Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables

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Contents

Figures

Tables

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1 Introduction

Climate change is caused by greenhouse gas (GHG) emissions stemming largely from the energy system (from combustion of fossil fuels, such as coal, lignite, oil and gas). CO_2 emissions from fossil fuel combustion represent between 70 and 80% of total GHG[1,2] emissions in the developed countries. In June 1996, the European Council endorsed the objective to limit global average temperatures increases to no more than 2°C above the pre-industrial level. In the energy sector, the EU is confronted with an increasing dependence on energy sources that are located outside the EU. This trend, combined with the continuously increasing energy prices experienced since 2004, exposes the EU economy to future energy crises. Therefore, both due to environmental concerns as well as the concern about the security of the EU energy supply, a business-as-usual energy future is not sustainable.

To address these challenges, the 2007 European Spring Council decided the following targets for the EU: a) reduce GHG at least by 20% in 2020 compared to 1990 levels; b) supply 20% of energy needs by 2020 with renewable energy sources (RES), including use of biofuels at 10% of liquid fuels in road transport; c) give priority to energy efficiency in all energy domains. In January 23, 2008 the European Commission proposed a full policy package of implementation measures to meet the EU's objectives on climate change and renewable energy for 2020.

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

The EU-ETS is a policy instrument to reduce CO_2 emissions in electricity plants and major industrial installations. It covers today already more than 40% of all EU-27 GHG emissions. In December 2006 the Commission proposed to include aviation in the EU-ETS. The proposed amendment of January 2008 to the Directive foresees a single EU-wide cap for the emissions covered by the EU-ETS, which is set at a level 21% lower than emissions in 2005 by 2020 for the ETS sectors. Harmonised allocation of emission allowances with full auctioning is foreseen for power plants starting in 2013 and a gradual increase towards the full use of auctioning to allocate allowances to the rest of the ETS sectors, with the exception of those installations exposed to a significant risk of carbon leakage.

The choice of an EU-wide cap under the EU-ETS implies that the rest of the total effort for GHG reduction (20% lower in 2020 than 1990) is assigned to the so-called non-ETS sectors, which represent today some 60% of total GHG emissions in the EU and relate to a wide range of sectors covering mostly small scale emitters, such as transport (e.g. cars, trucks), residential and services buildings, small industrial installations, agriculture, etc., including all types of greenhouse gases. These are typically sectors where Member States have the competence to implement policies and measures to reduce greenhouse gas emis-

[1] Non-CO_2 GHGs: methane, CH_4; nitrous oxide, N_2O; hydro fluorocarbons, HFCs; per fluorocarbons, PFCs; sulphur hexafluoride, SF_6

[2] CO_2 is also emitted by some industrial processes, without relation to combustion, such as the cement production

sions, supplemented by EU policies. The proposed Decision of the EU sets differentiated GHG emission reduction obligations by Member-State for those non-ETS sectors (see Table 1).

The third legislative proposal, namely the Directive on renewables, also defines differentiated quantitative targets by Member-State and assigns to the Member-States the corresponding responsibility (see Table 1). The proposed Directive improves and extends the Guarantees of Origin (GO) which may be used by the Member-State to trade renewable energy and meet their obligation in a more cost-effective way. The 10% biofuels objective is set as an EU-wide obligation and is included in the renewables target. The quantitative GHG emission reduction targets have been defined in two-steps: firstly, the total GHG reduction effort has been divided between the EU-ETS and non EU-ETS sectors at the EU-wide level; secondly, the EU-wide effort assigned to the non EU-ETS sectors has been further divided between the Member-States.

Meeting the GHG emission reduction target increases the use of RES but does not necessarily imply meeting the RES target, and vice-versa. This implies that the proposed RES targets by Member-State calls upon additional policies and measures on top of those required for meeting the GHG targets alone. Similarly, attaining 10% biofuels share is not necessarily derived from the overall RES target. Additional policies and measures may be needed for biofuels. It is therefore evident that specifying the targets in quantitative terms is a complex exercise. Naturally this also involves multiple decision criteria.

The PRIMES energy system model has been used as an impact assessment tool. A large series of tentative target differentiation schemes have been evaluated with respect to their implications on the Member-States' energy systems and in terms of energy costs and prices. The use of the PRIMES model ensured consistency of the analysis given that the targets induce simultaneous and complex changes in the energy system, compared to business-as-usual. Regarding the non-CO2 GHGs the analysis was carried out by using the GAINS[3] model results of IIASA.

[3] See http://www.iiasa.ac.at/rains/gains-methodology.html

Table 1: Targets by Member-State as proposed by the EC

Obligations for 2020		non EU-ETS target (*)	RES target (**)
Austria	AT	-16%	34%
Belgium	BE	-15%	13%
Bulgaria	BG	20%	16%
Cyprus	CY	-5%	13%
Czech Republic	CZ	9%	13%
Denmark	DK	-20%	30%
Estonia	EE	11%	25%
Finland	FI	-16%	38%
France	FR	-14%	23%
Germany	DE	-14%	18%
Greece	EL	-4%	18%
Hungary	HU	10%	13%
Ireland	IE	-20%	16%
Italy	IT	-13%	17%
Latvia	LV	17%	42%
Lithuania	LT	15%	23%
Luxembourg	LU	-20%	11%
Malta	MT	5%	10%
Netherlands	NL	-16%	14%
Poland	PL	14%	15%
Portugal	PT	1%	31%
Romania	RO	19%	24%
Slovakia	SK	13%	14%
Slovenia	SI	4%	25%
Spain	ES	-10%	20%
Sweden	SE	-17%	49%
United Kingdom	UK	-16%	15%

Explanations:
(*) reduction of GHG by 2020 compared to 2005
(**) Share of renewables in final energy demand by 2020

Source: European Commission DG ENV

The study was carried out between July 2007 and January 2008 and the results have been used by the Impact Assessment working document[4] of the European Commission SEC (2008) 85/3. The model-based scenarios were constructed using the Baseline scenario of November 2007 published by DG TREN[5]. All figures up to 2005 are based on Eurostat statistics (for non CO_2 GHG on UNFCCC statistics) and for time periods beyond 2005 they are based on the PRIMES model and the GAINS model of IIASA (for non-CO_2 GHGs) results[6].

