology is common across countries. Capital costs of new power generation technologies like Wind, Solar and Biomass decrease over time due to learning by doing and learning by research effects (the latter are exogenously defined in the model). The EU average unit production costs of representative power generation technologies for the year 2010[7] are presented in the Table 4 (unit production costs are expressed relative to the coal fired technology as in the model it is only relative prices that are important). Unit production costs are usually expressed in Euro/kWh produced and represent the Levelised Cost Of Electricity (LCOE) that includes the annualized investments costs, fixed and variable operating and maintenance costs and fuel costs. Capital costs for the ten power generation technologies included in the model are based on a variety of sources, key among which are the PRIMES model database, EIA estimations (EIA, 2013), the Fraunhofer institute (Fraunhofer ISE, 2013) and IEA analysis (IEA and NEA, 2010).

[7] Capital costs of power generation technologies cannot differ significantly by country since they refer to the same production technology. For instance PV produced in China will be imported roughly at the same price (excl. transport margins). Transactions costs exists and may alter the installation costs (i.e. days for license issuance etc.) of these technologies. These are not easily to quantify and hence are not explicitly included in the model.

Table 4: Unit production costs[8] (relative to hard coal fired)

	2010
Coal fired	1.0
Oil fired	2.4
Gas fired	1.2
Nuclear	0.7
Biomass	2.6
Hydro electric	0.7
Wind	1.5
Solar	3.0
CCS Coal	1.7
CCS Gas	1.6

Source: GEM-E3-NMS

The GEM-E3-NMS model has been used in order to quantify the adjustment of the economic and energy system of Bulgaria and Romania when an EU wide target of 40% compared to 1990 is imposed in 2030. The emission reduction target is imposed at the EU28 emissions level and the model calculates the least cost allocation of the abatement effort among each member state. In particular the emission reduction constraint generates a shadow value (carbon tax[9]), which increases the costs of GHG emitting activities. Then the internalization of this additional cost in to the cost structures and choices of the economic agents is governed by their "optimizing behaviour" (i.e. firms maximize profit, households maximize utility etc.). The resulting equilibrium prices and quantities, incorporating both the primary and secondary effects of the policy intervention, leads to an endogenous least cost allocation of the abatement effort. Different abatement options including energy efficiency, renewables and fuel switching have been considered in the analysis.

The public revenues generated from the carbon tax are recycled back into the economy (i.e. are not held by the government to reduce/increase its deficit/surplus) by reducing employers' social security contributions. This recycling option reduces the labour cost and has been found[10] to be efficient both in terms of GDP and employment adjustment.

In the GEM-E3-NMS the creation of un-sustained current account deficit is possible when no endogenous fiscal instrument is activated in order to prevent this imbalance. In the current simulations it has been assumed that the EU-wide interest rate would adjust so that EU current account would remain unchanged as

[8] The GEM-E3-NMS model being a computable general equilibrium model identifies only relative prices (demand functions are homogeneous of degree zero in prices hence it is not the price level that determines demand but rather the relative prices of goods). The unit production cost of the power generation technologies is not expressed as Euro/KWh but rather in relative terms.

[9] The higher the emission reduction constraint is imposed into the model, the higher the level of the carbon tax will be (and vice versa).

[10] A detailed analysis on the impact on alternative recycling options has been performed within the MODELS EC funded project, http://www.ecmodels.eu/index_files/Page660.htm

percentage of GDP from the reference case[11]. This ensures that the GHG mitigation effort is financed by domestic resources without deteriorating the current account position of the region.

The CGE framework ensures that feedback effects are considered: All sectors and countries are linked through endogenous bilateral trade transactions hence firms adjust their production level according to their production costs (cost of capital, labour and materials) and demand for their output.

GEM-E3-NMS power generation mix is calculated as the least cost mix of the different power generation technologies. Technologies compete with each other based on their relative prices and the substitution possibilities implied by the power generation production function used in the model. Additional constraints on power generation from certain technologies reflecting resource and capacity constraints can be introduced into the model. Alternatively the models' power mix can be calibrated to exogenously given shares. In the case where exogenous shares are used, these are taken from the output of an energy model that has quantified the same emission reduction target.

An important mechanism in general equilibrium models that determines the overall adjustment of the economic system is the crowding out effect (financing constraints): Negative GDP effects come primarily from the increase of unit production costs, as the decarbonised energy services are more expensive and production factor substitutions are imperfect. Because of the high labour and capital intensity of decarbonisation, revenues tend to shift from consumption to investment and primary production factor markets are stressed. Due to the capital resource constraints in general equilibrium models, increased investment in a given sector or for a given purpose can be achieved only by a reallocation of investment.

The additional investments needed to decarbonise the energy system, compared to the reference scenario, therefore imply that less capital is available for investments which are not part of the decarbonisation process.

With other words, the relative unit costs of capital tend to increase as a result of the substitutions in favour of domestic activity, which comes from higher capital intensiveness implied in the decarbonisation context relative to the reference case.

[11] The reference case includes the actual 20/20/20 EU climate package.

2.3 Methodological remarks – Bottom-Up approach

We use the **Bottom-Up approach** to analyse possible, plausible and feasible mitigation measures in Bulgaria and Romania, which could be implemented within the next few years so that considerable GHG-emission reductions by 2030 become feasible.

We focus on technology-related mitigation measures, however in our definition a technology can be seen as a technical instrument as well as one that changes behaviours of socio-economic agents and groups and therefore as a non-technical instrument. Main target of each of the measures is the reduction of GHG emissions.

After exhaustively screening possible mitigation measures, we selected, in cooperation with local experts, 7 and respectively 13 measures for Romania and Bulgaria to be evaluated in depth. Our selection criteria were: (a) expected implementability of the measure, (b) expected mitigation outcome and (c) availability of data for the in-depth evaluation process. Therefore all the evaluated measures are to be considered as examples only and at a certain extent all measures are transferable to the other country.

We assess the feasibility, plausibility and implementability of the measures in the two countries by the following indicators:

- Factor capacity (availability of appropriate labour force and capital),
- Competiveness in international markets and
- Time constraints.

In section **Fehler! Verweisquelle konnte nicht gefunden werden.** we present the main findings of the GHG-emission reductions potential of the evaluated measures in both countries and provide an overview of their economic analysis.

For each measure, we provide the Net-Present-Value (NPV) and the abatement costs. The NPV reflects the individual economic efficiency of an investment as difference of the investment and discounted cash flows. If an investment is economically efficient, the NPV is positive.

To ensure comparability of measures in their economic efficiency, abatement costs represent the costs per abated ton CO_2 for each measure. Negative abatement costs reflect a situation of monetary savings, mainly by fuel savings.

We assume an interest rate of 8% and all NPV and abatement cost calculations are based on the average life time of the different facilities.

We take a micro-economic perspective in our analysis. Therefore, fuel prices and interest rates are end-consumer prices. In the abatement costs' calculation, we neglect macroeconomic effects. All prices are kept constant over the period considered due to a lack of comprehensive price forecasts for Bulgaria and Romania. To overcome the resulting inaccuracy, we provide the sensitivity of the results. We take into account that the carbon intensity of power generation will change if the generation structure changes. The following table presents the fuel price parameters, interest rates and carbon intensities used for the calculations:

Table 5: Carbon intensity of fuels and electricity

	2015	2030
	tCO_2/GWh	tCO_2/GWh
Electricity Bulgaria (1)	563	378
Electricity Romania (1)	458	235
District Heating Bulgaria (2)	270	232
District Heating Romania (2)	249	253
Natural Gas	202	202
Coal	361	361

Source: (1) Authors assumptions based on IEA (2013a), IEA (2013b) and GEM-E3-NMS, (2) Euroheat (2013)

Table 6: Fuel prices used for the calculations

	Bulgaria	Romania
	Euro/ MWh	Euro/ MWh
Electricity	100	120
District Heating	43	52
Natural Gas Households	60	30
Natural Gas Industry	35	30
Natural Gas power generation	-	20
Coal	30	-

Source: Authors assumptions based on Eurostat, European Commission (2014) and Euroheat (2013)

3 Background information - Romania

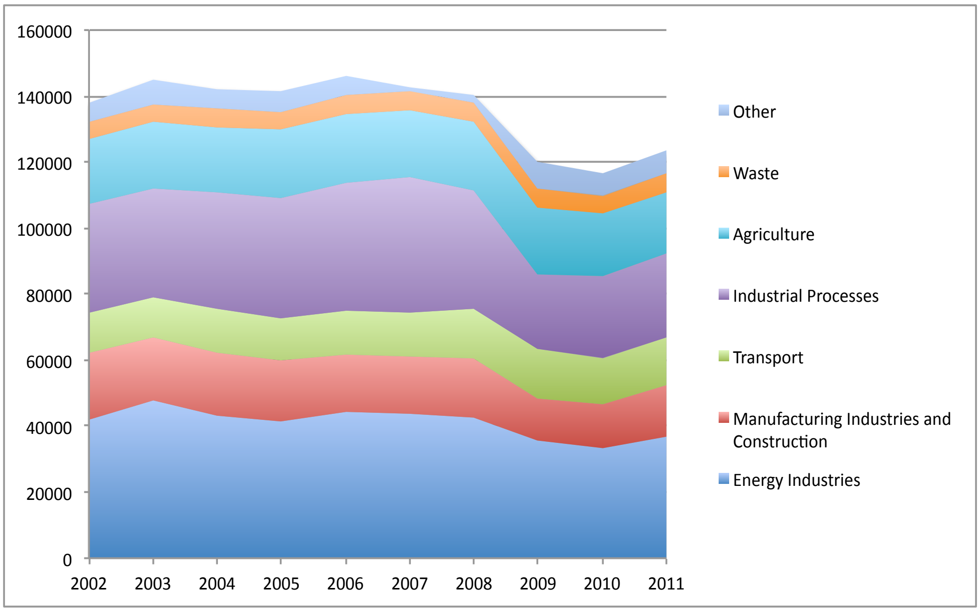
3.1 Overview of the emission status of Romania

3.1.1 GHG Emissions

In 2011, total greenhouse gas emissions in Romania were 123.3 $MtCO_2e$. Romania achieved its 2012 Kyoto commitment of not more than 256 $MtCO_2e$ (European Commission, 2012b) without any difficulty. Compared with the base year 1989, the actual reduction exceeded the target by 37 percent-points (European Commission, 2012b)

Between 1990 and 2010, GHG emissions in Romania have been reduced by 56%, which is the strongest reduction of all EU member states (European Commission, 2012b). In the decade after the end of the Soviet Union, emissions were reduced massively due to of the economic breakdown that hit Romania like other post-soviet countries. In the following decade, 2000-2010, GHG emissions could be stabilized despite the fast economic growth achieved by Romania before the global financial crisis (see Figure 3). Starting at 138.2 MtCO2e in 2002, they have risen slightly to 145.8 $MtCO_2e$ in 2006. The economic crisis caused a strong decline, and GHG emissions have started rising again only in 2011, but have not reached pre-crisis levels.

Figure 3: Romanian GHG Emissions by Sector from 2002 to 2011 (1,000 tCO_2e)



Source: Eurostat

3.1.1.1 Structure of Emissions

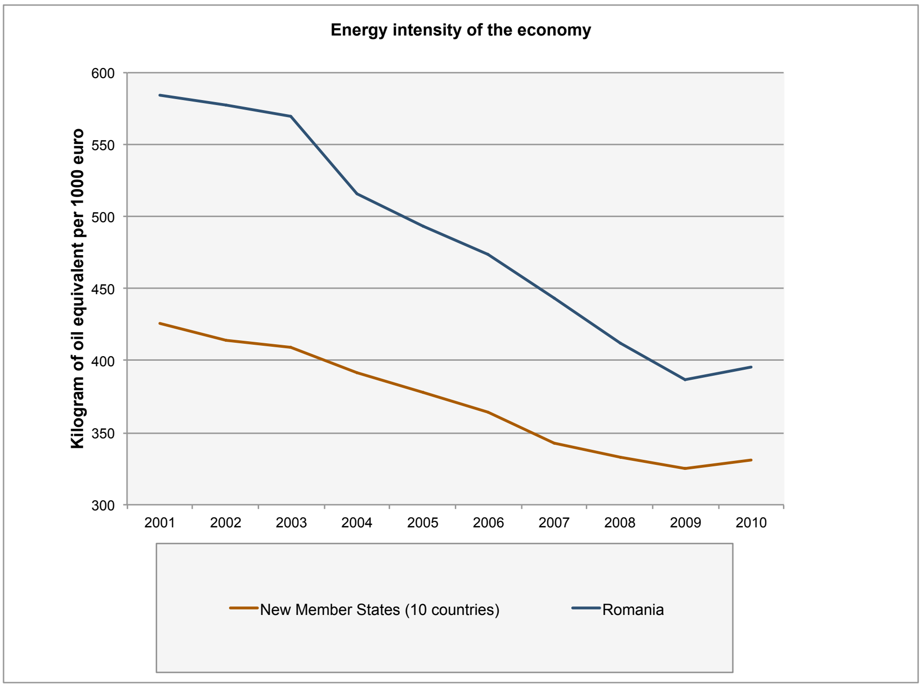
In 2011, the largest share of Romanian GHG emissions came from the energy industries sector (29.7%). Industrial processes made up for a fifth of total GHG emissions (20.4%), and agriculture contributed another 15.4%. Manufacturing Industries and Construction (12.8%) and the transport sector (11.8%) were further important emitters (figures from Eurostat database, 2013).

Between 2002 and 2011, the transport sector increased GHG emissions by nearly a quarter (+24.4%). Reductions of more than a fifth of GHG emissions occurred in the industrial processes (-23.9%) and manufacturing industries and construction sector (-22.3%). Energy industries reduced emissions by 13.3%. In total, Romanian GHG emissions decreased by 10.8% (figures from Eurostat database, 2013). Over the longer time frame from 1990 to 2009, strong emission reductions occurred in the energy industry, moderate reductions occurred in the manufacturing and construction sector, and an emission increase took place in transport sector.

3.1.1.2 Energy Intensity and GHG Intensity of Energy

As can be seen from Figure 4 energy intensity of the Romanian economy has decreased constantly throughout the past decade, except for a small increase in 2010. From 2001 to 2010, it was reduced from about 580 kgoe/1000 Euro to a bit less than 400 kgoe/1000 Euro, i.e., by a third altogether.

Figure 4: Energy Intensity of the Romanian Economy



Source: Eurostat (2013)

In Romania, the greenhouse gas emissions intensity of the energy consumed has decreased recently. In 2011 it reached a value of 86 Mt, which is 93.6% of its 2000 value (Eurostat Database 2013). However, the decree in EU28 average was -9% in the same time frame.

From 1990 to 2010, GHG intensity of the Romanian economy (which combines energy intensity of the economy and GHG intensity of energy) decreased by 63% altogether, which was among the strongest decreases throughout Europe (European Commission, 2012b).

3.2 Overview about the energy sector

3.2.1 Energy production and consumption

In 2011, Romania produced 27.6 Mtoe (or 321 TWh) of energy. It had a final energy consumption of 23.9 Mtoe (277 TWh), the largest share of which, 7.8 Mtoe (91 TWh) was consumed in the residential sector, 6.8 Mtoe (79 TWh) in industry, and 5.0 Mtoe (58 TWh) in the transport sector (IEA, 2013b).

3.2.2 Import/Export/Resources

In 2010, Romanian primary energy production was 27.4 Mtoe according to the National Institute of Statistics. Fossil fuel production (coal, natural gas, crude oil) keeps a majority weight in primary energy production (71.8% in 2010). Primary energy import was 11.7 Mtoe (136 TWh) in 2010. At 4.3 Mtoe (50 TWh), energy export was considerably lower.

As shows, imports of energy products have been higher than exports during the past decade. However, energy dependency has decreased slightly from more than 25% in 2003 and 2005 to 21% in 2011.

Table 7 shows, imports of energy products have been higher than exports during the past decade. However, energy dependency has decreased slightly from more than 25% in 2003 and 2005 to 21% in 2011.

Table 7: Energy imports, exports and dependency of Rumania

	2003	2005	2010	2011
Imports (Mtoe), all products	14.2	17.3	11.7	12.1
Exports (Mtoe), All products	3.9	6.4	4.0	4.3
Energy Dependence	25.5	27.6	21.7	21.3

Source: Eurostat. Energy Dependence indicator is calculated as net imports divided by the sum of gross inland energy consumption; 1Mtoe is equivalent to 11.63 TWh

Romania disposes of significant resources of coal, lignite, oil and natural gas. According to EURACOAL (2012), the economic potential of hard coal is 252 Mt, less than half of its total potential of 650 Mt. Assuming an annual production of 6.564.000 toe (production of 2009, IEA (2009)), hard coal could be used for at least 25 years. According to (Eurocoal, 2013) lignite resources in Romania are 1,500 Mt.

In sum, coal and lignite reserves could ensure energy supply until the end of the century. Romanian natural gas reserves are important, as well. According to the European Commission (2012), Romania has the third largest gas reserves in the EU.

3.2.3 The structure of electric energy production

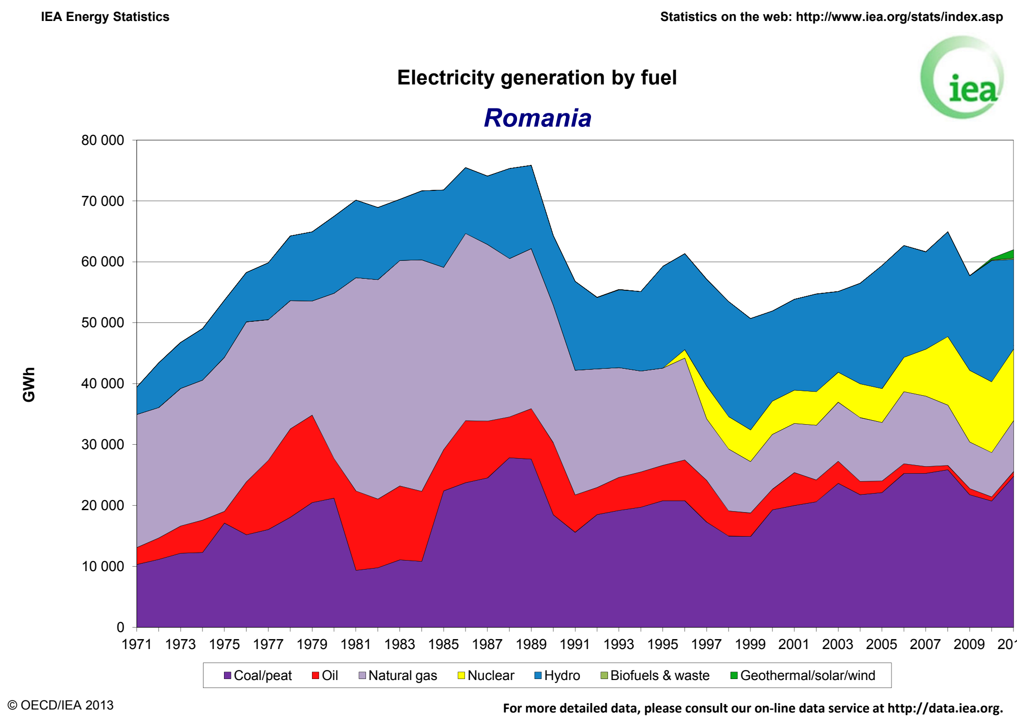
In 2011, total gross electricity production in Romania was 62.2 TWh (see Figure 5). About half of total electricity was produced from fossil reserves, i.e., 24.8 TWh from coal and peat plus 8.3 TWh from gas. Nuclear energy contributed 11.7 TWh of electric energy.

Among the renewable energy sources, hydroelectric energy including production from pumped storage plants was the biggest contributor, which made up for 14.9 TWh in 2011, nearly a quarter of total electricity production). Wind contributed a small but increasing amount of 1.4 TWh (IEA 2011b).

As Figure 5 shows, for about two decades there has been a trend of decreasing electricity production from oil and, though with greater variability, from natural gas, which has been replaced by nuclear energy and an increasing share of coal. RES other than hydro, especially wind, have appeared only recently and still make up for a minor share only.

Romania produces sufficient electricity for covering domestic demand. Since 2000, an increase in domestic demand has occurred, but less than the increase in Romanian GDP. In 2011, Romania exported about 2.4 TWh of electricity, which is roughly 3% of net electricity production.

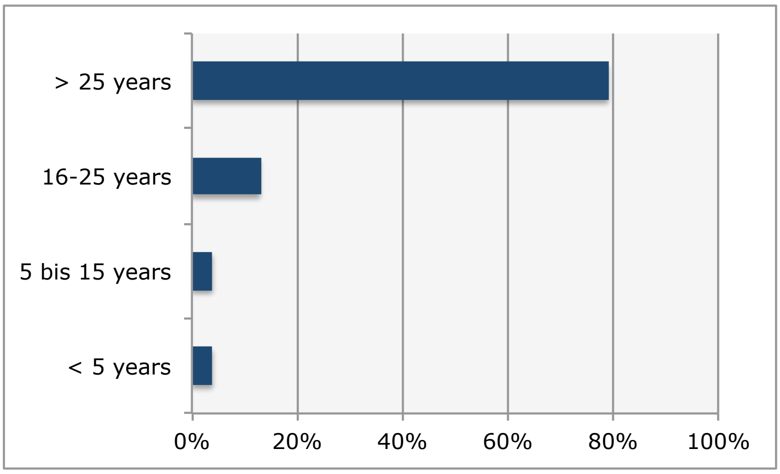
Figure 5: Electricity generation in Romania by fuel type



Source: IEA (2011)

In 2009, 80% of the Romanian electricity production capacities were older than 25 years. Until 2035, 55% of current capacities need to be decommissioned, and until 2020, 5.5 GW of new capacity have to be built (Romania News Watch 2011).

Figure 6: Age structure of the Romanian Power Plant Fleet



Source: KPMG (2012)

3.2.4 *Electricity Market structure*

In 2010, the three largest producers controlled 65% of electricity generation (EU Comission 2012). The three largest producers are Hidroelectrica (hydro power), Nuclearelectrica (nuclear power) and Electrocentrale Deva (thermal power plants). 95% of electricity is generated by 10 producers. There are six electricity generating companies with a share of at least 5% each.

The Romanian government owns most of the large generation companies. Hydro power from these generators is often sold below market prices, which makes it difficult for independent power producers to compete with the state-owned companies (European Commission, 2012c).

In 2007, electricity production was officially liberalized, but price regulations still exist. According to a roadmap adopted by the Romanian government in March 2012, regulation of end-user prices for non-households will be phased out by end 2013, and for household customers by 2017.

At wholesale level most electricity is sold through bilateral contracts. One quarter of Romania's electricity supply is traded via the Romanian electricity exchange, OPCOM. This share is expected to double when price regulation in the non-household sector ends (European Commission, 2012c).

The Romanian state owns the majority of shares in the electricity TSO (CN Transelectrica SA). It also has the direct ownership of the transmission systems.

Energy market regulation is provided by the Autoritatea Nationala de Reglementare in domeniul Energiei (ANRE), which has been in operation since 1998. In 2010 it employed 232 staff with an annual budget of 6.6 m Euro and had 10 regional offices. The EU Commission admonished the Romanian government that ANRE's independence and its financial autonomy were seriously curtailed in 2009 and 2010 due to two national laws that changed the regulator's status (European Commission, 2012c).

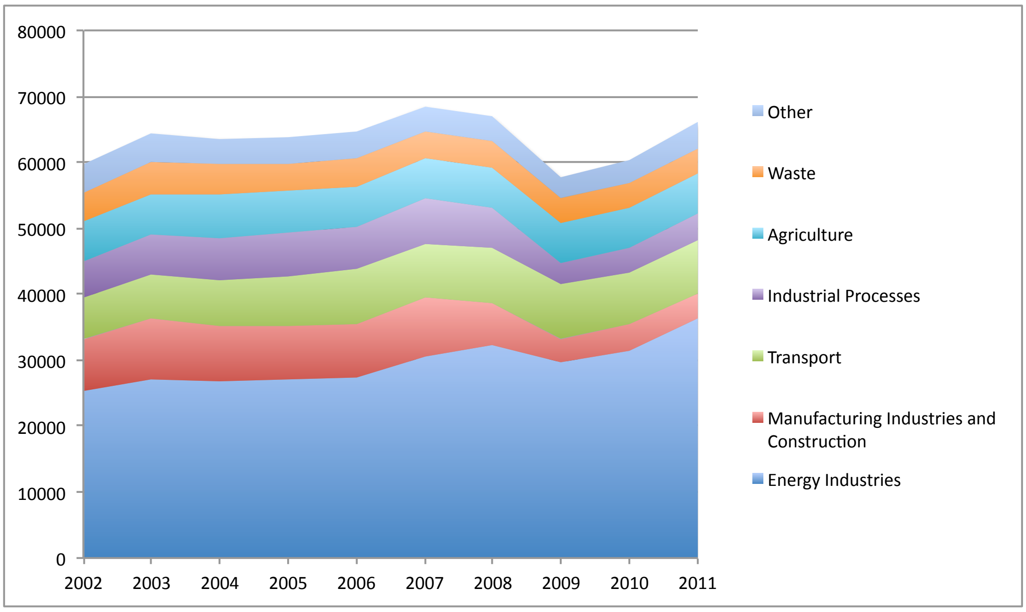
4 Background information - Bulgaria

4.1 Overview of the emission status of Bulgaria

4.1.1 GHG Emissions

In 2011, total greenhouse gas emissions in Bulgaria were 66.1 $MtCO_2e$. In 2012, Bulgaria strongly outperformed its Kyoto commitment of a maximum of 122 $MtCO_2e$. Compared with the base year 1989, the actual reduction exceeded the target by 42 percent-points (European Commission, 2012b). As Figure 7 shows, from slightly below 60 MtCO2e in 2002, GHG emissions exhibited a rising tendency during the past decade. There was a temporary contraction after the economic crisis of 2008, which has broken the rising tendency due to the weaker economic activity, overall uncertainty and lower output, and emissions fell down to a minimum of 57.8 $MtCO_2e$ in 2009 before they started to rise again. They have not yet reached the maximum pre-crisis level.

Figure 7: Romanian GHG Emissions by Sector from 2002 to 2011 (1,000 tCO_2e)



Source: Eurostat (2013)

4.1.1.1 Structure of GHG Emissions

A look into the structure of GHG-emissions shows that the largest source of emissions are energy industries, which contributed more than half of the Bulgarian GHG emissions in 2011 (55%). Further sources that made up for roughly a tenth of emissions, each, were the transport sector (12.3%) and the agricultural sector (9.3%). Other sectors contributed roughly 6% each, namely industrial processes (6%), waste (5.7%) and manufacturing industries and construction (5.5%) (figures for 2011 from Eurostat (2013)).

Between 2002 and 2011, GHG emissions were reduced by half in the manufacturing industries and construction sector (-54%), by nearly a third in the sector of industrial processes (-28.7%), and by 14.8% in the waste sector. These reductions were overcompensated by the emission increases in the larger sectors energy industries

(+43.8%) and transport (+32.8%), resulting in an overall increase of GHG emissions by 10.8% between 2002 and 2011.

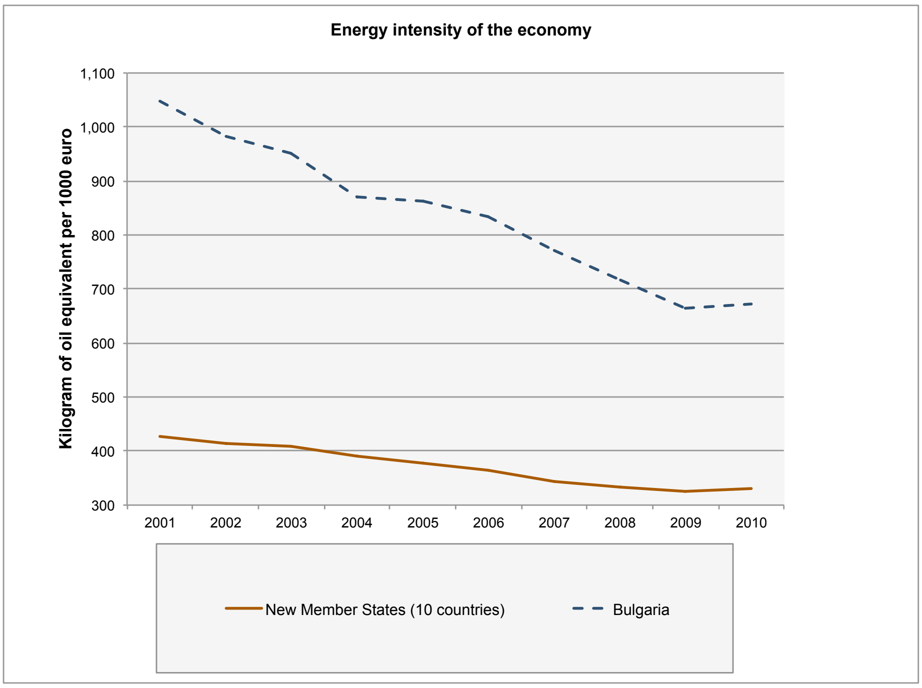
4.1.1.2 Energy Intensity and GHG Intensity of Energy

As Figure 8 shows, energy intensity of the Bulgarian economy has decreased strongly throughout the past 10 years. On average, it has been reduced by nearly 5% a year from 2001 to 2010. In comparison, the average annual reduction of energy intensity for the 10 new member states (NMS) of 2004 has been about 3% p.a. However, with more than 650 ktoe/1,000 Euro, Bulgarian energy intensity was still twice as high as the average of the ten NMS in 2010 (see Figure 8).

Compared to the EU average, energy intensity (measured by gross domestic energy demand per unit of GDP and taking into account the parity of purchasing power) of the Bulgarian GDP is 89% higher: 302 toe/ m Euro (2005) in Bulgaria compared to 160 toe/ m Euro (2005) in the EU (Energy Strategy, p.25). This is still the case although from 1990 to 2010, GHG intensity of the Bulgarian economy decreased by 62% overall, which was among the strongest decreases within Europe (European Commission, 2012b).

While energy intensity of the Bulgarian economy followed a clear downward trend over the past decade, greenhouse gas emission intensity of the energy consumed has increased recently, partly offsetting emission reduction. In 2011, the greenhouse gas emissions intensity of Bulgarian energy consumption was 107.8% of its 2000 value (Eurostat, 2013).

Figure 8: Energy Intensity of the Bulgarian Economy



Source: Eurostat (2013)

4.2 Overview about the energy sector

4.2.1 Energy production and consumption

In 2011, Bulgaria produced 12,4 Mtoe (or 144 TWh) of energy. It had a final energy consumption of 9,6 Mtoe (112 TWh), the largest shares of which were consumed in the transport sector (2,8 Mtoe or 32 TWh), in industry (2,7 Mtoe or 32 TWh), and in the residential sector (2,4 Mtoe) (IEA, 2013a).

The period before 2000 was characterized by a strong decrease of energy production due to the crash of central planning. After 2003 there was a strong growth in energy production in response to local demand, as a consequence of market oriented reforms and resulting growth of the overall economic activity in the country. Between 2003 and 2008 the production of energy almost tripled from 1,329 m Euro to 3,925 m Euro (real values).

4.2.2 Import/Export/Resources

Bulgaria depends on primary energy imports for satisfying its energy needs. As Table 8 shows, energy dependency was about 37% in 2011, down from 47% in 2005. According to the International Energy Agency (IEA), roughly 40% of coal and lignite consumption comes from imports (IEA, 2013a). 100% of the crude oil and nuclear fuel is imported from Russia, as well as nearly all natural gas consumed (Energy Strategy, 2011).

Table 8: Energy imports, exports and dependency of Bulgaria

	2003	2005	2010	2011
Imports (Mtoe), all products	11.4	13.0	11.7	11.8
Exports (Mtoe), all products	2.2	3.4	4.5	4.8
Energy Dependence (%)	46.8	47.5	40.1	36.6

Source: Eurostat (2013) Energy Dependence indicator is calculated as net imports divided by the sum of gross inland energy consumption; 1Mtoe is equivalent to 11.63 TWh

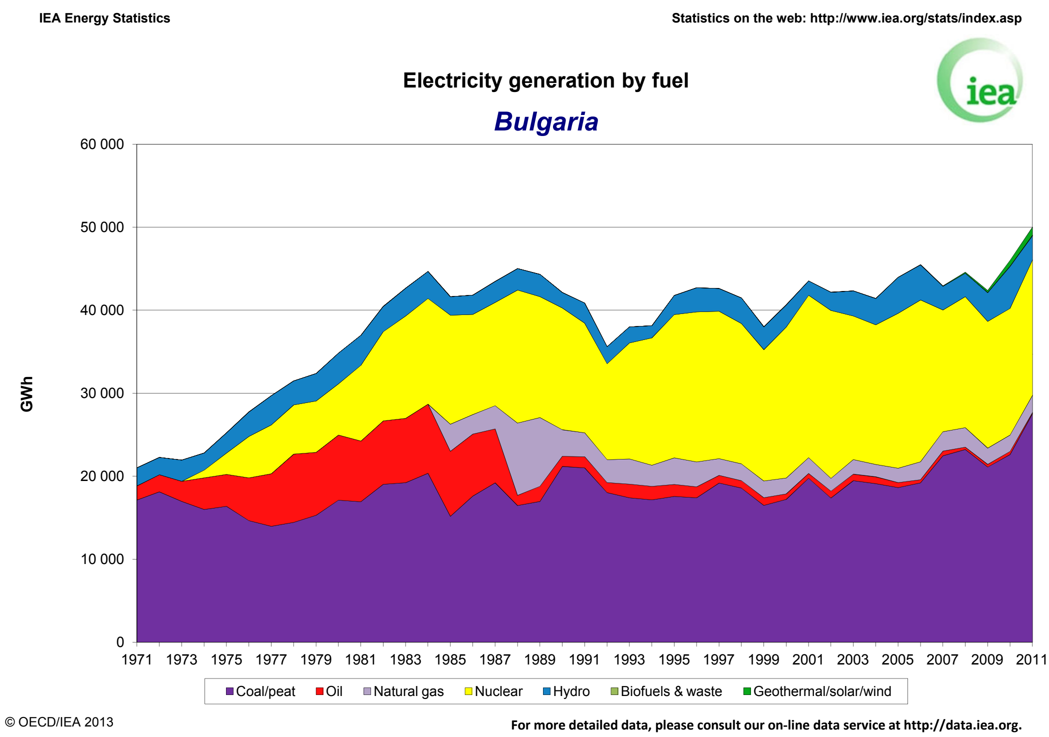
Eurocoal (2013) estimate that Bulgaria owns fossil reserves of about 200 tons of coal equivalent (TCE) or 1,628 MWh_{th} per capita. This is considerably lower than global average resources of 3,000 TCE per capita. Lignite, which has a relatively low energy content, make up for the largest part of Bulgarian fossil reserves. Assessments of Bulgarian lignite reserves range from 1.3 bln tons (Eurocoal, 2013) to 2.6 bln tons (EIA 2012). In 2010, Bulgaria extracted 27.1 million tons of lignite (IEA 2009). At constant extraction rates, know reserves of lignite could be used for up to 80 years.

