Moving towards a 30% carbon reduction target in the EU: economic impacts in Slovakia

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Preface

This study presents an analysis of the impact on the Slovak economy of the EU tightening its climate target from a 20 to a 30% reduction of greenhouse gas emissions in 2020 compared with 1990 levels. The goal of the study is to provide arguments in the debate as to whether such a move would benefit Slovak society as a whole and an indication of which groups in society would gain and which would loose.

We would like to thank Greenpeace Central and Eastern Europe and especially Jiří Jeřábek for his support and useful comments throughout the implementation of the project. We are also very grateful to Helene Princová from the Slovak Ministry of Environment and Pavol Široký from Greenpeace, Slovakia for their helpful comments. We would also like to thank Monika Nováčková who was processing and cleaning data and contributed to define assumptions.

Any errors naturally remain the responsibility of the authors.

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Executive summary

In this study we use partial equilibrium analysis to assess the impacts on the Slovak economy of the EU tightening its climate target from a 20 to a 30% reduction in greenhouse gas emissions by 2020 as compared to 1990. The main aim of the study is to assess the costs and benefits of meeting a more stringent climate target accruing to different players in the Slovakian economy, with a sectoral breakdown of these costs. Using statistical data (Slovstat, EU ETS Registry) and forecasts (PRIMES/GAINS), a broad macro-economic analysis was performed to assess the likely impacts not only on the electricity and industrial sectors but also on welfare more generally, including budgetary revenues and benefits accruing from abatement of associated pollutant emissions.

To frame this analysis, three scenarios were formulated that are summarised in Table 1.

Table 1 **Overview of modelling assumptions in this study in the two scenarios of -20 and -30% emission reduction of greenhouse gases**

	Reference	-20%	-30%
Emissions, 2005, ETS ($MtCO_2$)	25.2		
Emissions, 2005, non-ETS ($MtCO_2$)	16.4		
Implicit target, ETS sectors (compared to 2005)		-21%	-34%
Target, non-ETS sectors (compared to 2005)		13%	5%
Price of emission allowances (€/tCO_2)		17	30
Price of CERs/ERUs (€/tCO_2)		15	25
Amount of CERs/ERUs allowed (Mt/year)		2.6	4.3

In the -30% policy scenario, ETS installations are assumed to reduce their emissions by 34% below the 2005 verified emissions. The associated price of emission allowances is expected to increase from € 17/tCO_2 to € 30/tCO_2.
It should be underlined that the companies in the EU ETS sector do not need to physically reduce GHG emissions by 34% under the -30% reduction targets. As we show througout this report, industry and the electricity sector can use various instruments in order to achieve compliance with the climate policies. These instruments include using banked allowances and engaging in trade with EUAs and CERs. The general principle of the EU ETS is not imposing individual targets but rather influencing the decisions of the operators by introducing the market price of carbon.

In this study, projections were based on statistical data from a combination of sources, including the Slovak Statistical Office (Slovstat), the EU ETS registry and PRIMES/GAINS estimates. Technical and financial data on new technologies were based on sources in the scientific literature. Two models were employed: the MESSAGE model for electricity generation in the Slovak Republic developed by the Charles University of Prague and an Emission Trading Optimisation model using adapted cost curves for the Slovakian industry developed by CE Delft. Indirect effects were analysed using input-output tables of the Slovakian economy as well as external cost estimates from the ExternE project.
The analysis in this study shows that the total overall costs to the Slovakian economy of moving to a -30% target are on average the same as those of moving to the -20% target. The direct costs of meeting the more stringent

target are expected in total to be € 5 million lower than for the -20% policy target. Higher abatement costs under a -30% scenario are mitigated by greater fuel savings in industry and the electricity sector, higher auction revenues for the government and the higher value of the substantial amount of banked credits that the companies hold. In this way, the direct costs and direct benefits of the -30% scenario exactly outweigh each other.

Table 2 **Overview of direct costs and benefits associated with the -30% policy scenario compared to the -20% policy scenario in 2020 (€ mln)**

	Costs	Benefits	Totals
Industry	-117	0	-117
Electricity	-22	152	130
Government	0	56	56
Consumers/services	-65	0	-65
Not specified			
Totals	**-204**	**209**	**5**

Although the net costs are similar, there is a direct transfer of income from industry and consumers to the electricity sector and the government. The higher costs for industry relate mainly to the rise in electricity prices. In general, it is to be expected that these costs will be passed through, as they are equal for all companies in the EU. If companies are able to pass through these higher costs, consumers pay more and industry less. In addition, industry may profit from investments in abatement. It is anticipated that the additional investment of € 0.7 billion between 2009-2020 could raise GDP levels by about 0.7% in 2020, with most of this coming about through gains of the industry sector.

Additional indirect benefits can be expected as a result of improved air quality, as investments in energy-saving technologies generally act to lower emissions of SO_2, NO_x, CO and PM_{10} as well.

The total table of identified indirect costs and benefits associated with the -30% policy scenario is given below (Table 3).

Table 3 **Overview of quantified indirect costs and benefits associated with the -30% policy scenario compared to the -20% policy scenario in 2020 in this study (€ mln)**

	Benefits	Costs
Investments in abatement technology in industry	50	
Higher prices of industrial goods	120	
Loss of output due to higher prices in industry	0	-170
Net indirect impacts in rest of the economy	20	-60
Improved air quality	36	
Loss in tax revenues		-0.3
Totals	**226**	**-230**

It should be noted that the indirect effects are much more uncertain than the direct effects. However, our analysis shows that with the indirect effects the costs and benefits tend to outweigh each other.

For the electricity sector, the consequences of the -30% policy scenario relate mainly to fuel inputs. Cumulative consumption of most fuels remains unchanged. In the -30% scenario the share of browncoal is reduced from 4.5% in the Reference Scenario to 2.5% in the -30% policy scenario. The share of biomass rises from 5.3 to 5.9% in 2020. Furthermore, the use of natural gas is increased, while oil will no longer be used to generate electricity and heat. For all scenarios we assume that electricity production from nuclear energy is kept constant.

Total investments in the electricity sector between 2012 and 2020 equal € 80 million over and above the -20% policy scenario. The electricity sector will pass through the bulk of the opportunity costs of the auctioned allowances. This creates a net profit for the electricity sector, as the marginal producer (with the highest CO_2 costs) is expected to set the price on the electricity market. As the marginal costs of CO_2 are higher than the average costs of investments and fuel switches, electricity producers are expected to see a net gain of about € 152 million in 2020.

The industry sector will undertake additional investments of about € 700 million between 2012 and 2020. The main investments will occur in the iron and steel industry, refineries and pulp and paper. In 2020 industrial costs will be about € 117 million higher than in the -20% policy scenario, owing mainly to higher electricity costs. In our modelling, the price of electricity in the reference scenario would be equal to 14.3 €/MWh[1] and would increase to 18.4 and 26 Euro in the 20% and 30% scenarios, respectively. If industry passes through the higher costs in product prices, it will experience a fall in demand. On the other hand, demand will increase owing to the investment in abatement technologies. As our input-output analysis shows, the sum of these two effects is in general likely to be neutral for the Slovak economy as a whole.

[1] Price electricity in base-scenario is the expected price of electricity in 2020 if the Renewable Energy Directive is executed but there is no ETS.

Acronyms

AIC	Annualised investment cost (*present value in 2007 million Euro)*
CO_2fct	CO_2 emission factor (*t CO_2 per MWh)*
ETS	Emission Trading System
ETS sector	Group of facilities that are regulated within EU ETS Directive
FC	Fuel costs (*million Euro 2007 prices)*
HPP	Hydro power plant
HP	Heating plants for district heat supply and/or for industrial steam supply
CHP	Combined heat and power generation
ETOM	Emission Trading Optimisation Module
newRE	New installations based on renewable energy use
O&M	Operational and maintenance costs (*million Euro 2007 prices)*
RE shr	Share of electricity generated from renewable sources
RE	Renewable energy resource
TPP	Thermal power plant
TTPnew	New installations of thermal power plants
MESSAGE	Model for Energy Supply Strategy Alternatives and their General Environmental Impacts
IIASA	International Institute for Applied Systems Analysis
CCS	Carbon capture and storage technology
EUAs	EU Allowance Unit for one tonne of CO_2 used within the EU ETS
CERs	Certified Emission Reductions, 'carbon offsets' issued in return for a reduction of atmospheric carbon emissions through projects under the Kyoto Protocol's Clean Development Mechanism (http://www.carbonpositive.net/viewarticle.aspx?articleID=44#CDM). One CER equates an emission reduction of one tonne of CO_2

1 Introduction

1.1 An EU-wide debate

Over the last few years scientists and politicians engaged with climate change have reached a consensus that in order to prevent disastrous effects of global warming, the average temperature on Earth should increase by no more than two degrees Celsius above pre-industrial levels. If the global community is to secure this target, far more drastic steps need to be taken than on offer under existing climate policies. Unless we make an immediate start with curbing greenhouse gas (GHG) emissions faster than envisaged under the EU's present target of a 20% reduction, the future costs of abatement may become prohibitively high.

In March 2007 the European Council endorsed an EU objective of a 30% reduction in GHG emissions by 2020 provided that other developed countries committed themselves to comparable emission reductions and economically more advanced developing countries contributed adequately according to their responsibilities and respective capabilities. Now, four years on, there is wide debate as to whether the EU should adopt this more stringent emissions target or stick to the more conservative goal of -20%.

The economic effects in the EU of moving to a -30% goal have been assessed by the European Commission (EC, 2010) as well as in several independent studies (e.g. Potsdam Institute, 2010; CE, 2010c). In general, these studies indicate that the estimated economic impacts of going for -30% are modest and that benefits are anticipated in terms of increased employment and improved air quality. In many ways the costs of accepting a -30% target in the EU are now, in 2011, similar to the costs of accepting a -20% target in 2007. This is mostly because the economic crisis has already reduced the emissions of large installations in the ETS by 7-9% compared with business as usual (CE, 2010c). Taking into account the influence of banked allowances and the potential for covering emission targets using CDM, various studies have shown that the costs today of securing a -30% target are no greater than those of securing a -20% target before the economic crisis began.

This is not to say that the impacts of moving to a -30% target will be evenly spread across the regions of the EU. This study aims to investigate the specific impacts on the economy of the Slovak Republic.

1.2 The Slovak situation

Since the fall of communism the Slovak economy has undergone a period of rapid transition. Originally focussed on heavy industry and agriculture, it has become transformed into a service-based economy with a strong industrial focus on car manufacturing and electrical engineering. With its Volkswagen, PSA Peugeot Citroën and Kia Motors assembly plants, Slovakia now stands as the world's largest per capita producer of cars. For several years Slovakia had the highest economic growth rate of any OECD country.

In 1990 Slovakia's GHG emissions totalled 73.9 Mt of CO_2 eq. The EEA estimate for total GHG emissions in 2009 is 46 Mt CO_2 eq., which means a decrease of approximately 38% over this period. This downward trend has been driven mainly by reductions in the energy and agriculture sectors, which in 2008 were responsible for 52.1 and 6.3% of emissions, respectively. In particular, major decreases were observed in emissions from public power and heat generation and from energy use in manufacturing industries, households and services. Emissions from transport, waste and industrial processes increased (EEA, 2011).

The industrial sector is the largest energy consumer in Slovakia, representing about 34% of energy consumption (EEAP, 2007). Given significant industrial investments primarily in automobile and electrical engineering industry, a reduction of absolute energy consumption in industry is not expected in the coming years.

1.3 Methodology

The methodology adopted in this project is a form of quantitative cost analysis (also known as partial equilibrium analysis) that has become popular in many studies addressing the costs to industry of climate change policies. This method, originally developed by Climate Strategies (Hourcade *et al.*, 2007)[2] has been further refined in other studies, such as Öko-Institut (2008); CE (2008) and CE (2009)[3]. The main aim of these studies is to estimate the additional costs to the business sector of meeting particular climate targets, with a strong focus on sectoral differences in these costs. By combining this sectoral cost analysis with wider macro-economic approaches such as input-output models, a more accurate perspective can be obtained on the societal costs associated with a particular level of ambition of climate policies. As these costs are sectorally disaggregated and fully transparent with respect to calculation method and data sources, they tend to be better understood by policy makers.[4]

This approach breaks down into two separate calculations. First, the impact of climate targets on Slovak business and industry are calculated, thereby distinguishing between sectors that do and do not participate in the European Emission Trading Scheme (ETS). For an individual country like Slovakia, the ETS targets, price and allocation method can be considered exogenous. For example, if the Slovak economy manages to become a net seller of emission allowances in the ETS, this will hardly impact on the price of an allowance, as Slovakia is only a very small player in the overall scheme.

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2 Climate Strategies, 2007. Jean-Charles Hourcade, Damien Demaill, Karsten Neuhoff, Misato Sato; (contributing authors: Michael Grubb, Felix Matthes, Verena Graichen). Climate Strategies Report: Differentiation and Dynamics of EU ETS Industrial competitiveness impacts.

3 CE, 2008. Impacts on Competitiveness from the EU ETS: An analysis of the Dutch Industry, Sander de Bruyn *et al.*, Delft, 2008. Report for the Ministry of Finance.
CE, 2009. Impacts on Dutch industry from sharpening the EU CO_2 target from -20 to -30%. Report for the Ministry of Economic Affairs, Sander de Bruyn *et al.*, Delft, 2009.

4 In a follow-up study this structure can moreover often be augmented with a more detailed economic model (a general equilibrium model like ENV-Linkages or an econometric model like E3ME or GINFORS).

This first step combines two modelling approaches. First, the impacts of the climate policies on the electricity supply have been modelled using the model MESSAGE by the Charles University in Prague. This is a linear dynamic optimisation energy model, which searches for a optimal, i.e. the least cost, technology and fuel mix that leads to exogenously given electricity demand and demand for fuel under given economic, environmental, technical and policy constraints.

Second, the influence of climate policies, together with the estimated impacts in the electricity market have been modelled using a cost-database from CE Delft for industrial sectors that was adapted to the Slovakian situation.

As a second step, the wider economic impacts on the Slovak economy are explored using a variety of techniques. Estimation of wider effects includes impacts on import/export, budget revenues related to EU ETS auctioning and auxiliary benefits related to lower emissions of various pollutants and related external costs[5]. Some of these additional effects are calculated with the help of the MESSAGE model[6], while for other impacts, Input-Output tables of the Slovakian economy have been used.

The general assumptions underlying this modelling approach are:
- Forecasts of development in the economic structure using a forecast based on PRIMES baseline scenario in the EU Energy Trend 2030–2009 update (EC, 2010).
- Forecasts of the autonomous development in the energy efficiency of industrial processes were obtained from the EU Data Base on Energy Saving Potentials (Fraunhofer *et al*., 2009).
- Forecast of the exogenous demand for electricity, fuel used for district and residential heat, and fuel used by remaining economic sectors over the period 2009-2020 in the linear optimisation model having the annual rates of 1.37%, -1.58%, and of the range between 0 to 6.2% respectively.
- Both the discount rates and the cost of capital of 8% and a risk premium of 2% for industrial sectors.
- Average lifetime of installations context specific changing between 10-30 years. Technical and economic data of new technologies are taken from ‘Mapping Renewable Energy Pathways towards 2020: EU Roadmap’ (EREC, 2011) and ‘Renewable Energy Industry Roadmap for Slovakia: REPAP 2020’ (Resch *et al.*, 2010).
- Future price of fuels obtained from Slovak Energy Regulatory Office, and in the case of missing data, as an average of price trends as reported in IEA-World energy Outlook, 2009, EU Energy Trends to 2030 - update, 2009, Jaeger *et al.*, 2011 and Nezi and Capros, 2011.
- All prices are in 2007 constant prices.

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5 Quantification of the external costs attributable to airborne pollutants is based on default damage cost values per tonne of pollutant released in Slovakia as they were calculated within the EU funded project NEEDS (Preiss *et al.*, 2009).

6 For a description of the MESSAGE model, see Annex B.

2 Current and predicted trends

2.1 Introduction

This chapter presents the cost changes for various sectors of the Slovak economy (both ETS and non-ETS sectors) that can be expected if the EU's GHG emission reduction target is raised from -20 to -30% in 2020, compared with the 1990 emissions level. We first present data on the current situation and then the projections for the respective target levels. These forecasts are based on several crucial assumptions concerning, among other things, the price of carbon emission allowances (EUAs) and the use of flexible Kyoto mechanisms (CDMs). It should be stressed that the results are characterised by a high degree of uncertainty and would obviously differ if different assumptions were made. At the same time, however, every effort has been made to provide the best possible estimates, supported by a range of literature sources and discussions with experts (including Slovak experts).

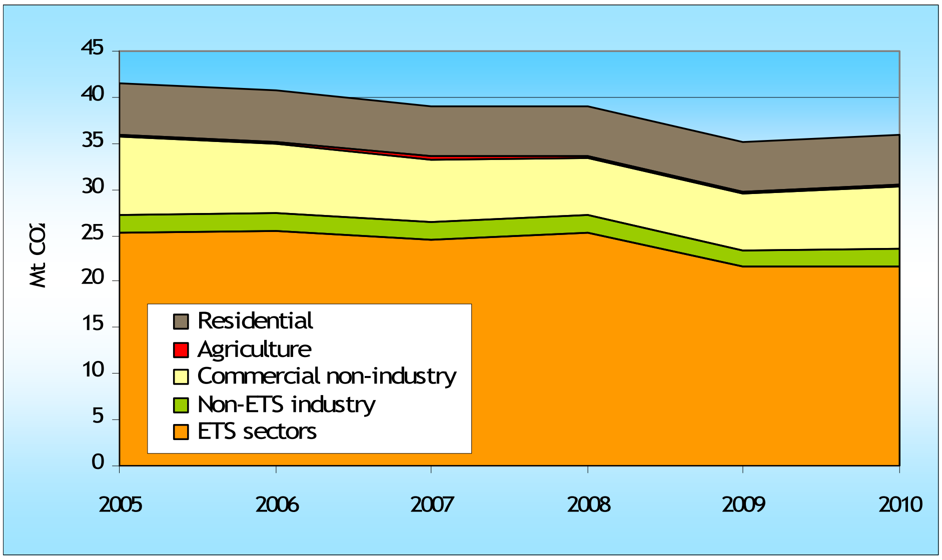
2.2 Current situation with respect to emissions

Data on historical trends and the current situation were derived from various sources, including EU statistics, Slovak Statistical Office (Slovstat) data and Eurostat.

2.2.1 Overall emissions

Emissions of CO_2 in the Slovak Republic showed a general decline since 2005 (Figure 1). Emissions especially declined in 2009 due to the effect of the economic crisis, but also without economic crisis emissions had declined with almost 6% in 2008 compared to 2005. The economic crisis implied that emissions in 2009 declined with more than 10% compared to the previous year.

Figure 1 Emissions of CO_2 (Mt) for the Slovak Republic, 2005-2010

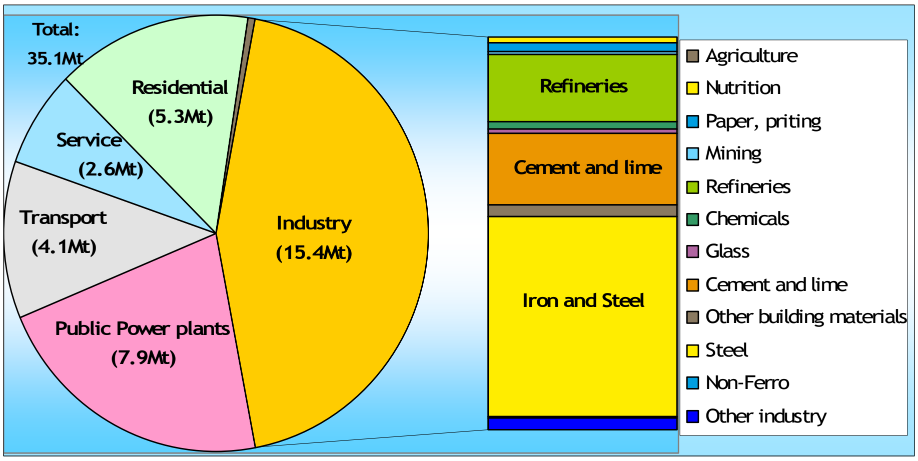


Source: Own estimate based on NEIS, EU Registry on ETS emissions. Data for 2010 are preliminary estimates.