Bulgaria is a net electricity exporting country. In 2011, Bulgaria exported 21% of gross electricity production (10,7 TWh), which made it one of the EU's largest electricity exporters. In 2012, a decline in electricity demand from neighbouring countries due to the economic crisis caused economic losses of 13.8 m Euro by April 2012.

4.2.3 The structure of electric energy production

In 2011, gross electricity production in Bulgaria was 50.8 TWh (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). More than half of total electricity, 27.5 TWh, was produced from coal and peat, and another third, 16.3 TWh, from nuclear energy. Gas contributed another 2.1 TWh. Among the renewable energy sources, hydroelectric energy including production from pumped storage plants was the biggest contributor (3.7 TWh), and wind contributed a small but increasing amount of 0.8 TWh (IEA 2011). Production from coal has followed an increasing trend, while nuclear production has slightly decreased, recently. After four smaller reactors have been shut down in 2006, there are only two nuclear reactors left, reducing the productive capacity of the Kozloduy nuclear power plant._Generation shares of oil and natural gas have been declining for about two decades and presently make only minor contributions. RES other than hydro, especially wind, have appeared only recently and still make up for a minor share, only.

Figure 9: Electricity generation in Bulgaria by fuel type



Source: IEA (2011)

4.2.4 Electricity Market structure

The Bulgarian electricity market is dominated by the state-owned 'Natsionalna Elektricheska Kompania' EAD (NEK) (DG Energy 2011, S. 7). NEK also controls electricity transmission via its subsidiary 'Electricity System Operator EAD' (ESO), the Bulgarian electricity TSO (European Commission, 2012). The electricity distribution network is privatized and owned by CEZ, EVN and Energo Pro (European Commission, 2012).

NEK is a subsidiary to the state-owned energy holding company "Bulgarian Energy Holding EAD" which was set up by the Bulgarian government in 2008. The BEH owns the Kozloduy nuclear power plant and a major lignite-fired power plant, Maritza East II, along with the main hydro producer and wholesaler NEK. Altogether, the BEH group produces around 60% of total electricity output in Bulgaria. The holding also comprises the gas TSO, 'Bulgartransgaz' EAD and the gas supplier incumbent 'Bulgargaz' EAD (European Commission, 2012).

Since 2002, the electricity sector has been subject to a privatization process. In November 2009, shares of NEK were offered at the Bulgarian stock exchange. Still, market transactions only make up for a minor share of 16.4% of domestic electricity sales, and price regulation remains dominant (Ministry of Economy, Energy and Tourism - Bulgaria 2012).

According to the European Commission (2012), "a quota system paralyses the functioning of the wholesale market, as generators are obliged to sell their output to NEK at regulated prices and cannot freely contract with suppliers. In addition, Bulgaria has a system of transaction-based transmission charges, including a number of network surcharges, which act as a barrier to exports and hinder the free flow of electricity across borders. The level of market integration is low: coordinated bilateral capacity allocations at borders are not offered for all timeframes from Bulgaria to Romania and Greece."

The electricity retail market is dominated by the three biggest utilities, which controlled 76% of the market in 2010. At end-consumer level, the market has not been opened, and electricity prices remain regulated for households and SMEs (European Commission, 2012).

The Bulgarian energy market is regulated by the State Energy and Water Regulatory Commission (SEWRC). According to the European Commission (2012), "its budget is insufficient to cover oversight of all the sectors it is responsible for and there are concerns about the stability of its management."

There have been infringement proceedings regarding the EU Second and Third Energy Package Directives, which still have been only partially transposed in Bulgaria (European Commission, 2012).

After the end of central planning, former large companies have been disaggregated and new investors have entered the energy market. The number of companies in the energy sector in Bulgaria has increased from below 200 in the early 2000s to 1400 in 2010 (National Statistical Institute Yearbooks 2001-2011). This increase is due mainly to an increase of small producers, many of which are renewable energy producers.

In 2011, there were six companies providing at least 5% of national net electricity generation each and 20 companies generated 95% of electricity.

5 Results - Top-Down approach

5.1 Reference scenario

The reference scenario serves as the benchmark against which the alternative scenario is evaluated. The reference projection is constructed by calibrating the model on published GDP and energy system forecasts by 2030. The exogenous variables of the model that are used to perform the calibration of the reference scenario are the technical progress, labour force, and the expectation on sectoral growth. The study used for the calibration of the macroeconomic part of the model is the DG-ECFIN Ageing report (European Commission, 2012a) that includes GDP and employment projections for all EU member states until 2060.

The reference scenario includes the most important energy and climate policies and measures already decided at the EU level.

The Reference scenario reflects to a large extent the main policy assumptions of the Reference scenario of the European Commission as specified in the EU Energy Roadmap 2050 (European Commission, 2011). The scenario is consistent with the EU Climate and Energy Package by 2020 (European Union, 2009). Beyond 2020, the Reference scenario assumes a linear annual reduction of the EU ETS cap, no additional policies for energy efficiency and RES penetration (but the measures implemented until 2020 will continue to deliver energy efficiency gains and RES facilitation after 2020 without specifying further targets beyond that date), limited electrification of the transport sector and non-ETS GHG emissions to remain below the cap specified for 2020.

The key projections at the world and EU28 level are presented in Table 9. The evolution of the main socio-economic variables (population and GDP) and GHG emissions is calibrated to the "Energy Trends to 2050" scenario based on the PRIMES model (Commission, 2013) for the EU-28 Member States.

Table 9: World and EU28 key reference projections

2015-2030 (annual % change)	GDP	GHG	Population
World	3.04%	1.49%	0.86%
EU-28	1.57%	-1.10%	0.15%

Source: GEM-E3-NMS

In the model the main driver for the GHG emission reductions in the EU-28 is the carbon tax. In the reference case used in the current study there is no distinction between ETS and non-ETS sectors. A uniform carbon tax is applied to all EU sectors (Table 10).

Table 10: Reference EU carbon price

	2010	2015	2020	2025	2030
$Euro_{2005}$/t CO_2	7	9	17	22	32

Source: GEM-E3-NMS model output

The next two sub-sections present in detail the reference projections made with the GEM-E3-NMS model for Romania and Bulgaria.

5.1.1 Bulgaria

GDP is projected to grow by 1.7% on average in the period 2010-2030. The main driver are investments that grow at a higher rate than any other GDP component. Exports are assumed to grow somewhat faster than imports hence the trade position of the country improves in the long term. Investments are projected to increase their share on GDP at the expense of private and public consumption. Population is assumed to decline and as a consequence the labour force of the country decreases by 1% per annum by 2030.

Table 11: Main macroeconomic aggregates

Bulgaria	in bn Euro	annual % change		
	2010	**2010-2020**	**2020-2030**	**2010-2030**
Gross Domestic Product	36.1	2.1%	1.3%	1.71%
Investment	6.6	2.5%	1.6%	2.05%
Public Consumption	7.2	1.6%	0.7%	1.15%
Private Consumption	22.8	2.0%	1.3%	1.70%
	2010	**2010-2020**	**2020-2030**	**2010-2030**
Trade balance as % of GDP	-1.6%	-0.9%	-0.6%	
Population (m. persons)	7.6	-0.6%	-0.7%	-0.67%
Labour force (m. persons)	3.4	-1.1%	-1.0%	-1.05%

Source: GEM-E3-NMS model output

The model uses the long term borrowing[12] interest rate to formulate consumption and investment decisions. Each Member State has a different interest rate. The model considers the long-run equilibrium interest rate[13], hence it does not take into account the short term increase in interest rates (i.e. in the period 2008-2012) induced by the financial crisis. The rates used for Bulgaria are presented in the table below:

Table 12: Interest rates

	2010	2015	2020	2025	2030
Bulgaria	3.3%	3.3%	3.2%	3.1%	3.1%

Source: GEM-E3-NMS model output

At a sectoral level services increase their share in total production from 36% in 2010 to 40% in 2030. Even in the reference scenario all economic sectors become more energy efficient (i.e. there is a marked decline in the amount of energy they consume to produce a unit of value added) hence the share of the energy sector in GDP decreases to less than 9% of GDP in 2030. Market services increase their share in GDP mainly at the expense of agriculture and consumer goods industries.

[12] This corresponds to an EMU 10yr bond yield

[13] The model assumes that the economy converges to long run steady-state equilibrium. Hence, the interest rate does not include any risk premium that can be attributed to short-term imbalances.

Table 13: Sectoral production, Bulgaria

	2010	2015	2020	2025	2030
	% share in total production				
Agriculture	9	9	8	8	8
Energy	13	11	10	10	9
Energy intensive industries	6	5	6	5	5
Equipment goods	5	5	5	5	5
Consumer goods	15	16	15	13	12
Construction	7	7	8	8	8
Transport	10	9	10	12	14
Services	36	38	38	40	40
Total	**100**	**100**	**100**	**100**	**100**

Source: GEM-E3-NMS model output

Nuclear and coal are the main power generation sources in Bulgaria in 2010 (Table 14). In the reference scenario it is assumed that the share of coal fired technologies will decrease from 47% in 2010 to 39% in 2030 as low and zero carbon power generation technologies will penetrate) in the power generation mix (mainly natural gas and wind). On the other hand, the penetration of biomass and CCS technologies is limited by 2030.

Table 14: Power generation mix in the reference scenario (Bulgaria)

	2010	2020	2030
Coal fired	47%	40%	39%
Oil fired	1%	0%	1%
Gas fired	4%	14%	15%
Nuclear	34%	30%	27%
Biomass	0%	0%	0%
Hydro electric	12%	10%	8%
Wind	2%	3%	5%
Solar	0%	3%	4%
CCS Oil	0%	0%	0%
CCS Gas	0%	0%	0%
Total	**100%**	**100%**	**100%**

Source: GEM-E3-NMS model output

Bulgaria registers high indicators for both energy and carbon intensities relative to the average EU-28 in 2010. It is estimated that in 2020, under reference assumptions, energy intensity will be close to 400 toe/m $Euro_{(2010)}$ and carbon intensity close to 900 t. CO_2/ m $Euro_{(2010)}$.

Table 15: Annual energy efficiency improvement

	2010-2020	2020-2030	2010-2030
Bulgaria	1.75%	1.56%	1.65%

Source: GEM-E3-NMS model output

In the reference scenario GHG emissions in Bulgaria decrease over the 2015-2030 period. In 2030 GHG emissions are found to be lower by 28% from 2005 levels and by 59% from 1990 levels (Table 16).

Table 16: Reference GHG emissions Bulgaria

Emissions 1990=100	1990	2005	2010	2015	2020	2025	2030
GHG	100	57	50	50	48	45	41

Source: GEM-E3-NMS model output

5.1.2 Romania

In the reference scenario, the average annual GDP growth of the Romanian economy over the 2010-2030 period is assumed to be 1.8% (Table 17). This growth is mainly supported by increasing investments and exports. Population and labour force are assumed to decline by 0.29% and 0.65% p.a. respectively (consistent with the projections of the ageing report from DG-ECFIN (European Commission, 2012a)).

Table 17: Main macroeconomic aggregates of Romania

Romania	in bn Euro	annual % change		
	2010	2010-2020	2020-2030	2010-2030
Gross Domestic Product	104.2	2.3%	1.2%	1.78%
Investment	21.8	2.5%	1.4%	1.96%
Public Consumption	10.6	1.7%	0.2%	0.97%
Private Consumption	77.7	2.2%	1.2%	1.68%
	2010	**2010-2020**	**2020-2030**	**2010-2030**
Trade balance as % of GDP	-5.7%	-4.3%	-3.4%	
Population (m. persons)	21.4	-0.2%	-0.4%	-0.29%
Labour force (m. persons)	9.9	-0.4%	-0.9%	-0.65%

Source: GEM-E3-NMS model output

The interest rate in Romania is assumed to remain virtually constant over the reference projection period (Table 18). The assumptions on interest rates are based on the experience of our local research partners.

Table 18: Interest rates for Romania

	2010	2015	2020	2025	2030
Romania	7.6%	7.7%	7.7%	7.6%	7.5%

Source: GEM-E3-NMS model output

Production in Romania is diversified across many industrial sectors (Table 19). Services, agriculture and equipment goods represent a large part of the overall economic production. In the reference projection it is assumed that the Romanian economy will become more services oriented. Thus, the share of services in total production is projected to increase from 26% in 2010 to 30% in 2030, while the share of the agriculture and energy sectors will decline by 2030.

Table 19: Sectoral Production in Romania

	2010	2015	2020	2025	2030
	% share in total production				
Agriculture	14	13	12	12	12
Energy	11	10	9	8	8
Energy intensive industries	10	10	10	10	9
Equipment goods	8	9	10	10	10
Consumer goods	19	19	19	18	18
Construction	7	7	7	8	8
Transport	5	5	5	5	5
Services	26	27	28	29	30
Total	100	100	100	100	100

Source: GEM-E3-NMS model output

The Romanian energy system is characterized by high energy and carbon intensities (almost double than the EU average in 2010). In 2020, under reference assumptions, energy intensity is projected to be close to 230 toe/m Euro$_{(2010)}$ and carbon intensity to 500 t. CO_2/ m Euro$_{(2010)}$. These intensities are almost double than the EU28 average. Energy system costs accounted for almost 19% of the Romanian GDP in 2010. The reference scenario projects that total energy system costs will increase as a percentage of GDP by 2030 (The EU average is 14% in the Reference scenario in 2030).

Currently the Romanian energy system is heavily based on fossil fuels, which account for 76% of total primary energy demand in 2010. In the reference case, the share of electricity in final energy is projected to increase from 16% in 2010 to 19% in 2030. The structure of electricity production is projected to change significantly by 2030. The share of coal-based power generation will decline markedly from 32% in 2010 to 16% in 2030. At the same time, the contribution of nuclear in power requirements is projected to remain relatively stable in 2010-2030 period. In the reference policy setting, the Romanian power sector is projected to make a transition towards natural gas and RES, which jointly account for 62% of total electricity production in 2030.

Table 20: Power generation mix in the reference scenario (Romania)

	2010	2020	2030
Coal fired	32%	25%	16%
Oil fired	1%	3%	3%
Gas fired	12%	16%	15%
Nuclear	19%	17%	19%

Biomass	0%	3%	5%
Hydro electric	35%	32%	29%
Wind	1%	4%	10%
Solar	0%	1%	3%
CCS Oil	0%	0%	0%
CCS Gas	0%	0%	0%
Total	**100%**	**100%**	**100%**

Source: GEM-E3-NMS model output

Table 21: Annual energy efficiency improvement

	2010-2020	2020-2030	2010-2030
Romania	1.56%	1.28%	1.42%

Source: GEM-E3-NMS model output

In the reference scenario GHG emissions in Romania decrease over the 2015-2030 period. In 2030 GHG emissions are found to be lower by 24% from 2005 levels and by 58% from 1990 levels (Table 22).

Table 22: Reference GHG emissions Romania

Emissions (Mt of CO_2 eq.)	1990	2005	2010	2015	2020	2025	2030
GHG	100	55	48	50	47	45	42

Source: GEM-E3-NMS model output

5.2 40% scenario

The carbon tax that is required to reduce emissions at the EU level by 40% compared to 1990 is 51 $Euro_{(2010)}$ / t CO_2 eq. in 2030, while in the reference scenario the carbon price is projected to reach 32 $Euro_{(2010)}$ / t CO_2 eq.

Table 23: Carbon tax in $Euro_{(2010)}$ per tn. of CO_2 eq. in the two scenarios examined

Carbon tax ($Euro_{(2010)}$ tn. CO_2)	2015	2020	2025	2030
Reference	9.36	16.68	21.85	31.51
40% reduction	10.42	18.11	29.05	50.55

Source: GEM-E3-NMS model output

The GEM-E3-NMS model calculates the allocation of the GHG abatement effort among all EU member states, so that at EU level the target is optimally reached. Within this context, total GHG emissions of Romania and Bulgaria are reduced by 38% and 44% compared to 2005 respectively (Table 24). Even in this case both countries would still register higher levels of energy and carbon intensities compared to EU Member States

In Bulgaria and Romania the revenues collected from this carbon tax amount to 0.2% and 0.3% of GDP respectively in 2030 and are used to reduce employers' social security contributions.

Table 24: Emission reduction in Bulgaria and Romania

	2015	2020	2025	2030	1990-2030	2005-2030
	% change from reference scenario					
Romania	-1.7%	-2.2%	-6.6%	-18.1%	-66%	-38.0%
Bulgaria	-1.8%	-2.8%	-11.3%	-22.7%	-68%	-44.5%

Source: GEM-E3-NMS model output

These emission reductions are the result of a multitude of adjustments that take place in the economic sectors of the two countries. In Bulgaria, more than half of the emission reductions achieved relative to the reference scenario come from the energy sector in 2020 and in 2030 (Table 25). The restructuring of the power sector is particularly important in Bulgaria, where coal holds a significant share in the reference scenario. In Romania, the energy sector also constitutes the most important source for emissions reduction although at relatively lower rates than Bulgaria, as it accounts for 33% of the carbon abatement effort in 2030. After the energy sectors, energy intensive industries constitute the second most important source of the overall abatement effort in both countries. In Romania the energy intensive industries provide 35% of the emissions reduction in 2030, while the agricultural sector has also potential for GHG emissions abatement and is projected to deliver 18%.

Table 25 Contribution to GHG emission reduction by main categories

	Bulgaria		Romania	
	2020	2030	2020	2030
Agriculture	8.19%	12.76%	11.08%	17.97%
Energy	66.67%	62.41%	46.84%	33.42%
Energy intensive industries	17.17%	15.97%	30.63%	34.76%
Equipment goods	0.38%	0.42%	0.98%	1.46%
Consumer goods	0.78%	0.85%	0.61%	1.06%
Transport	6.47%	6.94%	7.02%	7.51%
Construction	0.03%	0.15%	0.31%	0.43%
Services	0.32%	0.49%	2.53%	3.39%
Total	100%	100%	100%	100%

Source: GEM-E3-NMS model output

The net investments (additional to the reference) required to achieve the predefined GHG emission reductions are presented in Table 26. These investments sum up in Bulgaria to ca. 2.4 bn Euro and in Romania to ca. 2.7 bn Euro. Annual investment requirements increase over the period of time considered following the constantly more strictemission reductions and they amount to 1.1% and 0.3% of GDP in 2030 in Bulgaria and Romania respectively.

Table 26: Additional than the reference expenditures in a 40% EU-scenario

	Investment expenditure)			Annual investment expenditure		
	% of GDP			m Euro		
	2020	2025	2030	2020	2025	2030
Bulgaria	0.11	0.37	1.13	43	153	501
Romania	0.06	0.09	0.33	85	136	532

Source: GEM-E3-NMS model output

The imposition of strong climate policies in the M40 scenario induces changes in the economy driven by substitution away from fossil fuels and lower energy consumption per unit of economic activity. The decarbonisation of the Romanian and Bulgarian energy system includes the substitution of imported fossil fuels with equipment and services, part of which is domestically produced. Higher investments are required to enable these changes as low and zero carbon technologies are capital intensive. The GEM-E3-NMS simulations show that additional clean energy investments are not found to be sufficiently high to offset the activity depressing effects stemming from higher production costs. Consequently, the M40 scenario leads to a reduction of GDP in both countries examined in the analysis. GDP reduction is projected to be larger in Bulgaria (-1.3% in 2030) relative to Romania (-0.7% in 2030), due to the higher carbon and energy intensity of the former economy. The M40 scenario implies that the annual GDP growth rate of Bulgaria and Romania over the period 2015-2030 will be 1.44% and 1.45% respectively. It should be noted that in the reference scenario the respective growth rates were 1.53% and 1.50% in the same period.

Table 27: GDP effects of the M40 scenario on Romania and Bulgaria

	2015	2020	2025	2030	2005-2030 (annual growth rate)	2005-2030 (annual growth rate)
	% change from reference scenario				40% scenario	Reference
Romania	-0.04%	-0.13%	-0.27%	-0.70%	1.88%	1.91%
Bulgaria	-0.11%	-0.28%	-0.81%	-1.33%	1.86%	1.92%

Source: GEM-E3-NMS model output

At the sectoral level, the energy sector and energy intensive industries register the largest production reductions as compared to the reference scenario. Sectors contributing to the decarbonisation process such as equipment goods, electrical goods, construction (which is mainly related to energy efficiency investments) and a small part of agriculture (biofuels) are marginally affected by the imposition of strong climate policies. In the case of Romania, electric goods, consumer goods industries, other equipment goods and agriculture even increase their production compared to the reference scenario (Table 28).

Table 28: Sectoral production (cumulative over 2010-2030)

% change from reference	2010-2030	
	Bulgaria	**Romania**
Agriculture	-0.70%	0.17%
Energy	-1.90%	-1.53%
Ferrous metals	-3.46%	-4.77%
Non-ferrous metals	-3.63%	-0.69%
Chemical Products	-5.45%	-1.80%
Paper Products	-2.15%	0.33%
Non-metallic minerals	-4.48%	-1.77%
Electric Goods	-0.61%	2.56%
Transport equipment	-1.31%	-0.01%
Other Equipment Goods	-0.86%	0.23%
Consumer Goods Industries	-0.45%	0.85%
Construction	0.48%	-0.30%
Services	-0.28%	-0.31%

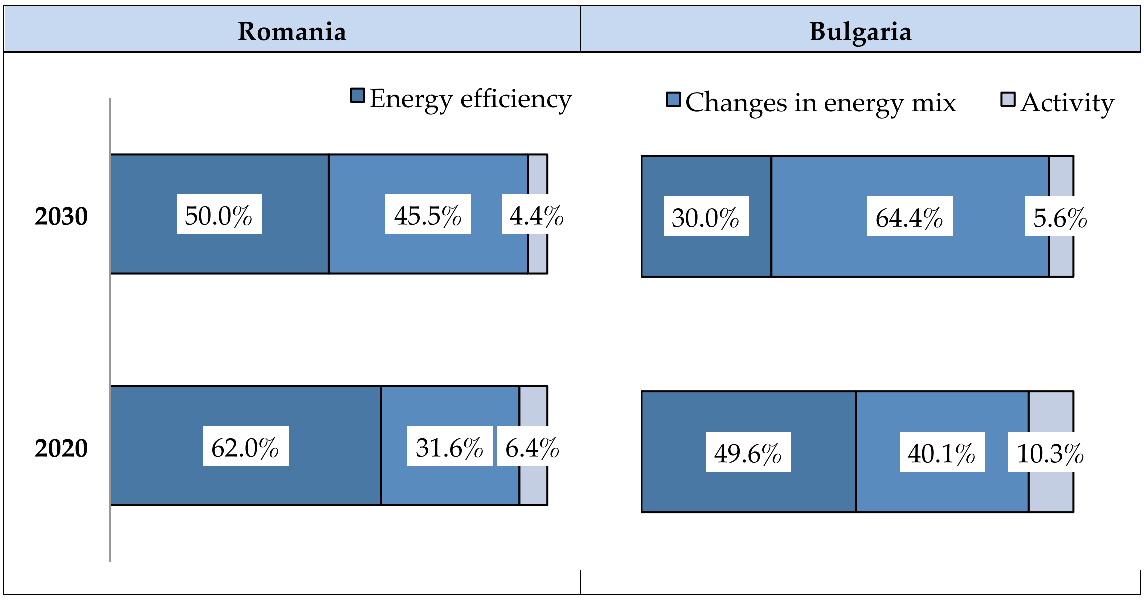
Source: GEM-E3-NMS model output

Reducing GHG emissions requires the adoption of different abatement options at different scales. The most important abatement options considered are: i) Fossil fuel substitution away from coal and oil, ii) Deployment of low-carbon energy sources such as RES, CCS and nuclear and iii) Energy efficiency improvements.

It was found[14] that the different abatement options are not equally important for each country. In the short term, where the potential for fuel substitutions in the power generation sector and the potential for structural changes in the transport sector are limited, the majority of emission reductions are achieved through the implementation of energy efficiency measures. This is particularly the case in Romania where energy efficiency measures are considered the most cost efficient abatement option by 2030 and deliver 62% of the overall emission reductions in 2020 and 50% in 2030 The role of efficiency improvements is projected to be important but limited in Bulgaria, where the deployment of RES options (especially wind) and the rapid emergence of coal power plants equipped with CCS after 2025 are found to be the driving forces for carbon abatement.

[14] The detailed decomposition methodology can be found in the Annex I.

Figure 10: Abatement options in Bulgaria and Romania



Source: GEM-E3-NMS model output

Emission reductions in the power sector are driven both by a reduction of electricity requirements and changes in the power mix. In cumulative terms, power generation in Bulgaria and Romania is projected to decline as compared to the reference scenario, by 1.6% and 0.3% respectively in the period 2010-2030. This is the net effect of the accelerated energy efficiency improvements on power generation requirements, which is further reduced due to the increase of generation costs induced by the higher penetration of renewables in the power system. The share of renewable electricity is projected to increase in both countries (by 6% in Bulgaria and 3% in Romania compared to the reference scenario in 2030– excluding hydro energy).

Table 29: Power generation mix changes

	Bulgaria			Romania		
	Reference		40% scenario	Reference		40% scenario
Power mix	**2010**	**2030**	**2030**	**2010**	**2030**	**2030**
Coal fired	47%	39%	26%	32%	16%	12%
Oil fired	1%	1%	1%	1%	3%	1%
Gas fired	4%	15%	12%	12%	15%	9%
Nuclear	34%	27%	28%	19%	19%	27%
Biomass	0%	0%	2%	0%	5%	6%
Hydro electric	12%	8%	9%	35%	29%	29%
Wind	2%	5%	9%	1%	10%	11%
Solar	0%	4%	4%	0%	3%	4%
CCS coal	0%	0%	10%	0%	0%	1%
CCS Gas	0%	0%	0%	0%	0%	0%

Source: GEM-E3-NMS model output

5.3 Key findings

The GEM-E3-NMS model has been used to quantify the macro-economic implications and the restructuring of the Bulgarian and Romanian energy and power generation system towards the European GHG emission reduction target of 40% compared to 1990 levels. The contribution of several emission reduction options including energy efficiency, RES deployment and fossil fuel switching in the overall emissions reduction achieved in Bulgaria and Romania has been evaluated. The model results show that:

- The least cost allocation of the abatement effort across EU member states implies that Bulgaria and Romania reduce their emissions by 44.5% and 38% respectively as compared to 2005 levels (68% and 66% compared to 1990).
- The adjustment to the new low carbon economy requires 1.3% and 0.7% of GDP for Bulgaria and Romania respectively in 2030.
- In the short-term, energy efficiency is considered to be the most cost efficient abatement option for both countries, whereas significant fuel switching is required by 2030.
- Improving energy efficiency requires goods and services that are mainly domestically produced (e.g. construction sector). This increases domestic activity in the sectors providing the energy efficiency services and equipment relative to the Reference scenario.

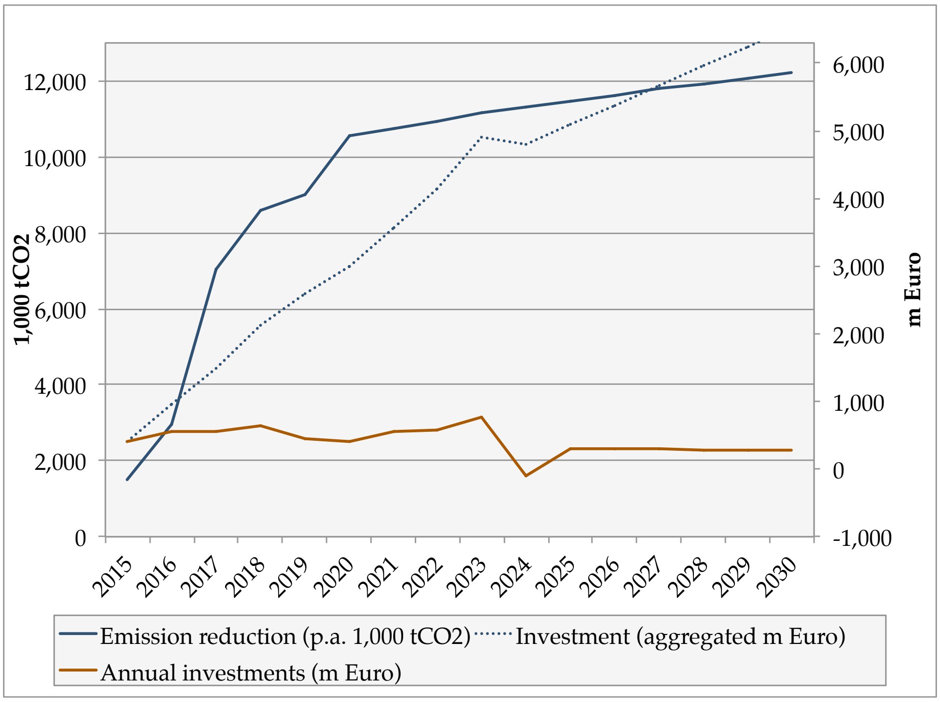
  Bulgaria and Romania are importers of equipment for renewables. Therefore, a significant increase (mainly in the short term where costs of certain RES technologies are high) would deteriorate their current account.

6 Results Bottom-up approach - Romania

6.1 Summary of the measures

The overall emissions reduction potential of the evaluated potential mitigation measures is ca. 12 Mt CO_2 and the investment needs are ca. 6 bn Euro till 2030 (see Figure 11). In Table 30 we summarise the investments and emission reductions per measure as well as the NPV and abatement costs.

Figure 11: Emission reduction and investment trajectories Romania 2015 – 2030



Source: Authors computations

Building sector

For the calculation of the aggregated effect of the measure we assumed that ca. 20.000 multi-family buildings would be retrofitted by 2030. Under given prices for natural gas and district heating and high interest rates, a retrofitting of existing multi-family blocks in Romania is not efficient from an economic point of view for the owners of dwellings if we assume costs of ca. 55 Euro per m^2 for retrofitting.

The investment needs for one average apartment in such blocks is ca. 2.200 Euro and ca. 103.000 Euro for the whole block. Under the assumption of a 25 years use of the residence, the NPV is in average -700 Euro (-32.000 per block), whereby the NPV for such appartment that use district heating is only -300 and that of natural gas -1.000 Euro. The same difference is reflected in the abatement costs. While the average abatement cost is 36 Euro/tCO_2 the costs for both types of heating vary between 12 Euro and 60 Euro.

The retrofitting of blocks that use district heating can become economical efficient if either prices for district heating increase 1% p.a. plus the interest rate is 7% instead of 8% or an interest rate decreased to 6% due to government support.

A retrofit of blocks that use natural gas might become efficient if retrofitting runs in parallel to usual modernisation and if government supports the investment.

We face a similar situation in retrofitting of public buildings. If we assume renovation costs of 60 Euro/m^2 the NPV is -146.000 with an average investment need of 300.000 Euro for such a building. The abatement costs are 75 Euro.

While the abatement cost of building retrofitting is high, the emissions reduction potential in the building stock of Romania cannot be neglected. Beside multi-family buildings and public buildings, commercial buildings would also need retrofitting. Most of the building stock has to be modernised within the next decade so that the costs for an energetic retrofitting can be reduced.

Household sector

With this measure we give an example for potential electricity savings in households. Therefore we assume that refrigerators, washing machines, electric ovens and dry tumblers will be replaced ca. 1-2 years before the end of their lifetime and that more efficient appliances will be used (5% more A+++, A++, A+ and 15% less A). Under these assumptions, a moderate emissions reduction of 65,000 CO_2 in 2030 will become possible. However an earlier and/or a purchase of more energy efficient appliances are not efficient from an economic point of view for a household. The (not weighted) average NPV for all appliances is 140 Euro (190 Euro investment) if we compare each appliance with the next lower efficiency class. The abatement costs per single average white ware is 780 Euro/t CO_2 (up to 1.400 Euro for some of the appliances) respectively 350 Euro/t CO_2 if we consider the whole measure till 2030. Due to insufficient data availability, the estimation of the results of this measure is not fully accurate. The wide supply of different appliances and their energy consumption cannot be taken into account. However it becomes clear that a speedup of the replacement of existing white ware is not meaningful from an economic point of view. Comparatively, a regulatory measure of maximum energy consumption for white ware appliances could lead to a significant decline of electricity consumption in households.

Energy sector

We focus on two potential mitigation measures in the Romanian energy sector. The first is the installation of 7 natural gas combined-cycle power plans (CCPP) with an aggregated installed capacity of 2,450 MW by 2019. The second measure evaluates the effects of 12 stand-alone biomass CHPs.

The estimation of these measures can only give an idea of the range of potential savings. The main reasons are the wide range of potential equipment costs (investments in Euro/kW) and the development of fuel prices. Nevertheless, both measures show an important emissions reduction potential compared to the use of coal power plants.

For the estimation of the abatement cost we compare the generation of electricity and heat of both types of fuel with the generation from a coal (lignite) power plant. The abatement costs of a modern natural gas CCPP is ca. 20 Euro/tCO_2 and that of a biomass CHP ca. 40 Euro.

Transport sector

While within the transport sector significant emissions reductions are possible, user behaviour plays a major role to enable them. In this evaluation, we focus on three aspects in the freight sector: "Modernizing intermodal terminals and building new intermodal terminals (Timisoara, Suceava and Brasov)", "Modernising diesel trains (replacing engines)" and "Structural change in mode of freight transport".

Modernisation of and building new intermodal terminals have no direct effect on emissions reduction.

We estimate that the emission reduction potential of a modernisation of 78 diesel trains sum up to ca. 64,000 tCO_2 till 2030. The measure is economically efficient under the assumption of a diesel price for rail companies of at least 40 Euro/MWh[15] (ca. 0.40 Euro/litre) and investments of 1 m Euro per train. The abatement costs in such a case are ca. -5 Euro/t CO_2.

A shift from road to rail transport can lead to an emission reduction of ca. 1 Mt CO_2. We assume a moderate increase of inland freight transport of 3% p.a. till 2030. We further assume that the relative share of inland road transport decreases from 48% today (52% rail) to 36% in 2030. We focus only on heavy trucks. An accurate assessment of the abatement costs is impossible due to inadequate data availability. Based on cost differences of freight transport per tonne-kilometre, we estimate that the abatement costs are ca. -5 Euro/tCO_2 but further investigations are needed.

Use of pumps

In the Romanian industry (and with lower intensity in other sectors) ca. 3.4 TWh electricity is used for pumps. We estimate that at least ca. 18% of this consumption can be saved through the optimisation of existing pumps and replacement of inefficient appliances. The annual saving potential of ca. 0.63 TWh corresponds to 1.4% of the Romania electricity consumption in 2011.

Due to the wide range of potential appliances and related costs of modernisation and new pumps and the weak availability of data, we were not able to specify NPV and abatement costs. Further research is needed to analyse the overall emission reduction potential of pumps and further technical applications in the industry sector and the related costs of the implementation.

Table 30 summarizes the aggregated results for the 7 measures we considered. It includes the aggregated investments till 2030, the emissions reduction potential in 2030 as well as the needed investment and the NPV per facility and the abatement costs for those measures where these figures can be estimated.

[15] The current end consumer price including VAT is ca. 1.3 Euro/litre.

Table 30: Results of the evaluation of mitigation measures in Romania

Expected investment needs 2015 - 2030	Expected emission reduction in 2030	Average investment per facility	Net-Present-Value of one installation	Abatement costs
mill Euro	*1,000 t CO_2*	*Euro*	*Euro*	*Euro*
Energy retrofit of residential blocks				
2,244	816	103,000	-32,000	36
Energy retrofit of public buildings				
1,201	369	300,000	-146,000	75
Early raplacement of old white ware with A+++, A++, A+ standard				
644	64	180*	-140*	780*/350'
Natural gas Combined-Cyle Power plants - (2.450 MW)				
1,065	9,229	600 Euro/kW	n.a.	20''
Standalone Biomass (solid, gas or municipal waste) CHP				
325	509	2,500 (Euro/kW)	n.a.	40''
Transport sector: Modernisation and new intermodal freight terminals				
182	n.a.	n.a.	n.a.	n.a.
Transport sector: Modernisation trains				
78	65	1,000,000	110,000	-5
Transport sector: Structural changes freight transport				
n.a.	1,048	n.a.	n.a.	-5
Trans-sectoral: Modernisation of pumps				
800	122	n.a.	n.a.	n.a.
Sum I				
6,539	**12,222**			

Source: Authors’ computations - * average appliances; ´ whole measure, “compared to coal

6.2 Measures summary: Building sector

6.2.1 Energy retrofit of residential multi-family blocks

6.2.1.1 Status quo

In 2008 ca. 7.3 million residences existed in Romania. Most of them are occupied by the owners and less than 15% are `social` apartments or used by private renters Atanasiu; Economidou and Maio (2012). The households' sector energy consumption was 94.5 TWh in 2010, representing about 36% of total energy consumption in Romania. The share is a little bit below that one estimated at the EU level (European Parliament, 2010), of 40%. Thereby the production of heat is the main consumer in the building stock.

Table 31: Decomposition of buildings by type (2008)

	Stock in 1,000	Surface area in m m^2
Total residential	**7,362**	**456.5**
Multi-family	3,173	152.4
Single-Family	4,189	304.0
Service		59.4

Source: Atanasiu et al. (2012)

One important component is heating for which the high energy consumption is determined by low level of insulation of residential building stock. 50% of the building stock is more than 40 years old (the majority of the buildings were built before 1961), another 23% being over 30-40 years old. According to Romanian regulations normal service life of residence buildings ranges between 40 and 50 years.

Necessary investments into the residential stock in Romania omitted in the last decades. Romania rank at one of the last places in the EU 27. In 2010 (last available data for Romania) only 12% of the overall gross investments flow in the residential sector. Thereby the gross investments for the sector scored 3.0% of the GDP (EU27 average 5.0%).

The state supports the retrofitting activities of residential buildings based on the following legal provisions:

Legal provisions applicable to the weatherization of blocks of flats in Romania:

- Government emergency ordinance no 18/2009 regarding the increase of energy performance of blocks of flats
- Government emergency ordinance no 63/ 2012 for the amendment of Government emergency ordinance no 18/2009
- Law no 238/2013 for the approval of Government emergency ordinance no 63/ 2012

Financing of the weatherization works (according to currently applicable legal provisions):

- o 50% - state budget, provided annual budgetary allowances are approved for the purpose
- o 30% - local budget, provided annual budgetary allowances are approved for the purpose
- o 20% - flats owners' associations from the associations' funds

According to the Ministry for Regional Development and Public Administration (2014) the state budget for such allowances were ca. 80 m Euro in 2009 and decreased 6.5 m Euro in 2012. In addition to that financial support exists a state guarantee programme with following conditions:

Table 32: Conditions of State gurantee programme for weatherization banking loans

Beneficiaries	owners of flats, owners of single family homes
Credit limit to be covered by state guarantee for owners' association	1,850 Euro/ room
Credit limit to be covered by state guarantee for single family home owners	7,400 Euro/ bldg
Local administration sources	max 30% of works cost
Owners sources	min 10% of works cost
Credit period	max 5 years
Total programme value	not available
Legal framework	GEO 69/2010 approved by Law 76/2011

Source: Ministry for Regional Development and Public Administration (2014)

We do not take the support into consideration in the following calculations. Main reason therefore is the very low amount of support in the past years.

6.2.1.2 *Target of mitigation measures*

The main target of wall insulation in existing multi-family buildings consists in reduction of heat use. This measure has the potential to reduce carbon emissions and thus contribute to progress towards decarbonisation targets.. The present assessment addresses only the households sector and residential buildings, respectively. It is this sector where the GHG mitigation measure is expected to have the most significant impact in Romania.

6.2.1.3 *Micro-perspective*

The assessment has considered as facility first an average size residence (a 'standard' house). In addition, since a large share of population is living in block of flats and this measure has been applied with priority for blocks of flats, we estimate also the impact for a standard block of flats.

The average block size is assumed to be 1,880 m^2. A decreased energy need due to insulation of a building has been estimated by MDRL to 40% of the energy utility bill, in other studies the estimations ranging between 30-50% (Muşatescu; Leca and Vlădescu, 2012).

We assume the average energy saving with 88 kWh/m^2. The total impact of implementing the insulation technology at one average size block (40 apartments per block and 47 m^2 per appartment) would represent almost 165 GWh/a.

According to Atanasiu et al. (2012), the main energy sources for heating purpose are natural (28%) gas and biomass (47%). The share of district heating is shrinking since 1990. In 2011 the share was decreased to 19% (Euroheat, 2013). For the following analysis we take into account such blocks, that are heated by central heating systems and natural gas and we assume that the use of both sources in multi-family buildings is significant above the national average.

For a block of 40 residences with central heating consumption, we consider that the emissions of CHG-gases will be reduced by ca. 49 t CO_2/a. and for natural gas consumption by 33.5 tCO_2/a. We assume the shares of central heating blocks and natural gas heated blocks with 50% for both types. Retrofitting costs per sqm living area is considered with 55 Euro.

The house owner decision to invest into a modernization is driven by the expected energy savings, energy prices and the costs of a modernization. Thereby we want to distinguish between individual heat consumption by district heating and the use of natural gas.

Table 33: Net-Present-Value for energy retrofit of multi-family buildings in Romania

Fuel price increase 0% p.a.				
Interest rate 8%				
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Abatement costs Euro/ tCO_2
central heating	103,400	92,000	**-11,400**	12
natural gas		53,000	**-50,400**	51
Average NPV based on fuel consumption shares			**-31,000**	36
Fuel price increase 0.5% p.a.				
Interest rate 8%				
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Abatement costs Euro/ tCO_2
central heating	103,400	96,000	**-7,400**	7
natural gas		55,000	**-48,400**	57
Average NPV based on fuel consumption shares			**-28,000**	32
Fuel price increase 1% p.a.				
Interest rate 5%				
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Abatement costs Euro/ tCO_2
central heating	103,400	127,000	**23,600**	-22
natural gas		73,300	**-30,100**	36
Average NPV based on fuel consumption shares			**-3,200**	7

Source: Authors' computations

The efficiency of a modernization is again depicted by a comparison of the net-present-value of energy savings and the investment and is based on the development of energy prices and discount rates provided in section 2.3.

Because of significant price differences for central heating on regional level between 0.03 and 0.07 Euro/kWh we depicted an upper and a lower bound for the net-present-value is given.

The abatement costs vary in dependency of the used fuel source between -22 Euro/t CO_2 and 57 Euro whereby for the average costs are between 36 for parameter set 1 and 7 for set 3.

6.2.1.4 Macro-perspective

At first we will direct our attention to the overall investment needs and energy savings if we assume that a significant amount of existing residence blocks and apartments would be modernized.

Table 34: Building modernization needs, by age

Year of construction	Share	Estimated area	Max. modernisation rate
	%	m m^2	%
Before 1961	31	123.4	30
1961-1970	19	75.6	70
1971-1980	23	91.5	70
1981-1989	14	55.7	90
1990-1999	7	27.9	90
>2000	6	23.98	100
	100	**398 m m^2**	**253 m m^2**

Source: Authors' estimations

Based on the modernization rates depended of the age of the building as depicted in Table 34 we estimate that ca. 250 m m^2 of residential family and multi-family buildings meet requirements for retrofitting. The investment needs for such retrofitting of 13 bn Euro till 2030 is with 2 bn Euro per year more that 60% of pre-crisis gross investment into the Romanian residence stock and from our perspective an unrealistic target. Hence, the more sensitive problem is the stock of old block of flats, since for those old buildings it is not enough to be insulated, but consolidated or even replaced by new ones. Since in these very old buildings are living persons at risk of poverty, the housing for these people would raise social problems on medium or longer term.

On this account we focus on a more realistic modernization rate. For an evaluation of the macro perspective we assume that the socio-economic environment is adapted so that on a micro level a modernization is economically. This implies that on the one hand either the prices for natural gas will increase as a result of the market liberalization or interest rates decrease.

The overall amount of multi-family buildings is 3,2000,000 with an aggregated living area of ca. 152 m m^2. We will assume that 70% of that living area (108 m m^2) met the conditions – building above 40 residences, consumption of natural gas and district heating and relevant age - for a retrofit and consider them in the further calculation. We assume further that the modernization rate (percentage of buildings that fulfil the conditions) will increase continuously from 1% to 3% in a time span of 8 years so that in 2030 38% (ca. 21,000) of "considered" multi-family buildings will be retrofitted.

Under given economic conditions the total investment of a retrofit of multi-family blocks in Romania sums up to 2.2 bn Euro till 2030. Fuel cost savings of ca. 1 bn Euro will be possible if we assume a constant price for central heating with natural gas.

The measure allows an emission reduction of 815,000 t CO_2 in 2030.

Table 35: Final results - Energy retrofit multi-family blocks in Romania

	Fuel savings	**Fuel cost savings**	**Investment**	**CO_2 emission reduction**
Year	1,000 GWh	m Euro	m Euro	1,000 t CO_2
2015	94	4	59	23
2020	830	34	119	200
2025	2,163	88	178	506
2030	3,587	147	178	815
Total 2015-2030	**25,650**	**1,052**	**2,244**	**5,979**

Source: Authors' computations

6.2.2 Energy retrofit of public buildings and offices

6.2.2.1 Status quo

According to Jaspers (2013) no official statistics regarding exclusively the public sector buildings are available. It is estimated, that publicly owned buildings represent ca. 25% of the total number of buildings described in Table 36.

Table 36: Breakdown of non-residential buildings Romania

Building designation		Number of units
Education	Kindergarten	3,769
	Schools	12,055
	Higher education	770
	Libraries	3,764
	Theatres, cinemas museums	898
Health	Hospitals	442
	Health centre	1,156
	Nursery	291
	Small health centre	28,193
	Drug stores, labs	8,239
	Social centres	1,664
Commerce	Small commercial shops	139,992
	Supermarkets	8,435
Tourism	Hotel, motels	1223
	Chalets, holiday villages, camping sites	2,994
Mail offices, financial services	Mail offices in cities	422
	Mail offices in villages	6,129
	Banks and insurance companies	5,882
	Small services companies	1,682
Public administration	City halls	325
	Town halls	2,851
	Head-offices of national public administration	234
TOTAL		**231,410**

Source: Jaspers (2013)

Ca. 15% - of the total floor area of buildings in Romania counts to the non-residential sector (BPIE, without year).The overall sum is ca. 443 m m^2. Based on the findings of a survey of Jaspers (2013) we have to assume that the efficiency status of existing non-residential building stock is weak. Even if differences between building types (e.g. schools and offices) exist, relevant energy savings through a retrofit are possible.

6.2.2.2 Target of mitigation measures

Target of the measure is an energetic retrofit of non- residential buildings so that energy consumption and therefore GHG-emissions can be reduced significantly.

6.2.2.3 Micro-perspective

For the following analysis we will only highlight to types of non-residential buildings, education buildings and offices. While the first are mainly in public use, offices are in public and private, hence we will not distinguish between both in the following calculations.

Following Jaspers (2013) we assume that the average energy consumption for heat of both can be reduced by ca. 50% respectively 70 kWh/m$_2$. The average retrofit costs are – following Jaspers (2013) - assumed with 60 Euro/m$_2$.

For the following calculation we assume an average building size of 5,000 m^2.

We face a similar situation as described in the measure Energetic retrofit of multi-family buildings. The NPVs are negative due to low fuel prices and high interest rates. From a micro economic point of view this measure is not efficient under assumed conditions. The abatement costs vary between 4 and 106 Euro/t CO_2.

Table 37: Net-Present-Value for energy retrofit of public buildings and offices in Romania

Fuel price increase 0% p.a.				
Interest rate 8%				
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Abatement costs Euro/ tCO_2
central heating	300,000	195,000	**-105,000**	45
natural gas		112,000	**-188,000**	106
Average NPV based on fuel consumption shares			**-146,000**	75
Fuel price increase 0.5% p.a.				
Interest rate 5%				
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Abatement costs Euro/ tCO_2
central heating	300,000	269,000	**-31,000**	13
natural gas		155,000	**-145,000**	82
Average NPV based on fuel consumption shares			**-97,000**	47
Fuel price increase 1% p.a.				
Interest rate 5%				
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Abatement costs Euro/ tCO_2
central heating	300,000	283,000	**-17,000**	4
natural gas		163,000	**-137,000**	39
Average NPV based on fuel consumption shares			**-77,000**	42

Source: Authors' computations

6.2.2.4 Macro-perspective

For the analysis of the macro-perspective we take only education buildings and offices into account. The overall floor are of such buildings is ca. 24,000,000 in Romania. We assume a penetration rate that starts with 2% in 2015 and an increase up to 10% in 2030 so that in 230 ca. 80% of all buildings that type will be retrofitted.

Based on these assumptions the total investments sum up to 1.2 bn Euro and fuel cost savings of ca. 400 m Euro will be possible. The emission reduction is ca. 370,000 CO_2 in 2030.

Table 38: Final results - Energy retrofit of public buildings and offices in Romania

	Fuel savings	Fuel cost savings	Investment	CO_2 emission reduction
Year	1,000 GWh	m Euro	m Euro	1,000 t CO_2
2015	34	2	29	9
2020	271	12	50	71
2025	683	31	87	180
2030	1,400	64	151	369
Total 2015-2030	**8,769**	**398**	**1,199**	**2,311**

Source: Authors' computations

We estimate the job creation effect based on the assumption of 14 work years per invested 1 m Euro (Ürge-Vorsatz; Arena; Sergio et al., 2010). This leads to ca. a job effect of ca. 1,200 in 2015 and 4,000 in 2025 in the construction sector.

Polystyrene is currently the most popular material used in insulation of buildings works in Romania (chosen in about 95% of insulation works) mainly due to the price advantage over alternative solutions available. There are over 60 polystyrene suppliers on the market. Especially due to the demand for the block of flats, their number has continued to increase. Some of them are international providers (Swisspor, Austrotherm, Hirsch-Porozell, Baumit, Henkel Caparol). Additionally, a Romanian professional association of polystyrene producers has been established.

Nevertheless, is likely that in the future the share of other, more expensive materials will increase (mineral or innovative materials) and other companies will appear on the market.

6.2.3 Measures assessment

Both measures describe a subset of potential and necessary investments into energetic retrofitting of the Romanian building stock. We did not take single-family houses into account. The reason is that we expect that the economical efficiency to be lower than in multi-family blocks if coal or fossil fuels are used for heating.

The aggregated emission reduction of both measures sums up to ca. 1.2 Mt CO_2 in 2030 and the investments to 3.7 bn Euro. However, considering that real conditions of retrofitting differ significantly between buildings, the costs of the retrofit and the potential energy savings can also differ. Further investigations and specific energy audits are necessary.

The emission reduction counts for ca. 1% of the actual emission of Romania.

The NPVs of described retrofitting measures are negative under the considered economic conditions so that a retrofitting from a micro economic point of view is not expectable. This situation can change if one or more of the following conditions will change:

- interest rates decrease due to an economic recovery in Romania,
- fossil fuel prices increase due to reduction of government interventions into the market,
- introduction of a comprehensive governmental support schemes with an adequate financial configuration and/or
- introduction of appropriate upper limits for energy consumption per floor m2.

As described in 6.2.1.1, governmental support enables financial support up to 80% of the retrofitting costs. However, the amount of support in the last years was extremely low so that this support is negligible.

Owners' associations play an important role in insulating blocks of flats. They have to be active and convince the owners to agree with the insulation works and to pay their share of contribution in case where subsidies from the national or local authorities are be granted. However, in the context where many blocks of flats are inhabited by families with wide ranges of incomes, some will not be able to afford the contribution to the insulation of the entire block. There are examples in which an entire block of flats is insulated with the exception of a few apartments whose owners couldn't afford the cost. Only appropriate support schemes can prevent such situations.

There are no barriers related to the existing skills of labour force for this mitigation measure since the technology of insulation is fairly simple and easy to learn and use. Nevertheless, the involved activities need to be coordinated and supervised by a skilled person, but there is a shortage of such professionals in Romania.

The insulation of buildings is in general welcomed by the civil society and there are no social barriers. We estimate that there are no rebound effects related to this measure. The bill for utilities represents an important share in the household budget over almost six months a year (related to seasonal temperature) and the energy savings made by the insulation would not necessary be an incentive to increase consumption.

Nevertheless, there are debates related to the impact of external wall insulation on aesthetics of historical houses (although the effects are positive on the classical blocks of flats built under the communist period), and the social factors associated with inconveniences produced by the works related to installation of insulation.

6.3 Measure Electricity: Household sector

6.3.1 Early replacement of old white ware with A+++, A++, A+ standard

6.3.1.1 Status quo

In Romania the per capita households electricity consumption of ca. 600 kWh is the lowest in the EU, however differences in the use of electricity for heating purpose exist. Differences in the electricity consumption exist a minly due lower equipment. Nevertheless, the major home appliances market experienced a boom in 2007-2008 period (2.5 bn Euro in 2008), then it went down to 1.5 bn Euro in 2009 and then dropped to about 300 m Euro in 2010 and has remained almost at the same level, due to economic crisis. The sales of major home appliances continued to decrease in the first quarter of 2013, according to GfK by -2.1% compared to the same period of the previous year.

The number of **refrigerating** appliances is higher than the number of households (about 9 million in 2010 refrigerating appliances versus 7 million households). According to NEEAP (2007) Annex 2.1 40% of the appliances are manufactured before 2000 and are at the end of their expected lifetime.

Regarding the share of households having **refrigerating** appliances, it was 93.7% in 2007 and we appreciate that it has increased with slower speed than registered during the economic boom period.

The share of households using **washing machines** in total number of households is much below 100%, due to lack of running water in a number of households, especially in rural areas. Nevertheless, its trend is positive, increasing from 69% in 2007 to 81% in 2011(INSSE, 2012).

Regarding **tumble dryers** and **dishwashing machines**, statistics are not available, but, according to GfK TEMAX, there is a significant increasing trend in the sales of the group of major appliances, including dishwashing machines, dryers and ovens (30-40 % in the last quarter of 2012).

As for **electric ovens,** used to be much less common in Romania compared to gas oven partly due to the fact that most of the households, especially in urban areas are coupled to the natural gas distribution network, while in those rural areas where common stoves fuelled with wood are not used, gas ovens are fuelled by refillable gas recipients.

6.3.1.2 Target of mitigation measures

Target of the measure is a CO_2 emission reduction by an earlier replacement of inefficient white ware appliances that are at the end of its lifetime by high efficient appliances.

6.3.1.3 Micro-perspective

In this micro perspective section we focus on the question if and how a replacement of single appliances could occur. Thereby the main question is if potential energy savings would support a replacement of an appliance before the end of its lifetime or not and if it is economically to purchase a more efficient appliances than a such one with low efficiency standard.

The following two tables give an overview of the parameters, which are used for the further computations. Data, which are not available at producers or sellers documentations, are filled by own assumptions. Thereby we do not provide data for the efficiency class A because of rare data availability.

Table 39: Energy consumption and prices of different white ware appliances

	Energy consumption in kWh/a				**Prices in Euro**		
	A+++	**A++**	**A+**	***Old appliance***	**A+++**	**A++**	**A+**
Dishwashing machines							
freestanding <=12 sets	230	250	275	*340*	601	490	334
freestanding >12 sets	220	265	285	*350*	780	468	356
In built <=12 sets	195	220	245		757	646	445
Washing machines	180	220	226		445	312	267
Freestanding refrigerators <=270l	110	170	200	*280*	600	400	245
Freezers	170	200	290	*350*	612	557	334
Electric ovens	230	330	350	*500*	1002	312	267

Source: ICEMENERG (ongoing Project), www.altex.ro, www.compari.ro and own assumptions

Purchase of new appliances before end of live time of old ones

At first we have to ask if a household would replace an old white ware appliance before the end of its lifetime based only on expected energy savings. We assume that the appliance is between 0 and 5 years before the typical end of its lifetime and the user expect an additional 5 years period of serviceability. The Net-Present-Value is calculated difference of the depreciated cash flow from energy saving over a period of 5 years and afifth of the price for a new appliance. We focus only on new appliances with the energy efficiency class A+.

There are several estimations regarding the lifetime of the major appliances, due to the differences in models, quality etc. Based on NEEAP (2007) and/or ICEMENERG (ongoing Project) and Environment Australia (2001) we take into consideration estimations regarding white ware lifetime of 15 years for refrigerators, freezers and washing machines, 10 years for dishwashers and 19 years for electric ovens.

Table 40: Net-Present-Value calculation white ware - replacement of old appliances

	Energy savings	Price share 5 years	Discounted fuel cost savings	Net-Present-Value
	kWh/year	Euro	Euro	Euro
Dishwashing machines				
freestanding <=12 sets	65	167	40	-126
freestanding >12 sets	65	178	40.	-137
In built >12 sets	60	234	37	-196
Washing machines	84	89	52	-36
Freestanding refrigerators <=270l	80	82	49	-31
Freezers	60	111	37	-74
Electric ovens	150	126	94	-33

Source: Authors' computations

Based on these assumptions, we summarize in Table 40 the economic parameters that determine households purchase decisions for that white ware all necessary data are available.

The energy savings for the different appliances are between 60 and 150 kWh for one year. This leads to discounted monetary savings based on the electricity price trajectory for households for the years one to five. The additional costs for the new appliance (price share 5 years - column 2) exceeds the potential monetary savings and therefore the Net-Present-Values are negative.

As long as the households' decision is based only on monetary parameters the purchase of a new appliance of type A+ instead of using an old one till the end of its lifetime is not economically viable and therefore not expectable. In addition, from this perspective an old appliance has to be used as long as it is functioning.

Purchase of appliances of higher efficiency classes

Next we want to ask if it is economically to choose an appliance with higher energy efficiency class at the end of the lifetime of the old appliance. Therefore we have to calculate the Net-Present-Value as difference of the energy savings as depreciated cash flow over the lifetime of a white ware and the price for the new appliance.

We compare each type of efficiency class with the next higher class.

The Net-Present-Value in Table 41 based on the described assumptions about potential energy consumptions and price differences of different white wares shows that the purchase of an appliance with a higher energy efficiency class is economically not efficient. Energy savings over the lifetime of the new appliance do not cover higher prices of a more efficient appliance.

Thereby it is independent if the purchase takes place in 2014 or later. A calculation for the year 2024 based on higher energy prices for the period after 2014 and under the assumption that the depreciation rate is only 5% shows that only Freezers (A++)

and Electric ovens (A++) becomes more efficient from a purely economic point of view.

The abatement costs are extreme high. Only electric ovens show a moderate value. All others vary between 500 and 1,600 Euro / tCO_2.

Table 41: Net-Present-Value calculation white ware - replacement by more efficient appliances

			Energy savings	**Price Diffe-rence**	**Discounted fuel cost savings**	**Net-Present-Value**	**Abatement costs**
			kwh/ year	Euro	Euro	Euro	Euro/ tCO_2
Dishwashing machines							
freestanding <=12 sets	A+++	A++	20	111	17	-94	1,096
	A++	A+	25	156	22	-134	1,252
freestanding >12 sets	A+++	A++	45	312	39	-273	1,414
	A++	A+	20	111	17	-94	1,096
In built <=12 sets	A+++	A++	25	111	22	-90	836
	A++	A+	25	200	22	-179	1,668
In built >12 sets	A+++	A++	50	312	43	-268	1,252
	A++	A+	15	111	13	-98	1,529
Washing machines	A+++	A++	25	134	28	-106	717
	A++	A+	13	45	14	-30	392
Freestanding refrigerator <=270l	A+++	A++	60				
	A++	A+	30	200	67	-133	376
Freezers	A+++	A++	30	155	33	-122	687
	A++	A+	90	267	72	-195	508
Electric ovens	A+++	A++	100	45	78	33	-80
	A++	A+	20	56	33	-22	126

Source: authors computation

6.3.1.4 Macro-perspective

In a macro perspective we have to evaluate the potential emission reduction through the use of new and more efficient white ware appliances.

Therefore we want compare two scenarios. In a baseline scenario the replacement rate of existing appliances of refrigerators and washing machines is based on the lifetime of old appliances and consumers choose more inefficient new appliances. In a policy scenario we assume that the replacement occurs faster and new appliances have a higher energy efficiency status.

Table 42: Replacement rate of refrigerator and washing machines (%)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Baseline scenario										
fabricated before 1995	40	40	20							
fabricated between 1996-2000	15	15	25	25	20					
fabricated between 2001-2003				20	30	30	20			
fabricated after 2004							10	30	30	30
Policy scenario										
fabricated before 1995	60	40								
fabricated between 1996-2000	15	25	30	20	10					
fabricated between 2001-2003		10	10	30	30	20				
fabricated after 2004							20	30	40	10

Source: Authors´ assumptions

In addition we assume that the share of efficient appliances increases (see Table 43).

Table 43: Share of efficiency classes of new white ware appliances – Policy scenario

Efficiency class	Baseline scenario	Policy scenario
A+++	10%	15%
A++	20%	25%
A+	30%	35%
A	40%	25%

Source: Authors´ assumptions

We neglect all efficiency classes lower than A. Reason for that is the low availability of data for this efficiency classes. We have to assume that price and electricity consumption differences between the classes are relatively linear so that the classes A++ to A are representatives for the real consumption shares.

The overall difference investments between the two scenarios are around 1.6 bn Euro over 20 years. Savings from a reduction of electricity consumption sums up to 1.3 bn Euro. However it is not advisable to compare these two figures because the monetary inflows and outflows differ in their time structure. While investments occur at the beginning of the planning period the maximum energy savings occur at its end.

Table 44 presents the results for the measure. The energy savings increase from 116 to 221 GWh/year till 2030. This leads – based on the assumptions about the electricity price evolution – to savings of an amount of 14 m Euro in 2015 and increases to 27 m Euro by the end of the planning period. Fluctuations in the series (e.g. negative additional spending) result from the replacement structure. The overall emission reduction potential between both scenarios is with 64,000 tCO_2 in 2030 nearly irrelevant. This leads to the question what emission reduction will become possible if we compare the actual situation with a potential status of 2030. Therefore we want to compare the emission of all white ware appliances in 2015 and 2030 under both scenarios.

Table 45 shows that the difference between 2015 and 2030 in the baseline scenario is much higher than the difference between the two scenarios. That means that without any intervention ca. 307,000 tCO_2 will be saved compared to 2015 in the baseline scenario while the policy scenario is just able to save additional 64,000 tCO_2.

Table 44: Final results – Early replacement of white ware

	Fuel savings	Fuel cost savings	Additional spending	CO_2 emission reduction
Year	GWh	m Euro	m Euro	1,000 t CO_2
2015	116	14	175	52
2020	142	17	-46	57
2025	199	24	15	66
2030	221	27	16	64
Total	**2,798**	**336**	**644**	**1,004**

Source: Authors´ computations

Table 45: Emission reductions of white ware replacement

	Baseline scenario	Policy scenario	Difference
	1,000 t CO_2		
Emission in 2015	1,757	1,705	**-52**
Emission in 2030	1,450	1,386	**-64**
Difference	**-307**	**-319**	

Source: Authors´ computations

6.3.2 Measures assessment

Our computations based on available data show that for consumers it is not economically efficient to replace existing white ware appliances before the end of their lifetime. If they need to be replaced, appliances with lower efficiency class are from an economic point of view more efficient. Obviously consumer's decision is not based only on economic parameters. Size, brand, look, practicability and technical add-ons are important criteria for the purchase decision so that the effective decision might differ from the economically efficient one.

We do not expect that replacement of old inefficient appliances to be driven by potential energy savings, which will not determine the purchase decision significantly if a replacement occurs. Increasing incomes and consumption habits will be the main factors driving the replacement rate.

It is worth mentioning that the current commercial offer is mainly made of products with lower range of allowed energy efficiency levels, reflecting the low purchasing power in Romania compared to Western European markets. For instance, studying the current supply for combined refrigerating appliances of four well known providers on the market, we found that about 84% are appliances with class A+, while only 2-4% with A+++ class. As well, super- or hypermarkets usually sell the most common/less expensive major appliances, such as A+ class devices.

- *Refrigerating appliances*: in Romania, A+ class models are mentioned among most energy efficient models, while in the EU are considered as inefficient models. We may notice also significant differences when looking at the EEI value. In Romania, this is ranging between 32% and

44% (the majority towards the upper limit), while on the EU markets the EEI value for the efficient products on the markets is maximum 22%.

- *Washing machines*: there are similar offers for the models with 7 Kg capacity, but in Romania the majority of products in the shops have lower capacity– the 'standard' model having 5 or 6 Kg capacity. Washing machines with above 8 Kg capacity are very rare on Romanian markets (and are not displayed either on topten.info.ro)
- *Dishwashing machines*: there are similar offers for freestanding models, but for built-in models, the offer in Romania includes in general less energy efficient products compared with the offer on topten.eu. They are mostly A+ class products that in EU are considered already inefficient. For instance, for a 14 different models set, the annual energy consumption for the models sold in Romania is ranging between 266 kWh and 285 kWh, while in EU is varying between 214 kWh and 238 kWh.

On the Romanian market there are already an important number of providers/brands for major appliances, about 50, among which: Arctic/Beko/Grundig, Bosch, Liebherr, Ariston/Hotpoint, Indesit, Whirlpool, Samsung, Siemens, LG, Zanussi/Electrolux, Gorenje, Candy (the latest offers among the cheapest products).

Arctic S.A. is Romania's largest producer of household appliances. In 2011 Arctic introduced new product range of refrigerators, freezers, washing machines and cooking appliances (Arcelik A.S., 2011). Since 2006 Romania has 26 active members of local producers, importers or retailers in the Association of European producers of home appliances (CECED): Amica, Arctic, BSH, Candy Hoover, Electrolux, Gorenje, Indesit, Philips DAP, Groupe SEB, Whirplool.

Currently there are not major obstacles in the business environment to specifically affect white ware local producers, importers or retailers, except the decrease of sales as effect of decreasing purchasing power of population, due to economic constraints and uncertainties. The economic crisis determined most domestic producers to reduce their activity or to orientate more the production towards exports (e.g. Arctic, which is currently exporting 80% of refrigerating appliances). They have also adapted the business model, practicing high or very high mark-ups on 'premium' products (that are already 'standard' products in Western countries regarding the energy efficiency, and a relatively modest mark-up for 'medium-class' products.

The energy consumption of the considered white ware appliances sums up to approximately 5% of the national electricity consumption in Romania. Although the figure is relevant, potential energy savings are insignificant and do not legitimate monetary governmental supports, especially because of expected windfall gains for consumers with higher incomes.

Government interventions should focus on a regulative framework that includes the following points:

- Increase the replacement rate of old inefficient appliances before the end of its usual lifetime.
- Add regulation that hinders inefficient appliances to enter the market, e.g. a prohibition of efficiency class lower than A or A+.

6.4 Measures summary: Energy sector

6.4.1 Natural gas Combined-Cycle Power plants - (2.450 MW)

6.4.1.1 Status quo

Combined Cycle Power Plant with natural gas and steam turbines (CCGT) and heat recovery steam generators (HRSG) are both innovative and efficient solutions to produce electricity in a low-carbon regime. Although tehe are no low carbon technologies at the same extent as the renewable energy technologies, CCGT and HRSG provide significant reduction of GHG emissions, due to increased technical efficiency, compared to other combustion technologies based on fossil fuels. CCGT and HRSG decrease the energy consumption of natural gas and thus the amount of GHG emissions.

CCGT technology combines two thermodynamic sources to obtain an increased efficiency of heat production process.

A **HRSG** is an energy recovery heat exchanger that recovers heat from a hot stream of gas. It produces steam that can be used in a process (cogeneration) or used to drive a steam turbine (combined cycle).

In Romania there are 26 cogeneration power plants operating in the national system, mainly providing district thermal energy. Most of them over passed the normal lifetime (80% of the cogeneration power plants are older than 35 years) and need to be modernized. According to feasibility studies, many of the existing facilities will be shut down by 2020, accounting for 1,950 MW, and only a few are planned to be modernized. The cogeneration facilities that will be shut down by 2030 totalize 2,495 MW. The facilities retirement schedule is partly drafted within the National Investment Plan, but meeting its goals will depend mostly on the availability of the financing sources for installing new facilities, the carbon price and the allocation of permits. In our computations, we assumed that all old facilities will be replaced by entirely new installed capacity using the measure under assessment.

In 2012, the largest producer of oil and natural gas in Romania, OMV Petrom opened the first CCGT facility of large capacity of 860 MW, which produces 8-9% of the total electricity of the country. By 2020, other 13 facilities using both technologies are estimated to be used in Romania, amounting for a total capacity of 3,593 MW, replacing most of the closed coal-fired power plants (4,152 MW net power).