The share of each sector in total emissions in 2009 is given in Figure 2. Industry is still the largest emitter of CO_2 in the Slovak Republic, contributing to about 40% of total CO_2 emissions. Public power plants contributed to 22% of 2009 emissions, and smaller shares are taken by the residential sector (15%), commercial transport and the service sector.

Three sectors of the Slovakian economy are in total responsible for 86% of industrial emissions. Iron and steel is the largest emitter of CO_2 emissions in industry, contributing to more than 50% of industrial emissions. Other important sectors include refineries and cement and lime production. The remainder of industrial sectors in the Slovakian economy are relatively small contributors to overall CO_2 emissions.[7]

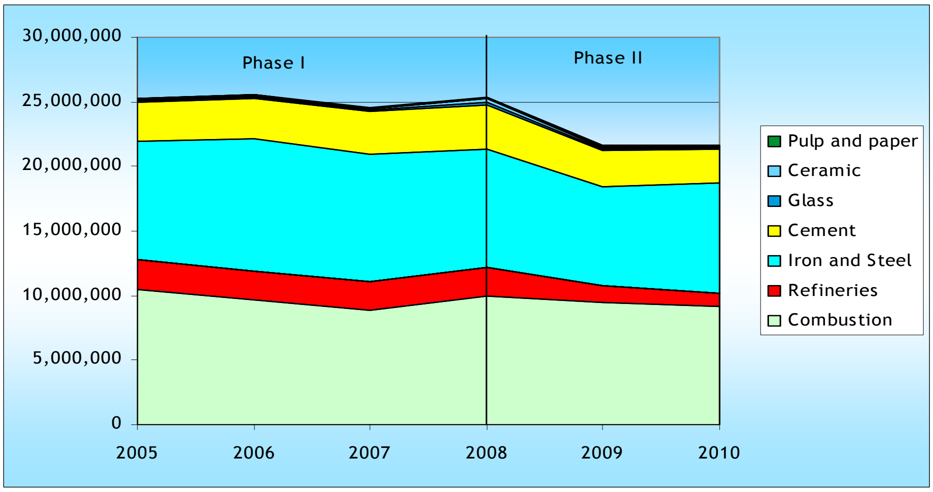
Figure 2 Distribution of 2009 emissions of CO_2 to various sectors



2.2.2 EU ETS sectors

As a result of the economic crisis, in Slovakia EU ETS sectors have showed a steady decline in emissions over the past few years (Figure 3).

Figure 3 Recent trends in tCO_2 eq. verified emissions of Slovak ETS sectors (tCO_2)



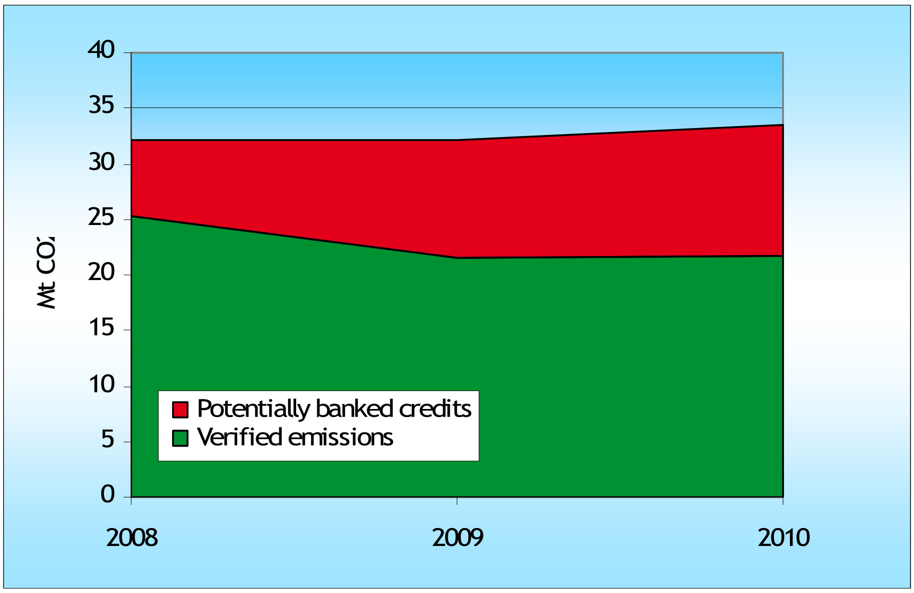
Source: EU Registry database on EU ETS emissions, retrieved on 15-4-2011.

[7] One should notice that this is an estimation of the emission situation in Slovak Republic combining various sources, but that a potential error of approximately 10% should be taken into account at the level of individual sectors.

Among ETS sectors, combustion is the largest single contributor to emissions, with a share remaining more or less constant over the years. In Phase II of the EU ETS more installations were included in the scheme, however, which means for combustion that the data before and after 2008 are not entirely comparable. Iron and steel production is the second largest contributing sector. Owing to the economic crisis, in 2009 the emissions of this sector fell by nearly 18% compared to 2008. Cement production, another key sector, has hardly been affected by the economic crisis, though. In 2010 emissions from Slovnaft, Slovakia's only refinery plant, were only half what they were in the years 2005-2008. Although a number of units are reported in the pulp and paper, ceramic and glass sectors, these have a negligible influence on total emissions from ETS sectors. Nonetheless, 2010 emissions from the glass and ceramic sectors were also down by nearly 50% compared to 2008.

In general, the allocated emissions were much higher than the verified emissions. Between 2008 and 2010, verified emissions were only about 2/3 of allocated emissions, creating a surplus of EUAs equalling more than 28 Mt CO_2 (see Figure 4). Most of these EUAs are most likely banked for use in Phase 3 of the EU ETS.

Figure 4 Difference between allocated and verified emissions in the EU ETS 2008-2010 (MtCO_2)



Slovakia is the only country in the EU that has introduced a corporate tax on profits from over-allocated emission allowances, effectively taxing the windfall profits on over-allocated emissions away. This tax is in operation for surplus allowances in the years 2011 and 2012. Although companies have sued the Slovakian government for introducing this tax, as being in violation with the EU ETS Directive, we assume in the quantitative analysis of this study that the tax will be in operation still.[8]

8 See: http://spectator.sme.sk/articles/view/43365/10/brussels_asks_slovakia_to_clarify_carbon_dioxide_emissions_allowance_tax.html.

2.3 Situation in 2020: general picture

The main goal of our analysis is to show the difference between the impact on the Slovak economy of a -20 and -30% target regarding reduction in GHG emissions. These targets refer to different ambition in climate policies. In order to compare the costs and benefits of these targets, a reference scenario was constructed (REF) in which no quantitative climate targets have been formulated. It is important to note that the REF scenario up to 2020 includes not only modernisation of the existing production capital and improvement in energy efficiency but also compliance with the Renewable Energy Directive (2009/28/EC). Thus the final costs and benefits of moving to a -30% target will be in this study assessed both in relation to the -20% target and to the REF scenario.

2.3.1 REF scenario without ETS

In estimating future emissions the future structure of the Slovak economy is of crucial importance, especially that of heavily emitting sectors like electricity production, iron and steel and to a lesser extent refineries and cement. Predictions by both GAINS (using the PRIMES 2010 forecasts) and the 'Energy Efficiency Potentials' project indicate that the future of iron and steel production and refineries, in particular, is not entirely rosy. It is estimated that future production will remain at the 2010 level, with no recovery of iron and steel or refinery capacity. This is a crucial assumption for future emission scenarios. Production of cement and chemicals, on the other hand, will still be growing.

Based on the existing situation in 2009, a projection was made of the likely future development of emissions in Slovakia, based primarily on the PRIMES forecasts used to underpin the 'Energy Trends 2030' projections of the European Commission. In addition, sectoral trends on energy efficiency were adopted from the EU's 'Energy Efficiency Potentials' project (Fraunhofer *et al.*, 2009)[9]. More elaboration on the forecasts can be found in Annex A.

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[9] See also: http://www.eepotential.eu/esd.php.

Table 4 Index numbers (2010 = 100) of the forecasts for the reference scenario

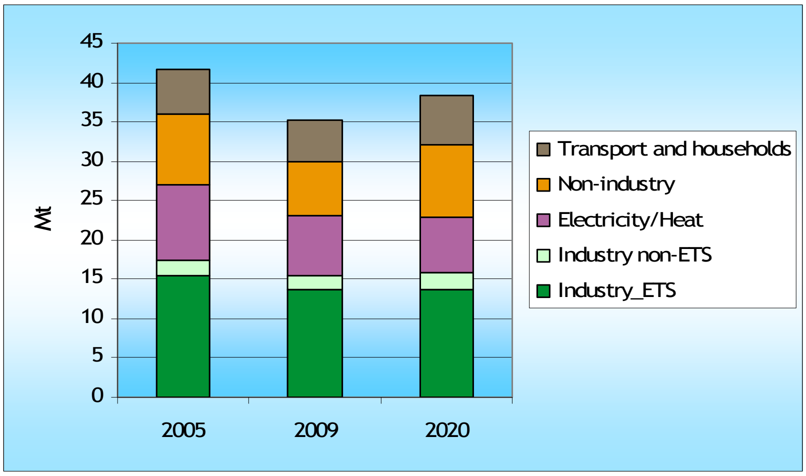
	Value added			Physical production			Energy intensity			CO_2 emissions		
	2009	2015	2020	2009	2015	2020	2009	2015	2020	2009	2015	2020
Industry	93	129	157	na	na	na	101	81	69	92	105	109
Nutrition	100	129	148	na	na	na	101	99	97	99	127	144
Paper, printing	100	129	159	100	105	105	101	100	99	99	105	104
Mining	100	103	88	na	na	na	101	86	82	99	89	72
Refineries	106	122	127	na	na	na	101	86	82	108	105	104
Chemicals	92	133	163	Na	na	na	101	84	74	91	112	120
Glass	97	128	155	97	106	107	101	100	99	96	106	106
Cement and lime	97	117	134	104	107	112	100	95	93	105	101	104
Cerramics, building materials	94	132	160	Na	na	na	101	100	99	93	132	159
Steel	90	112	121	90	96	89	101	99	98	89	95	87
Aluminium	91	116	129	91	103	103	101	99	99	90	102	102
Non-ferro, other	91	116	129	91	103	103	101	99	99	90	102	102
Other industry	85	140	168	na	na	Na	101	99	97	91	139	163
Electricity public pp	100	108	104	99	106	113	na	na	na	107	93	87
Economy	95	129	155	na	na	na	na	na	na	98	104	104

Source: Own calculations based on PRIMES, 2010; Slovstat; EU ETS Registry and EEE potentials.
na = not taken into account in the calculations or no data available.

In these REF forecasts, it is assumed that the Energy Directive will still be executed, but climate policies affecting industry (EU ETS and auxiliary policies) will come to a halt. Subsequently we immediately see that the emissions in the public electricity sector are still decreasing from around 7.6 Mt in 2009 to 5.8 Mt in 2020 (see Figure 5). This in spite of the increase in electricity demand (and supply) of 1.37% annually compared to 2009 leading to 30.4 TWh production in 2020 (compared with 26.2 TWh in 2009).

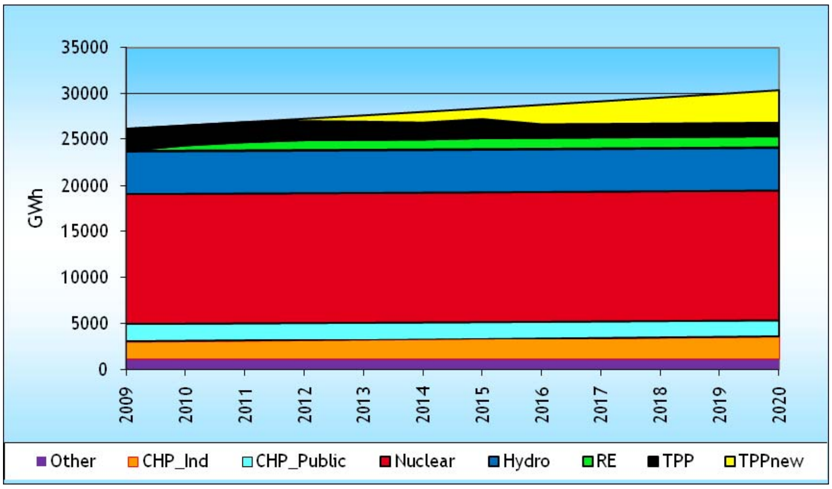
Figure 5 below shows the development of total emissions in the Slovak Republic under the REF scenario and compares them to 2005 and 2009 emissions. Although the REF emissions (37.3 Mt in 2020) are higher than in 2009 due to the impact of economic growth, they are still considerably below 2005 emissions (41.7 Mt). As the CO_2 reduction targets are set against the base year 2005, this will have a big impact on the reduction efforts for the Slovakian economy, as explained in the next paragraph.

Figure 5 **CO_2 emissions of the Slovak Republic in 2005, 2009 and 2020 under REF without ETS and quantitative targets for non-ETS sectors**



Electricity generation in the Slovak Republic will remain dominated by the use of nuclear energy. In the REF scenario it is assumed that its 54% share in 2009 will go down slightly at about 46% in the year 2020. Underneath lays the assumption that the new nuclear blocks in PP Mochovce will be replacing old blocks that are going to phase out in PP Jaslovské Bohunice so that the total 2009 level of 14 TWh produced nuclear energy remains constant over the period.[10]

Figure 6 **Electricity generation at REF scenario**



Note: Hydro – hydro power plants; TPP – thermal power plants recently operated; RE – new renewable energy sources; TPPnew – newly installed thermal power plants; CHP_Public and CHP_Ind – public or industrial respectively combined generation cycles. Data in the base 2009 year in the baseline scenario of the MESSAGE model therefore just describe real Slovak energy market and economy in that year.

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10 In addition it is assumed that electricity generation in both small privately owned plants (about 1.2 TWh), which use electricity for their own use and is not supplied to national grid, and in large hydropower plants (about 4.6 TWh) will remain in absolute terms constant over whole period. About 70 MW of newly installed biomass PP since 2015 – as it has been announced by ENEL – are included in the baseline with whole investment allocated to the year 2014, when we assume the investment of € 2,225 per kW (EREC, 2011).

Despite the increase in electricity supply, public power plants in total will use only 4% of fuels more in 2020 than in 2009 – mainly through the increase in biomass. Consumption of hard and browncoal in public power plants will decrease by 47 or 42% respectively and heating oil by 35%. The already very small CO_2 emission intensity to generate electricity drops to 0.124 tCO_2/MWh in 2020 – i.e. far beyond the EC benchmark that is set at the level of 0.465 t CO_2 per MWh.[11]

New installations would require new spending; annualised capital cost will rise from € 15 million to € 82 million with additional € 32 million of O&M cost in 2020, and fuel cost will be 43% higher. In our modelling, the price of electricity in the reference scenario would be equal to 14.3 €/MWh[12] in 2020 and would increase to 18.4 and 26 euro in 2020 in the 20 and 30% scenarios, respectively.[13]

2.3.2 Policy scenarios and situation in 2020

The EC Impact Assessment (EC, 2010) was used to establish the CO_2 reduction plans for the Slovak Republic. The present goal of -20% suggests in 2020 a reduction of -21% in the ETS sectors and a relative increase of 13% for the non-ETS sectors in Slovakia, equalling to a total reduction of 6% compared to 2005. While the targets for the non-ETS sectors are specific national targets given by the effort sharing decisions, there are no specific national targets for ETS sectors so we use here the overall -21% target as a calculation tool to derive the impacts of the ETS regulation on Slovakian ETS participants.

For the -30% target, the quantitative goals have not been set. While there is a general agreement that the move of -20 to -30% would imply a reduction of -34% compared to 2005 emissions for the ETS sectors, the relative goal for the non-ETS sectors would depend on the agreed burden sharing. There is some divergence in the literature what this would imply for the non-ETS sectors in Slovakia. While, for example, Wifo (2011) assumes a reduction of 6% for Slovakia compared to 2005, IEEP (2011), on the other hand, assumes an increase of 10%. However, both papers form a departure from the present allocation rules in the ETS/non-ETS sectors and burden sharing. If the same principles would apply, the ceiling in the non-ETS sectors would rather be in the line of +4-+5% compared to the emission level of 2005. For our calculations we assume a ceiling in the non-ETS sectors of 5% in 2020 compared to 2005 in the -30% scenario. In the -30% target it is assumed that the Renewable Energy Directive remains unaltered.

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11 This is actually an effect of changes in used technology; new installations of thermal power plant that will generate about 3.6 TWh of electricity in 2020 will be mostly using natural gas, and new renewable energy sources that will contribute by another 1.2 TWh will be dominantly using biomass and wind power. Some recently operated thermal power plants will expire and as a result electricity generated from recently operated thermal power plants will be continuously decreasing from 2.46 TWh in 2009 to 1.54 TWh in 2020.

12 Price electricity in Base-scenario is the expected price of electricity in 2020 if the Renewable Energy Directive is executed but there is no ETS.

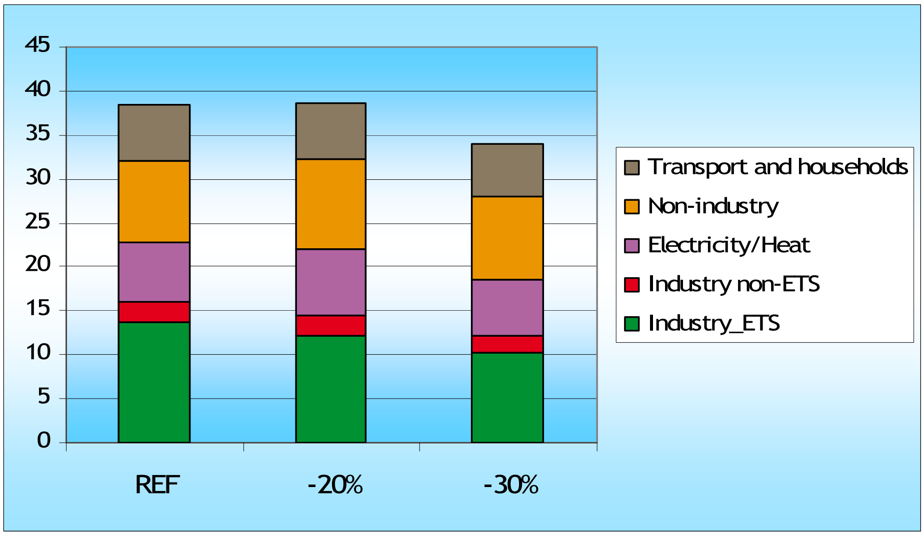
13 Compared to the situation in 2009, the electricity price will rise with € 17.9 per MWh in the -30% policy scenario.

Table 5 **Targets and implied reductions in ETS and non-ETS sectors in Slovakia**

	Targets in % in 2020		In $MtCO_2$		Targets		Mt CO_2 compared to 2020 REF	
			2005	2020	2020	2020	2020	2020
Target	-20%	-30%		REF	-20%	-30%	-20%	-30%
ETS*	-21%	-34%	25.2	20.7	19.9	16.6	0.8	4.1
Non-ETS	13%	5%	16.5	17.2	18.6	17.3	-1.4	-0.1
Total	-6%	-17%	41.7	38.0	38.5	33.9	-0.6	4.1

If the two scenarios are depicted in a graph, one can immediately see that the -20% target does not result in reductions compared to REF.
This implies that overall, the Slovakian economy can reach the 20% reduction target without additional efforts. This result is largely due to the expected decrease in electricity emissions due to the implementation of the Renewable Energy Directive. For industry, however, the targets still imply an absolute reduction. Hence, one can conclude that, although on average, the 20% reduction target does not include an effort for the Slovak Republic, there can be sectoral impacts, mainly for industry, that still will have an impact on the economy of the Slovak Republic. In addition, an influence can be expected from the fact that under the -20% reduction target, CO_2 is being priced through the EU ETS and additional impacts from this can be expected as well. These sectoral impacts for the -20% reduction target are analysed in Paragraph 2.4. The impacts of the -30% reduction target are being described in Chapter 3.