6.4.1.2 Target of mitigation measures

Combined Cycle Power Plant**s** with natural gas and steam turbines is the main solution to replace part of the closed and/or inefficient facilities and to ensure the required amount of energy. CCGT is also an efficient solution to ensure the compensation capacity required in the system when using the RES power plants, due to unpredictable production and consumption features.

The target of this measure is to ensure the energy security, by generating the power and heat needed to replace the old thermal power plants. The measure is enclosed in the Romanian Energy Security Strategy for 2011 – 2035 and assessed in national studies.

6.4.1.3 *Micro-perspective*

For the calculation of the energy saving per one facility, as any other data could not be identified, the average technical efficiency of an old thermal power plant in the sector (older than 25 years), which are envisaged to be replaced, was used in comparison with the estimated technical efficiency of the new facility. The energy saving refers to the primary energy consumption, by calculating the differences of input required to produce the same amount of output. The analysis of the individual energy consumption of the facility was inconclusive, but we assumed that own consumption was included in the calculation of efficiency, as input cost.

We assume duration of implementation of a Combined Cycle Power Plants with natural gas and steam turbines of 2.5 - 3 years, depending on the dimension of the facility. The preparatory period is two years. Table 46 presents an example that compares the energy in- and outputs and emissions of an existing 330 MW coal plant and a new 290 MW natural gas CCGT.

Table 46: Environmental impact of one single facility annually (290 MW)

Indicator	Unit	Value
Existing thermal power plant - Coal (330 MW)		
Average efficiency	%	30
Primary energy consumption	GWh/year	4,803
Electricity production	GWh/year	1,441
Emission factor coal	tCO_2/toe	~ 105
GHG-Emission	Mt CO_2/year	1.82
Thermal power plant - Gas CCGT & HRSG (95%) (290 MW)		
Average efficiency of CCGT&HRSG (95%)	%	57
Primary energy consumption	GWh/year	3,190
Electricity production	GWh/year	1,818
Emission factor natural gas	tCO_2/toe	~ 55
GHG-Emission	Mt CO_2/year	0.63
Differences		
Primary energy saving	GWh/year	1,613
Reduction of GHG-Emission	**Mt CO_2/year**	**1.18**

Source: authors' estimations

The GHG-emission reduction results from two effects: the new power plant produces electricity with higher efficiency and the CO_2 intensity of electricity from natural gas is only half of coal. To makes the following analysis more comprehensive we assume same THP energy outputs of old and new plants so that the emission reduction can be compared more precisely. This leads to the finding that the emission reduction per MWh electricity output is ca. 200 tCO_2/GWh.

We consider two parameters reflecting the economical efficiency of a replacement of old coal facilities by natural gas plants. These are the resulting generation costs for electricity (LCOE) and abatement costs.

LCOE (Levelized costs of electricity)

We want to compare the implementation of a natural gas TPP with three other generations: Modernisation of an existing coal TPP, implementation of a new hard coal THP, implementation of new lignite TPP.

The LCOE depend mainly on prices of the capacity, fixed and variable operation costs and fuel prices. Further parameters are interest rates, taxes and carbon prices.

Plant prices and operation costs for one specific generation technologies vary significantly and change over time. Our assumptions are based on Black & Vearch Holding Company (2012), Wissel; Rath-Nagel; Blesl et al. (2008) and Wissel; Fahl; Blesl et al. (2010). For the development of fuel prices we take following assumptions:

Natural gas

At the present Romania is able to produce ca. 80% of its natural gas demand. Imported gas from Russia costs ca. 300 Euro/m^3 while domestic gas only half (News Romania, 2013). We will assume that the average price will convert to Russian central EU price till 2023 – 280 Euro/m^3 (see for more details about natural gas price forecast KNOEMA (2014b)). From 2023 a 2% annual fuel price increase is assumed.

Lignite and hard coal

Romania has significant resources of lignite and hard coal whereby the recourses resources of hard coal are 200 times and that of lignite 34 times higher that the reserves (Eurocoal, 2013). However the country has to import hard (steam) coal for power generation.

We assume – following Grecu (2011) – that for power generation domestic lignite resources can be used. We let the price for lignite be 15 Euro/ton.

For hard coal we will assume – following Grecu (2011) – the domestic price of 55 Euro/ton till 2023 and from there on international coal prices of 70 Euro/ton based on World Bank projections provided by KNOEMA (2014a). From 2023 a 2% annual fuel price increase is assumed.

We assume a load factor of 80-90%. The efficiency of generation is assumed with 33% for a modernised lignite, 56% natural gas and 46% hard coal THP (Wissel et al., 2010). We do not take heat selling into account.

Table 47: LCOE (generation costs) for different types of power plants

	Investment	**Fixed OEM**	**variable OEM**	**LCOE in Euro/MWh**		
	Euro /kW	Euro / kW year	Euro/ MWh	Carbon price scenario Euro / tCO_2		
				0 Euro	5 Euro	10 Euro
Modernisation existing lignite	425	39	5	28	34	39
New natural gas combined cycle	500	19	2	59	61	63
New hard coal	1,500	35	4	45	49	53

Source: Authors´ computation

Table 47 summarizes the results for three different carbon prices. It has to be highlighted again, that these figures give only a rough estimation of a potential realisation of LCOEs. The main finding is the relative differences between the generation types.

Our estimations differ +/- 15% of that of the National Prognosis Commission (2012) provided 2012 in their study on investments into the electricity production and are in the range of these in international studies.

The gas generation is ca. 30% more expensive than the generation in a modern high efficient coal power plant and ca. 100% compared to a modernisation of an existing lignite power plant. For an assessment of the efficiency of the measures we calculate the abatement costs. Table 48 shows the abatement costs in relation to the modernisation of a lignite THP and implementation of a new hard coal facility. The abatement costs are positive due to higher generation costs of electricity from natural gas but are relatively low. With 7 Euro/tCO_2 a replacement of an old lignite THP is efficient if carbon prices are above 12 Euro the costs will become negative in respect to lignite and if higher than 80 Euro/tCO_2 in respect to a new hard coal THP.

Table 48: Abatement costs of Gas CCGT & HRSG

	Abatement cost
	Euro/ t CO_2
Modernisation existing lignite	7
New hard coal	19

Source: Authors´ computation

6.4.1.4 Macro-perspective

We consider a total capacity of 2,450 MW of CHP is feasible to be modernized until 2020, i.e. 7 theoretical facilities of 350 MW. The investments were assumed to be 5 brownfield and 2 greenfield type.

The estimated investments needed sum up to 1.06 bn Euro. With theses ca. 9.2 MtCO_2 can be abated in 2030. The power generation of the natural gas THPs in 2030 corresponds to ca. 17% of the actual electricity production in Romania.

Table 49: Final results – CCGT & HRSG

	Primary energy consumption	Electricity generation	Investments	CO_2 emission reduction
Year	GWh	GWh	m Euro	1,000 t CO_2
2015	0	0	47	0
2020	13,688	7,665	106	6,592
2025	19,163	10,731	0	9,229
2030	19,163	10,731	0	9,229
Total 2015 - 2030	**169,725**	**95,046**	**1,065**	**81,728**

Source: Authors´ computations

On average, one of the old thermal power plants that we considered to be modernized has 600 – 800 employees. One CHP could have 4 to 6 facilities and one of them would be replaced by implementing the measure. We cannot assume that by replacing one of the 4-6 facilities, the number of jobs in the old facility is going to be reduced proportionally. However, some of the existing jobs could be lost.

For one facility, we took the case of OMV Petrom, which created 40 jobs with the implementation of Brazi CHP. Instead, OMV Petrom could have relocated some of the employees having worked for the group for operational tasks at the moment of implementation. We assume that this is the case for the old thermal CHP as well and there will be jobs created that would compensate the loss of jobs in the old facilities. Based on these assumptions, we estimate that a new facility of 350 MW (compared to 860 MW in Brazi) would generate 30 net jobs.

We expect effects of 120 – 1200/day temporary jobs during construction of one facility. Giving the fact that the envisaged technology is very similar to the existing one, employed in functioning facilities, the labour force to implement technology is considered to be adequately skilled and available. Probably, in the case of engineering some additional qualification or training with the new technology is required.

6.4.1.5 Measures assessment

OMV Petrom already applies the technology of natural gas CHPs in Romania. Consequently, there is potential in the market for the adoption of the assessed technology.

There is no producer of CCGT & HRSG technology in Romania. Therefore, possibilities of joint venture, partnerships and import have to be created. Moreover, research and development have to be encouraged in order to update the relevant data in the field and to identify specific issues. Producers of old technology, of turbines, furnaces and other heavy industry components could upgrade their production lines, in order to become competitive.

There are many companies that can provide maintenance services, many distributers of components and some domestic producers of components, so that no constraint is to be expected.

The price of natural gas is still regulated and producers have to accept the gas mix from domestic production and imported gas. According to an agreement Romania signed with the IMF, the liberalization of natural gas price will be finalized in 2014 for industry and in 2018 for households.

The import of natural gas would probably increase, due to limited domestic resources. From a strategic point of view, different sources of supply have to be envisaged.

The modernization of thermal power plants is not sufficient in order to improve the distribution and to decrease the losses in the national system. New grids, network development and protocols are needed to ensure a better supply and sales predictability. Opportunities to increase export of electricity can be created, if the system functions at its entire capacity. Otherwise, the system becomes too fragile and unpredictability of supply increases.

Part of the investment will be provided from the national allocation plan of allowances until 2020. The difference has to come from companies' own funding or loans. We consider that both types of investments (brownfield and greenfield) are possible. In the first case, the advantage is offered by the opportunity to further develop and value the already owned land and industrial platform of the old facility.

Most of the thermal plants are insolvent and cannot access credit. Therefore, political or administrative solutions should be found to overcome this barrier.

In conclusion, we want to notice, that the volume of electricity production based on natural gas as described in this measure exceeds the amount resulted from the GEM-E3-NMS optimum macro-approach by the factor of two. What will determine if the capacity development of natural gas as described above will become significant will be the evolution of the cost of renewable and nuclear generated electricity in the coming years.

6.4.2 Standalone Biomass (solid, gas or municipal waste) CHP

6.4.2.1 Status quo

There are 11 mitigation technologies envisaged in the current Romanian master plan for Biomass (The Ministry of Economy and Commerce, 2010), but cogeneration in centralised systems using biomass turbines was recommended as one of the most efficient and also considered an emergent technology in Romania. For the 2020 horizon, the master plan estimates that the weight of heat and electricity produced in cogeneration using biomass in centralised systems will rise from 0.2% in 2009 to 6.8% of the final energy consumption of biomass (i.e. 321 thou. toe) and to 4.4% of the total final energy consumption, respectively.

At the moment, there are only 5 small units for local heating, but no large plant has been installed. The urban heating projects in cogeneration using biomass have already been tested with positive results in 5 small towns, with a population under 20,000 inhabitants, using local boilers from sawdust or municipal waste.

The national system of central heating provides heating services to 83,799 multilevel buildings, with 3.1 million apartments and 7.8 million people living there, out of which 50% have been decoupled from the central system due to certain reasons (outstanding payments to utility providers, individual solutions and inadequate public policies).

The current status of 90% of the providing companies, most of them operating in large cities, is insolvency or bankruptcy, due to outstanding debts, especially in the account of fuel suppliers. In November 2011, the total debts of thermal energy companies amounted to 4,565 m RON (more than 1 bn Euros), out of which 1 bn RON in Bucharest (both ELCEN, the local producer and RADET, the distributor, have the banking accounts blocked for 5 years now), but they also have debt claims (National Prognosis Commission, 2012).

The equipment is old and neither complies with the environmental standards, nor reaches the "normal" cogeneration efficiency (15-20% lower than EU cogeneration standard efficiency, of 75%). The energy losses on the entire chain production–transport – distribution – consumer are considerably high, from 50 to 70%. The most efficient heating system has 35% losses and the most inefficient 77% (National Prognosis Commission, 2012).

For the reasons mentioned above, the replacing of existing facilities is difficult to realize. In that sense, new companies and new developing areas should open to the market of heating supply.

According to the Romanian master plan for Biomass (2010), in 2020 the biomass contribution to final energy consumption from renewable sources (RES) will be of more than 65% of total RES, equivalent to 4,691 thou toe. RES contribution to total final energy consumption, related to EU 2020 objectives (European Parliament, 2009), was established at 24%.

The biomass potential is also important for electricity production, but at a lower scale. According to The National Action Plan on Renewable Energy, until 2020, new facilities of total power of 455 MW of biomass energy will be developed in cogeneration, requiring a total investment of 1.2 - 1.4 bn Euro.

6.4.2.2 Target of mitigation measures

This measure is assumed to contribute to the increase of the production of energy from renewable sources, in order to meet the EU 20-20-20 target established for Romania of 24% RES from the final energy consumption sub target of this measure is to use the renewable energy potential in centralised systems, in order to ensure energy security of the national system.

The cogeneration power plants with biomass will have to replace part of the closed and inefficient facilities and to ensure the required amount of energy, mainly thermal energy for residential buildings which are the main consumer of final energy in Romania, with 40% of the total final energy consumption, exceeding that of industry (National Prognosis Commission, 2012).

6.4.2.3 Micro-perspective

There are different technologies that can be deployed for energy cogeneration using biomass and the main practical advantage is that they are very similar to the common steam turbines. One of the most innovative technologies available is the **ORC (Organic Rankine Cycle)**, which is mainly used in small to medium sized thermal plants. The main difference with the common turbines is the use of organic fluid as a thermal agent instead of water. The higher density of organic fluid as compared to water density determines a lower speed of turbine, which has a positive effect in reducing pressure and erosion of metal parts and palettes. The ORC efficiency of almost 98% of the input thermal power, out of which 78% is transformed into thermal energy output and 20% into power.

The cogeneration in centralised systems is preferred to other technology solutions due to scale and an increased return on investment. At the future estimated prices of thermal energy, the investment in standalone thermal plants is significantly underleveraged. On the other hand, while providing additional electrical output, the investment in cogeneration can be more rapidly recovered due to green certificates schemes applying to energy production from renewable sources.

For the actual assessment we assumed a standard standalone biomass CHP, formed of one standard Rankine cycle (gas engine) and one wet mechanical cooling tower. This technology can be fueled either with solid biomass after combustion, either with gas obtained from gasifying the biomass or with gas obtained from municipal waste.

The standalone biomass CHP, using solid, gasified or municipal waste is estimated to be developed until 2020 in 12 facilities, with installed capacities of 50 MW (2 greenfield facilities) and 10 MW (total 10 facilities: 5 greenfield and 5 brownfield).

This measure is complementary with the CCGT&HRSG CHP one. The facilities would replace the old coal-fired facilities in thermal power plants owned by local governments, totalizing a capacity of 200 MW.

The duration of implementation of a standalone biomass CHP was estimated at 3 years in the case of the 50 MW CHP and 2 years for 10 MW CHP.

The average lifetime of a cogeneration power plant with biomass is 35 years.

This technology generates electricity as the main output and heat as a secondary by-product. It was supposed that biomass CHP would replace existing coal-fired capacities. All the calculations of primary energy saving and emission reduction were based on this assumption and the amounts were compared to those generated by coal-fired CHP replaced facilities.

Table 50: The environmental impact of one single facility annually

Indicator	50 MW greenfield facility	10 MW brownfield facility	10 MW greenfield facility
Electricity production GWh/year	175	35	35
Primary energy consumption of existing thermal power plant (coal) GWh/year	584	116.8	116.8
Average efficiency of coal-fired power plant	30%	30%	30%
Average efficiency of biomass CHP	40%	32%	32%
Primary energy consumption of new facility (natural gas) GWh/year	438	109.5	109.5
Primary energy saving GWh/year	146	7.3	7.3
Emission reduction of GHG from replacing coal-fired power plant 1,000 t CO_2	**212**	**42.4**	**42.4**

Source: Authors' computations

As described in chapter 6.4.1-Natural gas Combined-Cycle Power plants - (2.450 MW) – we want to provide information about the generation costs for a biomass cogeneration facility and estimations about the abatement costs compared to other generation technologies. We do not take the heat production into consideration.

We follow again Black & Vearch Holding Company (2012), Wissel et al. (2008) and Wissel et al. (2010) and assume – following (IEA, 2010)an average price for biomass of 20 Euro/MWh.

Table 51: LCOE (generation costs) for biomas CHP

	Investment	**Fixed OEM**	**variable OEM**	**LCOE in Euro/MWh**
	Euro /kW	Euro / kW year	Euro/ MWh	0 Euro/ t CO2
Solid biomass	2,500	132	3	128

Source: Authors´ computation

Table 51 summarizes our assumptions and the resulting LCOE for a biomass CHP. With 144 Euro/MWh the generation costs are three-times higher than theses of a new hard coal plant (see Table 47).

If lower prices for Biomass can be realised in Romania – e.g. 10 Euro/MWh – the generation costs decrease to 114 Euro/MWh.

With this figure our calculations are in the range of international surveys. Thereby the LCOEs vary significantly depending on the technology and the used biomass.

Table 52: Typical capital costs and LCOE of biomasspower technologies

	Capital Costs	LCOE
	USD/kW	USD/kWh
Stoker boiler	1,880 – 4,260	0.06 – 0.21
Bubbling and circulating fluidised boilers	2,170 – 4,500	0.07 – 0.21
Fixed and fluidised bed gasifiers	2,140 – 5,700	0.07 – 0 24
Stoker CHP	3,550 – 6,820	0.07 – 0.29
Gasifier CHP	5,570 – 6,545	0.11 – 0.28
Landfill gas	1,917 – 2,436	0.09 – 0.12
Digesters	2,574 – 6,104	0.06 – 0.15
Co-firing	140 – 850	0.04 – 0.13

Source: IERENA (2012)

The abatement costs – as relation to other generations and based on a biomass price of 20 Euro/MWh - range between 28 Euro/t CO_2 and 78 Euro/t CO_2 (see Table 53). Lower biomass prices of 10 Euro/MWh reduce the abatement cost by ca. 20%.

Table 53: Abatement costs of solid biomass CHP

	Abatement cost
	Euro/ t CO_2
Modernisation existing lignite	28
New hard coal	44
New natural gas combined cycle	78

Source: Authors´ computation

6.4.2.4 Macro-perspective

We assume the installation of 12 facilities with an aggregated capacity of 200 MW until 2025. The investments need to develop these 12 facilities of standalone biomass CHP is 324 m Euro. The GHG emission reduction in 2030 is estimated with ca. 0.5 $MtCO_2$.

Table 54: Final results - Solid biomass CHP

	Primary energy consumption	Electricity generation	Investments	CO_2 emission reduction
Year	GWh	GWh	m Euro	1,000 t CO_2
2015	0	0	4	0
2020	110	3,833	49	0
2025	1,314	45,990	0	500
2030	1,971	68,985	0	500
Total 2015 - 2030	**10,622**	**371,752**	**324**	**6,105**

Source: Authors´ computation

Making an extrapolation of a single facility, there will be around 240 permanent net jobs for the 12 CHP facilities and other 700 temporary jobs for construction (calculations based on information of Govora (2012)). It was considered that in the case of the existing plants, the required working force will be ensured with the existing employees, due to similar tasks and skills required to implement the new facilities.

The number of jobs loss was evaluated only for the replaced capacity, power stations to be closed due to technological outage and not to horizontal impact.

The measure could not determine an important shift in the ranking of producers of electricity/heat. As the Ministry of Economy appreciates, the investments will not influence competition, as the competition ratios will maintain the actual values. A few new companies would possibly enter the market, but with small capital impact and market power. However, at a local and regional market level, their presence could be important.

The market of centralized heating is dominated by state owned companies, having either the Ministry of Economy or the local government as the main shareholder.

6.4.2.5 Measures assessment

Power generation from solid biomass is more expensive than those of fossil fuels. Without green tariffs, biomass-based generation is not economically efficient for the producers. The development of green tariffs is under discussion due to increasing burdens for households and industry consumers in the case of implementation of biomass-based generation. To stimulate investments, green tariffs need to be guaranteed for at least 15 years.

The existing law that promotes RES using green certificates envisages a support of 3 certificates/1 MW for the energy produced from biomass, until 2016. At the moment, there are uncertainties regarding the scheme of green certificates to be applied from 2016 on.

Structural funds grants for biomass projects are provided in different programmes: for local authorities (in the operational programme for environment), for businesses (in the operational programme for economic competitiveness), for any kind of stakeholders (in the national programme for environment).

Given the fact that the envisaged technology is very similar to the existing ones in terms of skills, the available labour force necessary to implement the technology is considered to be properly skilled. There is a shortage of skilled labour force at local level to elaborate and to implement projects. Moreover, the administrative capacity of local government is also weak. Most probably, additional qualifications and training would be required for engineering staff.

Considering that no direct producer of biomass power technology exists today in Romania, no domestic added value out of such technology production is expected. Nevertheless, biomass power plants use components, buildings and storage facilities, which counts for at least 50% of the investment needed.

Increasing prices due to green tariffs are not very popular and will need to be supported by governmental support schemes. We assess that the development of biomass power generation – as well as those of other renewables – will be determined by the green tariffs schemes, whereby its acceptance will mainly be determined by the economic recovery of Romania.

We estimate that the amount of domestic biomass (and in principle waste) is sufficient for the implementation of a small number of facilities as described in this measure. In fact, the agricultural activities in Romania and the amount of forests allow a relevant use of all kinds of biomass technologies.

The technology was successfully tested in 5 cities. We can expect that the development of the power plants and their operation is uncritical.

6.5 Measures summary: Transport sector

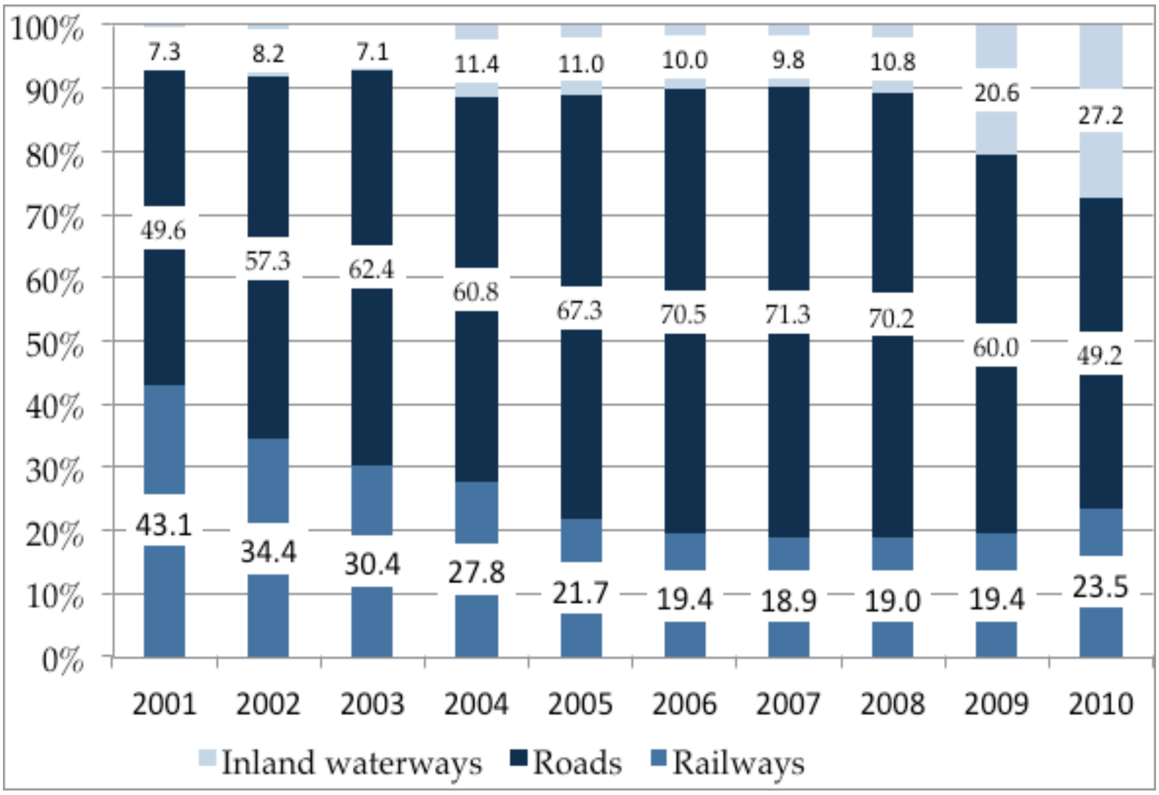
6.5.1 Developing intermodal freight transport

6.5.1.1 Status Quo

According to Eurostat data the inland freight transport in Romania compared to GDP has increased after 2000, but the pace slowed down with the economic crisis. The volume of freight transported in multimodal containers on railways represents on average 4% from total freight transport on railways over 2005–2009 period (see Figure 12).

As regards the structure, a comparison between 2000 and 2010 shows a shift towards road transport, in Romania, as well as in other new Member States. In contrast, eight 'old member' countries (Austria, Belgium, Denmark, Sweden, the United Kingdom, the Netherlands, Finland and Germany) presented modal shift towards more environmentally friendly transport modes.

Figure 12: Modal split of freight transport in Romania (%)



Source: Eurostat

The transport by road has an increasing trend, while transport by train started to increase its share slightly, after a dramatic drop. In 2010, 23.5% of goods have been transported by rail. In 2010, the main types of goods transported by train were: 43.5% coal and lignite, crude oil and natural gas, 26.6% coke and refined petroleum products, 7.5% chemicals, chemical products and man-made fibers, rubber and plastic products, nuclear fuels, 6.6% basic metals, 4.6% metal ores and other mining and quarrying products, 11.2% other types of goods.

According to INSSE, the stock available for freight transport in 2010 was:

- Diesel trains: 1,047 units (1792 thousand HP)
- Freight wagons: 43,311 (2003 thousand tons capacity)
- Goods road motor vehicles: 667,219

Romania's public railway infrastructure is state-owned and it is concessioned to the National Railway Company, CFR SA, as infrastructure manager. CFR S.A. is organized in 8 regional branches. A 2004 law divided railway lines into interoperable and non-interoperable lines, where the latter are mostly lines with reduced traffic, especially local traffic and can be concessioned to local managers.

More than 300 companies, private or state-owned, own industrial rail lines in Romania, amounting to almost 2,000 km all over the country.

The most important modernisation works are carried out in Romania for rehabilitating Corridor IV defined before Romania's accession to the European Union and corresponding now to the Priority Axis TEN-T 22. This is expected to cross Romania from West to East, having two branches: on the northern branch, it will cross cities such as Arad, Alba Iulia, Sighişora, Braşov, Bucharest and will reach Constanţa, on the coast of the Black Sea, and the southern branch will cross Timişoara and Craiova, ensuring the connection with Bulgaria, across the new bridge over the Danube at Calafat.

6.5.1.2 Target of mitigation measures

Intermodal transport, or mixed-mode transportation, involves using various transportation options and combine them, taking advantage of strengths and offsetting correspondent weaknesses of particular transportation modes.

Intermodal freight transport supposes the transportation of freight in an intermodal container or vehicle, using multiple modes of transportation: rail, ship, and truck. The method reduces cargo handling, thus improving security, reducing damage and loss, and shortens total transport time, at least for long distances. Additional advantage refers to the reduction of greenhouse gas emissions.

As far as **intermodal passenger transport** is concerned, the backbone of mixed-mode commuting is often one type of rapid transit, usually rail or metro, to which low-speed options (i.e. bus, tram, or bicycle) are appended at the beginning or end of the journey. Trains offer quick transit into an urban area and passengers can easily disembark and access various options to complete their trip.

A modern public transport infrastructure should satisfy a number of criteria, such as timetable reliability, in terms of frequency and speed of transport service delivery, good-value-for money and comfort. It should also enable cross-city or orbital journeys – either direct or through convenient interchange – and provide coverage to replace a personal car. The services should be well-integrated with each other, and the system as a whole should be well-integrated with other modes.

According to a recent study instructed by European Commission (European Commission, 2009), in Western countries high-speed trains account for approximately 40 % of traffic over medium distances and even more on certain routes, such as London–Paris, Paris–Brussels and Madrid–Seville. No plans for high-speed railways are currently scheduled in Romania and no impact studies on this topic have been identified, but one can imagine economic impact of and financing related barriers to such projects. In view of developing an integrated public transport infrastructure, it has been created the Metropolitan Authority for Transport Bucharest (*ATMB*)[16].

The current assessment will focus on modernising and developing of intermodal freight transport.

In view of reducing GHG emission, the major goals of modern intermodal transport are first to increase efficient use of public transport infrastructure and to reduce the weight of road transportation.

The objective stated in the recent Strategy for Intermodal Transport in Romania is that at least 40% of domestic freight transport will be realised through intermodal transport by 2020.

Developing an intermodal transport system in Romania by promoting a balanced development of various transportation modes will contribute directly to the decrease of traffic jam and will prolong the lifetime of existing road infrastructure while increasing the quality and efficiency of services, reducing the GHG emissions and minimising negative environmental effects. By developing intermodal transport, Romania could also contribute to attain the TEN-T strategy objectives of developing the European high-speed transport network. More precisely, it could contribute to connecting the main national routes to priority European TEN-T axes: priority axes 7, 18, 21 and 22[17].

Romania should exploit more efficiently the existing freight transport infrastructure by attracting freight volumes from the road sector to the rail and naval transport sectors, as is also stated in the first Intermodal Transport Strategy of Romania (Ministerul Transporturilor și Infrastructurii, 2011). The railway modal transport can be boosted by the development of the local logistics sector, the launch of new multimodal platforms and rail transport integration in the service portfolio of the third party logistics (3pl companies).

The same Strategy also brings some proposals for construction and modernizing intermodal terminals that are expected to better connect international traffic to domestic one.

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[16] *The authority is under the supervision of the Ministry for Transport and has been created by* Government Ordinance no. 21/2011 and approved by Law no. 8/2012. Its main responsibilities are strategic planning, monitoring, licensing, organising and controlling transport services in Bucharest metropolitan area for transport by metro, bus, microbus, tram, trolley, regional trains and maritime transport.

[17] Priority axis no. 7 – highways axis Igoumenitsa/Patras–Atena–Sofia–Budapesta–Nădlac–Sibiu–Bucureşti/Constanţa

Priority axis no.18 – inland waterways Rin/Meuse–Main–Danube

Priority axis no. 21 – motorways of the sea

Priority axis no. 22– railways axis Atena–Sofia–Budapesta–Viena–Praga–Nürenberg/Dresda–Curtici–Braşov

Thus, the identified areas are: Timişoara[18], Bucharest[19], Constanţa[20], Giurgiu/Olteniţa[21], Braşov[22], Suceava[23].

A cargo terminal is also envisaged for Cluj airport.

We share the pervasive opinion of NGOs that more political will is needed for the development of intermodal transport. In Western European countries the road transportation services provided by national railways companies are a priority.

Few modernization plans for the state owned Freight Transport by Rail Company (CFR Marfă) are planned in the current PNAAE 2 , but we may expect that with the envisaged privatisation of CFR Marfă the modernisation plans are very likely to change due to the expected easement of financial constraints following the privatization process.

Other public efforts to be undertaken in the near future refer to the implementation of the recently approved Romanian Intermodal Transport Strategy 2020, which includes, among others:

- **Fostering of RO-LA freight transport**: CFR Marfă, the national freight transport operator is to increase its RO-LA service offer using the national rail system provided that government subsidies are granted. An initial draft of state aid scheme has already been designed.
- **Modernization of freight transport terminals.** CFR Marfă will undertake the modernization of the Bucureştii Noi, Bacău, and Mediaş terminals. Such investments are expected to contribute to the sustainable development of the freight transport by rail.
- **Building of new transport terminals** in Timişoara, Braşov and Constanţa using European funds.
- **Ensuring an adequate wagon fleet** through modernization of existing intermodal transport specialised wagons. The measure is expected to allow CFR Marfă to timely meet client requirements.

Following the objectives stated in the strategic documents, we consider the measure of modernising intermodal transport for freight as having four components:

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[18] Timișoara has a connecting potential to Railways Priority axis no. 22, respectively Road Priority axis no. 7 entering Romania by Curtici/Nădlac, would allow choosing freight transportation among two transport modes (railways/road)

[19] Western part of Bucharest is connected to A1 (Bucureşti– Piteşti), Road Priority axis no. 7.

[20] Constanţa has already a good connection railways/road/air transport with Bucharest. Nevertheless, connection with Constanţa harbor should be exploited more efficiently, since the harbor makes the link between Europe and Asia.

[21] Giurgiu/Olteniţa area is connected to railways Bucharest – Giurgiu and Videle – Giurgiu (Pan European IX corridor), connected to express road Bucureşti – Giurgiu, it takes advantage of Giurgiu – Ruse bridge over Danube, as well as of the connection with Pan European transport corridor no. VII

[22] Brașov is situated in the central part of the Romania, on Priority Axis no. 22 and Pan-European corridor IV. There is also a proposal for extending TEN-T network Craiova – Piteşti –Brașov – Bacău.

[23] Situated on Pan-European corridor IX, Suceava area is important for logistics network, and is proposed for extension of the TEN-T network on Petea – Satu Mare –Baia Mare – Dej – Suceava – Rădăuţi – Prut, due to its potential to be connected to road, railways and air transport systems.

- **Modernizing intermodal terminals** and building new intermodal terminals (Timisoara, Suceava and Brasov)
- **Modernising diesel trains** (replacing engines)
- **Structural change in mode of freight transport**: decreasing share for road, in favour of railways mainly, in line with Intermodal Strategy 2020

6.5.1.3 Modernisation and new intermodal freight terminals

The modernisation of existing and the construction of 3 new intermodal freight terminals need an investment of ca. 182 m Euro.

We do not consider an emission reduction potential out of this construction, however theses IMT are a requirement for structural changes in the fright transportation.

Table 55: Investment needs for modernising intermodal terminals for 2013-2025

Modernization / new IMT	Investment in m Euro
Timisoara (new)	22
Brasov (new)	25
Constanta (new)	20
Oltenita-Giurgiu	10
Calafat – Craiova – Pitesti	15
Turda – Cluj-Napoca – Dej – Targu Mures	15
Brasov-Fagaras-Sf.Gheorghe	15
Galaţi – Bacău – Iaşi –Suceava	15
Giurgiu/Olteniţa – Bucureşti –Ploiesti	15
Others	30
Sum	**182**

Source: Authors assumptions

6.5.1.4 Modernisation of trains

We consider the modernisation of 6 engines per year on average, assuming the replacement value of 1 m Euro per engine. The aggregated investments sums up to 78 m Euro. A modernisation of an engine will reduce its energy (diesel) consumption by ca. 3.8 GWh per year. The aggregated energy savings sum up to ca. 250 GWh in 2030 and in its result emission reductions of ca. 64,000 t CO_2 will be possible.