Figure 7 **CO_2 emissions of the Slovak Republic in 2020 under REF and administrative emission ceilings for a -20% target and a -30% target ($MtCO_2$)**



2.3.3 CO_2 price developments

The EU ETS price was taken from EC (2009), which reports that the EU estimates a price of € 17/t in 2020 with a scenario of a 20% reduction in GHG emissions and a price of € 30/t in 2020 for a 30% reduction, with a proportionate increase in the use of CDM. As the price of the ETS will be largely independent for the Slovakian economy, we assume here to take this price into account for the present analysis.

One should take into account the following caveat:

- The full impact of the economic crisis on the price developments in the ETS has not been taken into account. However, one may expect that eventual impacts will be dealt with in Phase 4 of the EU ETS, after 2020, and that credits in Phase 3 can be transferred to Phase 4, so that in 2020 the price still can be expected to be € 17/tCO_2 if the targets in Phase 4 are adjusted equally.

Not only the price of EUAs matter, but also the prices of CERs. In the past, prices of CER were merely following the EUA price with a decreasing spread between the two prices. For the two scenarios we assume a CER price of € 15/tCO_2 for the -20% reduction target and € 25/tCO_2 for the -30% reduction target (see also Annex A.6). Eventual consequences from different price levels are qualitatively assessed in Paragraph 3.5.

2.3.4 Cost categories

In this study three gross cost categories for industry and electricity companies are being distinguished. They can be listed as follows:

1. **Indirect cost increases** due to an increase in the price of electricity used by end-consumers. Using the MESSAGE model the impact of the -20 and -30% policy scenarios were calculated compared to REF.
2. **Direct cost increase due to auctions.** Directive 2009/29/EC and the following comitology process have identified both the criteria and the sectors that will be subject to auctioning emissions in 2020. These criteria, applied to NACE 4 of each installation in the Slovakian ETS Registry, have been applied to determine the amount of emissions that will be auctioned in the future. In addition, the electricity part of CHP plants will also fall under auctioning.
3. **Direct cost increase due to meeting the targets**
   The costs comprise of various measures that companies can implement to comply with the environmental regulation. These measures include technological abatement measures, the purchase of CER/ERUs or EUAs or the use of banked credits. Which set of these elements can be chosen for Slovakia, will be elaborated in the next sub-paragraph.

2.3.5 Company behaviour on cost minimisation

Companies will try to minimise the costs of complying with the environmental regulations. For the companies that do fall under the ETS system, this means that the company will try to find the minimal costs of four possible ways how to comply with the environmental regulations:

The use of banked credits

The use of banked credits in the possession of ETS companies due to the over-allocation in Phase 2. Comparing the allocated and verified emissions between 2008-2010 we see that a total amount of 28 Mt emissions can be considered as being over-allocated in Phase 2. After 2011 to 2012, companies still receive around 18.5 million allowances over their actual needs. However, since these over-allocations are subject to an 80% tax, we assume that they will not be used for compliance in the Phase 3.

We assume here that 80% of the over-allocated emissions from 2008-2010 will be banked for use in Phase 3 by industry and public electricity (see Annex C). Furthermore we assume here that the banked emissions will be used in equal annual amounts in the years from 2013 to 2020.
Table 6 gives an overview of the amount of banked credits that is available for companies to reduce emissions in Phase 3 of the EU ETS according to the calculations in this project (see Annex A.3 and Annex C). In absolute amounts,

the iron and steel and public power plants (included in the category combustion) have the largest amount of banked allowances at their disposal for use in Phase 3 of the ETS. In relative amounts, especially the ceramics and paper sectors have received very substantial over-allocation.

Table 6 **Estimate of banked allowances (in $MtCO_2$) for various sectors due to over-allocation (2008-2010) assuming 80% of over-allocated resources is being banked**

	Emissions ETS 2009	Banked allowances 2008-2010	In % of 2009 emissions
Combustion*	8.70	12.08	139%
Refineries	2.11	0.83	40%
Iron and steel	7.61	6.22	82%
Cement	2.83	2.90	102%
Glass	0.13	0.09	67%
Ceramic	0.10	0.73	727%
Pulp and paper	0.08	0.41	498%
Others	0.04	0.09	231%
Totals	21.60	23.35	108%

* Combustion refers to both combustion in power generation plants (NACE 40), in industrial CHP (NACE 15-37) and other installations (e.g. hospitals).

For the calculations in this project, the combustion category has been divided among the various industrial sectors and power generation.

Use of flexible mechanisms

Phase 3 of the EU ETS allows the use of flexible mechanisms, such as CDM/JI. The Commission limits the total amounts of CDM/ERU[14] by three criteria: (1) 11% of the total allocated emissions in 2008-2012 for use in the period 2008-2020 - which would at the level of the EU imply about 1,120 Mt; (2) for countries that allowed more CERs to enter the market during Phase 2, they can keep this figure for the total amount of CERs to be used between 2008 and 2020. This put an upward bound of total 1,400 Mt on the use of CERs between 2008-2020. (3) the CERs that can be used can, alternatively, be calculated as 50% of the reduction in 2008-2020 compared to 2005. Given the CDM/JI offsets that have been released so far, this would in total also amount to about 1,300 Mt of CDM use between 2008 and 2020. For this study we use the latter approach and assume that half of the required reduction compared to 2005 levels can be covered by CDM for the ETS installations.

Table 7 gives an overview of the maximum allowed use of CDM for the various sectors in this study.

[14] In the remainder of this study we will only use CDM and CERs to categorise the impact of flexible mechanisms.

Table 7 Maximum amount of use of flexible mechanisms under the two scenarios

	Emissions (Mt)		Maximum CERs (Mt)	
	2005	ow. % ETS	-20%	-30%
Nutrition	0.35	47%	0.02	0.03
Paper, printing	0.32	91%	0.03	0.05
Mining	0.09	52%	0.00	0.01
Refineries	2.51	91%	0.24	0.39
Chemicals	0.46	3%	0.00	0.00
Glass	0.17	84%	0.01	0.02
Cement and lime	3.04	100%	0.32	0.52
Other building materials	0.36	34%	0.01	0.02
Steel	9.37	97%	0.96	1.55
Non-ferro	0.13	0%	0.00	0.00
Other industry	0.58	28%	0.02	0.03
Public power plants	9.67	92%	0.93	1.51
Total	27.04		2.55	4.13

It is important to note that the use of CERs may minimize the costs of compliance for companies. As the price of CERs follows closely the price of EUAs, companies have to make real costs for purchasing CERs. However, they still may want to do this because buying CERs may be more profitable than applying abatement measures. This is supported by up-to-date compliance data published by the European Commission: in the years 2008-2010 Slovakian installations surrendered in total 7.7 millions CERs.

Governments could use a limited amount of flexible mechanisms (CDM/JI) to comply with the reduction targets for non-ETS sectors. As the emissions volume involved is rather small, it was decided to neglect this in the quantitative analysis.

Abatement measures

For the remaining reductions in ETS sectors, abatement measures can be taken within industry and public electricity. Underlying the quantitative calculations in this study, databases covering more than 800 reduction measures have been taken into account. For emissions in the public power generation and iron and steel industry, specific measures for the Slovakian situations have been considered. For the other sectors, the measures have been identified by a combination of negative cost measures as identified in PRIMES, 2010 and the ECN database on abatement measures in the various industrial sectors.
The ECN database has been reviewed and adapted to the specific Slovakian situation (see also Annex A.8).

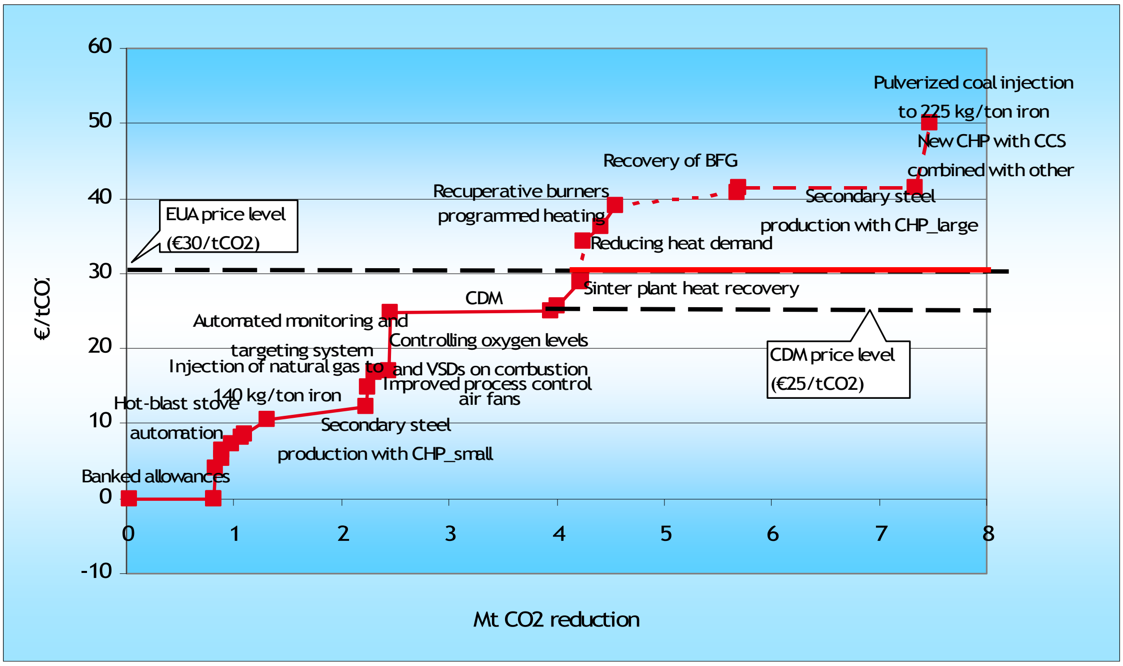
Buying allowances

Buying allowances. If the above three categories do not result in enough reductions, additional reductions need to be bought by buying EUAs on the market. This is by definition the most costly option available for companies that fall under the ETS regime. The marginal direct costs of meeting the two policy scenarios are therefore by definition equivalent to the EUA price level.

Modelling company behaviour

Which of these four options will be used depends on the relative prices. It is assumed that all companies strive at cost minimisation, seeking the cheapest options available given the climate policies constraints. This optimisation problem can, in the end, be represented as a cost-curve. Below we present the cost-curve for the iron and steel sector as an example. We see that the iron and steel sector will first use the banked allowances to comply with the regulations (0.8 Mton), and subsequently use technical measures up to the CDM price level (which in this Figure is shown as € 25/tCO_2 for a 30% reduction target). After the maximum amount of CDM is being used, the sector will continue to implement technological measures up to the level where it is cheaper to buy EUAs instead of reducing emissions. For any remaining emission reductions, the sector will buy EUAs instead of applying the more expensive abatement measures.

Figure 8 **Example of the marginal cost-curve underlying the iron and steel sector in this study**



However, companies may not be targeted at reducing the maximum amount of emissions, even if emission abatement may entail a benefit to the company. This is because firms are not rationally profit maximising agents and an information bias for energy efficiency investments exists. Firms must have regard to many other considerations - product quality, marketing, competitors' actions, other production inputs, occupational health and safety, to name a few - not just the benefits and costs of greater energy efficiency. As long as no strict environmental regulations enforce the implementation of energy efficiency measures, firms may simply disregard cost-effective options as attention is focused on other areas (Productivity Commission, 2005). This is particularly likely to happen in sectors where energy costs are only a small fraction of total production costs (OECD/IEA, 2007).

Non-rational behaviour of companies is taken into account in this study by assuming that firms will only start to investigate abatement opportunities if the policy scenario does force them to do this. For ETS companies, this implies that if the allocated allowances to sectors in 2020 are wide enough for covering their forecasted emissions (including the banked allowances that can be surrendered), these firms will not undertake abatement measures because of the information bias described above.

For the non-ETS sectors in our cost calculations it has been assumed that for industries falling partly under ETS and partly not, the Slovak government will create a level playing field by equalising the average costs for both types of companies in order to prevent competitive distortions in the national economy. However, the targets to comply with will still differ between ETS and non-ETS companies.

The cost minimisation problem was solved with the help of the Emission Trading Optimisation Module (ETOM), a simple spreadsheet tool that was developed by CE Delft for the Dutch ministry of Economic Affairs (CE, 2009).

2.3.6 Company behaviour on cost changes

The environmental regulation will alter the cost structure of companies. While for some sectors, the proposed environmental policy scenarios may entail a net benefit (mostly due to the possession of a large amount of banked credits), other companies may still have to make additional costs. These costs are potential costs for a company, as some companies may be able to pass through a certain amount of these costs to the customers.

Whether companies pass through the costs of EU ETS has been a widely debated topic (see e.g. Sijm, 2006; Walker, 2006; CE, 2010a; CE, 2010b). There are in general three views on this topic:

1. Companies do not pass through the additional costs of the environmental regulation and additional costs due to this regulation are hence reducing profits.
2. Companies pass through the average costs of the environmental regulation. All additional costs will hence be passed onto the customers and due to higher prices companies will face a loss in demand.
3. Companies pass through the marginal costs of the environmental regulation. The marginal costs for companies falling under the EU ETS is by definition equal to the price of an EUA (see also in Figure 8 above). For sectors that obtain free allowances, this will generate windfall profits.

Economic theory predicts that companies will be engaged in marginal cost pricing (Scenario 3). While taking profit-maximising decisions companies in principle take into account opportunity costs i.e. they try to use the resources in their most profitable alternatives. This relates also to carbon allowances i.e. if selling them is more profitable than keeping them for own use, the companies will most likely engage in allowance trade. According to economic theory the market value (price) of carbon allowances can be viewed as a sort of (marginal) cost, even if the allowances are received for free. These costs will be (partly) passed on to the consumers – the extent of this phenomenon depends on the market structure and on the elasticities of demand and supply curves. In literature devoted to carbon trading passing the value of freely obtained carbon allowances to product prices is referred to as windfall profits. Huge windfall profits have been estimated especially in the electricity sector all over Europe from the start of the EU ETS (see e.g. Sijm *et al.*, 2006). Other studies did find signs of substantial cost-pass-through of the opportunity costs of freely obtained allowances in other sectors, such as refineries, iron and steel, chemicals and various building materials (see e.g. CE, 2010c; ZEW, 2010a; ZEW, 2010b). These result in very substantial windfall profits in ETS sectors.

We would like to stress that windfall profits arise not necessarily because companies deliberately aim to make them but because prices are determined by the marginal unit in a given market – and carbon costs are often real tangible costs for marginal companies (CE, 2010b). However, business strongly claims they cannot pass through any costs. These claims are raised especially in sectors where foreign competition might be threatening for keeping market shares i.e. where the danger of carbon leakage (shifting the industry to the countries with less stringent climate policies) is more real.

The scope of this study is not broad enough to analyse the issue of cost-pass-through in more detail. Instead, we take average cost-pass-through as a central value and shortly discuss the impacts if no costs, or marginal costs will be passed through. The impact of cost-pass-through is being regarded in this study as an indirect impact from the environmental regulation and are being discussed in Paragraph 3.4.

2.4 The situation in 2020 under a move to a -20% target

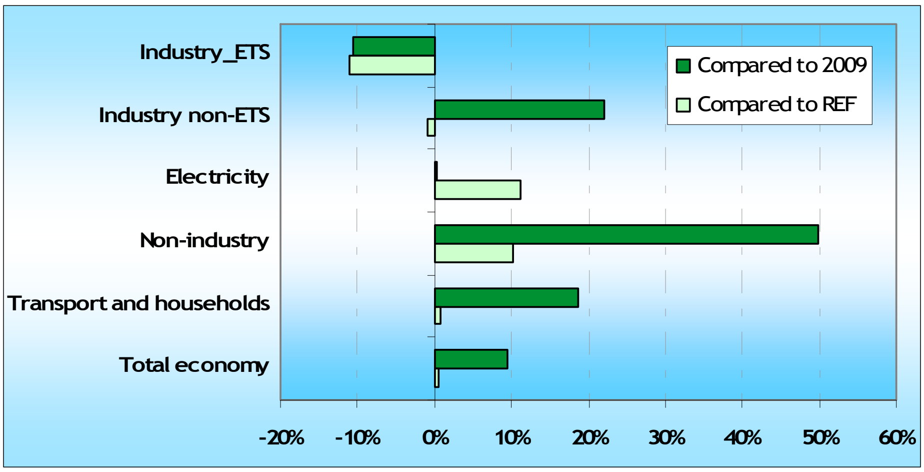
2.4.1 Current policy scenario

The -20% target can be regarded as the current policy scenario in this study. The policy scenario and associated targets are based on the EU ETS Directive and the Effort Sharing Decision. This implies that the EU as a whole will achieve 20% reduction in emissions compared to 1990. For the Slovakian economy this would imply that in 2020, installations in the non-ETS sectors have an absolute cap 13% higher than 2005 levels. The installations that fall under the EU ETS will receive less emission allowances for free and have to pay a price for every ton of CO_2.

Companies operating in the ETS sector have to lower their administrative emissions by 21% compared to 2005.[15] In the non-ETS sectors, emissions are still allowed to increase by 13% compared to 2005 due to the burden sharing.

In Paragraph 2.3 it was concluded that the 20% reduction target overall does not result in additional CO_2 emission reductions for the Slovak economy as the target is higher than the estimated Business as Usual scenario. This is primarily due to the substantial decrease of emissions between 2005 and 2009. The following figure gives the efforts of the various sectors of the Slovakian economy and compares them with 2009 actual emissions and the forecasted REF scenario.

Figure 9 Comparison of required changes in emissions in 2020 compared to REF and 2009 emissions



15 We call this administrative emissions because these are emissions that need to be covered by EUAs or CERs. The real emissions can be higher (see below).

We see that industry under the ETS regime still has to reduce its emissions. The targets for the electricity sector are equivalent to the present (2009) emissions.

Even though at the level of the national economy, the -20% scenario does not constitute a reduction effort, emissions may still decrease compared to REF because of two reasons:

1. Some sectors, notably industry, still have to reduce their emissions, which may come at a certain cost for the economy.
2. Business, electricity producers and consumers still are being faced with the fact that CO_2 emissions have a price and this will have an influence on their operations.

These two impacts will be discussed in the subsequent paragraphs for the various sectors.

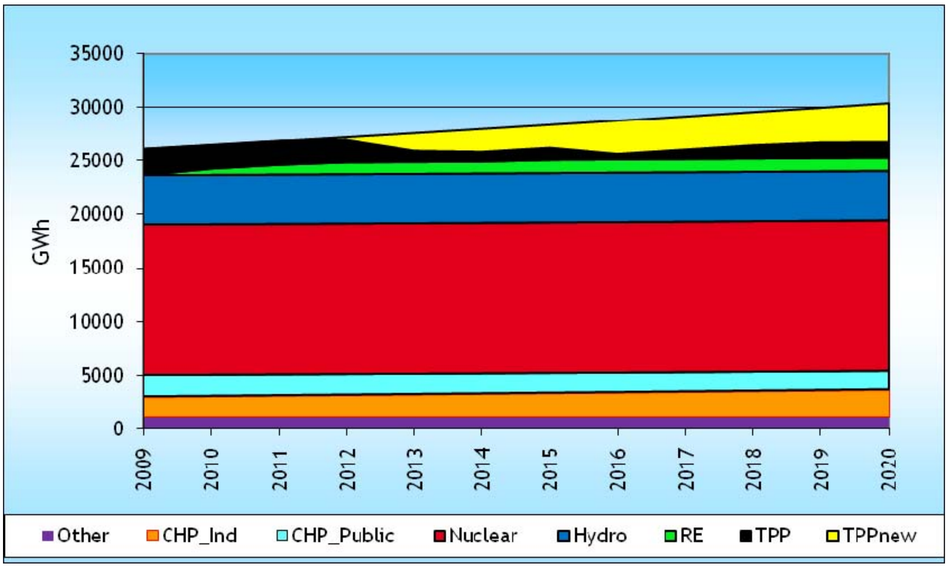
2.4.2 Emissions and costs for the electricity sector

Due to the impact of the Renewable Energy Directive, emissions from the electricity sector (NACE 40) are already supposed to decrease from 7.6 Mt in 2009 to 5.8 Mt in 2020. In the -20% policy scenario additional efforts will be undertaken because CO_2 has a price for the electricity producers creating additional incentives for power producers to reduce the emissions and switch to low-carbon technologies for power generation.

Calculations from the MESSAGE model show that a CO_2 allowance price of € 17/tCO_2 does have an influence on the technologies that are being applied to supply electricity and heat, but only in combined heat power cycles. In public CHP plants, about 0,4 Mt of emissions will be abated in 2020 compared to the reference situation. However, In the public power sector, the allowance price of € 17/tCO_2 will only speed up the investment resulting in fuel switch from browncoal to natural gas although the situation in the year 2020 will be the same. Since we compare in this study the end-situation in 2020, rather than the entire period, it seems as if the EUA price has no impact on the power sector, but due to the faster implementation of investments for fuel switches, CO_2 emissions go down over the entire period (2013-2020) with an additional 3.9 Mt CO_2.

Compared to REF, more new plants will be opened and the share of existing coal and browncoal fired power plants is diminished. Figure 10 gives the new structure of the public power market. Introducing the price of € 17 per tonne of CO_2 in the ETS sector implies a shift in electricity generating technologies, specifically from recently operated coal-firing thermal power plants to new thermal power plants using natural gas and partly to new renewable sources. Public electricity generation in nuclear and hydro power plants remains constant over the years as set in our assumption.

Figure 10 Electricity supply in Slovak Republic under the -20% target



Achieving this emission reduction will not imply any additional investment compared to the BAU, however, due to the fact that new installations will be implemented earlier as a result of emission allowance price, annualised capital cost will be € 35 million larger than in the baseline scenario over the period 2009-2020. These investment costs can be regained by saving on fuel inputs in the power sector, which was estimated to be € 38 million between 2009-2020. The total balance of payments for the electricity sector under the -20% target is summarised in Table 8.

Table 8 Cost changes in 2020 for the public electricity generation sector (NACE 40) under the -20% target compared to REF

	Unit	REF	-20%	-20% compared to REF
Emission price	€/tCO_2	0	17	
Total investments (2009-2020)	€ mln	834	834	0
Annualised investments	€ mln	74	74	0
O&M	€ mln	20	20	0
Fuel costs	€ mln	254	254	0
CO_2 auctions	€ mln	0	53	53
Total potential cost rise compared to 2009	**€ mln**	**348**	**401**	**53**
Increase electricity price compared to 2009	*€/MWh*	*13.9*	*16.0*	*2.1*
Costs passed through	€ mln	285	367	82
Net costs electricity	*€ mln*	*62*	*33*	**-29**

* Results only apply to electricity generation in public power plants.
Heat and CHP generated electricity in the NACE 40 sector are not included.

In 2020, the cost structure under the REF scenario is exactly the same as under the -20% scenario except for the price of CO_2 allowances. The power sector will have to pay an estimated € 53 million due to auctioning its emissions under the EU ETS in 2020 compared to the REF-scenario where no ETS takes place.[16]

The total potential cost rise of the power sector is equivalent to € 53 million compared to REF. However, part of this cost rise can be recovered because the electricity prices will rise because the power sector will partly pass through the costs. The amount of costs passed through depend on the marginal price increase of electricity and the pass-through rate. The economic literature finds compelling evidence that power sector is able to pass through the marginal costs of emission allowances (see e.g. Sijm *et al.*, 2006), so in this study we conservatively assumed a pass through rate of 80%. Taking the marginal price increases from the analysis in Annex A.7), we obtain the insight that under the -20% scenario a larger part of the additional investment costs can be passed through than in the reference scenario.

2.4.3 Emissions and costs for industry

Emissions in industry will be reduced under the -20% scenario with approximately 0.9 Mt CO_2 in 2020 compared to REF. This impact is solely due to abatement measures because of the emission price of € 17/tCO_2. The reduction takes place especially in the refineries sector, which is capable of reducing 18% of its emissions compared to REF, and in the cement sector. Other sectors have less impetus to reduce emissions according to this scenario.[17] For the sector building materials, the targets are particular stringent compared to REF. This is because this sector is assumed to grow substantially according to the forecasts (see Paragraph 2.3).

The overall industrial effort under an emission price of € 17/tCO_2 does not result in the desired reduction under this scenario – however due to the existence of a large amount of banked credits, Slovakian industry is very well capable of meeting the policy constraints.

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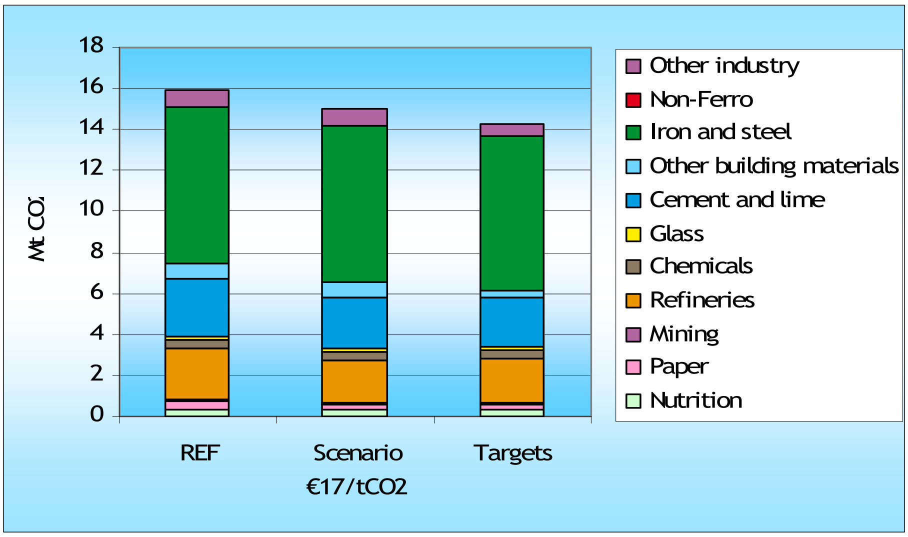
16 In addition, an estimated € 30-40 million auctioned credits must be paid for installations that supply heat and CHP installations in the public power sector.

17 One should notice that the sectors, for which the -20% target does not constitute a binding cap, need not reduce their emissions. That is why in our scenario the iron and steel sector, for example, does not reduce emissions under the -20% scenario because it can stay within the estimated allocated emissions by using the banked credits during 2008-2010.

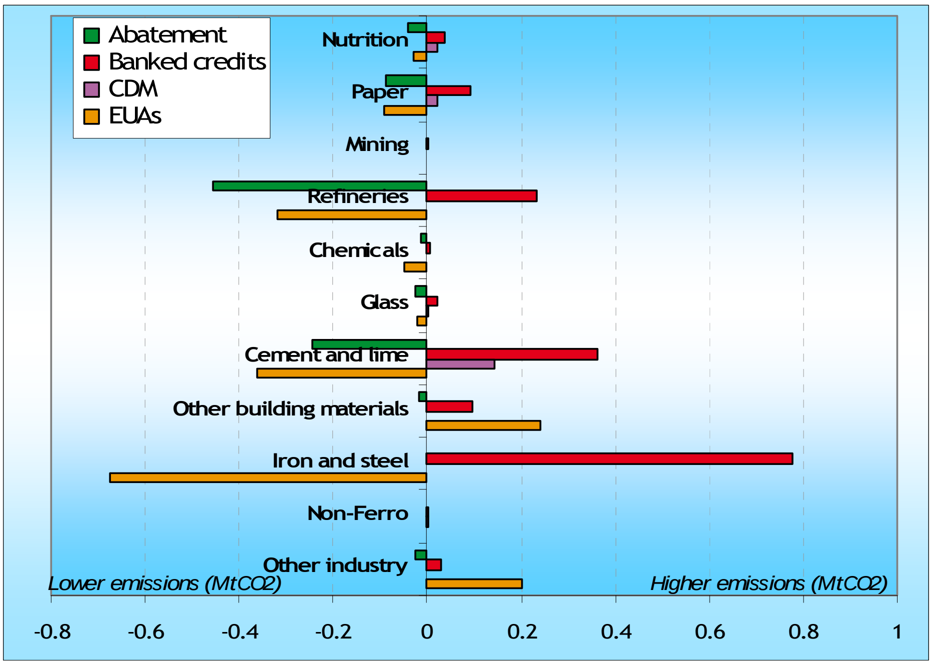
Figure 11 Overall emission development in the -20% policy scenario



Note: Targets refer to hypothetical targets. For ETS installations no quantitative targets exist. We assume here that the overall EU goal for ETS installations applies to every Slovakian installation.

The way the sectors of the Slovakian economy comply with the environmental regulation under the -20% scenario is depicted in the following graph. This graph is the result from the cost minimisation model ETOM that was used to estimate the company behaviour.

Figure 12 Impact of the regulation on sectoral behaviour (Mt CO_2)



This figure gives the changes compared to the REF for the various sectors because of their demand for EUAs compared with the supply through the allocated emissions under the -20% policy scenario in 2020. Some sectors, like building materials and other industry will meet the targets primarily by buying

EUAs on the ETS markets. Other sectors, notably the refineries and cement sector have a large potential for abatement of emissions cheaper than € 17/tCO_2. Such measures also exist in the iron and steel sector, but this sector does not have to reduce its emissions compared to REF due to the fact that the iron and steel sector can hand in the large share of banked allowances.
Table 9 gives an overview of the costs compared to REF for the -20% policy target.

Table 9 Overview of costs for industry under the -20% policy target

	Auctions*	Abatement	CDM	Buying/selling EUAs*	Electricity costs	Totals
Nutrition	1.5	0.4	0.3	-0.5	1.5	3.2
Paper	1.5	0.8	0.3	-1.6	3.7	4.7
Mining	0.0	0.0	0.0	0.0	0.5	0.5
Refineries	3.3	0.1	0.0	-5.4	0.0	-2.0
Chemicals	0.1	0.0	0.0	-0.8	7.0	6.3
Glass	0.3	0.2	0.0	-0.3	0.2	0.4
Cement and lime	0.0	1.9	2.2	-6.2	1.7	-0.4
Other building materials	0.1	0.2	0.0	4.1	1.5	5.9
Iron and steel	0.0	0.0	0.0	-11.4	17.5	6.1
Non-ferro	0.0	0.0	0.0	-0.1	0.2	0.2
Other industry	2.5	0.2	0.0	3.4	13.1	19.3
Total industry	**9.4**	**3.7**	**2.9**	**-18.9**	**47.1**	**44.1**

* These categories refer to gross positions at the ETS market. For example, auction refers to the amount of allowances that fall under an auctioning regime, while the Buying/selling of EUAs refer to the question if the sector, on overall, becomes a net seller or buyer of EUAs. If the individual company would be a seller of EUAs, it would of course use the own EUAs to reduce the auctioning costs. Therefore, the number in these tables refer to gross positions at the ETS market, not net-positions.

They show that under the -20% policy scenario total costs for industry (ETS and non-ETS) are about € 44 million. This is equivalent to 0.2% of industrial value added in 2020. If Slovakian industry is able to pass through its cost to the consumers, most of these costs will not be borne by industry, but by consumers (see also Chapter 3). For the economy as a whole it is important to notice that virtually all of these costs (auctions and higher electricity costs) are transfers to other sectors of the economy (see also Paragraph 2.4.6) and are therefore not considered as an economic loss.

2.4.4 Impacts on other sectors

The service sector, agriculture sector, transport and residential emissions and electricity and heat generation - not part of the ETS - equal about 16.0 Mt in REF. The emission ceiling for the -20% target is equivalent to 16.5 Mt implying that Slovakia would comply with the Effort Sharing Decision.

2.4.5 Impacts for the government

The government will receive auction revenues. In 2020, 100% of the public power plants, part of the ETS and the electricity part of industrial CHP installations will fall under an auctioning regime. For the relatively small share of emissions from non-exposed sectors, 70% of emissions in 2020 will fall under the auctioning regime. Sectors deemed with risk of carbon leakage will receive the allowances free up to the benchmark.

88% of the total emission allowances for auctioning will be distributed to member states based on its 2005 verified emissions. Another 12% will go to Member States with lower GDP and who have made significant reductions beyond their Kyoto commitments.

Although the allocation criteria for division of auction revenues are clear, it is not clear yet how much allowances will be auctioned in 2020. Estimates in some not-yet-published literature[18] show quite some differences. There are various problems, ranging from determining the fuel mix in electricity production to estimating the amount of CHP in industrial installations.

For our calculations we took the following premises:
- 88% of the total amount of auctioned allowances in 2020 is based on 79% of 2005 verified emissions for Slovakian installations that will fall under an auction regime. This implies that 79% of 2005 verified emissions in the power sector will fall under the auctioning regime, as well as the electricity part of other installations and 70% of remaining emissions of the sectors not deemed to carbon leakage according to the criteria by the Commissions.
- The 12% redistribution of allowances based on GDP is taken from an analysis from data from the ARRA calculation tool by Öko-Institut (see Annex C).[19]
- Aviation is taken from the ARRA calculation tool by the Öko-Institut.

The results are depicted in Table 10.

Table 10 Auction revenues in the Slovak Republic in 2020 of a -20% target excluding industry benchmarks

	Units	2005	2020
Targets ETS	%		-21%
Supply of allowances			
Electricity and heat in PP	$MtCO_2$	7.4	5.2
Industry (CHP)	$MtCO_2$	0.48	0.33
Industry (process)	$MtCO_2$	0.17	0.12
EU-wide redistribution	$MtCO_2$		1.3
Aviation	$MtCO_2$		0.03
Total supply	$MtCO_2$		7.0
Emission price	€/tCO_2		17
Auction revenues	**€ mln**		**119**
Demand for allowances			
Sold to public power	€ mln		53
Sold to industry	€ mln		9
Sold to other/foreign	€ mln		56

Total auction revenues for the Slovak government accrue to € 119 million in this calculation in 2020. This is higher than the figures by Climate Strategies has suggested (see e.g. Cooper and Grubb, 2011) but lower than the figures from the Öko-institut (see Annex C).

Not all allowances that are administratively allocated to the Slovakian government will be sold to Slovakian installations in our model calculations.

[18] We received publications not for citation from Climate Strategies and Öko-Institut.

[19] An Excel spreadsheet provided by Greenpeace Central and Eastern Europe.

Because the forecasts under REF show already decreasing CO_2 emissions for public electricity producers, the auction revenues for the Slovak economy are larger than the amount of money spend on buying EUAs by the industry and electricity sectors. The remainder of this will be sold to other installations, to industry for meeting benchmarks and to foreign demanders of EUAs. Calculations of the government revenues do not include the potential revenues related to windfall profit tax. According to this regulation, 80% of income obtained from selling over-allocated allowances in 2011 and 2012 would be taxed in Slovakia. Currently there are strong objections raised against the tax from the industry and it is not entirely clear if the tax will become reality and how should the eventual revenues be estimated. Therefore, we decided to leave the potential tax revenues out of the calculations. For more details about the estimates of auctioning revenues see Annex C.

CO_2 abatement measures will also lead to reduction in emission of other air pollutants such as SO_2, NO_x, CO or particulate matters (see next section for details). These reductions are however very small, about 1 to 2% compared to the BAU 2020 level, and loss on governmental revenue from emission charges is small, about € 0.1 million compared to the BAU 2020 level or € 0.6 million if they are compared to the 2009 reference level.

3 Impacts of a -30% target

3.1 Introduction

This chapter analyses the impacts on emissions and the Slovakian economy of moving to a -30% target compared to the -20% target.

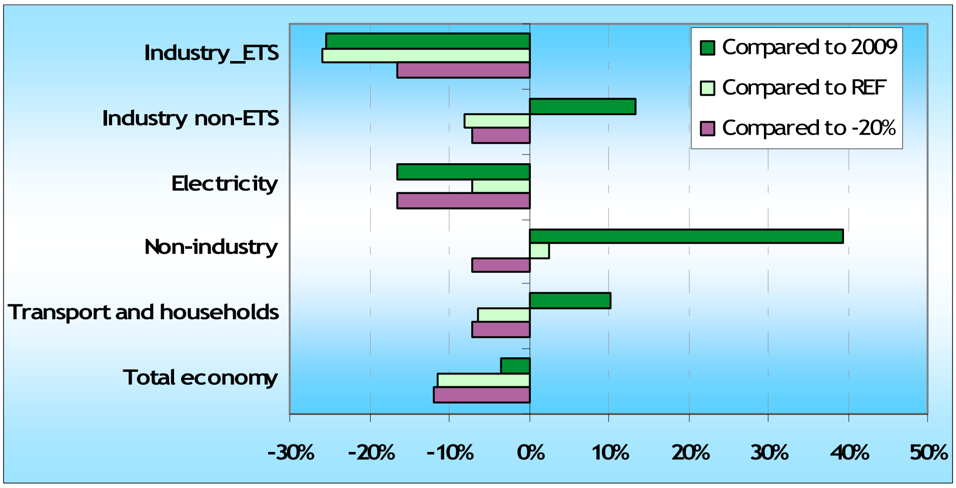
3.2 Overall impacts

3.2.1 Administrative targets

In the -30% policy scenario, targets are tightened compared to the -20% policy scenario. ETS sectors must, on average, reduce their emissions with 34% because less allowances are being issued. The non-ETS sectors reduce their allowed increase from 13% under the -20% target to +5%.

The impact of the new policy plan targets on the various sectors of the Slovakian economy is given in Figure 13.

Figure 13 **Comparison of required changes in emissions in 2020 compared to REF and 2009 emissions and the -20% policy scenario**

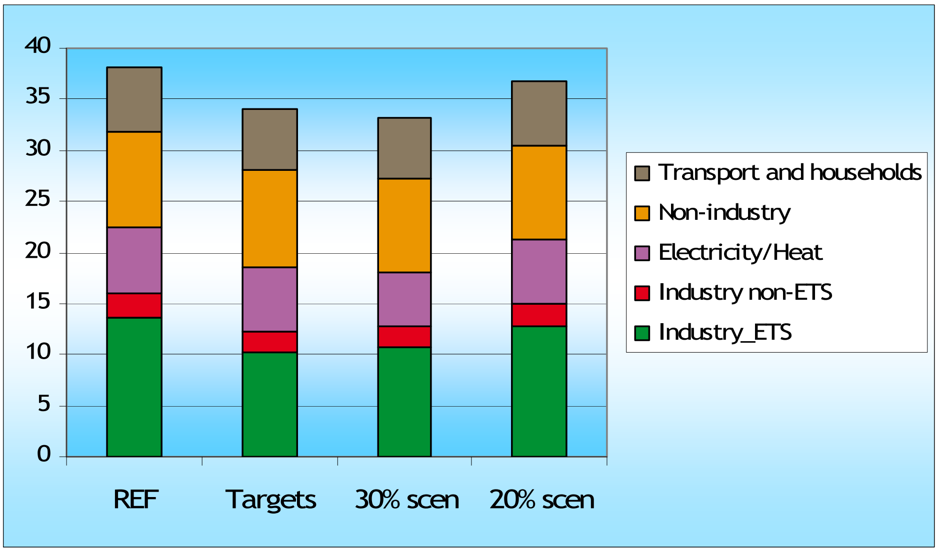


We see that all sectors have additional efforts to face compared to the -20% scenario. These efforts are larger for sectors that fall under the EU ETS. Compared to the present situation (emissions 2009), industry and electricity companies that fall under the ETS have to reduce their emissions in absolute terms. The other sectors are still allowed to increase their emissions.

3.2.2 Emissions

Because of the administrative targets and the higher CO_2 emission price of € 30/tCO_2, emissions will fall in the Slovak Republic, both compared to the REF and the -20% policy scenario. Figure 14 gives an overview of the estimated influences.