Table 56: Final results – CCGT & HRSG

	Fuel savings	Fuel cost savings	Investments	CO_2 emission reduction
Year	GWh	1,000 Euro	m Euro	1,000 t CO_2
2015	22.95	918	6	5.92
2020	128	5,112	6	28
2025	218	8,713	6	52
2030	250	10,007	6	64
Total	**1,858**	**74,306**	**78**	**479**

Source: Authors´ computations

6.5.1.5 Structural change in mode of freight transport

Road freight transport has higher emission per tkm than other transport modes. Reason for that is mainly the lower capacity of trucks compared to trains or ships. A shift from road freight transport to railway transports would allow reducing energy consumptions significantly. However the previous development in Romania showed an increase of road transports till 2009.

We want to highlight with this measure the amount of emission reduction potentials in Romania if the share of road transport can be reduced by 12 percentage points till 2030. Therefore we assume that the aggregated transport increases by 3% per year.

In 2030 an emission reduction of ca. 1 $MtCO_2$ will become possible if we neglect technological changes in the stock of trains and trucks. The change of the transport mode has in additional an effect on the need of fuels and therefore cost effects. In 2030 1.6 m Euro can be saved and over the whole period 1.2 bn Euro.

Table 57: Final results – CCGT & HRSG

	Fuel savings	Fuel cost savings	Investments	CO_2 emission reduction
Year	GWh	m Euro	m Euro	1,000 t CO_2
2015	307	12	n.a.	79
2020	1,244	50	n.a.	321
2025	2,472	100	n.a.	638
2030	4,060	160	n.a.	1,048
Total	**31,440**	**1,200**	**n.a.**	**8,116**

Source: Authors´ computations

Because of low data availability we do not provide investment figures. If we take only fuel costs into consideration abatement cost are ca. -5 Euro/t CO_2, however this figure do not contains OEM costs and investments.

According to the Strategy for Intermodal Transportation 2020 (Ministerul Transporturilor și Infrastructurii, 2011), realizing an efficient system of intermodal transport in Romania will lead to about 140,000 new jobs, a contribution to GDP of more than 10 bn Euro, revenues of 1.6 bn euro from taxes, as well as increasing exports.

6.5.2 Measures assessment

The main obstacle to the development of intermodal transport in Romania is cost related: high investments costs for intermodal transport units and terminals; high and/ or obscure operational costs (transfer and warehousing); lack of subsidies for transport operators and/ or of cost sharing support schemes between road and rail infrastructure operators.

As stated in the Strategy of Intermodal Transport 2020, the main barriers to developing intermodal transport include under financing railways, namely the lack of funds for maintaining the infrastructure of the railways and the lack of funds for maintaining and modernising the 26 intermodal terminals belonging to CFR Marfă.

Nevertheless, CFR Marfă holds a number[24] of RO-LA platforms, but does not use them. CFR declares not to have the financial capacity to put at work these platforms, suggesting that other institutions, such as Ministry of Finances or Ministry of Environment should be involved in this process.

Financing options as identified in the national intermodal transport strategy for the development of the sector include:

- International financial institutions loans/ grants;
- Non-reimbursable EU financing: sectoral (transport) operational programmes and TEN-T Programme;
- Infrastructure access tariffs
- Leasing (modernisation and/ or operation)
- Public-private partnerships
- State aid;
- State budget allocations.

According to the national intermodal strategy, the main barriers to the development of intermodal transport in Romania are:

Organizational – bureaucracy related barriers within the institutional framework of transport system, lack of cooperation between stakeholders with foreseeable delays in meeting the clients' requests; lack of and/or poor implementation of temporary freight transport by road restrictions (i.e. during the night or weekends), lack of clear division of responsibilities;

Technical – lack of an integrated transport optimisation system able to follow cargo trajectory from gate to gate;

Infrastructure – missing interoperability, underdeveloped terminal capacity, lack of adequate handling infrastructure of hubs and lack of uniformity in handling equipment;

Operational – broken or lacking transparency information flows in transport chain; lack of flexibility of operational activities, poor access to integrated information sources regarding available services; low integration of intermodal transport in logistics chains;

Legislative – lack of an integrated legal framework including financial, technical and organizational provisions related to intermodal freight transport and logistics.

Unfortunately, no concrete actions providing incentives for encouraging the intermodal transport have been taken yet. As a result, despite the fact that a number of RO-LA Intermodal platforms have been bought by CFR, they are not used, having been in conservation (abandoned) in Arad for four years now.

[24] We did not find official estimates on their total number, but in the TV news PROTV it was mentioned that there are 156 such RO-LA platforms, that have been bought for 30 millions euro.

6.6 Measure summary: Trans-sectoral measure

6.6.1 Modernisation of pumps

6.6.1.1 Status quo

From industry to commercial sector, to municipalities and households, pumps are widely used, as synthesised below.

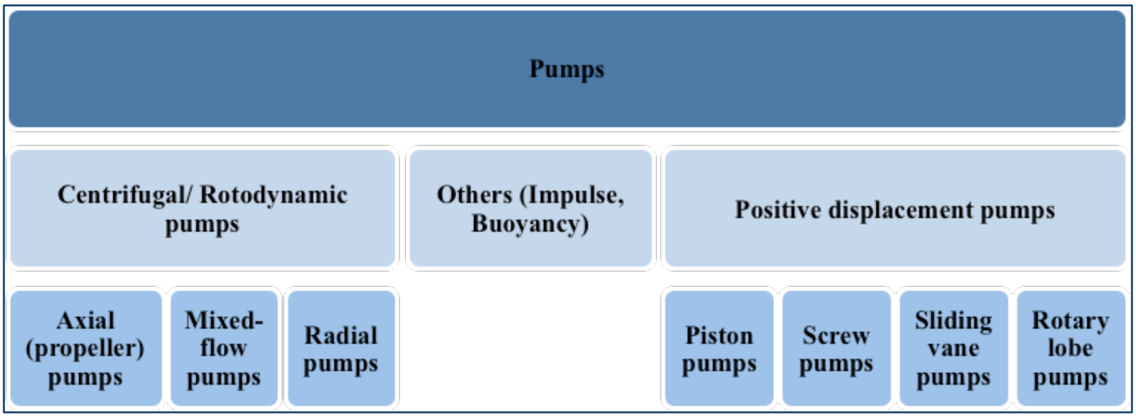
Table 58 Use of pumps according to the sector

	Industry	Commercial sector	Municipalities and households
Pumps use	cooling and lubrication services	heating, ventilation, and air-conditioning (HVAC) systems, for heat transfer	heating, ventilation, and air-conditioning
	transfer fluids for processing		water and wastewater transfer and treatment
	provide the motive force in hydraulic systems		land drainage

Source: Authors' edit from US Department for Energy (2006)

In addition to an extensive range of sizes, pumps also come in different types. They are classified by the way they add energy to a fluid as follows:

Table 59 Classification of pumps



Source: Authors' adaptation from the US Department for Energy (2006)

As in the figure above, according to the manner in which pumps add energy to the working fluid, pumps can be classified into two large categories: **positive displacement pumps** (which squeeze an amount of fluid equal to the displacement volume of the system with each piston stroke or shaft rotation) and **centrifugal pumps** (which add kinetic energy to a fluid using a spinning impeller). Worldwide, centrifugal pumps tend to be more common largely because they are simple and safe to operate, have a large range of application, require low operating costs and have long operating lives. Positive displacement pumps are, in turn, more appropriate for specific applications: when the working fluid is viscous, the system require high pressure, low flow pump performance or pump efficiency is highly valued.

A typical pumping system contains the following components:

- **Prime movers;** most pumps are driven by electrical motors;
- **Piping;** it is used to contain the fluid and carry it from the pump to the point of use;
- **Valves;** the flow in a pumping system may be controlled by valves that can either have specific positions, shut or open, or can be used to throttle flow;
- **End-use equipment;** the main purpose of a pumping system may be to provide cooling, to supply or drain a tank or reservoir, or to provide hydraulic power to a machine.

Pump systems can be classified in:

- **Open-loop systems;** such systems have an input and an output, as fluid is transferred from one point to another;
- **Closed-loop systems;** such system recirculate fluid around a path with common beginning and end points.

6.6.1.2 Target of mitigation measures

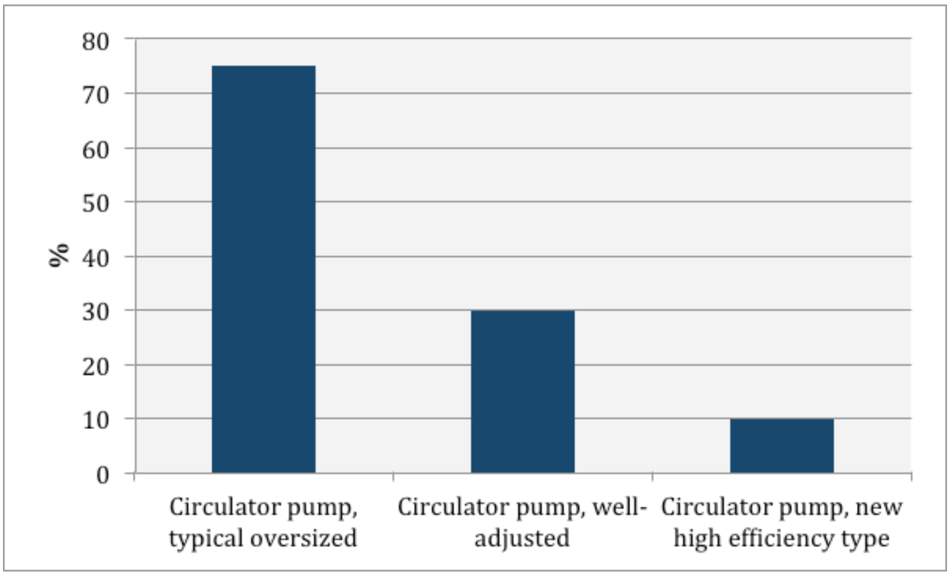
According to existing studies, on average, in the manufacturing sector alone, pumps represent 27% of the electricity consumption of the industrial systems. Therefore, **the reduction of electricity use via increased efficiency is the main target of the mitigation measure under assessment.**

For exemplification purposes, the potential reduction of electricity consumption by a typical circulator pump via implementation of variable speed drives is presented in the rest of the current section.

6.6.1.3 Micro-perspective

A typical circulator used in European heating systems has a power input of 60 to 90 W and several studies show that this is far oversized. A decrease of the pump capacity by at least 50% will result in better adjustments of the pump sizes to existing systems. Energy consumption will thus decrease. Furthermore, the employment of variable speed drives into existing circulator pumps is likely to generate an additional reduction in annual electricity use by 60 % or more (Figure 13).

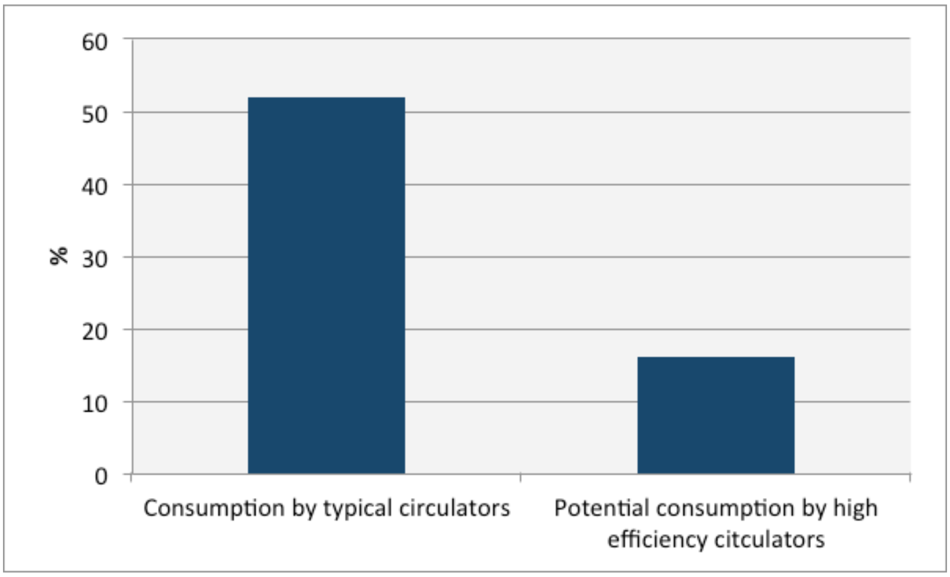
Figure 13: Power input of oversized correctly sized and permanent magnet motor circulators



Source: ICEMENERG (ongoing Project) Circulation pumps: recommendations.

Once such energy efficient pumps have become the technological standard for circulators, a reduction of 60 % or more in annual electricity used by circulators can be achieved (Figure 14).

Figure 14: Electricity consumption by circulators in the EU – today and in a BAT-scenario



Source: ICEMENERG (ongoing Project) Circulation pumps: recommendations.

The electricity saving potential across the EU-27 is thus estimated to more than 30 TWh per year from the above described measures (downsizing the pump capacity and enhancing its technical features).

Although expensive, pump replacement is cost-effective: Prices of Class "A" pumps are still higher at present than those of conventional pumps. According to the estimation of topten.eu, the huge electricity cost reduction will compensate for the price difference within 3 to 15 years operating time, depending on power reduction, size and yearly operating period. For medium-sized circulators in office and other larger buildings Class "A" pumps are highly profitable due to the resulting absolute power reduction.

6.6.1.4 Examples for the use of pumps

On a 650 MW combined cycle generating station, a total of 18 – 20 pumps may be used in applications as diverse as boiler feed, condensate extraction, circulating cooling water and for utility service. The total value of pumps employed is around 4 m US-Dollar.

On a 1 GW supercritical coal fired station, as many as 40 – 45 pumps will be used including applications for slurry handling for the flue gas desulphurisation units. The total value of the pumps can be ca. 11 – 12 m US-Dollar (excluding the turbines used for e.g. boiler feed) and where sea water rather than river water is used for cooling, the prices will be considerably higher because of the requirement to use stainless steel 316 or duplex stainless.

By contrast a 1700 MW pressurised water nuclear reactor for power generation may require up to 150 pumps with a value of up to 140 – 150 m US-Dollar. Unit values can range from 12,000 US-Dollar for utility service pumps to 20 m US-Dollar for the specialist reactor coolant pumps.

Much higher numbers of pumps are used in oil refineries. A 300k barrels per day oil refinery could have up to 600 to 650 pumps with a value of ca. 150 m US-Dollar

Similarly, chemical plants can have large numbers of pumps although given the vast range of products, numbers are highly variable. Unit values also tend to be much lower since the operating conditions (e.g. temperature, pressure) are usually less onerous than in refineries.

6.6.1.5 Macro-perspective

Due to the wide range of applications where pumping is required, there is a very wide diversity of pump types, designs and materials employed. The nature of the liquid being pumped will determine the type of the employed motor pump and the piping material. Pump configurations can also vary depending on the application/end use sector and the energy consumption/efficiency can accordingly. For instance, several pump types can be employed in a chemical plant: **air operated diaphragm pumps** for unloading raw materials, **centrifugal pumps** for supplying raw materials to the reactors and for transfers between the processing units, **metering pumps** for adding small quantities of reactants and/or catalyst and **eccentric screw pumps** for handling waste products or slurries.

Circulator pumps (closed-loop) are the most widely used pumps in the economy. The most energy efficient circulating pumps (class A) have a variable speed drive and a permanent magnet motor. In order to increase the efficiency of the circulation system, circulator pumps should not only be of class A, but also be correctly sized. As previously noticed, in practice, most installed pumps are oversized.

For the present estimation purposes, given the extensive range of features of the existing pump systems, a sectoral approach was preferred instead of building a bottom-up assessment. Therefore we do not provide a micro perspective for this measure.

In 2011 Industry and construction sector, together with Households accounted for more than 60% of the electricity consumption in the Romanian economy. The second largest major electricity consumption sector was Energy.

Taking into account that according to existing studies, on average, only in the manufacturing sector, pumps represent 27% of the electricity consumption of the industrial systems, for Romania's case we assumed that the consumption of electricity due to pump systems ranges from 0% to 50% from the sectoral consumption, as presented below.

Table 60 Pumps electricity consumption by sector, Romania, 2011

End use sector	Pumps electricity consumption by sector (TWh)	Weight in total pumps electricity consumption
Industry & construction	1.64	48.02%
Energy sector	1.28	37.52%
Households	0.23	6.79%
Other activities	0.16	4.61%
Agriculture	0.08	2.23%
Transport	0.03	0.83%
Total	**3.41**	**100.00%**

Source: authors' estimation, based on Electricity balance 2011

The total annual consumption of electricity due to pump systems was estimated at 6.44% from the total consumption at the aggregate level. More than 85% of the electricity used by pump systems (3.41 TWh) was due to Industry & construction and the Energy sectors in 2011.

The annual estimated optimization potential of the pump systems energy consumption, ranging from 0% to 30% of the estimated sectoral consumption, is presented below by sector, in TWh.

Table 61: Electricity consumption by pumps, optimization potential, annual

End use sector	Electricity consumption optimization potential (TWh)	Weight in total optimization potential
Industry & construction	0.29	46.94%
Energy sector	0.28	45.03%
Households	0.02	3.76%
Other activities	0.02	2.56%
Agriculture	0.01	1.24%
Transport	0.00	0.46%
Total	**0.62**	**100%**

Source: authors' estimation, based on Electricity balance 2011

The total optimisation potential of electricity consumption by pump systems is estimated at 0.62 TWh annually or 18.03% from the electricity consumption by pump systems in base year 2011.

However, one may find reasonable the assumption that such potential is not reached at once. For the evaluation purposes it was assumed that energy savings increase linearly such that the potential could be met by the time horizon, namely 2025. In other words, 1/13 or 1.4% of the total potential energy savings are realised annually, assuming no changes in sectoral activities occur and therefore no electricity consumption by pump systems. Such hypothesis may seem overly conservative but given the relatively low share of the aggregated electricity consumption due to pump systems in total electricity consumption of the economy (6.44%), for the purpose of the current estimation was considered reasonable. However, it was assumed that once the partial energy efficiency increase has been annually achieved, the following years would be negatively affected by the normal depreciation of the equipment. Thus, a 3% decrease of gained energy efficiency was taken into account each year.

As already mentioned, due to fairly high diversity in pump facilities and pump systems and to the lack of useful data, no micro-level evaluation was undertaken. Aggregating the micro-level assessment results would have been an equally difficult endeavour for the same reasons. Instead, we opted for a mezzo- and macro-level approach, using available data related to pump systems and own assumptions extensively. The assessment approach is available in an Excel file and is presented in the "Sector(s)" section of the current report. In current section we briefly mention assumptions employed in the assessment of the mitigation measure and the corresponding results.

We started from electricity consumption by sector available in the Electricity balance 2011, National statistical office and made assumptions regarding:

- The share of pumps in electricity consumption of the sector, varying from 0 to 50%. The pumps consumption is concentrated in: municipal water management, oil and gas extraction, coal processing and oil refining, chemical industry, pulp and paper, rubber and plastics, metal manufacturing, and construction (mainly land drainage).
- The optimization potential or the share of energy savings occurring by modernizing pumps and pump systems, varying from 0 to 30%. For sectors for which pumps are relevant, the modernization needs (optimization potential) have been considered 10% in general, but also 20% for chemical products and 30% for water management.
- The modernization need or the optimization potential was distributed evenly over the period 2013-2025, namely a rate of about 1,4% energy savings increase per year (of the total energy consumption of pumps)
- The depreciation of pumps efficiency (the decrease of energy savings) was assumed to be 3% per year.

The maximum energy savings per year (to be reached by the end of the interval) was estimated at 0.62 TWh. We will assume that the actual investment activities would lead to an improvement of 1/3 of this potential in 2030. The additional

The maximum CO_2 emission reduction per year (to be reached by the end of the interval) was estimated at 150,000 tCO_2 and the additional emission reduction (2/3 of this value) is 100,000 tCO_2.

For the assessment of the modernization needs a macro-level approach was also adopted employing available information regarding the value and structure of the world market for pumps in 2011 (Europump, 2011) and own assumptions/ hypotheses:

- The value of the pump market in 2011 was estimated at ca. 39 bn US-Dollar, covering pumps and prime movers (e.g. electric motors) but excluding parts. Because of either a lack of relevant data and/or poor quality data in many less developed countries, the value relates to 63 countries. It is however, a good proxy for the global market size. We excluded oil and oil/gas offshore technologies so that global market sum up to ca. 26 bn Euro.
- Romania was estimated to represent 0.2% of the market, based on their position in GDP ranking, i.e. 52 m Euro. This value consists expenditures for replacement of existing and new pumps.
- We expect that 20% energy savings are possible without significant investments. This includes mainly optimizations in the operation of equipment and potential downsizings.

Since we have considered a constant pace of modernisation for the whole period 2015-2030, and that Romania is mainly importing pumps, one could consider the annual value of 50 m Euro as additional yearly investment costs for modernization of exisiting pumps so that in 2030 the energy efficiency potential of 18% will be exploited.

Table 62: Final results – modernisation of pumps

	Fuel savings	Fuel cost savings	Investments	CO_2 emission reduction
Year	GWh	m Euro	m Euro	1,000 t CO_2
2015	32	3	50	15
2020	177	18	50	76
2025	302	30	50	116
2030	347	35	50	100
Total	**3,618**	**362**	**800**	**1,290**

Source: authors' computations

6.6.2 Measures assessment

We notice that these figures are only estimations based on extremely weak data availability. We do not calculate Net-Present-Values and abatement costs due to the uncertainty in the results and the fact that such figures would vary significantly among different types of applications.

In our understanding, the relation between investment needs and fuel cost savings overestimates the investment needs, so that at the first glance the measure looks economical inefficient.

However, energy costs counts for ca. 85% of the life time costs (Räder, without year) and investments only for 5%. Therefore, a wide range of appliances can be retrofitted with economic gains for users, economical efficiency depending on the age, type and use of pumps and the sector of their implementation.

For some existing pumps efficiency improvements become feasible without replacement and additional costs. Such improvements comprise mainly motor speed optimization.

The two main obstacles for an implementation of the measure are ignorance of potentials and access to capital.

Solution for the first obstacle is the energy audits and training of specialized personnel in industries in the analysis of efficiency potentials. Therefore governmental supports in trainings can be helpful.

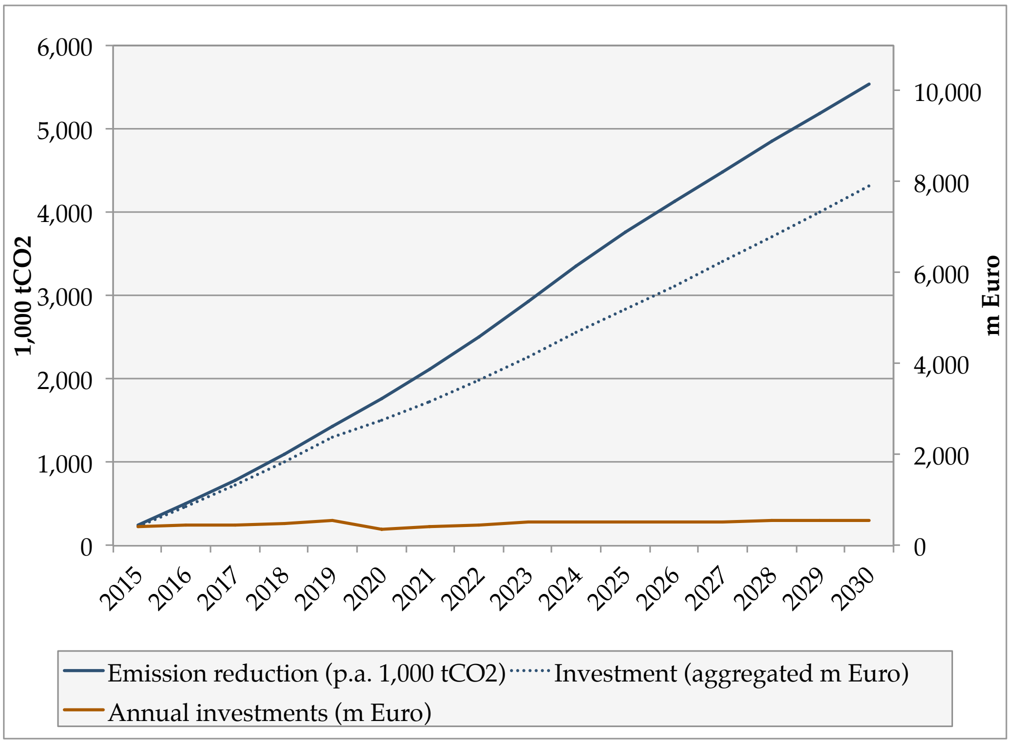
The second obstacle – access to capital – can be solved only for companies with positive economic perspectives. If capital has to be provided by credit, specific bank loans targeted to energy efficiency options need to be designed with the help of specialists being able to assess the economical feasibility of the investments.

7 Results Bottom-up approach - Bulgaria

7.1 Summary of the measures - Bulgaria

The overall emission reduction potential of the evaluated measures in Bulgaria is ca. 5.5 Mt CO_2 in 2030. The necessary investment to reach this result is ca. 10 bn Euro till 2030 while the annual investments are ca. 400 m Euro till 2030 (see Figure 15).

Figure 15: Emission reduction and investment trajectories Bulgaria 2015 - 2030



Source: Authors' computations

Building Sector

A significant emission reduction potential results from the **retrofitting of existing family and multi-family buildings as well as public and commercial buildings**.

We assume a trajectory of a modernisation that starts with 4,000 family buildings and 800 multi-family buildings in 2015, increases up to 14,000 resp. 2,500 in 2023 and stays at that level till 2030. Over the period 2015-2030 ca. 176,000 family buildings and 31,000 multi-family buildings will be retrofitted. Therefore, we consider mainly such buildings that are heated by fossil fuels and district heating and buildings constructed before 2000. The Net-Present-Value (NPV) is mainly determined by the type of energy source used for heating and the energy standard of the modernisation Class (Class A or B). In family houses, the average NPV (weighted average of all used energy sources) is ca. 2,400 Euro, with a value range between 34 Euro for a Class B retrofitting (lower standard) and using coal and 17,000 Euro for Class A and using electricity. The investment for one house is ca. 4,000 Euro (Class B) and ca. 4,800 Euro (Class A). The average abatement costs are -15 Euro/tCO_2.

The share of district heating and electricity as energy sources for multi-family buildings is much higher than those of single-family houses. The average NPV for blocks of ca. 1,300 m^2 is 57,000 Euro per block with the highest NPV results in a retrofit of blocks that use electricity (153,000 Euro). The investment needs are 53,000 Euro (Class B) and 63,000 (Class A). The average abatement costs are ca. -35 Euro/t CO_2 and range between 3 Euro and -67 Euro depending on the fuel source.

Public buildings use district heating, gasoil and natural gas for heating. We assume that till 2030 20% of the public buildings will be retrofitted. For the calculation of the NPV we assume lower energy prices (50% compared to private households) and a lower interest rate (6%). The abatement costs are around -35 Euro/t CO_2 and the NPV is ca. 93,000 Euro for a building of 3,200 m^2.

The currently highest energy standard of buildings is the near-zero (nZEB) standard. Compared to Class B standard, the (average) energy consumption per m^2 is reduced by 30%. We assume an early introduction of the nZEB standard so that all new buildings (21.000 by 2020 in our calculations) have to fulfill this standard. An early introduction of an nZEB standard is not efficient from an economic point of view. In our analysis, we focus only on the building-related part of the measure and do not consider the use of RES (see the RES at household level measures). The abatement costs at micro level for the building part is 48 Euro/tCO_2 and the NPV for one building with ca. 330 m^2 floor area is ca. -20.000 Euro. The additional investment compared to energy Class B building is ca. 40.000 Euro.

Households

In this sector we focus on the implementation of renewable energy sources at household level. The **implementation of renewable energy sources at household level** covers a wide range of potential technical solutions. In this evaluation we highlight three of them: solar water heating, PV solar and the use of wooden briquettes.

We evaluate the installation of **solar PV** equipment in all new nZEB buildings – 21.000 buildings by 2019. We assume further a penetration of up to 40.000 residences by 2030 for installation of **solar heating** equipment. As a third measure we evaluate the replacement of coal by **wooden briquettes**. Therefore we assume that till 2030 ca. 26,000 households (6% of households that use coal for heating) substitute coal.

Under given fuel prices and interest rates, solar PV installation is not efficient for households that consume the produced electricity from an economic point of view. The abatement costs are ca. 53 Euro/tCO_2.

Comparatively, the abatement costs for solar water heating (20 Euro) is lower but still positive. An increase of electricity prices by 1% p.a. and a lower interest of 6% (instead of 8%) would lead to a situation where the measures become economically efficient.

The economically efficiency of a substitution of coal by wooden briquettes depends only on the price development of coal and wooden briquettes. Wooden briquette prices differ between EU countries and they are highly volatile. Our calculations are based on a price of wooden briquettes of 170 Euro/t for Bulgaria. Under this assumption, prices of coal and wooden briquettes are equivalent so that the abatement costs are around zero.

Industry Sector

The **utilisation of excess heat** in the Bulgarian light industry is one potential measure in the industry sector but which accounts for only minor emissions reduction potential in our analysis (28.000 t CO_2 in 2030). We assume only 200 utilities by 2030 in our computations. However, this measure is highly economically efficient for companies. The average investment for one economizer is ca. 50.000 Euro and the NPV is 155.000 Euro. The annual savings of fuel costs (mainly natural gas) are ca. 24.000 Euro if we assume constant gas prices. We consider that this kind of technology can account for more than 100.000 t CO_2 reduction by 2030 if a higher penetration can be established. For a more in depth assessment, additional research is needed.

This measure is an example of a wide range of economically efficient mitigation options in industrial production. Further examples for efficient modernisation options are motor systems and industrial heat production. We expect that in the Bulgarian economy at least 2-3 Mt CO_2 can be abated by 2030 by implementing these measures. For an analysis of this potential and an identification of supporting policy measures, a better data availability is essential.

Transport sector

The transport sector contributes a significant part of the GHG emissions in Bulgaria, as it is the case in other EU countries. With the **Development of Intermodal freight transport,** we evaluated one possible measure for this sector but with only minor emissions reductions. We expect that the electrification of the road transport will not play an important role in Bulgaria over the next two decades and therefore will not lead to significant emissions reductions, at least due to an increase of the individual transport demand related to an expected increase in wealth.

Electricity consumption

With the measure **Implementation of LED lighting** we give one example for electricity savings in public and commercial buildings and in street lighting. The two lamp types that can be replaced in public buildings are luminescent lamps (ca. 22% share) and CFL lamps (ca. 78% share). We assume that over the next 10 years, all lamps of the two types will be replaced by LED lamps. The average NPV is 2.0 Euro per replacement with an investment need of 34 Euro. Therefore a replacement of luminescent lamps is more economically efficient (NPV ca. 37 Euro) due to higher costs of this lamps and resulting lower difference investments. The average abatement costs are 17 Euro.

We assume that by 2030 LED lamps can replace 1.3 million street lamps. Such a replacement is economically feasible. The NPV is 50 Euro if we assume a 10-year lifetime of the lamps and it is still positive if we assume only a 7-year lifetime. The investment need for one lamp is 113 Euro. The abatement costs are around -20 Euro/t CO_2.

Energy Sector

The two measures **Grid upgrade to fit the renewable potential** and **Introduction of 80% smart meters with load control functions** are necessary for an efficient implementation of further renewable energy capacities to the Bulgarian grid. The actual grid is widely out-dated and mainly structured for a central generation of electricity in coal, nuclear and large hydro power plants. For an implementation of renewable power plants with relatively low capacities, the grid needs to be expanded on different voltage levels. Without such expansion, new renewable capacities cannot run efficiently. On the demand side, a more efficient electricity use will support an efficient load management in the national electricity grids. A stepwise introduction of smart meters can support such efficient load management so that the overall generation capacities can be lower. Both measures can help to reduce emission by 2.8 Mt CO_2 in 2030. As this measure doesn't produce any emissions mitigation in itself, we estimate only the investment need.

Table 63 summarizes the aggregated results for the 13 measures we considered. It includes the aggregated investments till 2030, the emissions reduction potential in 2030 as well as the needed investment and the NPV per facility and the abatement costs for those measures where these figures can be estimated.

Table 63: Results of the evaluation of mitigation measures in Bulgaria

Expected investment needs 2015 - 2030	Expected emission reduction in 2030	Average investment per facility	Net-Present-Value of one installation	Abatement costs
mill Euro	*1,000 t CO_2*	*Euro*	*Euro*	*Euro*
Energy retrofit of family buildings to A and B class standard				
1,100	1,348	4,500	2,400	-15
Energy retrofit of multi-family buildings to A and B class standard				
2,183	1,829	55,000	57,000	-37
Energy retrofit of public buildings to A and B class standard				
2,554	1,547	135,000	93,000	-35
Early introduction of an ambitious nZEB standard for all new buildings [building part]				
890	227	40,000	-20,000	48
Implementation of RES on household level - Solar water heating				
	Solar PV for intsallation in all nZEB buildings			
254	54	10,200	-3,600	53
	Solar water heating			
500	166	1,500	-240	20.0
	Wooden briquettes			
0	152	0.0	n.a.	+/- 0
Utilisation of excess heat in industries				
10	28	50,000.0	155,000	-70.0
Implementation of LED lighting				
	Administrative buildings			
229	74	34.0	2	17.0
	Street Light			
154	98	113.0	50.0	-20.0
Development of Intermodal freight transport				
66	11	n.a.	n.a.	15.8
Sum I				
7,901	**5,534**			
Grid upgrade to fit the renewable potential				
638	n.a.	n.a.	n.a.	n.a
Introduction of 80% smart meters with load control functions				
852	n.a.	n.a.	n.a.	n.a.
Sum II				
9,380	**5,534**			

Source: Authors' computations

7.2 Measures summary: Building sector

With this set of measures we describe the potential effects of an energetic retrofit of existing family, multi-family and public buildings as well as a earlier introduction of near-zero emission residential buildings (nZEB). The macro evaluation of the measures is related to the existing stock of buildings in Bulgaria and forecasts of the construction of new multi-family blocks.