Figure 14 Actual emissions in 2020 (Mt CO_2) for the Slovak economy



Under the -30% policy scenario, emissions will be decreased in total with 5.5 Mt compared to the REF. Moreover, the implicit price of carbon of € 30/tCO_2 assures that additional reduction efforts are undertaken, especially in the electricity sector. In Paragraph 3.3 the impacts in the various sectors are elaborated in more detail.

Total use of fuel differs only slightly among all three scenarios. Compared with the BAU scenario, in which cumulative fuel consumption during the whole period amounts to 7,125 PJ, cumulative fuel use decreases by 0.4% and by 0.8% in the 20% target scenario and in the 30% target scenario, respectively. There is a shift from brown coal to biomass in both policy scenarios, more noticeable in the 30% target scenario. Cumulative consumption over the period of all other fuels remains almost unchanged. In the target year 2020, the fuel consumption in the 30% policy scenario is by 0.9% lower than in the two other scenarios (the 20% target scenario, and REF), in which fuel use is just same. The share of brown coal on the fuel mix in 2020 goes down from 4.5% in BAU over 4.2% in 20% policy to 2.5% in 30% policy scenario. Share of biomass goes up from 5.3% over 5.8% to 5.9% in 2020. As a result, biomass is used more in terms of PJ than brown coal in all scenarios including REF in the year 2020. Natural gas is used slightly less in the 20% target scenario and quite much more in the 30% policy than in the REF in 2020. The share of all other fuels remains about same in all three scenarios in 2020.

3.2.3 Direct costs and benefits

The following table gives an overview of the direct costs associated with the -30% policy scenario. These costs have been assembled running the MESSAGE and ETOM models that underlay the quantitative approach in this study. They refer only to the direct costs associated with the policy scenario: eventual indirect effects (e.g. larger investments, loss of market shares due to higher prices) are not taken into account.

Table 11 **Net costs and benefits in 2020 of direct impacts from the -30% policy scenario compared to REF and the -20% reduction target (€ mln)**

	Compared to REF			Compared to -20%		
	Costs	Benefits	Totals	Costs	Benefits	Totals
Industry	-116	0	**-116**	-72	0	**-72**
Electricity	-75	142	**68**	-22	60	**38**
Government	0	175	**175**	0	56	**56**
Other sectors	-53	0	**-53**	-18	0	**-18**
Totals	**-244**	**318**	**73**	**-112**	**117**	**5**

Note: Costs are (-) and benefits are (+).

Table 11 shows that the total benefits of the -30% policy scenario compared to REF accrue to € 73 million annually for the Slovak economy. Industry has costs equivalent to € 116 million. Some of these costs constitute revenues for other groups: industry pays a total of € 16 million to the government for the auctions and € 89 million to the electricity sector for the higher price of electricity. The electricity sector will have € 75 million higher costs in 2020 compared to REF, but receives benefits for the increase in the electricity price equivalent to € 142 million. Due to the emission price of € 30/tCO_2, the marginal price of electricity is expected to rise higher than the average cost increase creating additional revenues for power producers. The government will receive in total € 175 million of auction revenues, while the other sectors (service sector and consumers) pay for the higher electricity prices.

When we compare the direct cost estimates to the -20% scenario it is remarkable that the costs are roughly similar at the level of the national economy. The -30% target is in total € 5 million cheaper than the -20% target when referred to direct costs. The government and the electricity sector are better off in the -30% scenario while industry, the service sector and consumers have to pay more. However, the impacts on the industry sector can be mitigated if industry is able to pass through its costs to consumers – which is likely given the empirical evidence on cost-pass-through so far.
In Paragraph 3.4 we will elaborate on this in more detail.

3.3 Detailed sectoral impacts

In this section, the impacts on the various sectors of the Slovakian economy are described in detail.

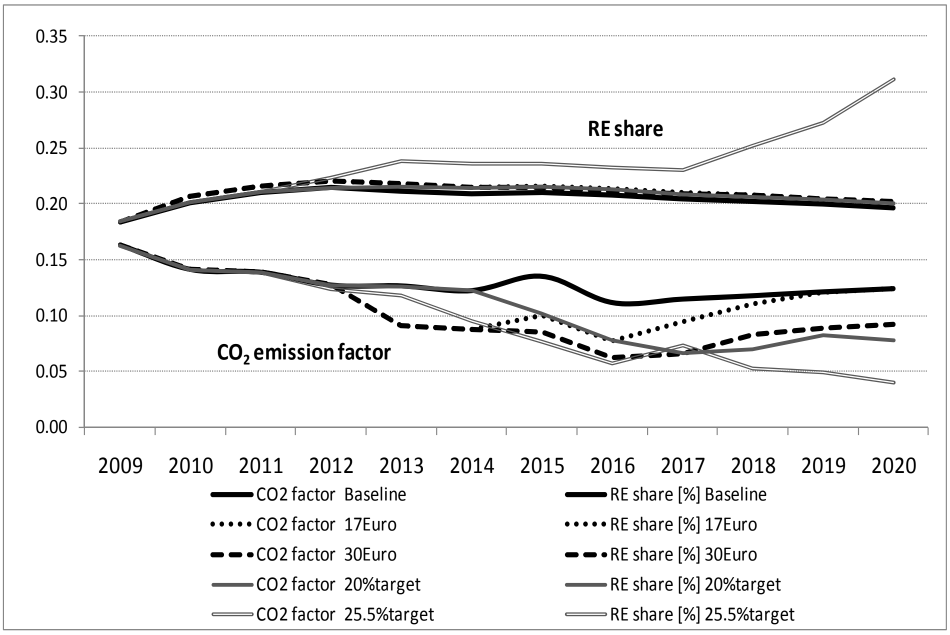
3.3.1 Impacts on electricity generation

Electricity generation in public power plants is expected to decrease already considerably under the REF due to the impact of the Renewable Energy Directive. In the -30% policy scenario additional efforts will be undertaken because CO_2 has a price of € 30/tCO_2 for the electricity producers. In 2020, all emissions of the public power generation sector will fall for 100% under an auctioning regime, creating strong incentives for power producers to reduce the emissions and switch to low-carbon technologies for power generation.

Calculations from the MESSAGE model show that the CO_2 allowance price of € 30/tCO_2 does have a much stronger influence on the technologies that are being applied to supply electricity and heat compared to the -20% policy scenario. Total emissions are reduced by 0.8 Mt of CO_2 compared to REF and the -20% policy scenario. This means CO_2 emissions in the power sector are reduced by a quarter compared to the REF 2020 level, or a third compared to the 2009 reference level. The average emission factor of 0.092 tone of CO_2 per

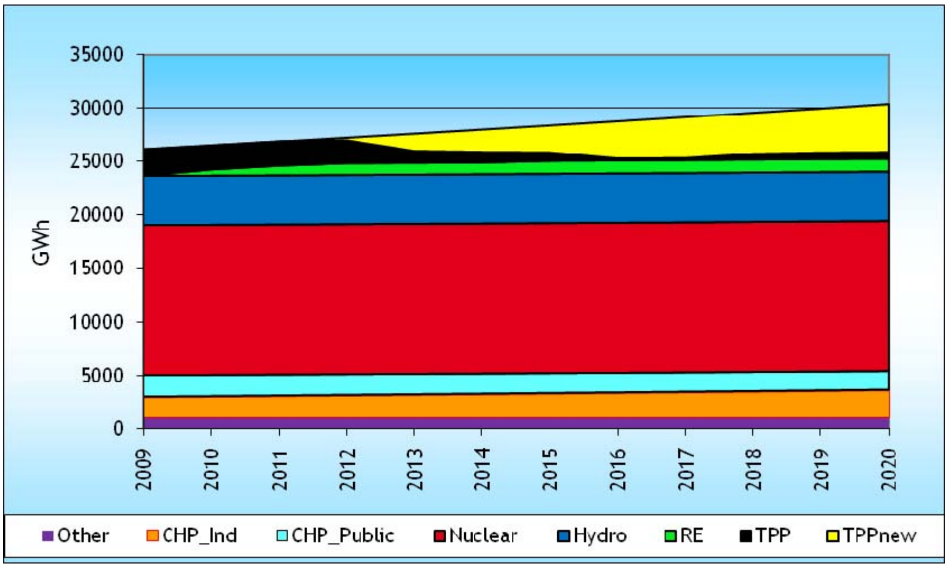
MWh generated in public sector is 26% lower than in the -20% target scenario and even 44% lower than in the 2009 reference year. For comparison the EU benchmark is set at 0.465 t CO_2 per MWh. Figure 15 displays the trend in CO_2 emission factor over the period and across scenarios.

Figure 15 **Share of electricity RES and emission factor (tCO_2 per MWh) for various scenarios, 2009-2020**



Introducing the price of € 30 per tonne of CO_2 in the ETS sector implies a shift – greater than in the 20% target scenario - in electricity generating technologies, specifically from recently operated coal-firing thermal power plants to new thermal power plants using natural gas and partly to new renewable sources. Electricity generated in public CHP plants decreases by 13% during 2009-2020 while electricity generation in industrial CHP slightly increases.

Figure 16 **Electricity supply in Slovak Republic under the -30% target**



In the 30% policy scenario, fuel consumption in public electricity sector decreases by 2.8% compared to the 20% policy scenario in 2020. Considering the fuel mix, there is a shift in fuel mix from hard and brown coal (which use decreases by 47 and 86% respectively) towards natural gas and biomass. The use of heating oils to generate electricity will become obsolete at the end of the analysed period. Including electricity generation in combined generation cycles in public and industrial CHP plants, the share of electricity from renewable energy will rise from 18.4 to 20.2% in 2020. The share of renewable electricity is however the same as in the -20% target scenario.

To achieve this reduction in public power plants, a total investment of € 915 million is needed until the year 2020, that is € 80 million more than the investment spent as in the baseline as in the -20% target. These investment costs can be partly regained by saving on fuel inputs in the power sector, which was estimated to be € 50 million (as in the baseline) or € 12 million (as in the -20% target) between 2009-2020. The total balance of payments for the electricity sector in the year 2020 under the -30% target is summarised in Table 12.

Table 12 **Cost changes in 2020 for the public electricity generation sector (NACE 40) under the -20% target compared to REF. Benefits are negative costs**

	Unit	30%	30% compared to REF	30% compared to 20%
Emission price	€/tCO_2	30		
Total investments (2009-2020)	€ mln	915	80	80
Annualised investments	€ mln	81	7	7
O&M	€ mln	22	2	2
Fuel costs	€ mln	250	-4	-4
CO_2 auctions	€ mln	69	69	16
Total potential cost rise compared to 2009	**€ mln**	**422**	**75**	**22**
Costs passed through	*€ mln*	*-520*	-234	-152
Net costs electricity	*€ mln*	*-97*	**-160**	**-130**

* This is only the electricity produced in public power plants, not in public CHP. The real benefits to the power sector from passing through (part of) the costs are therefore higher. Benefits are presented as negative costs.

The total potential cost rise in 2020 for the power sector is equivalent to € 75 million compared to the REF. However, the electricity price rises substantially because the higher price of carbon induces a substantial price increase by the marginal technologies using brown and hard coal (see Annex A). Therefore the power generation sector experiences a net gain in profitability equivalent to € 160 million. One should notice that this analysis excludes eventual reductions in demand for power due to the higher prices (see Paragraph 3.4).

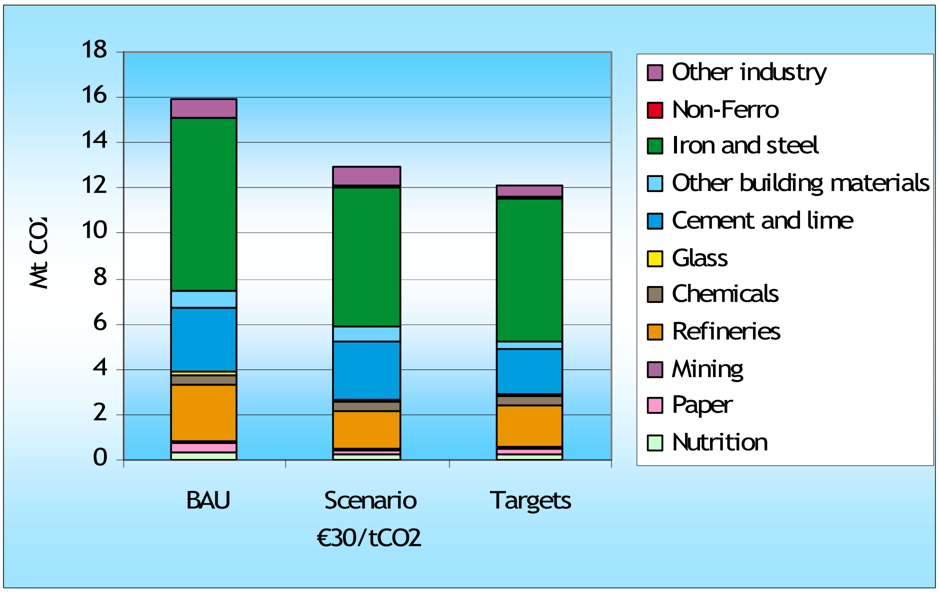
When these results are compared to the -20% policy plan, we see that the investments, O&M costs and costs of auctioning are now higher. On the other hand, the fuel costs are now slightly lower. The most pronounced impact for the electricity sector is, however, the higher revenues from passing through the additional costs to the consumers. In total, the -30% policy target constitutes a benefit of € 130 million for the electricity sector when compared to the -20% policy plan.

3.3.2 Impacts on industry

Emissions in the industry sectors will decrease from 15.9 Mt in REF to 12.9 Mt. A CO_2 price level of € 30/tCO_2 will induce an abatement of approximately 3 Mt (19% compared to REF). The hypothetical industry targets under the -30% scenario are more tight, implying an administrative emission ceiling of 12.1 Mt. However, these targets are easily being met by using a combination of banked allowances and CDM.

The developments of the individual sectors is depicted in Figure 17.

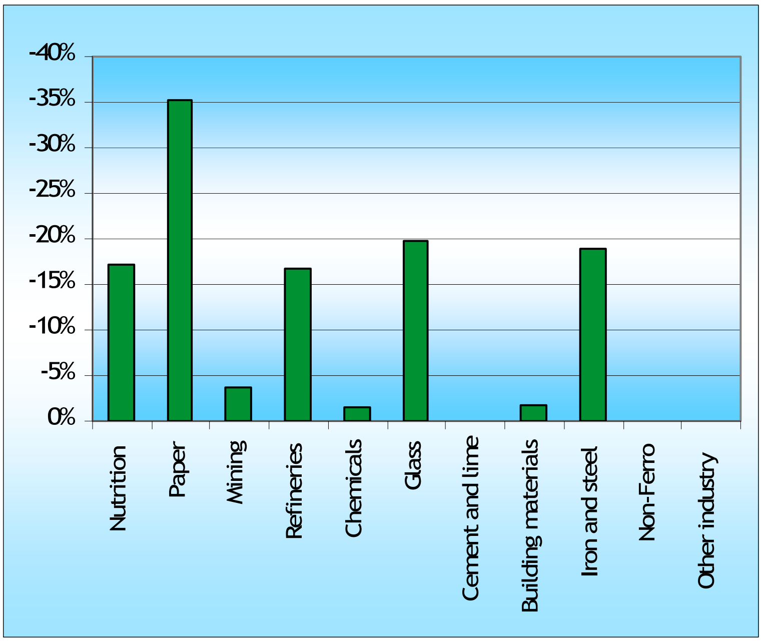
Figure 17 Development of emissions in 2020 ($MtCO_2$) for the various industrial sectors, -30% policy scenario



Note: Targets refer to hypothetical targets. For ETS installations no quantitative targets exist. We assume here that the overall EU goal for ETS installations applies to every Slovakian installation.

Paper, refineries, glass and iron and steel are the sectors where the emissions under the -30% scenario will be smaller than the targets, due to a relatively large emission potential abatement. The additional efforts of the industrial sectors with respect to abatement are given in Figure 18. It appears that especially emission abatement in the paper sector is larger due to various measures reducing heat demand. Nutrition, refineries, glass and iron and steel are other sectors with substantial additional emission abatement potentials.

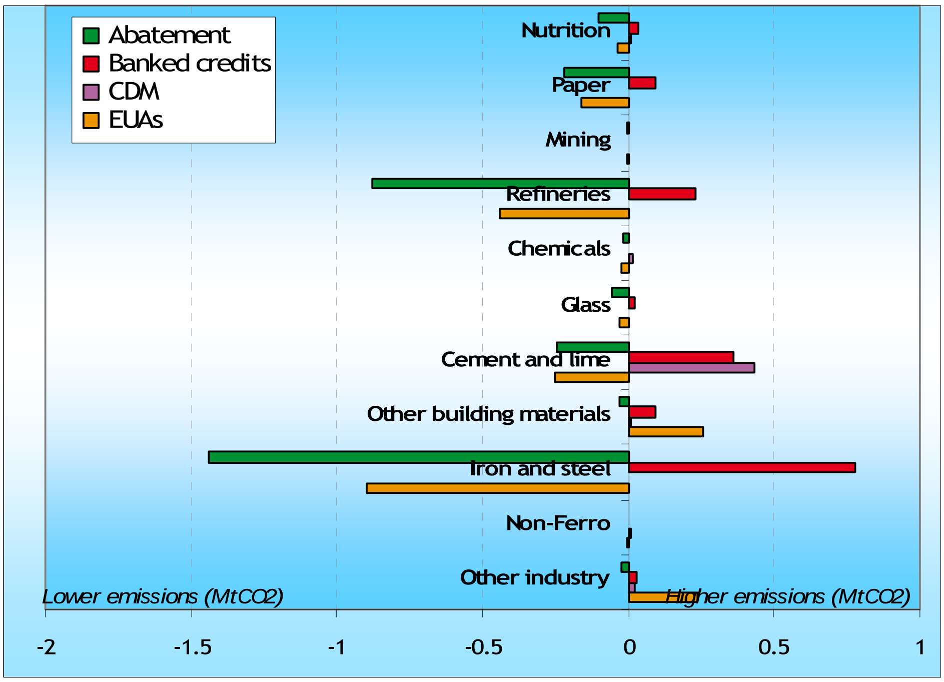
Figure 18 **Additional emission abatement in 2020 under the -30% scenario compared to the -20% scenario**



Note: Percentages are calculated by comparing the additional efforts to the emissions under the REF scenario.

The sectors that abate emissions more profoundly than the targets will become net sellers of emission allowances on the ETS market. The total emission balance of the various sectors is depicted in Figure 19.

Figure 19 **Impact of the regulation on sectoral behaviour with respect to meeting the targets (Mt CO_2) compared to the REF**



From this figure it becomes apparent that abatement in absolute terms is the largest in the refineries and iron and steel sectors. These sectors are also the largest sellers of allowances on the ETS market. When compared to the -20% scenario, especially the iron and steel sector has now become a large abater of emissions. The reason is that under the -20% scenario, the banked emissions of this sector were enough to meet the targets. The building materials and other industry will become net buyers of emission allowances. The cement sector will obtain a considerable amount of CDM.

Table 13 gives an overview of the costs compared to the -20% policy target for the various sectors and compares these to sectoral gross value added. It appears that the additional costs are mostly related to higher electricity costs and emission abatement. In terms of additional costs relative to value added, especially the metals industries have cost increases of about 5%. Cement and building materials also have expected increases in costs slightly above the 2.25%. Total average cost price increase of industry is 0.62% compared to gross value added in 2020.

Table 13 Overview of additional costs for industry in 2020 under the -30% policy target compared to the efforts in the -20% policy target (€ mln) assuming no cost-pass-through

	Auctions	Abatement	CDM	Buying/ selling EUAs	Electricity costs	Totals	In % of GVA
Nutrition	1.0	2.0	-0.1	-0.6	2.8	5.1	0.38%
Paper	0.8	4.1	-0.3	-3.3	6.9	8.2	0.82%
Mining	0.0	0.0	0.1	0.0	0.9	1.1	0.42%
Refineries	2.5	7.6	0.0	-7.7	0.0	2.4	1.26%
Chemicals	0.1	0.1	0.4	0.0	13.0	13.7	1.70%
Glass	0.1	1.0	0.0	-0.5	0.4	1.0	1.05%
Cement and lime	0.0	0.0	8.7	-1.5	3.1	10.3	2.28%
Other building materials	0.0	0.4	0.2	3.6	2.8	6.9	2.27%
Iron and steel	0.0	20.5	0.0	-15.6	32.5	37.4	4.86%
Non-ferro	0.0	0.0	0.1	0.0	0.4	0.5	5.86%
Other industry	1.9	0.0	0.5	3.7	24.3	30.5	0.23%
Total industry	**6.5**	**35.6**	**9.6**	**-21.9**	**87.2**	**117.1**	0.62%

* These categories refer to gross positions at the ETS market. For example, auction refers to the amount of allowances that fall under an auctioning regime, while the Buying/selling of EUAs refer to the question if the sector, on overall, becomes a net seller or buyer of EUAs. If the individual company would be a seller of EUAs, it would of course use the own EUAs to reduce the auctioning costs. Therefore, the number in these tables refer to gross positions at the ETS market, not net-positions.

If industry is able to pass through these costs to the consumers, not industry but consumers will pay for these costs. This may induce a fall in demand. In Paragraph 3.4 we will further elaborate on this.

3.3.3 Impacts on other sectors

The service sector, agriculture sector, transport and residential emissions and electricity and heat generation not part of the ETS equal about 15.5 Mt in the REF. These emissions have to be reduced under the 30% scenario to 15.4 Mt, implying a very small reduction of 0.1 Mt CO_2. It is most likely that this reduction has to be achieved in the residential sector.

In this study we did not undertake the effort to assign costs for these 0.1 Mt emissions as this is too small given the effort it would undertake to apply a full analysis of all possible measures in the residential sector. We notice here that according to the literature in the building sector many cost-effective measures exist that improve thermal insulation and reduce gas and electricity use which can be taken at zero costs (see e.g. 3CSEP, 2010). Therefore we do not expect that this effort will entail net costs to the Slovakian economy.

However, the service sector and consumers in Slovakia will have to pay for the higher electricity price. The total additional costs due to higher electricity prices are estimated to be € 100 mln in 2020 compared to REF – an increase of € 65 mln compared to the -20% target. We should notice here that we did not investigate in this study the reduction in electricity demand due to higher prices.

3.3.4 Impacts for the government

The government will receive auction revenues that are larger than under the -20% scenario because of the higher emission price. We assume in the -30% policy scenario that the total emissions to be auctioned are decreasing equiproportionally to the decrease in emissions so that both the amount of auctioned emissions and free allowances is reduced. One should notice that this is actually still a debate in the policy proposals that have been formulated to move to a -30% target.

The auction revenues are depicted in Table 14 and compared to the -20% target.

Table 14 Auction revenues in the Slovak Republic in 2020 of a -30% target excluding industry benchmarks

	Units	-30%	Relative to -20%
Targets ETS	%	-34%	-21%
Supply of allowances			
Electricity and heat in PP	$MtCO_2$	4.3	-0.8
Industry (CHP)	$MtCO_2$	0.28	-0.1
Industry (process)	$MtCO_2$	0.10	0.0
Redistribution	$MtCO_2$	1.12	-0.2
Aviation	$MtCO_2$	0.03	0.0
Total supply	$MtCO_2$	5.8	-1.1
Emission price	€/tCO_2	30	
Auction revenues	**€ mln**	**175**	**+56**
Demand for allowances			
Sold to public power	€ mln	69	+16
Sold to industry	€ mln	7	-3
Sold to other/foreign	€ mln	100	+43

Total auction revenues for the Slovak government accrue to € 175 million, an increase of € 56 million compared to the -20% policy scenario. Although the amount of allowances available decreases (primarily in the electricity sector), the higher price more than compensates for this.

Not all allowances will be sold to the Slovakian installations according to the model calculations. Because the -30% scenario results in substantial reductions in the public power generation, the amount of emissions that the Slovak government is allowed to auction will be larger than the amount of emissions required by electricity producers. Therefore, approximately € 3.3 million of EUAs, worth € 100 million, will be sold to other participants in the ETS, such as to industry not meeting the benchmarks, service sectors or participants to the ETS in other countries.[20]

3.4 Indirect costs and benefits

This section discusses the indirect impacts of the -30% policy scenario compared to the -20% policy scenario. We distinguish four indirect impacts in this study:

1. Larger investments in abatement technologies creating additional income and employment for the Slovakian economy. This is a potential net benefit.
2. Potentially higher costs of products and loss of competitive position of the energy-intensive sectors in the Slovak economy and associated employment. This is potential net cost.
3. Cleaner air of local air pollution (SO_2, NO_x, $PM_{2.5}$ and VOC) due to a reduction of energy use. This is a potential net benefit due to avoided damages. We compute also a loss in governmental revenue from charges on air pollutants that results on the other hand in cost decrease on the side of business.
4. Decrease in fuel imports reducing uncertainty and dependency on foreign suppliers. This is a potential net benefit.

This section shortly elaborates on these four indirect impacts and provides a quantitative estimation when possible. Table 15 gives an overview of the quantified indirect impacts in this paragraph.

Table 15 Overview of the quantified indirect costs and benefits associated with the -30% policy scenario compared to the -20% policy scenario in 2020 in this study

	Benefits	Costs
Investments in abatement technology	50	
Higher prices industrial goods	120	
Loss in output due to higher prices in industry	0	-170
Net indirect impacts rest of the economy	20	-60
Improved air quality	36	
Loss in tax revenues		-0.3
Totals	**226**	**-230**

These will be explained in the subsequent paragraphs. As a total conclusion it seems that the indirect costs are almost equivalent to the indirect benefits. However, one should notice that the indirect effects are much more uncertain than the direct effects.

3.4.2 Larger investments in abatement technologies

Due to the -30% policy plan additional investments will be undertaken in the Slovak economy. Total investments between 2009 and 2020 in the power sector under the 30% scenario equal € 915 million, an additional investment of € 80 million compared to the -20% policy scenario. The additional investment

[20] Without further knowledge of the precise influence of the benchmarks on the Slovak installations, we cannot attribute this to further categories. We assume here in the final calculations that all of these allowances will be sold to foreign participants in the ETS scheme.

in the industry is estimated to be between 2012-2020 about € 700 million compared to the -20% scenario. This results in additional energy savings of about 15PJ.

The additional investments will entail economic gains for the Slovak economy. The size of the investment multiplier typically depends on the leakage impacts to other countries. However, as other EU countries will have additional investments as well due to the tighter policy targets, leakage impacts will occur only to non-EU countries. We expect therefore that the larger investment will primarily result in investments in Slovak industries.
The impact of these investments on the Slovak economy have been analysed with an input-output table taking into account potential leakage impacts to non-Slovak suppliers of abatement technology.[21] This analysis shows that the higher investment and lower fuel use have a net positive indirect effect on the Slovak economy. In total, there is a benefit of about € 0.6 billion to be expected between 2009 tot 2020.This implies that GDP will be about 0.7% higher in 2020 in the -30% policy plan compared to the -20% policy plan.
The main reason of this mechanism is that the Slovak economy is heavily dependent on fuel imports and is capable of producing machinery and installations itself. So saving on fuel imports and increasing equipment gives in general a positive balance. Indeed, industry value added increases by € 0.5 billion in 2020 through these investments. Long-term multiplier effects may exist as well through these investments, but these have not been taken into account.

Investments in abatement efforts could be supported by the government with the use of the revenues from auctions and/or with the use of EU funds directed to energy efficiency and GHG reduction programmes. Such public support schemes leverage additional private capital and help to initiate new investments. This may result in higher emission reductions and at the same time help in alleviating the burden on industry and the residential sector due to the increased energy prices.

3.4.3 Loss of competitive position for companies and cost-pass-through

The analysis in Paragraph 3.3 showed that the -30% target entails additional costs for industry in 2020 equivalent to € 117 million compared to the -20% target. Companies being faced with these higher costs can opt for three different approaches:

1. They may not raise their prices. In that case the additional costs will diminish their profits. This may have a long-term impact on both the capital markets and the investment opportunities for Slovak business. Such long-term impacts cannot be quantified properly without a detailed economic model of the Slovakian economy.
2. They may decide to pass through these average costs to their consumers. This will raise the prices of their products and induce a fall in demand and associated impacts (e.g. loss in other sectors that deliver to these industries).
3. They may decide to pass through the marginal costs of emission allowances and generate in this way windfall profits. This may be beneficial for the industrial sector but for the economy as a total, additional losses will occur because the marginal cost-pass-through is much higher than the average cost-pass-through.

21 Because we do not know precisely to which sectors the additional investments will go, we assumed that 60% of the additional investments go to NACE 29, 30% to NACE 31 and 10% to NACE 37.

The impacts of the average cost-pass-through scenario was assessed using input-output tables of the Slovak economy. This indicates that indirectly, a loss of € 240 million may occur in 2020 if companies pass through the average costs of the ETS. About 75% of these impacts occur in the industry sectors themselves, while 25% of these impacts take place in other sectors of the Slovakian economy.

For industry, the loss of market shares is counterbalanced by the benefits of passing through the costs and the additional investments in abatement technology. In industry, value added is shifted from the energy-intensive sectors towards the labour intensive sectors suggesting a net increase in employment. For the total economy, the balance between the positive effects from investments and negative impacts from passing through the costs may be slightly negative. In total, our results suggest that the other sectors in the economy will entail a loss equivalent to € 50 million in 2020 due to higher costs of products.

3.4.4 Impacts on air quality

CO_2 abatement measures will have an effect on other air pollutants such as SO_2, NO_x, CO, and particulate matter, which we compute for all stationary sources for each scenario using the MESSAGE model. The -30% target, i.e. the CO_2 allowance price of € 30 per tonne, will lead to less emissions of air pollutants included in the model as compared to the -20% target, or the REF scenario. For instance, SO_2 emissions in 2020 are 7% smaller than under the -20% target or 9% smaller than in the REF. Results for other pollutants including NO_x, CO and fraction of particulate matters are displayed in the appendix.

Reduction of classical air pollutants has two economic effects. First, the reduction in emission leads to a reduction in damage, which we quantify using so called ExternE method (see for instance Weinzettel *et al.*, 2011). Specifically, we compute avoided external costs due to emission reductions related to impact on human health, crops, building materials and biodiversity that are associated with climate change. Table below shows detailed results regarding the external costs reported in millions Euro per each pollutant and per each impact category.

Table 16 Damage costs and loss of public revenue from emission charges

	2009	REF	-20%	-30%
NO_X	142	162	160	154
PPMco	2	2	2	2
PPM_{25}	38	41	40	39
SO_2	317	198	193	180
CO_2	666	714	703	688
Total of externalities, € mln	**1,165**	**1,117**	**1,099**	**1,063**
Human Health	438	351	344	326
Loss of Biodiversity	12	12	12	11
Crops	9	11	11	11
Materials	18	13	12	12
North Hemispheric modelling	22	16	16	15
Climate Change	666	714	703	688
Total of externalities, € mln	**1,165**	**1,117**	**1,099**	**1,063**
Percentage change				
- wrt REF2020			-1.6%	-4.8%
- wrt 2009		-4.1%	-5.7%	-8.8%

	2009	REF	-20%	-30%
Absolute change, € mln				
- wrt REF2020			-18.1	-54.0
- wrt 2009		-48.0	-66.1	-102.0
Emission charges, € mln	10.1	9.5	9.5	9.2
- wrt REF2020			-0.10	-0.34
- wrt 2009		-0.53	-0.62	-0.87

Table 16 reports also the second category of economic impact – loss of public (governmental) revenues. Air pollution released by stationary sources is charged in Slovakia with a rate of € 64 per tonne of SO_2, € 48 per tonne of NO_x, € 32 of tonne of CO and € 160 of tonne of particulate matters. Reduction in these emissions results in losses in public revenue from these emission charges. Using these charge rates, we find that this loss is quite small compared to the avoided damage. Indeed, the -30% target will result in the loss of the revenue of about € 0.34 million in 2020 (compared to the REF 2020 level) or € 0.24 million (compared to the -20% target) respectively. On the other hand, the losses on the side of the public sector in fact mean cost reductions on the side of business, yielding zero net social cost.

3.4.5 Impacts on fuel imports

The introduction of the EU ETS leads to lower import dependency in both scenarios compared with the REF. Below in Table 17, the overall change of the amount of imported fuels is given. In 2020, the direction of import change is the same as the overall change by all fuels except the natural gas. In 20% policy scenario the import of natural gas is lower than in the REF by 1,371 TJ but in 30% policy scenario the import is higher by 3,970 TJ. This is because the consumption of natural gas is since 2019 higher in the 30% policy scenario than in the REF. Table 18 shows the differences of fuel imports in 2020 compared to the REF.

Table 17 Overall fuel import change, cumulative over 2009-2020 (TJ)

	Hard coal	Brown coal	Natural gas	Oils*
€ 17	-2,618	-14,910	-27,298	-727
€ 30	-17,151	-14,910	-20,258	-1,056

Note: * heating fuel oils.

Table 18 Fuel import change in 2020 (TJ)

	Hard coal	Brown coal	Natural gas	Oils*
€ 17	-219	-1,276	-1,371	-19
€ 30	-219	-1,276	3,970	-123

Note: * heating fuel oils.

In monetary terms, the overall fuel imports between year 2009 and 2020 are lower than in the REF by € 272 million and € 245 million in 20% policy and 30% policy scenario, respectively. Although imports of hard coal in 30% policy scenario in the years 2015–2017 is lower, the higher imports of natural gas cause that the overall import dependency in 30% policy scenario is higher than in 20% policy scenario.

3.4.6 Other impacts not considered

There are some other impacts on the economy that were not considered in this study. One of them is impact of higher energy prices on energy demand. We envisage that this impact would be, however, negligible. Many empirical studies show that price elasticity of energy is very low, typically much below one (see the surveys in e.g. Espey and Espey, 2004 and Dahl, 2004). Besides, this effect is partly taken into account by including energy efficiency improvements in forecasts of energy use.

We also did not in further detail analyse the impact of higher electricity prices for the residential Slovak citizens. If the citizens are able to implement cost-effective measures to reduce electricity demand, as identified in the literature, there could be a net gain for Slovak consumers. However, the impact from the residential sector was left out in this analysis.

Another impact that is left out of the quantitative analysis is impact on labour market. It can be expected that some jobs will be lost due to higher prices and lower demand resulting in falling production and employment in some sectors. On the other hand, additional investments induced by the need of innovation will have an opposite effect. More intensive use of renewable energy sources might imply increase in employment per PJ but because of decreased demand for energy, the absolute effect might be different. Quantification of these effects would require an extensive analysis and such an analysis falls outside of the scope of this study.

4 Conclusions

4.1 Overall conclusions

This study has analysed the costs and benefits for the Slovakian economy of moving to a -30% target compared to the existing -20% policy plans. The study consisted of investigating in detail the Slovak emissions of CO_2 in the years 2005-2010, formulating future scenarios with respect to economic growth, energy efficiency and CO_2 emissions and carefully applying the current legislation, as outlined in various EC documents, onto the expected CO_2 emissions in the year 2020. From this reference situation, the study applied the alternative policy plan of moving to a -30% target, as being discussed in the EC. The study consisted of running two models, one for industry and one for electricity generations, for the impact of the policy plans on the emissions in the Slovak Republic in the year 2020. Some additional tools were used, such as input-output analysis and external cost estimates, to picture the potential indirect effects.
In the -30% policy scenario, ETS installations are assumed to reduce their emissions by 34% below the 2005 verified emissions. The associated price of emission allowances is expected to increase from € 17/tCO_2 to € 30/tCO_2.
It should be underlined that the companies in the EU ETS sector do not need to physically reduce GHG emissions by 34% under the -30% reduction targets.
As we show througout this report, industry and the electricity sector can use various instruments in order to achieve compliance with the climate policies. These instruments include using banked allowances and engaging in trade with EUAs and CERs. The general principle of the EU ETS is not imposing individual targets but rather influencing the decisions of the operators by introducing the market price of carbon.

As an overall conclusion it appears that the target of -30% can be met without additional direct costs for the Slovak economy. The direct costs are grossly the same as under a -20% target – the modelling effort in this study indicated that the -30% policy target is in 2020 in total about € 5 million cheaper than the -20% policy target. Higher abatement costs under a -30% scenario are being mitigated by more fuel savings in industry and the electricity sector, higher auction revenues for the government and a higher value of the substantial amount of banked credits that companies hold. In this way, the direct costs and direct benefits of the -30% scenario exactly outweigh each other.

Table 19 presents the direct impacts.

Table 19 Direct costs and benefits associated with the -30% policy scenario compared to the -20% policy scenario in 2020 (in mln €)

	Costs	Benefits	Totals
Industry	-117	0	-117
Electricity	-22	152	130
Government	0	56	56
Consumers/services	-65	0	-65
Not specified			
Totals	**-204**	**209**	**5**

Indirectly, this study identified a number of substantial benefits to be associated with the -30% target. The additional investment of € 0.7 billion between 2009-2020 could raise GDP levels by about 0.7% in 2020. Additional benefits can be identified in the improved air quality and a reduction of dependency on fuel imports. Although industry will be faced with higher costs, they are most likely to pass these through onto the consumers. This will result in a loss in market share for industry. It appears that the loss in value added from energy-intensive sectors more or less equals the benefits from higher investments.

The total table of identified indirect costs and benefits associated with the -30% policy scenario is given below (Table 20).

Table 20 Overview of quantified indirect costs and benefits associated with the -30% policy scenario compared to the -20% policy scenario in 2020 (in mln €)

	Benefits	Costs
Investments in abatement technology	50	
Higher prices industrial goods	120	
Loss in output due to higher prices in industry	0	-170
Net indirect impacts rest of the economy	20	-60
Improved air quality	36	
Loss in tax revenues		-0.3
Totals	**226**	**-230**

One should notice that the indirect effects are much more uncertain than the direct effects. Our analysis shows that with the indirect effects the costs and benefits tend to outweigh each other.

4.2 Sectoral conclusions

For the electricity sector, the -30% policy scenario has consequences mainly with respect to the input of fuels. Cumulative consumption of most fuels remains unchanged. In the 30% scenario the share of brown coal is diminished from 4.5% in the reference scenario to 2.5% in 30% policy scenario. Share of biomass goes up from 5.3 to 5.9% in 2020. Furthermore, the use of natural gas is increased while oil will no longer be used to generate electricity and heat.

Total investments in the electricity sector equal € 80 million between 2012-2020 in addition to the -20% policy scenario. The electricity sector will pass through the major part of the opportunity costs of the auctioned allowances. This creates a net profit for the electricity sector as the marginal producer (with the highest CO_2 costs) is expected to set the price on the electricity market. As the marginal costs of CO_2 are higher than the average costs of investments and fuel switches, electricity producers are expected to experience a net gain of about € 150 million in 2020.

The industry sector will undertake additional investments of about € 700 million between 2012-2020. compared to the -20% scenario. Main investments take place in the iron and steel industry, refineries and pulp and paper. In 2020 industrial costs will be about € 117 million higher than in the -20% policy scenario. Main reason is the higher electricity costs.
If industry passes through the higher costs into the product prices, they will experience a fall in demand. On the other hand, demand increases due to the investment in abatement technologies. The sum of these two effects is in general likely to be neutral for the Slovak economy as our input-output analysis shows.

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Annex A Emission data and forecasts

A.1 Emission data

The statistical information from the NEIS data from Slovakia[22] has been combined with the registry of the EU ETS. Information from the European Commission on the 4-digit NACE classification has been used (and in some changes verified and adapted) to determine to which NACE classification each installation belongs. If total emissions from the registry bypassed the NEIS emissions at NACE 2-digit classification, the installations were scrutinised and in this way some mistakes in the information from the Commission was found. For Chemicals (24), Minerals (26) and Metals (27), a further classification at NACE 4 level was provided using both microdata from NEIS and the EU registry. This further classification, even if not reported always in this report, was needed to connect the emissions with the database on technical measures from ECN.