7.2.1 Energy retrofit of family buildings to A and B class standard

7.2.1.1 Status Quo

The majority of the houses in Bulgaria having a construction permit issued before 1999 are characterized by low energy performance. All buildings, built in this period, are designed and constructed without thermal insulation on external walls and floors and insufficient thermal insulation on roofs or lack of thermal insulation in the attics. All in all, at least visually, from observations, it may be concluded that the majority of old houses are still in their original appearance as regards energy efficiency. According to data from the last population census *(NSI, 2012)* hardly 16% of the residences in the country total have external thermal insulation, including those constructed after 1999, when thermal insulation has become mandatory for building construction. The total number of residences in family houses is 2.6 m in Bulgaria. Ca. 70% of them are located in towns. The majority of the appartments are heated by firewood (34%) followed by electricity (28%) and coal (20%). For 16% the district heating system provides heat *(NSI, 2012).*

7.2.1.2 Target of the measure

The target of this measure is to ensure reduction of energy consumption for space heating in the houses designed and constructed according to the energy efficiency standards before 1999 by renovation of the buildings to Energy Class A and B standards. This includes the introduction of thermal insulation of external walls; thermal insulation of roofs or attic floors and windows replacement with new energy-efficient units.

7.2.1.3 Micro-perspective

We assume that the installation may start in 2015 when the period of accounting of the effect starts. According to the European Committee for Standardization (CEN, 2007) the average lifetime for insulation of building envelope is >25 years. We assume an average floor area of 100 m^2 per house. We focus on houses that use coal and electricity for air heating but present the NPV calculations for natural gas too. We distinguish further between retrofit to Class A and B standard. The estimated number of inhabited residences in houses having the best potential for successful implementation of the measure, divided by type of heating and the total floor area of these dwellings, is presented in the Table 64.

The average specific final energy consumption for heating of houses is assumed to be 282 kWh/m^2/a. The average specific final energy savings from energy renovation of houses to Energy Class B standard are calculated at 134 kWh/m^2/a. Since the average house is calculated at 100 m^2, annual final energy savings per building are 148 kWh/a.

The specific energy consumption for Energy Class A standard is equal to ½ of the specific energy consumption for Energy Class B standard. Taking this into account, the average specific energy consumption for heating in houses for Energy Class A standard is 67 kWh/m^2/a. The average annual final energy savings per building renovated to Energy Class A are 215 kWh/a.

Table 64: Calculation basis for the measure energy retrofit of family buildings

Dwellings	Number	Floor area, m^2	%
electricity	66,568	5,161,105	11%
gasoil	1,280	99,236	0.2%
natural gas	2,469	191,444	0.4%
coal	532,187	41,260,902	88%
total	**602,504**	**46,712,687**	**100%**

Source: Authors' estimation

Average annual final energy savings of electricity for an average house renovated to Class B is 14,760 kWh and 21,472 kWh for Class A standard.

The annual reduction of CO_2 emissions as a result of energy renovation of a single house depends on the previous used fuel sources and the development of the carbon intensity of electricity. An emission reduction in year one to Energy Class B will be 5.4 tCO_2 per year and as a result of energy renovation of a single house to Energy Class A 7.8 t CO_2 per year. We assume a constant average price for retrofitting of 48 Euro/m^2.

We present three Net-Present-Value calculations based on assumptions of the development of prices for energy sources and a discount rate in Table 65. As lower the interest rate (and therefore the discount rate) and as higher expected fuel prices increases, NPV becomes higher and the economical efficiency of the measures increases. Nevertheless we can show that the NPV is positive for all fuel sources so that from a micro economic point of view a retrofit of existing family houses is reasonable.

Table 65: Net-Present-Value for energy retrofit of family buildings in Bulgaria

	Class A			**Class B**		
Fuel price increase 0% p.a.						
Interest rate 8%						
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro
electricity	4,800	22,460	**17,660**	4,000	15,441	**11,441**
gasoil		23,436	**18,636**		16,112	**12,112**
natural gas		14,648	**9,848**		10,070	**6,070**
coal		7,031	**2,231**		4,834	**834**
Average NPV Class A and B based on fuel consumption shares						2,440

Fuel price increase 0.5% p.a.						
Interest rate 8%						
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro
electricity	4,800	23,414	**19,414**	4,000	16,096	**12,096**
gasoil		24,431	**20,431**		16,796	**12,796**
natural gas		15,269	**11,269**		10,497	**6,497**
coal		7,329	**3,329**		5,039	**1,039**
Average NPV Class A and B based on fuel consumption shares						2,720
Fuel price increase 1% p.a.						
Interest rate 5%						
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro
electricity	4,800	32,681	**28,681**	4,000	22,467	**18,467**
gasoil		34,101	**30,101**		23,444	**19,444**
natural gas		21,313	**17,313**		14,652	**10,652**
coal		10,230	**6,230**		7,033	**3,033**
Average NPV Class A and B based on fuel consumption shares						5,440

Source: Authors' computations

The same results from the calculation of the abatement costs. The average abatement cost the parameter set 1 (Fuel price increase of 0% and an interest rate of 8%) is ca. -15 Euro/tCO_2. Under the assumption of increasing fuel prices (1%) and a lower interest rate (5%) the average abatement costs for all buildings and retrofitting standards is -36 Euro/tCO_2.

7.2.1.4 Macro-perspective

Based on the described parameters and assumptions we will estimate the aggregated potential of emission reduction in the light of an ambiguous but meaningful renovation rate in Bulgaria. Therefore we assume that the renovation rate for Class B residences can be increased to the EU average directly up to 1%. For the following years we assume an increase up to 3% in 2023 and a constant value till 2030. We assume that the rate for Class A is ¼ of B. This leads to an aggregated renovation rate of 37% (Class B) and 9% (Class A) of existing buildings over the next 15 years so that at the end of the planning period 220 buildings will be retrofitted.

The estimations are that the total energy savings for the period till 2030 from energy renovation of houses to Class B are 18,596.1 GWh and 6,763.2 GWh for Class A. The total savings are calculated at 25,359.3 GWh. The savings in year 2030 will be 3,547 GWh. Compared with 2011, this is around 3.2% of the actual national final energy consumption.

Within the assumed annual financial framework, the estimated investments needed to implement energy renovation of houses to Class B until 2030 is 846.1 m Euro and 253.8 m Euro for Class A. The total investment until 2030 is EUR 1,100 m Euro. Table 66 summarizes the results of the measure.

Table 66: Final results – Energy retrofit of family buildings in Bulgaria

	Fuel savings	Fuel sale savings	Investment	CO_2 emission reduction
Year	1,000 GWh	m Euro	m Euro	1,000 t CO_2
2015	94.0	3.6	29	34.3
2020	823.1	31.6	59	316
2025	2,136.8	82.1	87	818
2030	3,547.1	136.2	87	1,348
Total 2015-2013	**25,359**	**974**	**1,100**	**9,692**

Source: Authors' computation

7.2.2 Energy retrofit of multi-family buildings to A and B class standard

7.2.2.1 Status quo

According to the definitions in the document *Census and Dwellings Stock in 2011, Vol. II Dwellings Stock (NSI, 2012)*, residential apartment block houses are residential buildings with 4 or 5 floors on the average or higher (6 or more floors). The buildings with 3 floors and 2 or more residences per floor are also part of this category. According to this source the total number of multi-family buildings is ca. 67,000.

The data presented in the *Census and Dwelling Stock in 2011, Vol. II Dwellings Stock, Book 1 Residential Buildings, NSI, Sofia, 2012* shows that 96.4% of the inhabited residential buildings higher than three floors are located in the towns and just 3.6% in the villages. On that basis the authors decided to use for the analyses only the data about the multi-family residential buildings located in the towns. The average total floor area of the multi-family residential buildings is 1,327.7 m^2.

The majority of the apartments are heated by firewood (34%) followed by electricity (28%) and coal (20%). For 16% the district heating system provides heat (NSI, 2012).

As described in chapter 7.2.1 Energy retrofit of family buildings to A and B class standard, most residential buildings in Bulgaria have a low energy performance. Differing from 7.2.1 we focus in this measure on the energy retrofit of multi-family residential buildings.

7.2.2.2 Target of mitigation measure

The target of this measure is to ensure reduction of energy consumption for space heating in the multi-family buildings designed and constructed according to the energy efficiency standards before 1999 by renovation of the buildings to Energy Class A and B standards.

7.2.2.3 Micro-perspective

Installation may start in 2015 when the period of accounting of the effect starts. The average saving lifetime of the typical energy efficiency measures in buildings according to European Committee for Standardization is more than 24 years. The time horizon of the analysis of all energy efficiency measures included in this report is up to year 2030. For that reason it is assumed that multi-family residential buildings constructed before year 2000 should be analyzed as potential buildings to be renovated within this time horizon.

The measure may allow reduction of energy consumption for space heating in the multi-family residential buildings up to 50-60 % if Energy Class B is achieved and up to 70-80% if Energy Class A is achieved, calculated on a single-building level.

We assume following calculation basis for the fuel consumption in the different types of multi-family buildings (Table 67).

The average specific final energy consumption for heating of the analysed multi-family residential buildings is 187.9 kWh/m^2/a. The average specific final energy consumption for heating in the multi-family residential buildings after calculation of the impact of the recommended energy efficiency measures for Energy Class B standard is 89.5 kWh/m^2/a.

The average specific final energy savings from energy renovation of multi-family residential buildings to Energy Class B standard are calculated at 98.4 kWh/m^2/a. Since the average multi-family building in the towns is calculated at 1,328 m^2, as described in the section “Sector” above, the average annual final energy savings per building are 130.7 MWh/a.

Table 67: Calculation basis multi-family houses – Floor are by type of heating source

Dwellings in Blocks	**Floor area, m^2**	**%**
district heating	38,416,441	35%
electricity	63,932,777	58%
coal	8,736,848	8%
Total	**111,086,066**	**100%**

Source: Authors’ estimation

Taking this into account, the average specific energy consumption for heating in multi-family buildings for Energy Class A Standard is 44.8 kWh/m^2/a. The average specific annual final energy savings in building renovated to Energy Class A are 143.2 kWh/m^2/a. The average annual final energy savings per building renovated to Energy Class A are 190.2 MWh/a. The average annual reduction of CO_2 emissions due to energy renovation of a single multi-family residential building to Energy Class B will be 78 t CO_2 per year and due to energy renovation of a single multi-family residential building to Energy Class A 97 t CO_2 per year.

We assume costs of ca. 40 Euro/m^2 for the retrofit in class B and 48 Euro/m^2 for class A. Table 68 presents the Net-Present-Value calculations for an energy retrofit.

Table 68: Net-Present-Value for energy retrofit of multi-family buildings in Bulgaria

	Class A			**Class B**		
Fuel price increase 0% p.a.						
Interest rate 8%						
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro
central heating	63,744	87,260	**23,516**	53,120	59,982	**6,862**
electricity		202,931	**139,187**		139,493	**86,373**
coal		62,909	**-835**		43,243	**-9,877**
Average NPV Class A and B based on fuel consumption shares						58,700

Fuel price increase 0.5% p.a.						
Interest rate 8%						
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro
central heating	63,744	90,964	**37,844**	53,120	62,528	**9,408**
electricity		211,545	**158,425**		145,414	**92,294**
coal		65,579	**12,459**		45,078	**-8,042**
Average NPV Class A and B based on fuel consumption shares						63,000
Fuel price increase 1% p.a.						
Interest rate 5%						
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro
central heating	63,744	126,968	**63,224**	53,120	87,277	**23,533**
electricity		295,275	**231,531**		202,969	**139,225**
coal		91,535	**27,791**		62,921	**-823**
Average NPV Class A and B based on fuel consumption shares						110,000

Source: Authors' computation

As we can see, with constant energy prices, a discount rate of 8% and a life time of the investment of 25 years a retrofit is economically for such buildings, that use electricity for heating and district heating in both efficiency standards and for coal heated buildings in Class A. A retrofit of buildings that use coal is not efficient due to low costs of coal but we can assume that the share of such buildings is minimal. Increasing energy prices and a lower interest rate lead to a situation where the retrofitting becomes much more efficient from a micro economic point of view.

The abatement costs vary between -37 Euro/t CO2 for the first parameter set of interest rates and fuel prices and -75 Euro for the last one.

7.2.2.4 Macro-perspective

The main purpose of the analysis in this report is to determine the potential for GHG emission reductions up to 2030. This is the reason why the residences in multi-family buildings, heated by firewood or other RES, where a sufficient number of GHG emissions could not be reduced, are excluded from the energy analysis. The residences heated on gasoil or natural gas are also excluded from the analysis as their number is negligible (totally 1.35%).

We assume identical penetration rates as in chapter 7.2.1. Starting with 1% in 2015 the rate increase up to 3% in 2023 for class B standard and for class A we assume penetration rate of ¼ of class B. Till 2030 ca. 39,500 buildings can be retrofitted and the aggregates investments sum up to 2.2 bn Euro.

Table 69: Final results – Energy retrofit of multi-family buildings in Bulgaria

	Fuel savings	Fuel cost savings	Investment	CO_2 emission reduction
Year	1,000 GWh	m Euro	m Euro	1,000 t CO2
2015	148	11	58	66
2020	1,304	97	116	552
2025	3,395	254	173	1,307
2030	5,631	421	173	1,828
Total 2015-2030	**40,266**	**3,015**	**2,183**	**14,931**

Source: Authors' computation

7.2.3 Energy retrofit of public buildings to A and B class standard

7.2.3.1 Status quo

In the last years energy efficiency measures are implemented in many public buildings, especially state and community owned. The measures have been funded mainly by grants from the Operative Programmes of the European Commission and from the NPP Kozloduy Decommissioning Fund. A lower percentage of measures are implemented by loan financing.

Nevertheless the majority of the old public buildings are still not renovated. Unfortunately official statistic for the energy efficiency renovated public buildings is not available. We face a situation – similar to that of residential buildings – that the majority of the public buildings in Bulgaria are characterized by low energy performance characteristics.

The total floor area of the non-residential buildings according to the National Statistic Institute (NSI) is 66 977 thousand m^2. According to the definition in the Statistical Reference Book 2012 of the NSI non-residential buildings are: buildings for different non-residential need, including administrative buildings and other buildings for the purposes of commerce, production, education, culture, sports, health care, agriculture, rest, short stay. Assumption is made by the authors that for the analysis of the public buildings the data for non-residential buildings by the NSI could be used.

Official information requested by the authors and received in a letter from the Sustainable Energy Development Agency shows that the total floor area of the public buildings where energy audits are executed is 16,605 thousand m^2, which is about 25% of the total floor area of the public buildings.

The fuel and energy mix used for heating in public buildings is estimated on the basis of a database of 36 energy audits in public buildings delivered by the Energy Efficiency and Renewable Sources Fund. It is accepted that the fuel mix for the public buildings is the same as the fuel mix in this data base: gasoil – 39%, central heating – 32%, natural gas – 26% and electricity 3 %.

7.2.3.2 Target of the measure

The target of this measure is to ensure reduction of energy consumption for space heating in the public buildings designed and constructed according to the energy efficiency standards before 1999 by renovation of the buildings to energy class A and B class standards.

7.2.3.3 Micro-perspective

The average saving lifetime of the typical energy efficiency measures in buildings according to European Committee for standardization is more than 25 years. The time horizon of the analysis of all energy efficiency measures included in this report is up to year 2030. For that reason it is assumed that only public buildings constructed before year 2000 should be analyzed as potential buildings to be renovated within this time horizon.

Installation may start in 2015 when the period of accounting of the effect starts.

The average specific final energy consumption for heating of the analysed public buildings is 160.8 kWh/m^2/a.

The average specific final energy consumption for heating in the public buildings after calculation of the impact of the recommended energy efficiency measures for Energy Class B standard is 65.2 kWh/m^2/a.

The average specific final energy savings from energy renovation of public buildings to Energy Class B standard are calculated at 95.6 kWh/m^2/a. Since the average public building is calculated at 3190 m^2, as described in the section "Sector" above, the average annual final energy savings per building are 305 MWh/a.

The specific energy consumption for Energy Class A Standard is equal to ½ of the specific energy consumption for Energy Class B Standard. Taking this into account, the average specific energy consumption for heating in public buildings for Energy Class A Standard is 32.6 kWh/m^2/a.

The average specific annual final energy savings in public building renovated to Energy Class A are 128.2 kWh/ m^2/a. The average annual final energy savings per building renovated to Energy Class A are 409 MWh/a.

Using the described fuel mix and rounding the calculated annual number of public buildings to be retrofitted the calculated average emission factor for the building renovated to energy class B is 243.1 tCO_2/GWh and for the buildings renovated to energy class A 246.3 tCO_2/GWh. The annual reduction of CO_2 emissions due to energy renovation of one average public building to class B is 74.1 tCO_2 per year and to class A 100.7 tCO_2 per year.

The costs for renovation for Class B standard are assumed with ca. 80 BGN/m_2 (40 Euro/m_2) and for Class A 96 BGN/m_2 (48 Euro/m_2.)

Differing from all other calculations in the building sector of Bulgaria we assume an interest rate of only 6%. Reason for that is that we can assume that governmental authorities do not have to finance on the public capital market. We assume further fuel prices that are reduced by ca. 50% compared to private consumer prices.

Table 70: Net-Present-Value for energy retrofit of family buildings in Bulgaria

	Class A			**Class B**		
Fuel price increase 0% p.a.						
Interest rate 8%						
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro
central heating	153,120	130,671	**-22,449**	127,600	97,441	**-30,159**
electricity		261,342	**108,222**		194,882	**67,282**
gasoil		418,147	**265,027**		311,812	**184,212**
natural gas		156,805	**3,685**		116,929	**-10,671**
Average NPV Class A and B based on fuel consumption shares						93,000

Fuel price increase 0.5% p.a.						
Interest rate 8%						
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro
central heating	153,120	136,800	**136,800**	127,600	102,011	**102,011**
electricity		273,599	**273,599**		204,022	**204,022**
gasoil		437,759	**437,759**		326,436	**326,436**
natural gas		164,159	**164,159**		122,413	**122,413**
Average NPV Class A and B based on fuel consumption shares						104,000
Fuel price increase 1% p.a.						
Interest rate 5%						
Fuel source	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro	Investment in Euro	Discounted fuel savings in Euro	NPV in Euro
central heating	153,120	153,120	**143,352**	143,352	127,600	**106,897**
electricity		34,101	**286,703**	286,703	23,444	**213,794**
gasoil		21,313	**458,725**	458,725	14,652	**342,071**
natural gas		10,230	**172,022**	172,022	7,033	**128,277**
Average NPV Class A and B based on fuel consumption shares						116,000

Source: Authors' computation

7.2.3.4 Macro-perspective

Another assumption is made by the authors that the energy efficiency measures are implemented in less than 30% of the cases where energy audits are executed, which means that about 10% of the total floor area of the public buildings is already energy renovated. Based on that assumption it is calculated that buildings with a total floor area of 60,279 thousand m^2 are available for energy renovation to class A or class B.

We assume that until 2030 100% off all public buildings can be retrofitted. Therefore we assume an increasing penetration rate starting with 2% in 2015.

Table 71 provides the final results of this measure. The aggregated investments sum up to 2.5 bn Euro and in 2030 an emission reduction of 1.5 $MtCO_2$ will become possible. Fuel sale savings sum up to 2.2 bn Euro.

Table 71: Final results – Energy retrofit public buildings in Bulgaria

	Fuel savings	**Fuel cost savings**	**Investment**	**CO_2 emission reduction**
Year	1,000 GWh	m Euro	m Euro	1,000 t CO_2
2015	40	7	67	40
2020	353	68	134	355
2025	924	178	205	929
2026	1,048	202	205	1,053
2030	1,541	298	205	1,547
Total 2015-2013	**10,972**	**2,121**	**2,554**	**11,029**

Source: Authors' computation

7.2.4 Early introduction of nZEBs standard residential buildings

7.2.4.1 Status Quo

According to the Directive of the European Commission concerning the energy performance of buildings, which has to be transposed also in the legislation of every EU Member-State, after 2019 all the new buildings should have nearly zero energy consumption. Every country should set independently the value of the indicators characterizing the buildings with nearly zero energy consumption (nearly Zero Energy Buildings – nZEB) depending on its specific peculiarities, such as climate, economic conditions etc. Bulgaria is not yet ready with the transposing of the Directive in its legislation.

The requirements concerning the energy efficiency of new buildings in Bulgaria are defined by the Spatial Development Act (SDA) and the related by-laws (Ordinance No. 7 (State Gazette, 2005) concerning energy efficiency, heat conservation and energy savings in buildings and Ordinance No. 5 (State Gazette, 2007) concerning the technical passports of newly constructed sites), as well as by the EEA and the related by-laws (Ordinance No. RD-16-1594 (State Gazette, 2009a) concerning energy efficiency auditing, certification and evaluation of the energy savings in buildings and Ordinance No. RD-16-1058 (State Gazette, 2009b) concerning the indicators for energy consumption and energy performance of buildings).

7.2.4.2 Target of mitigation measure

The target of this measure is to analyse the possibilities for energy saving and for reduction of CO_2 emissions by introduction of nZEB standard in construction of new buildings at the beginning of 2015 rather than by the end of 2019. The analysis cover the buildings that will be constructed in the period from 2015 to 2019, but the impact in terms of energy savings and reduction of greenhouse gases covers the whole period from 2015 to 2030.

7.2.4.3 Micro-perspective

The measure may allow reduction of energy consumption for space heating in an average house up to 80-85 % as compared to buildings of Energy Class B, the class to which most of the buildings would be constructed, if the early introduction of the nZEB standard is not realized. If additional CO_2 compensation is envisaged by production of "green" energy on a building level the total energy/CO_2 saving could reach even 100%. The total energy saving effect in the whole building sector depends of the number of new constructions.

In 2012 building permits have been issued for the construction of 4,238 residential buildings of a total area of 1,433 thous. m^2. The average floor area of the newly built residential buildings is 338 m^2.

The specific annual final energy consumption for space heating and DHW of a family house, constructed under the currently enforced standard (Energy Class B) according to the BPIE document "Implementing Nearly Zero-Energy Buildings (nZEBs) in Bulgaria - Towards a Definition and Roadmap", is 168.9 kWh/m^2.

The specific annual final energy consumption for space heating and DHW of a multi-family residential building, constructed under the currently enforced standard

(Energy Class B) according to the BPIE document "Implementing Nearly Zero-Energy Buildings (nZEBs) in Bulgaria - Towards a Definition and Roadmap", is 86.1 kWh/m^2. If we assume that in the case of new buildings the ratio of the total area of houses and the total area of multi-family buildings would be preserved as in the case of existing residential buildings the average specific annual consumption for residential buildings of Energy Class B will be 128.8 kWh/m^2.

The specific final annual energy consumption for space heating and DHW of nZE family house according to the BPIE document "Implementing Nearly Zero-Energy Buildings (nZEBs) in Bulgaria - Towards a Definition and Roadmap" is 24.5 kWh/m^2.

The specific final annual energy consumption for space heating and DHW of nZE multi-family residential building according to the BPIE document "Implementing Nearly Zero-Energy Buildings (nZEBs) in Bulgaria - Towards a Definition and Roadmap" is 21.5 kWh/m^2.

The average annual specific final energy consumption for residential buildings of Energy Class B has been calculated as 23.05 kWh/m^2. The specific annual energy saving in nZE residential buildings as compared to Energy Class B is 105.79 kWh/m^2. For an average building of 338 m^2 total area the annual energy saving is 35,757 kWh.

Average additional investment for thermal isolation, windows, etc. of nZE residential buildings is assumed with 124 Euro/m^2. For the following calculation we do not distinguish between different fuel sources but assume an average fuel price of 0.05 Euro /kWh in 2015 that results mainly from natural gas and district hearting prices. The life time of the building is calculated with 40 years.

In the following we depict the Net-Present-Values of the measure from an investors perspective under three different parameter sets (see Table 72). All NPV are negative so that we have to assess that from a micro economic pint of view a nZEB standard is at the moment not efficient. The threshold for the measure is reached if we can assume a fuel price increase of 1% p.a. and an interest rate of 4%. The last becomes plausible if we assume a state support for such a measure. Therefore additional (macro economic) efficiency analyses are needed.

Table 72: Net-Present-Value and abatement costs for nZEBs standard

Parameter set	Investment	Discounted fuel cost savings	NPV	Abatement costs
	Euro	Euro	Euro	Euro/tCO_2
Fuel price increase 0% p.a. and interest rate 8%	41,977	21,300	-20,677	48
Fuel price increase .50% p.a. and interest rate 8%	41,977	22,500	-19,477	45
Fuel price increase 1% p.a. and interest rate 5%	41,977	30,600	-11,377	26

Source: Authors' computation

The abatement costs are 48 Euro/t CO_2 in the first parameter set and decrease under the assumption of increasing fuel prices (1% p.a.) and a lower interest rate (5%) down to 26 Euro/t CO_2.

7.2.4.4 *Macro-perspective*

The most updated statistical data about the construction of new buildings in Bulgaria is presented in the Statistical Reference Book 2013 of the National Statistical Institute (NSI, 2013). Statistical data about the issued building permits has been published, which is presented in the table below with certain additional calculations.

Table 73: Issued permissions for construction of buildings, 2009-2012

Types of buildings	2009	2010	2011	2012
Residential buildings – quantity	64,28	4,891	4,799	4,238
Incl. dwelling in these – qty..	201,66	12,832	10,973	10,616
Average dwellings in one building	3.1	2.6	2.3	2.5
Floor area – thous. m^2	2,720	1,689	1,607	1,433
Average area of buildings	423.1	345.3	334.9	338.1
Administrative buildings – qty..	305	215	221	170
Floor area – thous. m^2	306	151	150	84
Average area of buildings	1,003.3	702.3	678.7	494.1
Miscellaneous buildings – qty.	4,569	4,360	5,325	49,38
Floor area – thous. m^2	2,736	2,181	2401	2,081
Average area of buildings	598.8	500.2	450.9	421.4

Source: NSI (2013)

The total floor area of the residential buildings that will be constructed under the early introduced nZEB standard would not be over the current status of construction in 2012. It is assumed that the total floor area of the residential nZEBs constructed in the period 2015-2020 would be 7,165 thousand m^2.

The aggregated emission reduction potential of the measure is 737,000 Mt CO_2 in year 2030, whereby the building part counts for 620,000 Mt and the PV installations for ca. 116,000 Mt CO_2. Additional investments – compared to a Class B standard average building – sum up to 890 m Euro, fuel sale savings are ca. 531 m Euro till 2030 under the assumption of constant prices.

Table 74: Final results early introduction of nZEBs standard

	Fuel savings	Fuel cost savings	Investment	CO_2 emission reduction
Year	1,000 GWh	m Euro	m Euro	1,000 t CO2
2015	151	7	178	45
2020	758	37	0	227
2025	758	37	0	227
2030	758	37	0	227
Total 2015 - 2030	10,613	531	890	3,184

Source: Authors' computation

7.2.5 *Measures assessment*

In this analysis, emission reduction measures in the building sector have an above-average significance in respect to residential heat consumption. In 2011 the residential heat consumption and therefore approximately its emission counts for

34% of the national heat consumption. If we taken additionally non-residential buildings into account the figure increases to 48% (IEA, 2013a).

The aggregated evaluated emission reduction potential of the five measures in this section sum up to 4.9 Mt CO_2 in 2030 and represents ca. 5% of Bulgaria's actual CO_2-emission from fuel combustion (IEA, 2013a).

In our understanding these measures can be classified as part of the set of measures that determine the reference scenario emission reduction described in chapter.

We assess that the earlier introduction of nZEB standard for all building retrofitting related measures is efficient form a micro economic point of view. The abatement costs vary between -37 Euro/tCO_2 and -15 Euro/tCO_2 under given economic conditions.

The aggregated investments of the retrofitting measures sum up to 5.8 bn Euro (6.7 bn Euro with nZEB standard measure). Thereby the investment increases from 150 m Euro in 2015 up to 470 m Euro in 2023. This investment trajectory corresponds with 0.4% of the GDP of Bulgaria in 2015 (GEM-E3-NMS output) and with 1.3% in 2030.

The implementation of these mitigation technologies will lead to a creation of jobs at the construction companies, where the number of employees is fluctuating depending on the available signed contracts for construction.

Following Ürge-Vorsatz et al. (2010) we assume that 14 new jobs will be created per investment of 1 m Euro for the reconstruction of one building. The total number of the new jobs will be ca. 2,200 in 2015 and increases to 6,500 in 2023. The employment effect is (in relation to the existing jobs in the construction sector of 160,000 in 2011) ca. 2% in 2015 and 4% in 2030.

There are numerous domestic and foreign suppliers of thermal insulation materials and energy efficient windows on the Bulgarian market, as well as an adequate number of construction companies, designers and energy auditors, capable of ensuring successful implementation of the measure. No shortage of skilled workforce or available technologies is expected.

Basically, all the technology used for the implementation of the measure, as well the construction and domestic companies can supply other related services.

Both the production of mitigation technologies and their implementation /maintenance need skilled labour force. We can consider that the workforce to implement the technology is adequately skilled and available. For the case that the retrofitting penetration rate can be increased and additional employees additional training programs for non-skilled workers have to be implemented.

Generally speaking, under given economic conditions energetic retrofitting is economical efficient but depends on the used fuel. Lower interest rates and increasing fuel prices would improve the situation significantly.

This leads to the assessment that from a purely economic cost-benefit perspective households and owners of public buildings should implement energetic retrofitting.

A distinction needs to be made between private and public investments.

The main possible sources of financing for retrofitting of public buildings and implementation of projects related to this measure are grants under the Operational Programme "Regional Development" for the period 2014-2020, NPP Kozloduy Decommissioning Fund, Bulgarian Energy Efficiency and Renewable Sources Fund, bank loans, ESCO companies, state and municipal budgets.

The main possible sources of financing for the construction of new buildings and retrofitting are bank loans and own resources of the investors. At this stage, in Bulgaria no specialized sources of funding for new construction of highly efficient buildings or other mechanisms for financial encouragement of investments in energy efficiency in new construction have been offered.

High interest rates and an overall economic risk reduce investors' activities. The actual economic crisis has thereby a significant influence. According to the National Statistical Institute Bulgaria (2013), the number of constructed residences decreased by ca. 55% between 2009 and 2012. Buildecon (2010) summarizes that the reconstruction rate in Bulgaria is low especially in villages, due to low income, high unemployment and low capital availability.

A serious barrier is, however, the ownership, since in Bulgaria the individual apartments in multi-family residential buildings have different owners. In this situation, in order to implement and energy efficiency retrofit of an entire multi-family building, it is necessary to obtain the agreement of at least 75% of the residence owners. It is possible for the owners to form an association, which in its capacity of a legal entity might represent them when addressing financing institutions and construction companies, but assessments so far shows that such practice is very rarely used.

It is typical for multi-family buildings that individual owners might apply thermal insulation only on the walls of their residences, which appears as a "Patch" on the facade. In this way, however, the energy saving effect for these owners is lower than it would have been if the entire building was insulated.

Further information and awareness programs targeted to house-owners concerning the benefits of energy efficiency renovation of their houses and the possible sources of financing might be useful for the successful implementation of the measure.

The comparatively higher investment needed for construction of new buildings under the nZEB standard might be a reason for the standard not to be welcomed by the investors, who construct new buildings for the purposes of profitable sale in the short-term. The higher selling prices of the finished building will make difficult deal conclusions on the real estate market, which is anyway suffering from depression after the big drop due to the economic crisis. In the case of constructions, in which the buildings will be for personal use by the investors, it is again possible that there will be quite a number of opponents to the new standard. In the latter case, it will be necessary to undertake steps for launching information campaigns, which would present to the public the advantages of nZEB and the benefits for the users of the higher investments to be made.

7.3 Measures summary: RES utilization in family houses

The introduction and use of RES energy at household level is a measure, which may ensure significant reduction of GHG emissions, but requires high investments. Thereby several technology options exist. Such are e.g. PV, solar heating for domestic hot water (DHW), air-air heat pumps and further or the use of alternative non-fossil fuels. With this set of measures we describe three potential applications of RES utilization in family houses (a) solar heating, (b) substitution of coal by wooden briquettes and (c) PV installation in combination with the introduction of nZEB residential buildings (see chapter 7.2.4).

7.3.1 Solar heating for domestic hot water

7.3.1.1 Status quo

At this stage solar installations for DHW production enjoy broader application in public buildings with high water consumption, such as hospitals and hotels. This technology is gradually gaining popularity among the population as well. According to the *Census and Dwelling Stock in 2011, Vol. II Dwellings Stock, Book 1 Residential Buildings, NSI, Sofia, 2012,* by 2011 in the country there were 27,291 inhabited residential buildings with solar installations, which accounts for 1.8 % of all the inhabited residential buildings.

Since 2005 the European Bank for Reconstruction and Development finances the Residential Energy Efficiency Credit Line (REECL). Under this programme house-owners may obtain credit for free support to the amount between 20% and 35% for construction of solar systems for DHW production.

7.3.1.2 Target of mitigation measures

The first target of this measure envisages reduction of electricity consumption for production of domestic hot water in houses by utilization of solar energy as RES. On a single house level this measure may decrease the electricity consumption for DHW between 30-35 %. This will lead to reduction of GHG emissions.

7.3.1.3 Micro-perspective

It is envisaged that for every house two solar collectors (about 4 m^2) and one thermal-insulated tank with a volume of 100 litres will be installed. The specific energy consumption of the system will be about 1,360 kWh/year, calculated for Sofia by means of specialized software of the BASF Company. At the standard rate of 80 litres hot water per capita and average number of occupants 2.6 persons per residence, the necessary quantity of hot water has been calculated at 3,976 kWh/year. Therefore, the solar installation will cover about 34 % of the DHW demand of the appartment. The investment is such a solar installation will be approx. BGN 3,020 of EUR 1,544.

According to the Saving Lifetimes of Energy Efficiency Improvement Measures in Bottom-up Calculations by European Committee for Standardization the average lifetime for solar collectors are 19 years.

At a standard rate of 80 l hot water per capita and 2.6 people average number of occupants per residence, the required quantity of DHW has been calculated at 3,976 kWh/year.

The annual reduction of electricity consumption through use of solar collectors is 1,360 kWh per year. It leads to an annual emission reduction of ca. 1,1 tCO_2 per year, those resulting from the fuel switch from coal to wooden briquettes in one house with a floor area 100 m^2 is 8.4 t CO_2 per year.

The Net-Present-Value of the implementation of solar collectors of ca. -1544 Euro is under given economic parameters (electricity prices and interest rates) negative (see Table 75). Monetary savings from a reduction of electricity consumption of ca. 120 Euro/year undershoot necessary investments into the technology. If we assume a minor increase in electricity prices (0.5% p.a.) the threshold interest rate that makes the investment economical efficient is 6%.