A.2 Electricity data

Electricity consumption data were obtained only for 2005-2008, as no figures were available for 2009. Industrial electricity consumption in 2009 is assumed to have been reduced in accordance with the reduction in CO_2 emissions in EU ETS sectors. This means we have assumed that in 2009 power consumption was 14% lower than in 2008.

Data on autoproduction of electricity and heat were taken from Slovstat. Under the EU ETS, in the case of emissions from CHP a distinction must be made between emissions attributable to electricity (which will gradually come under an auction regime) and those attributable to heat output (which are freely allocated if the sector is eligible for free allocation of allowances). The exact split will depend, among other things, on the purpose of the CHP unit. If it is intended primarily for heat generation, the CHP will produce relatively more heat and less electricity. This is above all the case in heavy industry. Because no specific information was available on the heat-electricity split in the various Slovak sectors, Dutch figures were used as a benchmark for each. Note that this assumption only affects the amount of allowances a sector must buy from 2013 onwards, not its total emissions.

A.3 EU ETS data

The registry of the EU ETS has been used for obtaining information on emissions of individual installations between 2005-2010. Information from the European Commission on the 4-digit NACE classification has been used (and in some changes verified and adapted) to determine to which NACE classification each installation belongs.

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22 The SHMÚ (Slovak Hydrometeorological Institute) is responsible for developing and maintaining the National Emission Inventory System (NEIS) – the database of stationary sources to monitor the development of SO_2, NO_x, CO emissions at regional level and to fulfil reporting commitments under the national regulations and EU Directives. The NEIS software product is constructed as a multi-module system, corresponding fully to the requirements of current legislation. The NEIS database contains also some technical information about the sources like fuel consumption and use for the estimation of sectoral approach.

Banked credits

Banked credits from 2008 to 2010 were taken by the difference between allocated and verified emissions. The banked credits were, on the basis of information from the EC, allocated at NACE 4-digit for all the installations. We assume that 80% of the over-allocated emission credits are used for banking allowances. For the iron and steel sector, for example, this figure could imply that some of the over-allocated allowances have been used for covering electricity generation with CCF gasses.

Since Slovakia introduced a windfall profit tax on over-allocated emission allowances, we did not take into account eventual over-allocated allowances in 2011 and 2012 into account. For Phase 3 (2013-2020), we assume that the banked credits (or the monetary equivalence thereof in case companies already decided to sell these allowances) are used by companies in equal proportion every year. That is: every year 1/8th of the total sum of banked credits over the years 2008-2010 are being used by companies to cover their emissions.

Augmentation of the ETS coverage

Phase 3 will contain a different approach than Phase 2 in the sense that the system covers more GHG emissions and has a different system boundary than ETS under Phase 2. In CE (2010a), it appeared that this especially has impact on the aluminium and chemical industries, while other industries are relatively unaffected. We did not take into account the coverage of other gasses in this study. For the CO_2 emissions, we assume that 25% of the emissions from the chemical industries that are currently not under ETS will fall under ETS in the future. For the aluminium industry, we assume that the CHP emissions will remain under EU ETS.

Free allocation and benchmarks

For each of the installations belonging in 2005 to the EU ETS registry, it was determined whether this installation will be prone to carbon leakage according to the criteria of the Commission. Installations prone to the risk of carbon leakage will receive prolonged free allocation of allowances up to the benchmark up to 2020. Most of the installations in the Slovak Republic will be marked as prone to carbon leakage: only in the nutrition, paper and printing, chemicals and other industry some installations will fall under the auctioning rule which will, ultimately, in 2020 result in full auctioning for these installations. The share of emissions that will fall under auctioning that we calculated from the ETS registry is given in Table 21.

Table 21 Amount of emissions that will fall under auctioning regime in 2020

Nutrition	6%
Paper and graphics	2%
Mining	0%
Refineries	0%
Chemicals	8%
Glass	0%
Cement, calcium and gypsum	0%
Ceramics, building materials	0%
Iron and steel	0%
Non-ferro	0%
Other industry	56%

Hence, most of the emissions of the sectors will be freely allocated up to the benchmarks that the European Commission has established. From the documents that have been calculated the benchmarks, we estimated that about 5-10% of the current total emissions in these sectors will be above the benchmark and will be auctioned. It goes beyond the level of detail of this study to determine for each installation and sector the amount of emissions that are above the benchmark. Moreover, it is very likely that due to technological progress in 2020 none of the emissions in the EU will be above the benchmarks that were based on 2008 emissions. As it is presently unclear if in 2016 the benchmarks will be tightened, we assume in this study that in 2020 no emissions will be above the benchmarks.

A.4 Forecasts

For the business as usual (REF) projections a combination of PRIMES/GAINS data and data from the 2009 EC project on Energy Efficiency Potentials (http://www.eepotential.eu/) was used. As neither of these forecasts properly model the impact of the economic crisis, the predicted growth rates between 2010-2015 and 2015-2020 from the two studies were applied to the actual emission data for 2009 in order to factor in the impact of the crisis. It should be noted that this approach would assume that the 2008/2009 financial crisis had a structural character that has permanently lowered the level of income and associated emissions compared with the situation prior to 2008. As this is not entirely clear yet, we used an uplift factor of 2.5% to take into account accelerated growth rates compared to the forecasts used.

For the forecasts we used the economic data from PRIMES 2010 baseline. This scenario assumes an overall growth rate of the Slovakian economy of 4.8% per annum between 2010 and 2015 and 3.7% between 2015 and 2020. Using additional information from the Energy Efficiency Potentials study (Fraunhofer *et al.*, 2009), we have been able to translate these into sectoral growth forecasts in value added and physical output for a few selected industrial sectors.
For CO_2 emissions, the forecasts were based on the physical production of cement, paper, glass, steel and aluminium for these sectors and the forecasts of value added for the other sectors. Autonomous improvements in energy intensities have been taken from the Energy Efficiency Potentials study.

For electricity consumption, a middle scenario was selected (see Annex B).

The statistical basis of our data form the data from Slovstat on employment, CO_2 emissions, electricity consumption and value added for the year 2009. Since 2009 formed a year of deep depression for the Slovakian economy, these data have been updated to the base year of 2010 using recent information from Slovstat on the development of industrial production in 2010 compared to 2009, the verified emissions in the ETS registry and the assumption on an autonomous improvement in energy intensity of 1% per annum. Since 2010 was showing only a slow recovery of the growth of the Slovakian economy, we assumed in addition that in 2011 the economy will grow with an addition 2.5% to recover from the deep recession in 2009.

Within each sector there is a characteristic split between emissions deriving from ETS and non-ETS installations. This split was calculated for the year 2009 and assumed to remain constant through to 2020.

A.5 Policy scenarios

The policy scenarios applied targets as outlined in the main report. Some more detailed assumptions underlying the policy scenarios are:

Detailed assumptions in the -20% scenario

For the -20% we calculated the costs for industry based on the following premises:

- As the non-ETS industrial emissions are not subject to reduction, no additional policies are being formulated in this area. So the influence of the EUA price only influences the ETS sectors.
- Only the industry that is being faced in 2020 with a net shortage of allowances (after taking account the banked allowances) is taking measures to abate emissions into account.

Detailed assumptions on the -30% scenario

For the -30% we calculated the costs for industry based on the following premises:

- As the non-ETS industrial emissions are also subject to reduction, additional policies are being formulated in this area to abate emissions. We assume here that the Slovakian government will aim to create a level playing field so that no competitive distortions between ETS and non-ETS sectors will occur.
- Only the industry that is being faced in 2020 with a net shortage of allowances (after taking account the banked allowances) is taking measures to abate emissions into account.
- Compared to the -20% the amount of auctioning stays the same. In essence this means that the additional reduction effort is achieved by reducing the amount of free allowances to each sector. In relative shares, this implies that the share of auctioning increases under the -30%. On the cost perspective of individual companies this implies a pessimistic scenario, as most likely the reduced effort will be met by also reducing the amount of emissions to be auctioned.

Assumptions related to both scenarios

The project did not take into account any impacts on the level of industrial output if the EU adopts a more stringent target of -30%. Instead, these were modelled as the additional costs of the policy scenario without taking into account the potential reduction of emissions if these costs were indeed realised. Such a procedure could only be fully taken into account in a CGE economic model – a modelling approach which in this case would have had drawbacks of its own. Changes in the energy input mix due to relative price changes and fuel substitution impacts were not taken into account either. In other words, in the REF scenario the CO_2 emissions per unit energy input remain constant between 2010 and 2020.

A.6 EU ETS price and associated CDM prices

The EU ETS price was taken from EC, 2009, which reports that the EU estimates a price of € 17/t in 2020 with a scenario of a 20% reduction in GHG emissions and a price of € 30/t in 2020 for a 30% reduction, with a proportionate increase in the use of CDM.

As Figure 20 shows, international prices for Certified Emission Reductions (CERs) under CDM follow the EUA price. There are many reasons for this, one being that purchase of CERs has been facilitated for participants in the EU ETS through the CITL-ITL link[23]. Swaps between EUAs and CERs are tending to reduce the price differential, as indicated by the trend in 'spread'.

Figure 20 Developments in EUA prices and CER prices and associated spread

Source: ECX, 2009a.

We have assumed here that with a price of € 17 for EUAs, the price of CDM will be € 15, while with a price of € 30 for EUAs, the associated CDM price will rise to € 25.

A.7 Electricity price increase

In Phase 3 of the EU ETS, the electricity price will increase compared to the present situation if the price of EUAs will be higher than it is now. Under Phase 1 and 2 of the EU ETS, most of the electricity companies were already engaged in marginal cost pricing passing through the opportunity costs of the freely obtained allowances (Sijm *et al.*, 2006, 2008). Therefore, the decision of the Commission to auction allowances to electricity producers will not have an impact on the price development.

According to the results of the MESSAGE model, the average carbon intensity of public electricity generation in the Slovak Republic equals 0.33 tCO_2/MWh. However, the carbon intensity of the most carbon intensive technologies equal between 1.22 and 1.17 in 2020 (e.g. the Hard coal Vojany plant). As explained in detail by Reinaud (2005), the electricity price increase will be influenced by the marginal technology with the highest total electricity price under the new price levels of EU ETS. However, due to merit-order effects, the ETS can have the impact that the marginal technology shifts. As we do not know which technology will have the marginal price (and be the price setter on the electricity market) we take here the average of the average price increase and

[23] The European Community Independent Transaction Log (CITL) is linked to the International Transaction Log (ITL) of the United Nations. Moreover, banking is possible and the credits can be carried over to the next trading period.

the marginal price increase into our modelling efforts. The calculations are shown in Table 22.

Table 22 **Cost price rise of electricity sector**

		REF	-20%	30%
Total potential cost rise from MESSAGE	€ mln	*348*	*401*	*422*
Electricity production*	GWh	24,983	24,983	24,983
Increase electricity price compared to 2009	€/MWh	13.9	16.0	16.9
Marginal technology	(tCO_2/MWh)	1.22	1.22	1.17
Marginal price increase compared to 2009**	€/MWh	14.64	20.74	35.10
Average of two approaches	€/MWh	**14.3**	**18.4**	**26.0**

* This is only the electricity produced in public power plants, not in public CHP. The real benefits to the power sector from passing through (part of) the costs are therefore higher.

** Taken into account a price of carbon of € 12/tCO_2 in 2009.

A.8 Abatement costs

Abatement costs were derived from various sources.

1. The MESSAGE model uses a cost-database of measures for electricity and heat production based on various sources (e.g. Ecofys, 2010). This covers about 35% of total CO_2 emissions excluding emissions in the residential and transport sectors.
2. For the iron and steel sector, costs, as identified in the literature (EPA, 2010) were taken. As the Kosice plant of US Steel is operated by a US company we believe that the potential measures to be taken may more or less similar to the measures identified in the US. The measures identified here have been adapted to the size of the Slovakian steel mill. This covers about 30% of total CO_2 emissions excluding emissions in the residential and transport sectors. Slovakian emissions are dominated by one steel mill company. This complex includes coking battery, blast furnace, steel processing and industrial CHP using coal, NG and industrial gases (coking gas, blast furnace gas and others) as fuel. In steel processing the same mixture of these gases is used. Process is permanently up-grading. The possibility of CO_2 abatement is mainly in CHP case as in technology (fuel switch, combined cycle installation), nevertheless it must take in consideration the most economical use of technology gases.
3. For the other industrial sectors the Dutch database of measures, as identified in the Optiedocument (2006, 2010) were taken. The data for industrial sectors in Slovakia were adjusted using information on the specific structure of the Slovakian industry. This covers another 30% of total CO_2 emissions excluding emissions in the residential and transport sectors. The Dutch cost-database has been adjusted taking into account: (1) in Slovakia the Ammonia is produced in large chemical company. In NAP I and II period (2005-2012) only industrial CHP is included ETS framework. New EU regulation will bring NH_3 process in ETS framework as the technology with carbon leakage. From fuel balance the CO_2 production is estimated to be about 170 kt CO_2; (2) Ethylene s produced in petrochemical company, included in ETS. From fuel balance at processes of ethylene, polypropylene and polyethylene production CO_2 emission is on the level 90–91 kt. Options for CCS have been assumed to be 25-50% more expensive in Slovak Republic compared to the Dutch situation because of additional infrastructural costs for CCS compared to the Dutch situation. This effectively implies that CCS will only play a role for small flows of concentrated CO_2 in the chemical and refinery industries in our model.

According to predictions of TNO (2010), CCS technology for electricity producers will not be used in Slovakia until 2020. Prices of energy carriers for end-users are adjusted to the general price level but differ to the extent that industry has purchasing power on the market. For example: the average price level for natural gas assumed in this study is € 8.2/GJ, but this price differs between € 7.8/GJ for large industrial complexes (refineries, iron and steel) to € 8.9/GJ for medium and small industries. In all cases, the price is without taxes and subsidies.

Emissions in the agricultural sector (very small), transport and residential sectors were taken together as a separate category for which no costs have been allocated for reasons given in the report.

A.9 Price levels

We obtain the real 2010 prices of crude oil, brown coal, nature gas, heavy oil, light oil, and biomass from Slovak Regulatory Office for Network Industries. These prices were entered into our models (price level 2007). The 2010 hard coal price and price trends for crude oil, hard coal and nature gas are created as average from price trends in IEA-World energy Outlook 2009, EU Energy Trends to 2030-update 2009, and Jaeger *et al.* (2011) - Baseline 2009. Browncoal price trend folows the hard coal price trend, heavy oil and light oil price trends follow the crude oil price trend. Biomass price trend is obtained as average from PRIMES model price scenarios for Large Scale Solid Biomass in Nezi and Capros (2011, p. 11). Table 23 reports fuel prices as used in our model, whereas Table 24 provides a comparison of our prices with those used in other studies.

Table 23 Fuel prices in the MESSAGE model

€ 2007/GJ	Gas	Hard coal	Browncoal	Biomass	Light oil	Heavy oil
2010	5.7	2.65	3.8	4.8	9	6.4
2015	6.8	2.8	4.1	4.9	11.1	7.9
2020	8.2	3	4.3	5.2	13.6	9.7
2025	8.3	3	4.2	5.7	14.5	10.3
2030	8.4	2.9	4.1	5.8	15.4	11

Table 24 Comparison of fuel prices (€ 2007/GJ)

		Crude oil	Gas	Hard coal
2010	EU Energy Trends to 2030	9.2	5.6	2.2
	IEA-World energy Outlook 2009	7.7	5.4	2.5
	URSO 2010	7.8	5.7	-
	MESSAGE_CUEC	**-**	**5.7**	**2.7**
2020	EU Energy Trends to 2030	11.1	7.7	3.2
	NewGrowth-2020 Baseline 2009	11.9	9.4	3.9
	IEA-World energy Outlook 2009 - Reference Sc.	12.8	8.2	2.8
	IEA-World energy Outlook 2009 - Scenario 450	11.5	7.5	2.2
	MESSAGE_CUEC	**-**	**8.2**	**3**
2030	EU Energy Trends to 2030	13.8	10	3.8
	IEA-World energy Outlook 2009 - Reference Sc.	14.7	8.5	3.1
	IEA-World energy Outlook 2009 - Scenario 450	11.5	6.7	1.8
	MESSAGE_CUEC	**-**	**8.4**	**2.9**

A.10 New technologies

Technical and economic data of new technologies are taken from 'Mapping Renewable Energy Pathways towards 2020: EU Roadmap' (EREC, 2011) and 'Renewable Energy Industry Roadmap for Slovakia: REPAP 2020' (Resch et al., 2010) and the main input data are reported in Table 25.

Table 25 New renewable energy sources applied in MESSAGE model

Sector	Energy source	Plant size MW	Plant factor	Operation time h/a	Plant life yr	Investment (€/kWe)	FOM (€/kWe.r)	Efficiency	Output limit MWh
Electricity	Biomass_Ela	25	90%	7,534	30	2,225	84	26%	2,657
	Biomass_Elb	25	90%	7,534	30	2,610	115	28%	
	Biomass_Elc	25	90%	7,534	30	2,995	146	30%	
	Biogass_agr_Ela	0.5	87%	7,534	25	2,550	115	28%	1,182
	Biogass_agr_Elb	0.5	87%	7,534	25	4,290	140	34%	
	Wind1	2	90%	4,030	25	1,125	35		1,125
	Wind2	2	90%	4,030	25	1,325	40		
	Wind3	2	90%	4,030	25	1,525	45		
	Photovoltaic1	0.05	90%	1,051	25	2,950	30		217
	Photovoltaic2	0.05	90%	1,051	25	3,850	36		
	Photovoltaic3	0.05	90%	1,051	25	4,750	42		
Industrial % district heat	Biomass_50	50	80%	4,030	30	360	14.4	75%	
	Biomass_a	10	80%	4,030	30	350	17	89%	
	Biomass_b	10	80%	4,030	30	380	16	89%	
	Biomass_lc	5	80%	4,030	30	390	17	87%	

Annex B Description of the MESSAGE model

MESSAGE - a model for Energy Supply Strategy Alternatives and their General Environmental Impacts - is a dynamic linear optimisation model originally developed by the International Institute for Applied Systems Analysis that can simulate and optimise any energy system from resource mining or import through to final demand. Its core work is to identify the ‘technology set’ that minimises total social costs (or maximises profits) when due consideration is given to fuel prices, other factor prices and the cost of emissions subject to three types of constraint: policy-relevant (emission ceilings, extraction limits, etc.), environment-specific (fossil fuel reserves) and technology-specific (e.g. maximum share of co-burnt biomass).

In this model the emphasis is on a detailed, technologically-based treatment of the specific sectors. Benefiting from its bottom-up structure, a vast amount of detail on the technologies available to the respective sectors is embedded in the model. In general, this type of model permits description of the system in terms of a wide range of technologies and factor mixes (such as production fuel-mix in the case of the energy sector). It has the drawback, however, of lacking a framework to provide any comprehensive projection of economic outcomes, because there is no feedback with other sectors or the economy as a whole, and like any linear optimisation model it cannot simulate the response of demand to prices or supply. Aggregate demand for energy, or the output of other, non-energy sectors, constitutes one of the main (exogenous) inputs to the model. The main advantage of this type of models is its very detailed technology set. MESSAGE is designed to formulate and evaluate alternative energy supply strategies consonant with user-defined constraints such as limits on new investment, fuel availability and trade, environmental regulations and market penetration rates for new technologies.