Table 75: Net-Present-Value and abatement costs - DHW measure

Parameter set	Investment	Discounted fuel cost savings	NPV	Abatement costs
	Euro	Euro	Euro	Euro/tCO_2
Fuel price increase 0% p.a. and interest rate 8%	1,544	1,306	-238	20
Fuel price increase .50% p.a. and interest rate 8%	1,544	1,351	-193	15
Fuel price increase 1% p.a. and interest rate 5%	1,544	1,774	230	-19

Source: Authors' computation

The abatement costs vary between 20 Euro/tCO_2 for the first parameter set and -19 Euro/t CO_2 for the third.

7.3.1.4 Macro-perspective

Due to the negative NPV and therefore necessary government support, we assume a low penetration rate for the technology of solar collectors at the beginning of the planning period. Starting with 0.2% in 2015 we assume an increase up to ca. 2.5% in 2030 so that at the end of this period ca. 20% of considered residential buildings use the technology.

The aggregated investment for the implementation of solar water heating system in ca. 330,000 buildings in Bulgaria sum up to ca. 500 mill Euro in the period till 2030. With these investments electricity in the amount of 2.8 GWh (119 m Euro) can be saved till 2030 and in its result an emission reduction of 166,000 tCO_2 will be possible in 2030 (see Table 76).

Table 76: Final results – RES utilisation on households level – DHW measure

	Fuel savings	Fuel cost savings	Investment	CO2 emission reduction
Year	GWh	m Euro	m Euro	1,000 t CO_2
2015	10	1	12	6
2020	87	7	21	46
2025	217	19	36	103
2030	440	38	61	166
Total 2015-2030	2,786	245	500	1,250

Source: Authors' computation

7.3.2 Wooden briquettes

7.3.2.1 Status quo

Forests cover ca. 4.1 m ha of the area in Bulgaria (BirdLife, 2009). According to Trichkov and Dinev (2013) the volume of forestry waste in Bulgaria is 1.06 million m^3 per year and ca. 373,438 m^3 are economically accessible. The energy content corresponds to 77,000 toe per year and could replace ca. 7.5% of the national heat consumption of 43,556 TJ (IEA, 2013a).

The use of firewood in Bulgaria is very popular. Following NSI (2012) 34% of dwellings in Bulgaria use this energy source for heating purpose. On the other hand, the use of products from wood waste - wooden briquettes as well as wood pellets - for space heating is not very broadly spread among the population. Main reason for that is that fire wood and coal are cheaper. As one of the most negative energy sources coal is used in 20% of the residences for air and water heating. A reduction of its use can reduce the CO_2 emission of the residential stock significant. Compared to coal, fire wood and wood products have no net-GHG-emission.

7.3.2.2 Target of mitigation measure

Target of the measure is therefore to reduce GHG emissions by an increasing utilization of wood residuals and a fuel switch from coal to wooden briquettes for production of heat for residences.

7.3.2.3 Micro-perspective

The use of wooden briquettes needs no additional investments into new ovens. In this point a difference to the use of pellets exists. An efficient use of pellets needs new heating equipment with a sufficient controlling of air supply.

Therefore we focus on the use of wooden briquettes. On a single appartment level this measure may lead to the reduction of 85-90 % of the GHG emissions for heating.

The wooden briquettes, as well as the firewood and coal, are burned by the Bulgarian population most often in heating stoves and more rarely in boilers. In both cases, however, the charging of fuel and cleaning of the stoves or boilers is performed manually. Therefore, the fuel shift does not require any additional investment on the part of the population or any change in the habits of servicing the space heating system. The use of wooden briquettes instead of coal, however, is cleaner and the people's homes will be polluted to a lesser degree.

The economically efficiency of a substitution of coal by wooden briquettes depends only on the price development of coal and wooden briquettes. Wooden briquette prices differ between EU countries and they are highly volatile. Our calculations are based on a price of wooden briquettes of 170 Euro/ton for Bulgaria (Energment, 2013). This figure is equal to a price of 0.34 Euro/kWh. Under this assumption, prices of coal and wooden briquettes are equivalent so that the abatement costs are around zero.

If we assume a higher price for wooden briquettes of around 0.043 Euro/kWh as described in Overgas (2013) currently wooden briquettes are 30% more expensive than coal.

The fuel switch is only efficient form a micro economic point of view if wood briquette prices are equal to that of coal. Hence, the price for the briquettes depends highly on the transport distance so that in some regions the source can compete with coal. Furthermore, reported prices differences – e.g. Trichkov and Dinev (2013) declare, that the price for wood pellets (which are not identical but similar to briquettes) is the same as for brown coal.

7.3.2.4 Macro-perspective

For the further calculation we assume a low but increasing penetration of the use of wooden briquettes in Bulgaria. It starts from 0.2% of the coal fires residences in the country up to 6% in 2030.

We do not take pellets into account but it can be assumed that the technology might become more popular in Bulgaria especially because of the national export orientated pellet production.

A forecast for the development of price differences of coal and wooden briquettes is difficult. As in all the other measures we do not take increasing prices for coal into account, but we will assume here, that the price of wooden briquettes can, mainly due to the relatively young technology in Bulgaria and a relatively independency of export markets (compared to pellets) decrease by 1.5% per year.

Table 77: Final results - RES utilisation on households level – wooden briquettes

	Fuel savings	CO_2 emission reduction
Year	GWh	1,000 t CO_2
2015	18.2	6.2
2020	52.8	18.0
2025	153.1	52.2
2030	444.4	151.6
Total 2015-2030	**2,239**	**764**

Source: Authors' computation

7.3.3 Solar PV

7.3.3.1 Target of the measure

According to the "Building Performance Institute Europe (BPIE)" report (BPIE, 2012) the most effective option from a financial point of view in the case of nZE family houses with additional CO_2 compensation in Bulgaria is the highly efficient insulation of the building envelope, which helps minimize thermal losses from heat conductivity and infiltration and air source heating pump for space heating. The remaining energy/CO_2 compensation is achieved through installation of a rooftop PV system.

7.3.3.2 Micro-perspective

According to the BRIE analysis the CO_2 (remaining energy demand) compensation by a PV system for nZE family houses is 100 % and for multi-family residential buildings 71.18%. The calculated average value of residential buildings under the above assumption is 86.06 %. For an average building of 338 m^2 total area the quantity of energy compensated by a PV system is 6,705 kWh/year. We assume a 1% reduction of electricity output doe to aging.

The final emission reduction results mainly from the expected energy source of a standard Class B building. We assume an average emission factor as described in chapter 2.3 for this building type. If the electricity emission factors are used the annual reduction of CO_2 emissions as a result of the PV installation of an average residential building of total area 338 m^2 under the nZEB Standard instead of to Energy Class B is 3.7 t CO_2 in 2015.

The investment needs for an average PV installation is assumed with ca. 1.700 Euro/kWp, so that the investment need for an average residential building is ca. 10.200 Euro. We have to highlight that this is only an estimation based on actual market reports and concrete investigations about potential energy outputs and costs are necessary.

Table 78 gives an overview about the economically efficiency of a PV installation combination with the early introduction of nZEB standard in Bulgaria.

We assume that the owner of the facility consumes the whole electricity production. This has two reasons: on the one hand we choose an installed capacity that allows no feed in and on the other hand, the actual regulation on PV in Bulgaria doesn't secure allowances and feed in tariffs.

We distinguish between three parameter sets as follows:

Without an increase of electricity prices and a constant interest rate of 8% the measure is economically not efficient. The NPV is -3,600 Euro.

Increasing electricity prices (1% p.a.) lead to higher savings so that the NPV decreases slightly (set two).

A decrease of interest rates has a significant effect on the NPV. If we assume only 5% interest rates the NPV increases up to -700 Euro but the measure is still inefficient from a micro economic point of view.

As we can see is this technology is inefficient from a micro economic point of view under given support conditions and the assumption that no feed-in occurs or no feed-in tariff is paid. We expect that further research is necessary to evaluate the feasibility in more detail and depending on the given regulatory framework. The abatement costs vary between 53 Euro/t CO_2 in parameter set one and 11 in set three.

Table 78: Net-Present-Value and abatement costs for the PV solar measure

Parameter set	Investment	Discounted fuel cost savings	NPV	Abatement costs
	Euro	Euro	Euro	Euro/tCO_2
Fuel price increase 0% p.a. and interest rate 8%	10,200	6600	-3,600	53
Fuel price increase 1% p.a. and interest rate 8%	10,200	7150	-3,050	45
Fuel price increase 1% p.a. and interest rate 5%	10,200	9,500	-700	11

Source: Authors' computation

7.3.3.3 Macro-perspective

We assume in our calculations that PV installations will only take place if nZEB buildings will be constructed. The overall sum of constructions (as described in 7.2.4) is assumed with 21,000 buildings till 2019. We are aware of the fact that this is a relatively low penetration rate but as long as PV installations are expensive other, RES solutions needing less government supports are more plausible.

Table 79 summarizes our results. The potential electricity generation increases up to 142 GWh after 2019. Based on the actual electricity price, the aggregated fuel sale costs are ca. 20 m Euro compared to an investment of 254 m Euro. The resulting emission reduction is 54 Mt CO_2 in 2030.

Table 79: Final results PV solar in combination of an early introduction of nZEBs standard

	PV generation	Fuel cost savings	Investment	CO_2 emission reduction
Year	GWh	m Euro	m Euro	1,000 t CO2
2015	28.4	2.8	51	16
2020	142	14	0	76
2025	142	14	0	68
2030	142	14	0	54
Total 2015 - 2030	1,990	199	254	961

Source: Authors' computation

7.3.4 Measures assessment

Under the present economic conditions an implementation of solar systems (heat and PV) is inefficient. Main reasons for that are low electricity and fuel prices and high interest rates. Therefore, we choose a moderate penetration rate of an implementation so that the aggregated CO_2 emission reduction counts for only 370 $MtCO_2$ in 2030.

We expect that in the coming years the use of wooden briquettes and solar DHW can bring the highest potential contribution to emission reductions in Bulgaria among the RES used in households.

As described above, a minor constant price increase and a (government supported) lower interest rate for investors can change this situation immediately. This holds especially for the DHW measure.

A significant advantage of wooden briquettes is that no additional investments are (in general) necessary for users. Prices are relatively low and with proper governmental instruments (reduction of fossil fuel supports and/or financial supports for wooden briquettes) their competitiveness can be increased.

Solar PV applications are more expensive in respect to other RES at household level. Under the current widely insecure support conditions, an implementation at household level is economically inefficient. Nevertheless, decreasing prices for PV equipment and relevant regional differences in the energy yield will make implementation efficient for some investors, so that the (relatively low) penetration of 21,000 installations with an emission reduction of 54 $MtCO_2$ in 2030 becomes realistic.

All investments into RES at household levels should take place in combination with an energetic retrofitting and modernisation. This will reduce costs and a compensation of negative by positive NPV can influence investors positively. Potential governmental support schemes have to take this fact into account.

We estimate that job creation for production, installation and maintenance of solar thermal and PV systems will be in the order of ca. 300 in 2015 and 1,200 employees in 2030. It is plausible to assume that these jobs are additional jobs.

A calculation of (net) effects for jobs out of the wooden briquettes measure is hardly possible. We expect that job losses will occur in the mining industry so that the net effect might be zero.

The technologies used for implementation of the measure as well as for installation of solar systems or production of wooden briquettes and other related services could be supplied by domestic companies.

On the Bulgarian market there are numerous suppliers of solar systems for DHW production if the conditions of interest from house-owners and of availability of funding for installation of the solar systems, no shortage of technologies or of skilled workforce may be expected.

The wooden briquettes on the Bulgarian market are mainly of local manufacture. In the case of coal, there is both local low-calorific coal of low price and imported high-calorific and more expensive coal, mainly from Ukraine and Russia. Although the calorific value of the wooden briquettes is comparable with that of imported coal, the higher selling price of wooden briquettes makes the price of the heat energy produced from them higher than the price of heat energy produced from coal. The financial support by the government for production of a limited quantity of wooden briquettes at a price, which would make the price of heat energy produced from them lower than that produced from coal, would rather have a minimum effect on the import of coal, but would not affect local production. On the other hand, it would encourage local production of wooden briquettes, which is expected to gradually, in a long-term perspective, increase the aptitude of the population to using wooden briquettes.

The solar heat installation technology is already applied in many hotels and hospitals and in more than 27,000 residential buildings. Through more active popularization campaigns and identification of mechanisms for financial promotion in terms of incentives for the population, the implementation of the measure would gain more active support and it is estimated that by 2030 the number of houses, in which this technology is used, will increase manifold.

So far wooden briquettes are very scarcely used, but the envisaged measure might contribute to their gradual establishment on the market as fuel for space heating.

The existing suppliers on the market, as well as the construction companies and other parties involved, are adequate for the implementation of the measure.

Even if the amount of 1,200 Euro for one DHW installation is relatively low, it accounts for 200% of the average monthly household income and 2,400% of the average monthly household savings in Bulgaria. Even if the average households will not first install this technology we have to assume that an investment by households with higher incomes might need bank loans. Under the current economic situation and high interest rates in Bulgaria and the related inefficiency of the measure, we estimate that bank loans will be difficult to obtain for the measure. The same situation has to be assumed for solar PV installations.

Barriers might result from political risk related to a specific measure. Reasons for that might be contradictory policy targets, misunderstanding or lobby specific politics.

In this case, political barriers are related to maintaining the price of electricity at lower levels than the market-based one. Thus the investment in solar installations for DHW production is paid off at a slower pace, which makes the projects more unprofitable for financing. The administrative barriers are related above all to the heavy and slow procedures of allocation of funding. Another political barrier is also that no funding is allocated under the Operational Programmes for improvement of energy consumption or for introduction of RES energy in small private buildings.

7.4 Measure summary: Electricity savings from LED

7.4.1 LED in Administrative Buildings

7.4.1.1 Status quo

The electricity consumption for lightning in administrative as well as commercial buildings plays a much more important role that in residential buildings. Main reason is the longer daily presence of persons in the buildings.

According to several international publications, the share of electricity consumption for lightning in non-residential buildings vary from 20% to 30% (see e.g. SEAI (2003)).

Lighting as a sector is not tracked in the national Bulgarian statistics. An analysis by the Branch Chamber for LED Technologies and Lighting under the project „Improvement of the standardization system in Bulgaria“, performed by Assoc. Prof, Dr. (Eng.) Krassimir Velinov, presents summary information about the existing capacity in lighting in Bulgaria, which has probably been obtained analytically. According to that source the lighting in administrative buildings in Bulgaria features total installed capacity of 150 MW and the average annual usage rate is 2,000 hours.

7.4.1.2 Target of mitigation measure

The target of this measure is to ensure reduction of energy consumption for lighting systems in administrative buildings.

7.4.1.3 Micro-perspective

With respect to lighting in administrative buildings, in the majority of cases there is no systematized information concerning its state even at the building manager's office. On the basis of personal observations, the authors assume that as of today LED lighting will not find application in administrative buildings.

In the administrative buildings, the average installed power of the lamps in a single existing fluorescent lighting fixture is accepted to be 72 W (4 lamps of 18 W or 2 of 36 W). The approximate system watts per lighting fixture with 72 W lamps is 79.2 W. The average installed power of CFLs is accepted to be 20 W. The average luminous efficiency of fluorescent lamps is 38 lm/W, of CFLs it is 23 lm/W and of LED lamps it is 76 lm/W.

The calculated installed power of cluster of LED lamps to replace cluster of fluorescent lamps of 72 W is 36 W. The calculated installed power of a single LED lamp to replace a single CFL of 20 W is 6 W.

The calculated energy savings from replacement of fluorescent lamps is 86.4 kWh/a for one cluster of lamps with a total power of 72 W. The CO_2 emission reductions are 70.7 kg/a.

The calculated energy savings from replacement of a CFL are 28 kWh/a. The CO_2 emission reductions are 22.9 kg/ a.

For further calculations we assume a constant price of ca. 34 Euro for one LED light. Difference investments are taken into consideration – the price for a CFL light is assumed with 3.58 Euro and for a luminescent lamp of 7.36 Euro.

The results for the Net-Present-Value calculations depend on the kind of the replaced lamp. The replacement of fluorescent lighting in administrative buildings the NPV is for one lamp with a lifetime of ca. 10 years (25,000 hours) with 38 Euro positive while for CFLs it is negative with -8 Euro under the assumption of 8% interest rate. A lower interest rate of 5% leads to NPV of 48 Euro, 29 respectively. The Abatement costs vary between -53 Euro/t CO_2 and 37 Euro /t CO_2 in parameter set one.

Table 80: Net-Present-Value and abatement costs for LED lights in administrative buildings

Parameter set	Investment	Discounted fuel savings	NPV	Abatement costs
	Euro	Euro	Euro	Euro/tCO_2
Replacement of Luminescent lights				
Interest rate 8%	34	72	38	-53
Interest rate 5%	34	82	48	-68
Replacement of CFL lights				
Interest rate 8%	34	26	-8	37
Interest rate 5%	34	29	-5	20

Source: Authors' computation

Based on the information on the existing shares of different light types in administrative buildings Table 81 provides the information on average NPV and abatement costs.

Table 81: Net-Present-Value and abatement costs for LED lights in administrative buildings

Parameter set	Investment	Discounted fuel savings	NPV	Abatement costs
	Euro	Euro	Euro	Euro/tCO_2
Average: 22 % Luminescent lights + 78% CFL lights				
Interest rate 8%	34	36	2	17
Interest rate 5%	34	41	7	1

Source: Authors' computation

7.4.1.4 Macro-perspective

We assume a penetration rate of 10% p.a. so that in 2025 all administrative buildings are equipped with LED lights. From 2027 on a reinvestment will become necessary. After the 10th year when the lamp replacement is 100% completed the annual reduction of CO_2 emissions due to introduction of LED lighting into administrative buildings will be 73 t CO_2 per year. The aggregated investments sum up to 229 m Euro while fuel costs savings are ca. 217 m Euro (see Table 82). In addition 61 mill Euro reductions in maintenance cost will become possible.

Table 82: Final results for LED in administrative buildings in Bulgaria

	Fuel savings	Fuel cost savings	Investment	CO_2 emission reduction
Year	GWh	m Euro	m Euro	1,000 t CO2
2015	19	1	16	11
2020	117	11	16	62
2025	195	19	0	92
2030	195	19	16	74
Total 2015-2030	2,238	217	229	1,054

Source: Authors' computation

7.4.2 LED Street lights

7.4.2.1 Status quo

An analysis by the Branch Chamber for LED Technologies and Lighting under the project „Improvement of the standardization system in Bulgaria“, performed by Assoc. Prof, Dr. (Eng.) Krassimir Velinov, presents summary information about the existing capacity in lighting in Bulgaria. According to that source street lighting has a total capacity of 100 MW in Bulgaria and average annual usage rate 4,300 hours. The measure is oriented towards achievement of reduction of electricity consumption for lighting and hence reduction of GHG emissions. This will be attained through introduction of modern LED lighting in the street lighting systems in a number of settlements in Bulgaria.

7.4.2.2 Target of the measure

Within a period of 10 years with a uniform intensity all existing street lighting fixtures and all fluorescent and compact fluorescent lamps should be replaced.

7.4.2.3 Micro-perspective

The introduction of LED units in the street lighting systems began to gain pace in the recent 2-3 years, although their application is as yet on a very small scale. On the other hand, there are ready project proposals and applications under different programmes for grant funding, which envisage replacement of the street lighting on individual sections in different municipalities with LED lamps. Part of these projects will be realized in the coming two years. The authors do not have a reliable source of information about the lighting wattage. Therefore we assume for the purposes of this analysis that 10% of the existing lighting capacities will be replaced by LED units. These capacities are not included in the quantities of luminaries, which will be replaced in the framework of the measure.

The general evaluation that can be made about the state of street lighting in the country is that it is inefficient from energy consumption point of view. High-pressure sodium lamps (HPS) of 150 W, 100 W, 70 W and 50 W, which have been installed in the framework of energy efficiency projects implemented in the past 15 years, predominate.

It is envisaged through implementation of this measure to have, in the framework of 10 years, all the existing lighting fixtures and lamps replaced by highly efficient LED street lighting units. The approximate lifetime of the LED street lighting for buildings is 50,000 hours against 15,000 hours for HPS lamps.

For the purposes of evaluation of the measure it has been assumed that the average unit capacity of the existing street lamps is 100 W and the lamps are of the HPS type. The approximate system watts per single HPS lamp are 133 W. The approximate system watts per single LED lamp, suitable to replace 100 W HPS lamp, are 66 W.

In the street lighting the average installed power of the existing HPS lamps is accepted to be 100 W. The approximate system watts per lamp are 133 W. The installed power of the alternative LED lamp is 66 W according to Stan Walerczyk in his *Report EHID & LED For Exterior, Hibays, Etc.*

The calculated energy savings from replacement of an average HPS street lamp by LED lamp are 288.1 kWh/a. The CO_2 emission reductions are 235.9 kg/a.

We assume an average electricity price of 0.75 Euro/kWh for street lighting. One single LED street lamp costs ca. 112 Euro and its installation 1.20 Euro.

Based on this assumption and under consideration saved investments for currently used HPS lights the Net-Present-Value is positive with ca. 50 BGN (42 Euro) if we assume a 10 years lifetime. Under the assumption of an interest rate of 5% the NPV is 74 Euro. The abatement costs are -20 and -31 Euro/t CO_2 respectively.

From a micro economic point of view is this measure efficient.

Table 83: Net-Present-Value and abatement costs for LED street lights

Parameter set	Investment	Discounted fuel savings	NPV	Abatement costs
	Euro	Euro	Euro	Euro/tCO_2
Interest rate 8%	113	163	50	-20
Interest rate 5%	113	187	74	-31

Source: Authors' computation

7.4.2.4 Macro-perspective

In the street lighting 1.3 million lighting fixtures will be replaced with LED lighting. We assume a penetration rate of 10% p.a. so that in the period 2015-2024 all existing lamps will be replaced. Until 2030 50 % street lighting LED units should be replaced for elapse of their technical/service life.

Within the assumed annual rate of replacement of 10 % of the existing street lamps with LED units, the estimated investments needed is 100 m EUR until 2024 when 100% of the lamps will be replaced.

In the period 2026-2030 an annual investment of 50 m EUR will be needed to replace the LED street lamps, whose lifetime has expired. The total investment until 2030 is 150 m EUR). The avoided maintenance costs and investments for the existing lamps in street lighting are estimated at 29 m EUR. The emission reduction in 2030 sums up to 98 MtCO_2.

Table 84: Final results for LED street lights in Bulgaria

	Fuel savings	Fuel cost savings	Investment	CO_2 emission reduction
Year	GWh	m Euro	m Euro	1,000 t CO_2
2015	25	2	10	14
2020	155	12	10	83
2025	259	20	0	123
2030	259	20	10	98
Total 2015-2030	2,982	224	154	1,404

Source: Authors' computation

7.4.3 Measures assessment

The aggregated emission reduction potential of these measures is moderate. The main reason is the relatively low consumption of electricity for lighting.

Following Bertoldi; Hirl and Labance (2012), the electricity consumption for lightning in residential buildings is e.g. ca. 10% of overall residential electricity consumption in the EU27. In 2030 an emission reduction of ca. 170 MtCO_2 can take place. Necessary investments sum up to 379 m Euro whereby fuel cost savings will be ca. 441 m Euro.

As described above the implementation of LED light in offices is efficient if a replacement of luminescent lights takes place because of their higher costs compared to CLF lights. We estimate that the replacement of a significant amount of existing lights will become possible if the implementation is embedded into a broader energetic restructuring of offices. This would include the replacement of inefficient cooling and heating equipment and electronic devices. Therefore comprehensive analyses (energy audits) have to be conducted.

Regarding the replacement of street lighting, this measure can be implemented efficiently from an economic point of view. Therefore replacement should be take place with moderate to higher penetration than the usual modernisation rate of lamps would allow. We do not expect any substantial job creation effect out of these measures.

On the Bulgarian market there are numerous suppliers of LED lamps for both buildings and street lighting, some from domestic l manufacturers and many from importers. From the point of view of supply of lamps and installation activities, all conditions for successful implementation of the measure are available.

Regarding the state of lighting in buildings and street lighting systems one may conclude that quite often inadequate maintenance or even intentional unlit sections due to shortage of budgetary funds is observed. This leads to poorer quality of lighting and a number of other negative effects of social nature. It also leads to the necessity to adjust the baseline in the projects for energy efficiency retrofit of lighting, since the local authorities' intention is after implementation of such a project to increase the number of lit sections and if possible to have the measure implemented in the entire site. Without adjustment of the baseline in certain cases it might turn out that the project has even failed to achieve savings under the real baseline state. This situation does not make financing of such projects with bank loans or through ESCO schemes impossible, but rather more difficult, since the financing party should be convinced in the secured return of its investment.

7.5 Measure summary: Industry

The efficient use of waste energy has to be seen as one potential and feasible efficiency measure among others in a wide range of industrial applications such as efficient improvements on Motors, Pumps, Heating and Cooling systems and others. This measure is an example of a wide range of economically efficient mitigation options in industrial production. Further examples for efficient modernisation options are motor systems and industrial heat production. We expect that in the Bulgarian economy at least 2-3 Mt CO_2 can be abated by 2030 by implementing these measures. For an analysis of this potential and an identification of supporting policy measures, better data availability is essential.

7.5.1 Utilisation of excess heat in industries

7.5.1.1 Status quo

Most of the waste heat in Bulgaria is emitted into the ambient environment in the energy-intensive industry enterprises like cement, lime, ceramics and bricks, iron and steel, non ferrous metals, petroleum, fertilizers and other products and materials production. In addition, waste heat exists in almost all sectors of the Light industry as well. Three main sources of heat are used: district heating or cogeneration companies, electrical boilers and fossil (in some cases renewable) fuel combustion boilers.

Furthermore, evaluations made in recent surveys show that almost all steam production boilers in the light industries are not equipped with economizers and operate with efficiency much below 90% due to the high temperature of the flue gases. We estimate that more than half of the boilers that use gasoil will switch to natural gas, and the total gas consumption of the boilers will increase up to 0.33 Mtoe (14 PJ) by 2025.

7.5.1.2 Target of the measure

The target of this measure is to ensure reduction of CO_2 emissions from the natural gas consumption in the Light industries and Agriculture by upgrading of steam production boilers and increasing the energy efficiency of steam production. The measure may allow reducing the natural gas consumption on heat production of Light industries and the Agriculture on about 4%. The fuel switch from oil to gas requires replacement of the oil burners with gas burners.

7.5.1.3 Micro-perspective

There are many different commercial recovery units for the transferring of energy from hot medium space to lower one; e.g. Recuperators, Regenerators and Economizers. These systems have many benefits, which could be direct or indirect. Beside direct benefits – as the reduction of energy consumption, an implementation of the technology leads to indirect effects. Main benefits are the reduction of direct air pollution, reduction in the equipment sizes and reduction in auxiliary energy consumption.

Average cost of an economizer installation (including design works at the boiler site, production, transportation, installation and start up of certain economizer for a 4 MW boiler) is estimated on 51,129 Euro.

The economizer installation reduces annual fuel consumption on 4% due to the increase of the efficiency. Economizers for boilers with natural gas would have 15 years lifetime. It is assumed that the economizer installation results in an increase of the fuel efficiency on 4%. The fuel economy will be 60.2 toe (2,520 GJ) for the years 1 to 15 if the boiler efficiency is 90%. The current price of 1 GJ natural gas sold by Bulgargas at high pressure pipes is 19.04 BGN/GJ (9.7 Euro/GJ, 637.72 BGN/1000 m^3, 33.5 GJ/1,000 m^3). As a result of upgrading of one boiler the annual reduction of fuel costs will be 23,000 Euro per year.

Table 85 summarizes the main assumptions and the annual environmental impact of one facility.

Table 85: The environmental impact of one single facility annually (4.5MW)

Indicator	%	GJ/year	t/year
Free of emissions Heat production in new facility		2,268	
Reduction of primary energy consumption of an existing boiler	4.0	2,520	
Average efficiency of the boiler before upgrading	86		
Average efficiency of the boiler after upgrading	90		
Energy saving of primary energy (natural gas)		2,520	
Emission reduction of GHG from the boiler after upgrading			564

Source: Authors' computations

Based on the annual fuel cost savings and the necessary investment we calculate the Net-Present-Value (parameter set one) for a single implementation in year one that gives a hint on the economically of the measure. The NPV is positive 154,595 Euro – the discounted fuel cost savings over the life time of the facility (15 years) are higher than the investment in year one. The investment is economically from a rational economic point of view of an investor.

Lower interest rates improve the economical efficiency. We did not take increasing fuel prices into account but it is obvious that this would lead to a better situation for investors.

Table 86: Net-Present-Value and abatement costs for use of excess heat in industries

Parameter set	Investment	Discounted fuel savings	NPV	Abatement costs
	Euro	Euro	Euro	Euro/tCO_2
Interest rate 8%	50,000	206,000	155,000	-70
Interest rate 5%	50,000	250,000	199,000	-87

Source: Authors' computation

7.5.1.4 Macro-perspective

Installation may start in late 2014 with period of accounting of the effect starting in 2015. For the first year eight units may be installed and in the next years the number of installed units may increase on 4, reaching 28 in year 2020. Total 108 average boilers may be upgraded for 6 years period 2015-2020.

Table 87 summarizes the macro results. The estimated investments needed to retrofit and modernize the thermal plants up to 10.2 m Euro. The aggregated total energy savings for the period till 2030 are 5,342,400 GJ (160 mill m^3 natural gas), whereas in 2030 an amount of 504,000 GJ can be saved. The measure will lead to an emission reduction of 28,000 tCO_2 in 2030 (see Table 87).

Table 87: Final results for the utilisation of excess heat in Bulgaria

	Fuel savings	Fuel cost savings	Investment	CO_2 emission reduction
Year	1,000 GJ	m Euro	m Euro	1,000 t CO_2
2015	20	0.2	0.4	1
2020	272	3	1	15
2025	474	5	0.4	27
2030	504	5	0	28
Total 2015-2030	5,342	52	10	299

Source: Authors' computation

7.5.2 Measure assessment

There is only one producer of this technology in Bulgaria. Nevertheless it has very limited market of boilers in the country and produces mainly equipment for boilers for export. The boiler producer does not produce significant number of boilers due to the requirement of the Energy Act to not install new boiler plants with capacity above 5 MW. Any heat demand higher than 5 MW shall be supplied from cogeneration of heat and electricity according to the Law.

The cogeneration equipment is expensive and the light industry enterprises almost never replace the old boilers.

The procedures for financing of certain energy efficiency measures from bank loans are very complicated and enterprises have no capacity to apply for loans.

One solution of overcoming these barriers is to promote this technology in the energy efficiency funds and simplify the loan acceptance procedure. An interest rate of 8% allows about 3 years payback period.

Nevertheless most of the light industrial enterprises are close to insolvency due to financial and economic crisis that started in 2009 in Bulgaria and is not over yet. Considering that these enterprises cannot access easy loans, policy solutions should be found to eliminate this barrier.

Both, the production of mitigation technologies and their implementation /maintenance need skilled labour force but we do not expect a significant job creation effect with low penetration as described.

Giving the fact that the envisaged technology is very similar to the one used in currently functioning facilities, the labour force to implement technology is considered to be adequately skilled and available.

7.6 Measures summary: Transport sector

7.6.1 Status quo

Transport is a very fast developing sector of the Bulgarian economy. It has a production of 4,659 m Euro from 19084 companies in 2010. The GVA is 1,463 m Euro that is 6.7% of the Bulgarian economy. The sector has been constantly developing in the period 2000-2008. However, in 2009 there is a decline (16.5%) to 4,231 Euro in the level of production due to the world economic crisis. In 2010 the rate of production increases again to 4,659 m Euro (9%). The number of employees decreases by 12% in the time period 2000-2010. However, the production increases by 92% for the same period. That clearly shows the improved productivity within the sector. The production of the sector continues to rise in the years after 2012. The main freight transport that crosses the country, are loads from Turkey to EU and back. 257,000 trucks, transit through Bulgaria from Kapikule per year, serve the Turkish export (source Intermodal magazine 2008). 146,000 more trucks serve the import to Turkey.

Road transport is less energy-efficient and produces more emissions per kilometre than rail and inland waterways transport. Therefore, the use of vehicles for freight transport has greater social and environmental impact, such as pollution, global warming, road accidents, etc.

7.6.1.1 Target of mitigation measure

Target of the measure is the development of intermodal fright transport in Bulgaria. This includes the development of intermodal terminals and a use of the RO-LA ("Rollende Landstrasse") technology. In addition the implementation of the IMT will require introduction of new or modification of the existing system of charges (vignette taxes, environmental taxes, tax on vehicles, etc.).

7.6.1.2 Micro-perspective

The design and permitting procedure for the construction of an intermodal terminal in Rousse (at the Danube River) is already started. It is designed for transfer of loads from and to tracks, trains and ships. At the beginning it could serve the transfer of the transit tracks from train to road and from road to train.

The average lifetime of intermodal terminals is more than 30 years. The building of the terminals will be done in stages: (1) Russe - the construction has started. The assessment assumes that the IMT Russe already been constructed, (2) Kulata, (3) Vidin and (4) Svilengrad.

According to international evaluations (Evropa, 2012) estimated investment value for construction of one intermodal terminal is 16.3 m Euro and the project duration is 2 years.

The estimation of the micro perspective impact for each IMT is made by the authors, based on 35 trucks passing through the IMT per day, and taking into account the fuel consumption of 35 trucks on road and electricity consumption of train with electricity traction for transportation of 35 of trucks. Table 88 summarizes the environmental impact of the IMT measure for its four distances.

A definition of the abatement costs is difficult. The reason is that we did not take cost differences of the transport equipment into account. The abatement costs only for the IMT terminals and its resulting emission reduction potential for the period till 2030 are ca. 16 Euro/tCO_2. Further research that analyses the transportation costs of different transport modes is needed here.

Table 88: The environmental impact of the 4 distances

Indicator		Russe - Kulata	Vidin – Kulata	Russe - Svilengrd	Vidin - Svilengrd
Energy consumed for IMT transporting	GJ/ year	66,363	46,713	56,168	70,986
Energy consumed for Road transporting	GJ/ year	165,908	125,355	100,716	177,465
Emission reduction of GHG	%	30	34,36	2	30
Emission reduction of GHG	t/year	3,594	3,159	130	3,844
Energy saving	%	60	62,74	44	60
	GJ/ year	99,545	78,642	44,548	106,479

Source: Authors' estimations

7.6.1.3 Macro-perspective

The penetration rate is expected to be one route every three years. First route can be operational in 2016, the second in 2019, the third in 2022 and the forth in 2025. The duration of implementation of an intermodal terminal is 2 years. The preparatory period is two years.