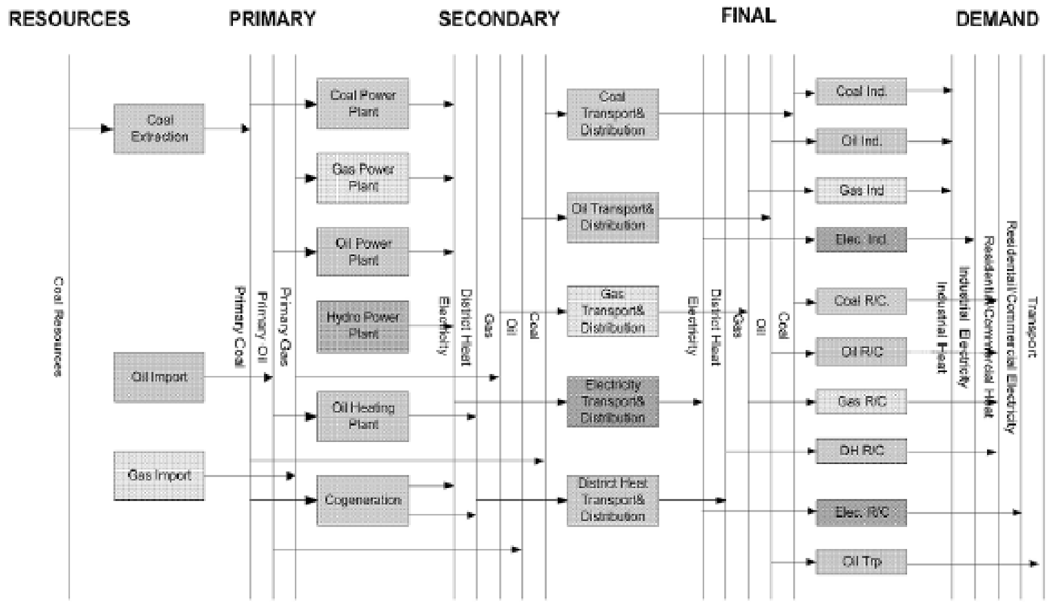
For the last five years the MESSAGE for the Slovak economy has been used by Jiří Balajka to arrive at projections of emissions for use in the National Report on Climate change, the Biennial report to the EU and other documents. The most recent version includes numerous emission sources recorded in the NEIS database, specifically covering IPCC categories 1A1, 1A2, 1A4a, 1A4c and 1A5a. The national energy balance simulation is broken down into several horizontal levels, which simulate the individual steps of energy conversion from primary resources to final energy use according to demand, and several vertical energy chains for individual types of energy supply system and energy demands. The horizontal levels include:

1. A level for primary energy use, which calculates fuel costs as well as the scope for fuel substitution based on national resource availability and import potential.
2. A level simulating the fuel mix input to individual chains, characterised by emission factors as well as emission abatement technologies.
3. A level simulating the sale or purchase of CO_2 emissions allowances in order to meet annual emission quota for individual or grouped emission sources within the energy chain.
4. A level simulating energy conversion from fuels to energy carriers (electricity, heat, process fuels, etc.) and simulating measures to improve energy efficiency on the supply side of the energy balance.
5. A level simulating losses occurring during energy distribution and conversion.

6. A level simulating energy final uses, the energy demand of individual energy chains and energy saving measures on the demand side of the energy balance.

Figure 21 documents the structure of the MESSAGE model.

Figure 21 Structure of the MESSAGE model



Source: International Atomic Energy Agency, 2002, MESSAGE-User manual, p. I-2

Several types of energy chains are activated in the Slovak MESSAGE, with a further breakdown into emission sources included in the National Allocation Plan (NAP) and those not:

- The chain of electricity generation in publicly operated power plants, all of them included in the NAP.
- The chain of publicly operated cogeneration plants (CHP) and rating plants, split into sources in and outside the NAP.
- The chains of manufacturing sectors such as metallurgy, chemistry, engineering, pulp and paper, mineral products, wood processing, mining and others, each split into NAP and non-NAP sources.
- The chains of non-industrial sectors such as services, institutions and agriculture, each split into NAP and non-NAP sources.

The model permits prediction of the impact of a wide range of policies, including increased energy costs, changes in taxation, emission charges and carbon market prices in the ETS framework, as well national SO_2, NO_x and $PM_{2.5}$ ceilings, all of which represent exogenous model variables, as holds for final energy demand. All emissions are reported in accordance with IPCC nomenclature.

Methodology in brief

The MESSAGE is designed to formulate and evaluate alternative energy supply strategies consonant with the user-defined constraints such as restrictions on new investment and/or technology (e.g. new nuclear power, or CCS technology), fuel availability (e.g. biomass potential) and trade (e.g. maximal limit on energy import), environmental regulations (e.g. restriction to quarry coal in certain area) and market penetration rates for new technologies (e.g. share of renewable technologies in energy mix); see, for instance, IAEA (2002, p. I-3). The MESSAGE simulates how certain energy system would look like if something happens (for instance, when new regulation is introduced, energy prices will change, or energy demand will rise). As its result, one can assess how certain policy will affect energy use, technology and fuel mix, new investment and additional costs, or releases of emissions. Practical usage of MESSAGE model for policy evaluation is quite wide: one can assess the impact of emission restrictions such as the one introduced within EU ETS, changes in emission charges, carbon tax or subsidy of renewable energy, change in price of fuel, or implementation of other restrictions in using specific technologies or availability of specific fuels.

To understand our model better, one can ask what such dynamic, linear and optimisation model does mean? In brief, optimisation means that the objective of this type of model is to search for such technology set satisfying final demand with or without policy under pre-defined technological, economic or environmental constraints with least total costs (or maximal profit). Each technology is described by its technological characteristics, emission factors and fuel intensity, investment, fuel and O&M costs, lifetime or prospected market penetration. Linear means that the optimal (least costs) technology set results from using linear programming technique for determining optimal dispatch policy satisfying exogenous constraints. It basically means that cost objective function is minimised without any cycles in the model such as feedback with the rest of the economy and interactions with other economic sectors. Moreover, there is no respond of energy demand on changes in energy supply like in a partial equilibrium energy model such as PRIMES model, and as such final energy demand in MESSAGE is merely given by the analyst. And dynamic model means that its optimisation takes into account costs and benefits for long time period, i.e. the optimum is evaluated in terms of minimal net present value of total costs; see more about the MESSAGE model in Ščasný *et al.*, 2011.

Benefiting from its bottom-up structure, this type of model allows description of the system by a wide range of technologies – recently utilised or prospected to be used in future –, factor mixes and constraints. Emphasis on very detailed technologically-based treatment of concerned sector is just the main advantage of linear optimisation model. However, this type of model lacks the framework to provide a comprehensive prediction of economic outcomes, such as impact on GDP or employment. Unlike the linear optimisation models, macro structural models, such as computable general equilibrium (see e.g. Rutherford and Paltsev, 1999) or macro-econometric type of model (e.g. Ščasný *et al*. 2009), are complex in their consideration of feedbacks and interactions among system components and also provide better understanding of economy-wide implications of underlying economic processes. As such they can provide more precise predictions of macroeconomic developments given a particular set of assumptions. A drawback of these models is, however, a relatively rudimentary treatment of each analysed sector, which is described in a highly aggregated way usually by a neoclassical production function allowing substitution possibilities through elasticities of factor substitution. As a matter of fact, these models usually do not include specific technologies, or do not work with technology clusters, and thus lack optimisation processes to choose the best (optimal) technology set (model description of each type see e.g. in Ščasný *et al.*, 2011).

Our approach and data

The MESSAGE model is build for Slovakia on 2009 data and it is designed as follows:

Our model is a single country energy dynamic linear optimisation model having no inter-linkages with markets beyond geopolitical boundary of Slovak Republic. The model searches for the optimal, i.e. the least cost, technology and fuel mix under predefined constraints and policy to fulfil exogenously given total electricity demand or demand for fuel.

The model contains emission releases and fuel use for all stationary sources operating in Slovakia as they are recorded in NEIS database as well as on the base of fuel consumption by individual small consumers (residential family houses, etc.). Emissions from mobile sources directly contributes to CO_2 emission balance of the model, when we assume that the 2009 level as reported in NIR 2010 is annually growing with a rate based on the assumption applied at projection for Bienal Report SR (ECOSYS, 2010) (that is +8.2% in 2010, +0.82% in 2011-15, and +0.37% in 2016-20). Fuel uses by mobile sources do not however enter into the model.

The energy conversion chains in the model follow final energy demand that is divided further into several categories: grid electricity, industrial heat demand, fuel use in technological processes, to satisfy district heat demand and for residential heating. Special attention is given to large energy consumers such as US steel, gas utilities and oil refinery.

In each sub-category, if relevant, we distinguish a part that is not regulated by EU ETS scheme, and a part that belong to the ETS sector and for which we only allow emission trading. The ETS sector as defined for the ETS III phase has not been however implemented into the model yet.

The optimisation process is performed only in several nodes of energy balance. Specifically, optimal technology set is chosen for electricity generation delivered to grid, industrial heat demand, and district heat demand. There is no optimisation in remaining fuel nodes as in fuel consumption in technology units, where the fuel mix is given by applied process and can be hardly changed. Fuel demand by mobile sources, and therefore fuel use in these segments is merely given by our assumption on their demand.

The calibration of final energy demand for the first year of projection, 2009, is based on fuel consumption from the NEIS database and using information on energy conversion efficiency in whole energy chain (from primary sources to final energy demand). This approach enables building our model with more detailed structure than what one get if quite aggregated data as reported by official energy statistics are used in modelling. Emissions of CO_2 in 2009 are computed from fuel use as reported in NEIS database and if necessary revised for large emitters according to the verified CO_2 levels for the year 2009.

For later years, fuel use and emissions are determined jointly by the optimisation process (i.e. searching for least cost technology set) and energy demand (which need to be satisfied). However, fuel use and emissions are determined merely by fuel demand in those market segments, for which we do not assume any change in technology (e.g. steel or cement production).

Reductions in CO_2 are possible in the model only through supply side abatement measures. Effect of demand side abatement measures may be included only through setting demand level; in fact, our definition of fuel use takes into account energy saving potential. The magnitude of electricity generation we set for the model also implicitly assumes an autonomous adjustment due to price increases in electricity consumption. Specifically, we implement following CO_2 abatement measures in the MESSAGE model:

- Biomass and coal co-firing in energy sources included in ETS sector.
- New installation of biomass combustion for district and industrial heat supply in both ETS and non-ETS sector.
- New installation of biomass combustion for electricity supply in grid (ETS sector).
- Wind power. And
- PV generators.

However, we do not assume any option for carbon capture and storage, due to the fact its cost is still prohibitively high.

We assume demand for electricity will rise by 1.37% annually, which implies its generation in 2020 at the level about 16% larger than in the 2009 base level (26,155 TWh). It is assumed that electricity generation from nuclear power plants is kept constant, i.e. we keep the 2009 level (14.081 TWh) during the whole modelling period. Then, small part of electricity (about 1.2 TWh) produced in small privately owned plants, which use electricity for their own use and thus is not supplied to national grid, is also kept constant over whole period. Actual generation of electricity from large hydropower is assumed to remain constant over the whole period as well (about 4.6 TWh). Last, there are about 0.8% of electricity generated from other renewable energy sources, mostly from biomass co-burnt in CHPs, in 2009. A part of biomass co-burnt with fossil fuel in combined generation cycles is attributed to electricity generation according to energy inputs used in combined generation.

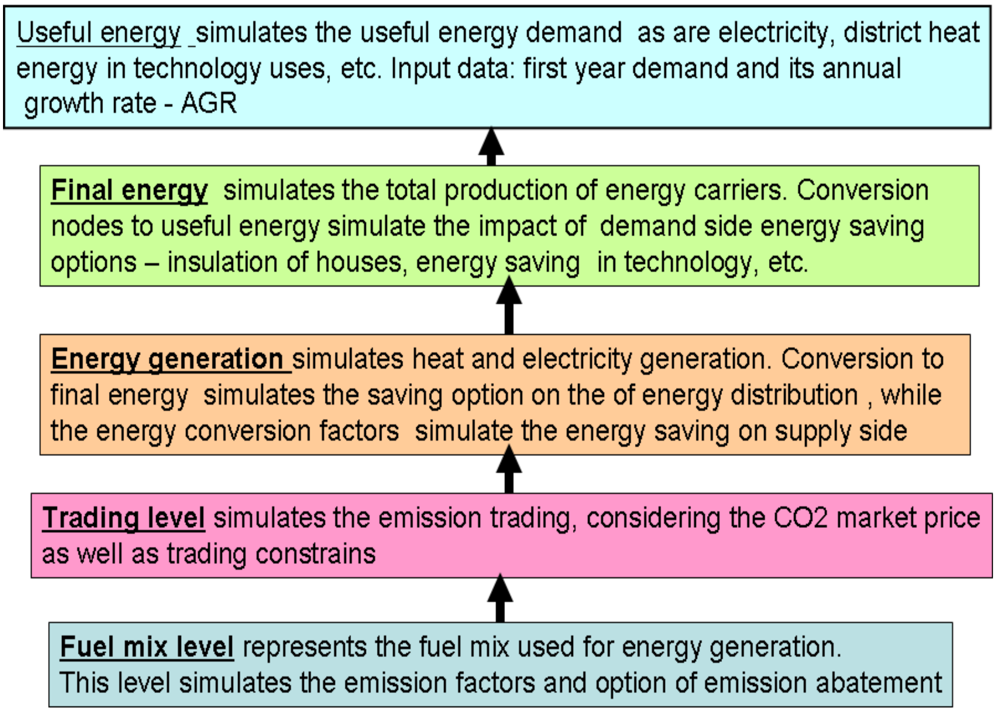
Assumption on fuel demand in other combustion processes and technological processes is based on autonomous saving potential and annual growth rate in production of given sector. While the former assumption is based on the EU database on Energy Saving Potentials as defined for its Low Policy Intensity scenario (http://www.eepotential.eu), the latter is based on Baseline PRIMES scenario as set in the EU Energy Trend 2030–2009 update (EC, 2010); see details later. Specifically, we assume that fuel demand for district heat, residential heat and demand of market and governmental institutions will decline by about 16% until 2020, demand for fuel in gas utilities, refineries, agriculture, mining and textile will remain constant over the period, whereas demand for fuel in remaining industrial sectors will rise in the range of 0.4% to 6.2% annually.

Prices of fuels for the base year are based on 2010 real prices as reported by Slovak Energy Regulatory Office. Price trajectory for later years is derived from energy trends reported elsewhere in literature.

Modelling and split of energy demand

The MESSAGE model is a linear dynamic optimisation model of energy market in Slovakia. The model searches for optimal technology set, which ensure generation of exogenously pre-defined level of energy demand under certain pre-defined physical, technological or economic constraints. The MESSAGE model simulates the energy flow from primary energy sources to final/useful energy demand. Using the data for the first year of projection, the total energy flow connected with emission production is calibrated for this first year balance. The design of energy chain structure has to enable changing the technology structure, energy conversion efficiency and emission output of whole system in order to find less economical costs at predefined constraint in technology and/or environment, and constraint due to policy (e.g. emission level, carbon market price, etc.). Next figure illustrates design of energy chain applied in the model.

Energy chain levels



Considering impact of Slovak economy on releases of emission, whole chain is split on several vertical chains to follow new rules of post Kyoto ETS period and take into account importance of individual contributors to energy and emission balance.

Assumptions on electricity generation and fuel demand

Although electricity generation and consumption is increased thank to economic revival in 2010 (for example, 4% GDP growth went hand-to-hand with 6% increase in electricity generation and 4.7% increase in its consumption), other factors such as changes in energy efficiency and impact of climate change policies will affect electricity consumption as in Slovakia as in the EU which both will determine electricity generation in Slovakia. Prediction of electricity generation is thus determined by future trends both in foreign trade and in domestic consumption patterns. All of these effects on electricity generation in Slovakia can be modelled only by a Pan-European partial equilibrium or better by general equilibrium type of model; an exercise that is not possible to perform within this project. In our predictions, we therefore do not count trade explicitly, but rather we implicitly assume that any exports and imports are included in the pre-set demand level. The prediction on electricity generation in Slovakia – the exogenous variable which values we need to set for the model – are thus based on our best guess on electricity domestic consumption.

Electricity consumption in Slovakia was about 27.4 TWh in 2009, while 26.1 TWh (SEPS, 2011a) was generated domestically. Import of electricity

exceeded its export since 2007, and, on average, about 4% of electricity consumption in Slovakia was covered from net imports (SlovStat).
We review several sources in order to set a path in electricity consumption for Slovakia, particularly Energy Safety Strategy, 2008 (SEPS, 2011b), REPAP, 2020 (Resch *et al.*, 2010), EU Energy Trends, 2030 based on PRIMES model (EC, 2010), with predictions ranging between 32 to 41 TWh in 2020.
Then, we also consider an estimate by Greenpeace resulting in 1% annual decrease in demand for electricity. Finally, an average rate of 0.55% in consumption during the period 1998-2008 and also an estimate of +0.12 elasticity of demand with respect to GDP as econometrically estimated were applied. Last two sources combined (the suggestion of Greenpeace and our calculations based on PRIMES) resulted in a value of electricity consumption around 30.4 TWh in 2020 which we use to define electricity demand in the MESSAGE model. This value follows a prediction by Greenpeace, but it also implicitly counts for further decreases in electricity consumption in Slovakia most likely involved by increase in electricity price as an effect of regulation (ETS, support of renewable energy, etc.) as due to increasing worldwide demand for energy.

Consumption of heat, when subtracting own use by plant and transmission and distribution losses, was 34.3 PJ in 2009, when the majority of heat supplied was used by households (19.2 PJ) and commercial and public services (9.3 PJ). We observe significant reductions in heat use in both of these sectors with a decrease of about 6.0 or 1.4% respectively, during 2005 and 2009, and overall, heat consumption in Slovak economy declined by about 4.4% during the period 2005-2009. In the MESSAGE model, it is however the amount of fuel used for heat generation that determines the level of emission in relevant model sectors (e.g. district heating, service and governmental institution in the sector nodes of the model).

We use two sources of data to set our assumption on fuel use for heat generation. First, we use the EU database on Energy Saving Potentials (see Fraunhofer *et al.*, 2009), specifically, the unit consumption of space heating per dwelling for 2010-30 in its Low Policy Intensity scenario (LPI); second, we further assume that the number of dwellings remains constant over the period as suggested in Baseline PRIMES scenario in EU Energy Trend 2030–2009 update (EC, 2010). Combining these two pieces of information, we get a reduction in fuel use by 1.58% per annum that results overall in 16% reduction by 2020 compared to the 2009 initial level.

Similarly as we set fuel demand for heat generation, we also set demand for fuel used in technological processes. First, we assume autonomous savings as reported in the EU database mentioned above, and increases in value added as reported in the EU Energy Trends (EC, 2010).

Annex C Estimation of over-allocation of EUAs and auctioning revenues

C.1 Auctioning revenues: lower and upper bound

Our estimates of auctioning revenues lay considerably below the estimates of the Öko-Institut, but above the estimations from Climate Strategies. Our estimates are equal to € 119 and € 175 million for the -20 and -30% targets, respectively. Table 26 gives information from the calculations from the Öko-Institut model.

Table 26 Estimated auctioning revenue, 2013-2020

	2013	2014	2015	2016	2017	2018	2019	2020	Total 2013-2020
20% reduction									
EUAs, millions	16	16	16	15	15	15	15	15	124
Free allocation	4	3	3	2	2	1	1	0	15
Price	13	13	14	14	15	15	16	16	116
Value, million €	160	169	178	188	202	215	230	245	1,587
30% reduction									
EUAs, millions	15	15	14	14	14	14	13	13	111
Free allocation	4	3	3	2	2	1	1	0	15
Price	24	24	25	26	27	28	28	29	211
Value, million €	263	275	291	308	324	341	358	375	2,535

The reason of these differences with our estimates is that the model developed by Öko-Institut assumes that in 2020 all emissions in the ETS sectors will fall under auctioning, while in fact most of the industrial sectors are excluded from this scheme. The model does not distinguish between electricity (under auctioning) and heat (under free allocation) of CHP units. Moreover, the model seems to assume that auctioning for non-exposed industrial sectors will be equivalent to that of the power sector.

It should be noted that our estimate of the auction revenues does take into account that part of the auctioned allowances will be redistributed among the Member States. The estimates from the Öko-Institut are even lower than that presented by Smol (2010), who estimates that in Slovakia in 2013 19.01 Mt of CO_2 will be allocated for auctioning. Given the large difference in estimated auction outcomes, we would propose that the estimates from the Öko-Institut provide the upper bound of auction revenues, and our estimates the lower bound.