The aggregated impact results from our connections that lead to total energy savings for the period of 3,796,122 GJ (89,743 t) Diesel oil. Table 89 summarizes the macro results of the evaluation for the IMT measure. The aggregated investment for the development of the four terminals sum up to 65 m Euro and the emission reduction in 2030 is around 11,000 tCO_2.

Table 89 : Final results for IMT in Bulgaria

	Fuel savings	Fuel cost savings	Investment	CO_2 emission reduction
Year	1,000 GJ	m Euro	m Euro	1,000 t CO2
2015	0	0	5	0
2020	178	4	5	7
2025	329	8	0	11
2030	329	8	0	11
Total 2015-2030	**3,796**	**95**	**66**	**127**

Source: Authors' computation

7.6.2 Measure assessment

The emission reduction potential of the described measures is relatively low under the given assumptions. Nevertheless a comprehensive restructuring of inland road transport would lead to relevant GHG reductions.

One problem is that the percentage of the expenses for fees for use of the railway infrastructure is about 2.5 times higher than the fee for use of the motor transport (vignette fee). Therefore it is necessary to create a stimulating system for the fees (vignette fees, ecological fees, duty on vehicles and others) that will ensure competitiveness of the implementation of the intermodal transportations. As long as transport costs for road transportation are lower than of rail, a transport mode shift is not realistic.

At the moment no Bulgarian company is available to deliver equipment and rolling stock. Job creation effects are negligible for Bulgaria. The employment effect will appear in two sectors – railway and construction:

- Construction sector during the construction of the terminals
- Railway infrastructure company during the operation of the terminals
- Railway rolling stock company during the operation of the trains

During the construction design and permitting of the IMT 15 designers for 3 months every of them for every of the terminals will be hired. During the construction of the terminals construction company and construction supervision company will be hired.

We have to assume a reduction of the loading of the road infrastructure in the country and reduction of the maintenance works on the main roads in the country.

As far as the measure considers the transit flows only there will not be any effect on the local competition between the road transportation companies. Significant effect may be achieved if the experience gained with the transit transportation flow results in a further development of intermodal transportation in the country and for the export of goods.

Beside the problem to receive loans for the implementation of the measure further barriers are to be taken into account: incoherent policies and decisions, weak planning and evaluation in the transport sector, weak administrative capacity to implement projects, inefficient subsidies and policies: the social assistance for passenger transport, weak coordination between road transportation companies and railway infrastructure company, outstanding debts and impossibility to access loans for the railway infrastructure company, strong competition of road and railway transportation and technology transfer limits and costs.

7.7 Measures summary: Energy sector

Bulgaria made a significant progress in the development of renewable energy production over the past years. Nevertheless the administrative, economic and not least technical conditions weaken the further development and the actual use of existing generation capacities. With the following two measures we give examples how a better use of existing capacities as well as a better integration of new ones can lead to a more efficient use of renewable energy sources in Bulgaria. We do not count the results in the overall emission reduction potential of the described measures for Bulgaria because without additional investments in renewable sources, theses two measures will not bring any contribution to GHG emission reductions.

7.7.1 *Grid upgrade to fit the renewable potential of the country*

7.7.1.1 *Status quo*

Bulgaria made significant progress in the development of renewable energy sector over the past years, e.g. wind plants have reached already in 2012 the NREAP indicative electricity production goal for the year 2014.

The development of the RES integration led to serious negative impacts on the power system operation and dispatching, and the financial results of the electricity sector. The renewable electricity generation was constructed much faster than it was technically and legally possible for the owners of the electric grids to construct the new transmission and distribution lines and substations.

Due to these reasons recently (2010-2013) not all of the RES electricity was accepted by the power system and penalties were paid to the producers.

7.7.1.2 *Target of mitigation measure*

The measure investigates the needs of a connection of new RE to the grid and a grid upgrade to fit the needs for tie in and transmission of the electricity from renewable generation capacities.

7.7.1.3 *Micro-perspective*

According the "Regional Investment Plan Continental South East - Final" (ENTSOE, 2012), based on data from the 11 countries the following stages in the development of the Bulgarian transmission grid in regard to RES integration should be foreseen:

- **Earlier commissioning to accommodate investment need**: for the integration of more than 2,000 MW high penetrating new wind generation in the north-east part of Bulgaria.
- **Project to accommodate additional investment need:** the new 400 kV line Dobrudja-Burgas in Bulgaria will enable the safe integration of 2,000 MW RES in Dobrudja region and will increase transfer capacity from the region and in North-South direction;
- **Connection "in/out" in Medgidia (RO) of existing 400 kV OHL Isaccea (RO) - Varna (BG):** new wind farms shall be connected in Medgidia (RO).

The necessary extensions of the Bulgarian transmission grid can be summarized as follows:

1. **Part of East-West corridor from Bulgaria to Italy:**

    - Maritsa East 1 (BG) - N. Santa (GR): new interconnection BG-GR, 400 kV single circuit, 130 km;
    - Maritsa East 1 (BG) - Plovdiv (BG): new 100 km single circuit, 400 kV in parallel of the existing one;
    - Maritsa East 1 (BG) - Maritsa East 3 (BG): new 13 km single circuit, 400 kV in parallel of the existing one;
    - Maritsa East 1 (BG) - Burgas (BG): new 150 km single circuit OHL, 400 kV. to accommodate 2000 MW RES

2. **Project to help evacuate large amount of RES generation in Dobrudzha region (2,000 MW). It also contributes to North-South transfers and increases the security of supply in Burgas region:**

    - Dobrudzha (BG) - Burgas (BG): new 400 kV single circuit OHL, 140 km, in parallel of the existing one;
    - Vidno (BG) - Krushari (BG): new 400 kV double circuit OHL, 2x70 km, in North-East Bulgaria, Dobrudzha region, to accommodate 2000 MW RES;
    - SS 400/110 kV Svoboda (Krushari) (BG): new 400/110 kV substation to accommodate 2,000 MW RES;
    - in/out in Svoboda (BG) on actual 400 kV OHL Isaccea (RO) - Varna (BG): new 400 kV double circuit OHL, 2x10 km, to accommodate 2,000 MW RES.

Table 90 summarizes the costs of the technologies that are basis for the further calculations.

Table 90 Investment need for grid upgrade to accommodate new RES electricity generation

1. Average investment for tie-in to the transmission grid per 1 MW of installed RES capacity		
1.1. Average transmission grid upgrade investment for tie-in of 1 MW RES:	106,000	BGN/MW
1.2. Average distribution grid upgrade investment for tie-in of 1 MW RES:	217,500	BGN/MW
2. Additional average investments for grid reinforcements to accommodate new RES generation		
2.1. 400 kV bay	65,00,000	BGN
2.2. 400/110 kV transformer	12,000,000	BGN
2.3. 110 kV bay	230,000	BGN
2.4. Double-circuit OHL 110 kV	240,000	BGN/km
2.5. Single- circuit OHL 110 kV	210,000	BGN/km
2.6. Double-circuit OHL 400 kV	420,000	BGN/km
2.7. Single-circuit OHL 400 kV	360,000	BGN/km
2.8. Cable line 110 kV	700,000	BGN/km
2.9. Replacement of 110 kV OHL conductor	89,000	BGN/km

Source: Author's judgment based on aggregated data from designed and commissioned RES projects

7.7.2 Macro-perspective

According to the NREAP (Ministry of Economy and Energy Bulgaria, 2010) in 2020 the installed electrical generation capacity from RES should reach 5,189 MW, and the RES electricity should reach 7,604 GWh. These figures show that the annual electricity production must be increased in 2020 by c.a. 114 GWh, although the NREAP indicators for installed capacity have already been achieved.

Table 91 summarize the results for the connection of new renewable capacities to the transmission and distribution network in Bulgaria. With an overall investment of 366 m Euro 2,280 MW new RES capacities can be integrated into the Bulgarian power system. The additional electricity generation might sum up to 3.5 TWh in 2030.

Table 91: Final results for connection of new RE to the grid in Bulgaria (I)

:	Potential New RES capacity connected to the transmission grid:	Tie indirect investment s	Potential New RES capacity connected to the distribution grid	Tie in direct investments	Total installed TES capacity
Year	MW	m Euro	MW	m Euro	MW
2014	947	51	100	11	1,047
2015 -2016	0	0	100	11	100
2017 -2030	80	8	120	13	200
Total	**2,067**	**112**	**2,280**	**254**	**4,347**

Source: Author's estimations - **Potential annual increase of the renewable electricity generation capacities connected to the transmission and distribution networks**

Table 92: Final results for connection of new RE to the grid in Bulgaria (II)

	Total tie-in investments	Potential Electricity generation by the new Capacities	Electricity not accepted by the Power System due to lack of transmission capacity	Emission reduction due to acceptance of the new REE by the upgraded grid
Year	m Euro	GWh	GWh	1,000 tCO_2
2014	32	1,675	838	686
2015	6	1,835	918	752
2020	9	3,275	1,638	1,341
2025	11	5,115	2,558	2,095
2030	11	6,955	3,478	2,848
Total	**188**	**69,678**	**34,839**	**28,533**

Source: Author's estimations **- Potential annual increase of the renewable electricity generation capacities connected to the transmission and distribution networks+**

Additional investment requirements result from the upgrading of the transmission capacities to transmit the renewable electricity. The aggregated sum of necessary investments is 261 m Euro till 2030 (Table 93).

Total TIE-in investments and additional investments for the grid upgrade of RES electricity sum up to 638 m Euro for the whole measure.

The network capacity would allow accept only 50% of the potential production of renewable electricity from the new capacities. Most probably these capacities will not be installed. If the grid is extended as proposed, all renewable electricity will be accepted by the network. The additional renewable electricity will replace electricity produced from other fossil generation capacities and this replacement will result in significant CO_2 emission reduction, as shown in the Table 94. Thereby we have to taken into account that the modernisation and enlargement of the grid is only a necessary but not sufficient need for the emission reduction. Therefore we do not calculate abatement costs for this measure.

Table 93: Final results for grid upgrade

Additional grid installations invested:	pcs.	km	m Euro
New 400/110 kV transformers	2		12
New 400 kV bays	14		47
New 110 kV bays	42		5
New double-circuit 110 kV OH lines		90	11
New single-circuit 110 kV OH lines		200	22
New double-circuit 400 kV OH lines		80	17
New single-circuit 400 kV OH lines		533	98
New 110 kV cable lines		120	43
Replacement of 110 kV OHL conductor		120	6
Total additional grid reinforcement investments:			261

Source: Author's estimations **- Additional transmission capacities needed to transmit the renewable electricity from new capacities**

Table 94 Potential production of electricity from newly installed renewable capacities

Year	2015	2020	2025	2030	Total
Potential RE Production from new RE capacities (GWh)	1,835	3,275	5,115	6,955	69,678
Increase of the RE produced due to investments in the network (GWh)	918	1638	2,558	3,478	34,839
Emission reduction (1,000 tCO_2)	752	1,341	2,095	2,848	28,533

Source: Author's estimations

7.7.3 Introduction of smart meters and other smart technologies

7.7.3.1 Target of mitigation measure

One of the measures to achieve better integration of RES in the load diagram of the electric power system is the implementation of the so-called "smart meters" and "smart technologies". With the implementation of the intelligent metering systems it is expected to achieve the following targets:

- To provide direct interaction and communication between electricity customers and suppliers.
- To increase the electricity consumption efficiency of end-users, in such a way that they can directly control their consumption.
- The measurements must reflect accurately the actual consumption of the end user and to supply information about the real time of the consumption.
- The electric grids must become a key factor for a future power system with low carbon emissions and other GHG emissions.
- To increase grid efficiency, to reduce costs to cover the peak loads of the electric power system through remote control of meters for reduction of the consumption, on/off of the supplied consumers and appliances.
- To reduce primary energy consumption.

The benefits for the project of introducing smart meters are assessed following the European Commission Recommendation 2012/148/EC. The benefits are estimated divided into two groups: benefits for the project and benefits only for the distribution company.

7.7.3.2 Micro-perspective

The assumptions made by "Energo-Pro Grid" SC for the replacement of 80% (960 000 pcs) of meters until 2020 and are given with: Discount rate - 10 %, Useful life - 7 years, Rate of return on investment - 10 %, Time for the implementation for 80 % of customers - 6 years. The main results from the distribution companies' submissions are summarized in the following tables containing the different scenarios of implementation of smart metering systems (SMS):

Table 95: SMS integration scenario results I

Parameter	units	20% SMS	40% SMS	60% SMS	80% SMS
Number of the SMS	pcs.	242 000	484 000	726 000	968 100
Investment costs	m Euro	35,2	70,3	105,5	140,7
Total estimated benefits for the project	m Euro	61,8	99,2	136,1	175,2
Total benefits only for the company	m Euro	27,5	55,4	82,9	112,7
NPV total for the project	m Euro	13,0	10,1	7,0	5,2
NPV for the company	**m Euro**	**-10.4**	**-20.7**	**-31.2**	**-40.4**

Source: Distribution company „Energo-Pro Grid" SC

Table 96: SMS integration scenario results II

Parameter	units	20% SMS	40% SMS	60% SMS	80% SMS
Number of the SMS	pcs.	318,798	637,602	956,400	1,275,200
Investment costs	m Euro	32.5	65	97.9	131.1
Total estimated benefits for the project	m Euro	74.1	107.1	139	170
Total benefits only for the company	m Euro	27	50.9	72.5	92.7
Net present value total for the project	m Euro	23.5	19.6	14.8	9.5
Net present value for the company	m Euro	-8	-19.1	-31.9	-45.8

Source: Distribution company „EVN Bulgaria Electrorazpredelenie" PLC

Table 97: SMS integration scenario results III

Parameter	units	20% SMS	40% SMS	60% SMS	80% SMS
Number of the SMS	pcs.	408,060	816,120	1,224,180	1,632,250
Investment costs	m Euro	47.6	95.1	142.7	190.3
Total estimated benefits for the project	m Euro	102.4	154.5	204.6	252.5
Total benefits only for the company	m Euro	56.5	96.8	135	170.7
Net present value total for the project	m Euro	29.4	26.7	23.1	18.2
Net present value for the company	m Euro	-1.7	-13.4	-26.3	-40.6

Source: Distribution company „CEZ Razpredelenie Bulgaria" AD:

The distribution companies have shown with calculations the necessary increases in the electricity prices for the end consumers to have income, which will make the introduction of smart meters possible to be financed by them.

The calculations give significant increments of retail electricity prices for the different distribution companies and different scenarios of the percent of implementation of smart meters. Highest increment is observed in the company CEZ. Data for the increment of the CEZ electricity prise in case of implementation of the smart meters in three years period for different target percentage of replaced meters (20%, 40%, 60% and 80%) with gradual increase of the number of meters, as calculated by the SEWRC is given below:

Table 98: Retail electricity price increase due to introduction of smart meters

Parameter	measure	20% SMS	40% SMS	60% SMS	80% SMS
2015	st.*/kWh	1.03	2.54	3.02	3.02
2016	st./kWh	2.58	5.49	7.51	9.16
2017	st./kWh	3.01	7.12	10.81	14.46

* 1 st.=0.01 BGN; 1 BGN = 0.51 Euro

The lowest penetration rate (20%) would lead to a gradual increase of electricity price on 1.03 st/kWh during the first year of implementation, on 2.28 st/kWh (0.016 Euro/kWh) during the second year of implementation and on 3.01 st/kWh (0.0154 Euro/kWh) during the third year of implementation, when the target 20% is reached. The last value is almost 20% of the current electricity retail price.

The average cost of the installation of one meter that was considered by the distribution companies is 119 Euro. The installation costs does not account for the load control function. In the further analysis it is assumed that the total installation cost for one smart meter, including control functions, is 220 Euro.

A plan of the distribution companies to reach replacement of 80% of electric meters by smart meters in 6-year period, from 2015 till 2020 is elaborated. The main parameters of this plan are given below:

Table 99 Investments in the Smart Meters according to the distribution companies

Penetration rate;		Annual figures 2015 - 2020	Total 2015-2020
"Energo Pro"	pcs.	161,350	968,100
"CEZ"	pcs.	272,042	1,632,250
"EVN"	pcs.	212,533	1,275,200
Total smart meters	pcs.	645,925	3,875,550
Total costs for implementation	m Euro	77.02	462.10

Source: Author's computations

The following investment costs for implementation of the plan will be needed if we taken account load factor actions.

Table 100: Modified investment plan to achieve load control action

Penetration rate;	Year	Annual figures 2015 - 2020	Total 2015-2020
Total smart meters	Pcs.	645,925	3,875,550
Total costs for implementation	m EUR	142	852

Source: Author's computations

It is assumed that these new RES will operate in the average of 1,600 h/year availability of the installed capacity and will be able to produce renewable electricity of 6.9 TWh in 2030.

The regulation capacity of the Power System would allow accept only 50% of the potential production of renewable electricity from the new capacities. Most probably these capacities will not be installed. If the smart meters are introduced and extended as proposed, all the renewable electricity will be accepted by the network starting from 2016. The additional renewable electricity will replace electricity produced from other fossil generation capacities and this replacement will result in significant CO_2 emission reduction, of 2,848 MtCO_2 in 2030. Thereby it has to highlight that the measure is necessary but not sufficient for the RES implementation into the Bulgarian power mix.

The plan implementation would allow the Power system to accommodate the other half of half of the renewable energy sources, which were reported in the previous chapter on the power grid upgrade.

Table 101: Potential emission reduction due to installation of smart meters

	Total potential installed RES capacity	Total smart grid investment s	Potential Electricity generation by the new capacities	Electricity accepted by the Power System due to SMS load control installation	Emission reduction due to acceptance of the new REE by the Power System due to installation of smart meters
Year	**MW**	**m Euro**	**GWh**	**GWh**	**1,000 CO_2**
2015	100	142	1,835	-	-
2020	200	142	3,275	1,638	1,341
2025	230	0	5,115	2,558	2,095
2030	230	0	6,955	3,478	2,848
Total 2015-2030	**4,347**	**853**	**69,678**	**33,084**	**27,096**

Source: Author's computations

7.8 Measures assessment

The ownership of the Transmission network in the country is now assigned to the National Electricity Company (NEK), which is 100% state owned company. The company is electricity trader and supplier of electricity NEK has to transfer the ownership to the Transmission System Operator.

There exists significant delay in the introduction of liberalized electricity market in the country. The market liberalization is hindered by the high level of production capacities with long-term power purchase agreements, cogeneration capacities and renewable capacities. All these capacities cannot participate to the market and as such, only a small portion of the electricity generation capacities enter the liberalized market.

8 Concluding remarks

The objective of this study was the evaluation of the socio-economic consequences of various emission reduction targets – if set at country level – in Bulgaria and Romania. Due to the current political debate about an EU-wide 40% emissions reduction target for 2030, our analysis focused on this 40% goal. At the macro level, we analysed the effects of a least cost contribution of both countries to such an EU-wide emissions reduction target and its trajectory.

In order to investigate the socio-economic consequences of various emission reduction targets, we used two main approaches. We used a **Top-Down** approach for a macroeconomic analysis of potential investments into renewable energies and energy efficiency activities, which we complemented by a **Bottom-Up** approach focused on a number of mitigation measures and their potential impacts and barriers to implementation.

The top down approach is based on the GEM-E3-NMS model which has been used to quantify the adjustment of the economic and energy system of Bulgaria and Romania when an EU wide target of 40% compared to 1990 is imposed in 2030. The emission reduction target is imposed at the EU28 emissions level and the model calculated the least cost allocation of the abatement effort among each member state considering an optimal behaviour in terms of cost structures and choices of the economic agents. The resulting equilibrium prices and quantities, incorporating both the primary and secondary effects of the policy intervention, led to an endogenous least cost allocation of the abatement effort. Different abatement options including energy efficiency, renewables and fuel switching have been considered in the analysis.

The different abatement options correspond to different scenarios, all compared against a reference scenario which serves as the benchmark. The Reference scenario reflects the main policy assumptions of the EU Energy Roadmap 2050 of the European Commission. The scenario is consistent with the EU Climate and Energy Package by 2020 and beyond 2020 it assumes a linear annual reduction of the EU ETS cap, no additional policies for energy efficiency and RES penetration, limited electrification of the transport sector and non-ETS GHG emissions to remain below the cap specified for 2020.

The different abatement options considered are: i) Fossil fuel substitution away from coal and oil, ii) Deployment of low-carbon energy sources such as RES, CCS and nuclear and iii) Energy efficiency improvements.

We concluded that the different abatement options are not equally important for each country.

In the short term, where the potential for fuel substitutions in the power generation sector and the potential for structural changes in the transport sector are limited, the majority of emission reductions are achieved through the implementation of energy efficiency measures. This is particularly the case in Romania where energy efficiency measures are considered the most cost efficient abatement option by 2030 and deliver 62% of the overall emission reductions in 2020 and 50% in 2030. The role of efficiency improvements is projected to be important but limited in Bulgaria, where the deployment of RES options (especially wind) and the rapid emergence of coal power plants equipped with CCS after 2025 are found to be the driving forces for carbon abatement.

Our results show that a contribution of Bulgaria and Romania to an economically optimal emission reduction of 40% in the EU28 till 2030 requires a 66% (Romania) and 68% (Bulgaria) emissions reduction compared to 1990 (or 23% and 18% reductions from the reference scenario) or 38% and respectively 44.5% as compared to 2005 levels.

In order for both countries to reduce their GHG emissions, important structural changes in the energy sector as well as in the industry sector are required. The Bulgarian energy sector has to contribute to more than 80% to the national emissions reduction target and the Romanian one to more than 50% in 2030. This is mainly driven by an increase of the use of renewable energy sources and an increase of the use of nuclear compared to the reference scenario.

In the short-term, energy efficiency is considered to be the most cost efficient abatement option for both countries, whereas significant fuel switching is required by 2030. Improving energy efficiency requires goods and services that are mainly domestically produced (e.g. construction sector). This increases domestic activity in the sectors providing the energy efficiency services and equipment relative to the Reference scenario. Bulgaria and Romania are importers of equipment for renewables. Therefore, a significant increase (mainly in the short term where costs of certain RES technologies are high) would deteriorate their current account.

It should be emphasized that, due to the need of modernization of the existing power generation and the grids in both countries, retrofitting of the energy sector by 2030 will be unavoidable even in the reference scenario. Social, economic as well as societal challenges are to be expected from a decrease of the production and use of domestic fossil fuels. Resulting structural changes in the mining sector have to be anticipated early and have to be supported by educational and training programs.

There are three main processes that drive emission reduction in the industry and households: (1) structural change of the economy to less energy intensive supplies and/or demands, (2) energy efficiency increase by replacement of out-dated equipment and (3) replacement of equipment before its end of life time. The replacement of machinery and durable goods as well as the energy retrofitting of existing facilities (e.g. buildings) can led to economic benefits resulting from fuel sale savings. It will be a challenge to assure that companies and consumers in both countries will use such win-win options. Therefore energy price policy has to be adapted, financing frameworks and schemes have to be improved and adequate regulatory schemes and support have to be established.

Romania and Bulgaria are two EU member states that face significant challenges in respect of economic restructuring and development. Therefore it is particularly important to evaluate the impact on GDP growth in both countries of such emissions reduction. The GDP changes in 2030 in Bulgaria and Romania (compared to the reference scenario) will be low (-0.7% in Romania and -1.3% in Bulgaria) and implies a slight decrease in the annual rate of economic growth by 0.09 and 0.05 percentage points over the period 2015-2030 for Bulgaria and Romania respectively. Considering that economic forecasts over such time horizons are highly uncertain, this means that the effects of such emissions reduction trajectories on economic growth are practically undetectable.

The results of the macroeconomic evaluation give an overview of the expected economic impact in both countries when they perform the described emissions reduction trajectories. The results show in which sectors the most efficient (economically optimal) reductions are possible but they do not define discrete measures at a micro level.

We complemented the results of the macroeconomic evaluation with a microeconomic evaluation based on a bottom up approach of possible, plausible and feasible mitigation measures in Bulgaria and Romania, which could be implemented within the next few years so that considerable GHG-emission reductions by 2030 become feasible.

After exhaustively screening possible mitigation measures, we selected, in cooperation with local experts in each country, 7 and respectively 13 measures for Romania and Bulgaria to be evaluated in depth. Our selection criteria were: (a) expected implementability of the measure, (b) expected mitigation outcome and (c) availability of data for the in-depth evaluation process. Therefore all the evaluated measures are to be considered as illustrative examples only and at a certain extent all measures are transferable to the other country.

We assess the feasibility, plausibility and implementability of the measures in the two countries by the following indicators:

- Factor capacity (availability of appropriate labour force and capital),
- Competiveness in international markets and
- Time constraints.

These illustrative 13 measures in Bulgaria and 7 in Romania lead to emission reductions of 5.5 Mt CO_2 and respectively 12 Mt CO_2 by 2030.

It is important to emphasize that not all of the measures are economically feasible from a microeconomic point of view. Abatement costs range from -35 Euro up to 350 Euro/t CO_2. The feasibility and economical efficiency of the measures depend on several conditions: e.g. the development of fuel prices and their subsidies, the development of technology costs and the development of capital markets. Furthermore, the framework of policy instruments and measures will have a significant influence on the implementability of these single measures.

An important outcome of this study is that for a macro and micro economic efficient implementation of emissions reduction targets in the relevant socio-economic sectors of Bulgaria and Romania and their efficient political support, further information and better data are desirable. More comprehensive analysis that focus on single economic players and technologies can help to increase the economic efficiency of the implementation and avoid windfall gains.

Focus on Romania

The overall emissions reduction potential of the evaluated potential mitigation measures is ca. 12 Mt CO_2 and the investment needs are ca. 6 bn Euro till 2030. In table xx section xx we summarised the investments and emission reductions per measure as well as the NPV and abatement costs.

In the residential b**uilding sector,** where we assumed that ca. 20.000 multi-family buildings would be retrofitted by 2030, under given prices for natural gas and district heating and high interest rates, retrofitting of existing multi-family blocks in Romania is not efficient from an economic point of view for the owners of dwellings (average NPV of -700 Euro and average abatement cost of 36 Euro/t$CO_{2)}$.

The retrofitting of buildings using district heating can become economical efficient if either prices for district heating increase 1% p.a. plus the interest rate is 7% instead of 8% or an interest rate decreased to 6% due to government support, while the retrofit of buildings using natural gas might become efficient if the retrofitting runs in parallel to usual modernisation and if government supports the investment.

The situation of retrofitting public buildings is similar.

While the abatement cost of both residential, public and commercial building retrofitting is high, the emissions reduction potential in the building stock of Romania is also high and therefore cannot be neglected. Additionnally, such retrofitting improves the well being of the persons using the buildings.

We took an example for potential electricity savings at household level, in the replacement of whiteware ca. 1-2 years before the end of their lifetime by more efficient appliances. Such a measure leads to moderate emissions reduction of 65,000 CO_2 in 2030. However, purchasing more energy efficient appliances is not efficient from an economic point of view for a household (average NPV for all appliances of 140 Euro; abatement costs per single average white ware is 780 Euro/t $CO_{2)}$.

Due to insufficient data availability, the estimation of the results of this measure is not fully accurate. The wide supply of different appliances and their energy consumption cannot be taken into account. However it becomes clear that a speedup of the replacement of existing white ware is not meaningful from an economic point of view. Comparatively, a regulatory measure of maximum energy consumption for white ware appliances could lead to a significant decline of electricity consumption in households.

In the e**nergy sector, we** focused on two potential mitigation measures in the Romanian energy sector. The first is the installation of 7 natural gas combined-cycle power plans (CCPP) with an aggregated installed capacity of 2,450 MW by 2019. The second measure evaluates the effects of 12 stand-alone biomass CHPs.

The estimation of these measures can only give an idea of the range of potential savings. The main reasons are the wide range of potential equipment costs (investments in Euro/kW) and the development of fuel prices. Nevertheless, both measures show an important emissions reduction potential compared to the use of coal power plants.

For the estimation of the abatement cost we compared the generation of electricity and heat of both types of fuel with the generation from a coal (lignite) power plant.

The abatement costs of a modern natural gas CCPP is ca. 20 Euro/tCO_2 and that of a biomass CHP ca. 40 Euro.

While within the transport sector significant emissions reductions are possible, user behaviour plays a major role to enable them. In this evaluation, we focused on three aspects in the freight sector: "Modernizing intermodal terminals and building new intermodal terminals (Timisoara, Suceava and Brasov)", "Modernising diesel trains (replacing engines)" and "Structural change in mode of freight transport".

Considering that modernisation of and building new intermodal terminals have no direct effect on emissions reduction, we estimated that the emission reduction potential of a modernisation of 78 diesel trains sum up to ca. 64,000 tCO_2 till 2030. The measure is economically efficient under the assumption of a diesel price for rail companies of at least 40 Euro/MWh[25] (ca. 0.40 Euro/litre) and investments of 1 m Euro per train. The abatement costs in such a case are ca. -5 Euro/t CO_2.

A shift from road to rail transport can lead to an emission reduction of ca. 1 Mt CO_2. We focused only on heavy trucks and assumed a moderate increase of inland freight transport of 3% p.a. till 2030. We further assumed that the relative share of inland road transport decreases from 48% today (52% rail) to 36% in 2030. An accurate assessment of the abatement costs is impossible due to inadequate data availability. Based on cost differences of freight transport per tonne-kilometre, we estimated that the abatement costs are ca. -5 Euro/tCO_2 but further investigations are needed.

In the Romanian industry ca. 3.4 TWh electricity is used for pumps. We estimated that at least ca. 18% of this consumption can be saved through the optimisation of existing pumps and replacement of inefficient appliances. The annual saving potential of ca. 0.63 TWh corresponds to 1.4% of the Romania electricity consumption in 2011.

Due to the wide range of potential appliances and related costs of modernisation and new pumps and the weak availability of data, we were not able to specify NPV and abatement costs. Further research is needed to analyse the overall emission reduction potential of pumps and further technical applications in the industry sector and the related costs of the implementation.

Focus on Bulgaria

The overall emission reduction potential of the evaluated measures in Bulgaria is ca. 5.5 Mt CO_2 in 2030. The necessary investment to reach this result is ca. 10 bn Euro till 2030 while the annual investments are ca. 400 m Euro till 2030.

A significant emission reduction potential results from the retrofitting of existing family and multi-family buildings as well as public and commercial buildings.

We assumed that over the period 2015-2030 ca. 176,000 family buildings and 31,000 multi-family buildings will be retrofitted. The average NPV, mainly determined by the type of energy source used for heating and the energy standard of the modernisation, is for family houses ca. 2,400 Euro and average abatement costs are -15 Euro/tCO_2. As the share of district heating and electricity as energy sources for

[25] The current end consumer price including VAT is ca. 1.3 Euro/litre.

multi-family buildings is much higher than those of single-family houses, the average abatement costs are ca. -35 Euro/t CO_2.

The situation is similar for public buildings using district heating, gasoil and natural gas for heating.

At the household level, we focused on the implementation of renewable energy sources at household level, namely solar water heating, PV solar and the use of wooden briquettes.

Under given fuel prices and interest rates, solar PV installation is not efficient for households that consume the produced electricity from an economic point of view. The abatement costs are ca. 53 Euro/tCO_2. Comparatively, the abatement costs for solar water heating (20 Euro) is lower but still positive. An increase of electricity prices by 1% p.a. and a lower interest of 6% (instead of 8%) would lead to a situation where the measures become economically efficient.

The economically efficiency of a substitution of coal by wooden briquettes depends mainly on the price development of coal and wooden briquettes. Wooden briquette prices differ between EU countries and they are highly volatile. Our calculations are based on a price of wooden briquettes of 170 Euro/t for Bulgaria. Under this assumption, prices of coal and wooden briquettes are equivalent so that the abatement costs are around zero.

The utilisation of excess heat in the Bulgarian light industry is one potential measure in the industry sector but which accounts for only minor emissions reduction potential in our analysis (28.000 t CO_2 in 2030). While we assumed only 200 utilities by 2030 in our computations, this measure is highly economically efficient for companies. The average investment for one economizer is ca. 50.000 Euro and the NPV is 155.000 Euro. The annual savings of fuel costs (mainly natural gas) are ca. 24.000 Euro if we assume constant gas prices. We consider that this kind of technology can account for more than 100.000 t CO_2 reduction by 2030 if a higher penetration can be established. For a more in depth assessment, additional research is needed.

This measure is an example of a wide range of economically efficient mitigation options in industrial production. Further examples for efficient modernisation options are motor systems and industrial heat production. We expect that in the Bulgarian economy at least 2-3 Mt CO_2 can be abated by 2030 by implementing these measures. For an analysis of this potential and an identification of supporting policy measures, a better data availability is essential.

The transport sector contributes a significant part of the GHG emissions in Bulgaria. With the Development of Intermodal freight transport, we evaluated one possible measure for this sector but with only minor emissions reductions. We expect that the electrification of the road transport will not play an important role in Bulgaria over the next two decades and therefore will not lead to significant emissions reductions, at least due to an increase of the individual transport demand related to an expected increase in wealth.

With the measure Implementation of LED lighting we gave one example for electricity savings in public and commercial buildings and in street lighting. We assumed that over the next 10 years, all lamps will be replaced by LED lamps. The average NPV is 2.0 Euro per replacement with an investment need of 34 Euro. Therefore a replacement of luminescent lamps is more economically efficient (NPV ca. 37 Euro) due to higher costs of this lamps and resulting lower difference investments. The average abatement costs are 17 Euro.

We assume that by 2030 LED lamps can replace 1.3 million street lamps. Such a replacement is economically feasible. The NPV is 50 Euro if we assume a 10-year lifetime of the lamps and it is still positive if we assume only a 7-year lifetime. The investment need for one lamp is 113 Euro. The abatement costs are around -20 Euro/t CO_2.

The two measures Grid upgrade to fit the renewable potential and Introduction of 80% smart meters with load control functions are necessary for an efficient implementation of further renewable energy capacities to the Bulgarian grid. The actual grid is widely out-dated and mainly structured for a central generation of electricity in coal, nuclear and large hydro power plants. For an implementation of renewable power plants with relatively low capacities, the grid needs to be expanded on different voltage levels. Without such expansion, new renewable capacities cannot run efficiently. On the demand side, a more efficient electricity use will support an efficient load management in the national electricity grids. A stepwise introduction of smart meters can support such efficient load management so that the overall generation capacities can be lower. Both measures can help to reduce emission by 2.8 Mt CO_2 in 2030. As this measure doesn't produce any emissions mitigation in itself, we estimate only the investment need.

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