[4] See http://ec.europa.eu/commission_barroso/president/focus/energy-package-2008/index_en.htm

[5] See http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2007/index_en.htm

[6] M. Amann, L. Höglund Isaksson, W.Winiwarter, A. Tohka, F. Wagner, W. Schöpp, I. Bertok, C. Heyes (2008) Emission scenarios for non-CO2 greenhouse gases in the EU-27 : Mitigation potentials and costs in 2020. Final Report, May 2008, International Institute

2 Problem Definition

2.1 The Baseline GHG Emissions

The EU emitted 5211 Mt of CO_2-equivalent in 2005, 6.6% down from 1990 (5578 Mt). The ETS sectors, excluding aviation, emitted 2193 Mt of CO_2 in 2005, accounting for 42% of total GHG emissions. Emissions from power generation accounted for 61% of emissions by ETS sectors in 2005.

Table 2: GHG Emissions - Business as Usual - EU27

GHGs (Mt CO2 equivalent)	1990	2000	2005	2020	2030
All GHGs	5578	5101	5211	5496	5380
All CO2	4379	4128	4267	4610	4639
ETS sectors		2290	2340	2557	2573
ETS without aviation		2156	2193	2339	2319
Aviation		134	147	218	255
Non-ETS sectors		2811	2871	2940	2806
Energy related non-ETS		1838	1927	2054	2065
Non CO2 GHGs	1199	973	944	886	741

Under business-as-usual assumptions, total emissions of GHGs in the EU are projected to rise by 5.5% in 2020, compared to 2005. The emissions of non CO_2 GHGs[7] are projected to decrease by 6.2% in 2020 from 2005, contrasting an increase of 9.3% of CO_2 emissions. In the ETS sector without aviation CO_2 emissions are also projected to rise in 2020: 6.7% up from 2005. If aviation is included in the ETS, the increase of CO_2 emissions becomes 8% compared to 2005. Emissions of CO2 from non-ETS sectors are also projected to rise in 2020: 6.6% up from 2005.

The business-as-usual projection (see Table 2) shows an unequal evolution of emissions across the Member-States. Emissions from ETS including aviation are projected to increase in all Member-States (except for Malta). Emissions of CO2 in non-ETS sectors also rise in all Member-States, except Germany, the UK, Denmark and Finland, but this increase is significantly higher in Member-States that had (in 2005) a lower GDP per capita than the EU average. Emissions of non-CO2 GHGs are projected to decrease in most Member-States, with the exception of few new Member-States, as well as Spain and Belgium.

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[7] The non-CO_2 GHGs are included in the non-ETS sector.

The table below summarises the changes of emissions by Member-State in the Baseline scenario in 2020 relative to emissions in 2005. This table shows the Member-States in descending order of GDP/capita in 2005.

Table 3: Baseline projection of GHG Emissions (2020)

PRIMES Model Database		Baseline in 2020: % changes from 2005							
		All GHGs	All CO2	Non CO2 GHGs	ETS (CO2)	non-ETS (GHGs)	ETS w/out aviation	Aviation	other non-ETS
Bulgaria	BG	4.9	17.2	-32.7	10.7	-3.9	9.2	108.2	43.6
Romania	RO	27.1	38.1	1.0	31.6	23.0	31.0	154.7	51.7
Latvia	LV	61.3	68.3	45.9	77.9	54.9	77.9	76.7	61.7
Lithuania	LT	22.4	30.1	7.6	28.5	19.1	27.2	93.3	32.0
Poland	PL	13.3	17.9	-5.7	13.2	13.5	12.8	91.4	28.6
Slovakia	SK	20.3	23.5	6.6	25.2	14.6	24.8	114.5	20.3
Estonia	EE	15.3	19.7	-7.7	15.9	14.0	15.4	69.7	35.3
Hungary	HU	14.8	16.3	10.7	17.4	13.4	16.2	68.6	15.3
Czech Rep.	CZ	-1.7	-0.4	-10.2	-7.2	5.7	-8.7	111.2	12.9
Malta	MT	-18.4	-19.4	-12.5	-37.8	11.6	-49.6	43.7	27.0
Slovenia	SI	17.6	23.6	-9.2	8.9	24.5	8.4	65.0	41.2
Portugal	PT	11.5	18.0	-11.6	22.5	2.3	20.7	48.0	11.7
Greece	EL	3.6	7.9	-13.4	0.4	7.0	-1.0	27.5	22.3
Cyprus	CY	0.2	1.7	-9.0	-5.1	6.1	-14.1	32.1	12.6
Spain	ES	9.4	10.7	2.9	7.9	10.7	3.6	59.4	14.0
EU27	EU	5.5	8.0	-6.2	9.3	2.4	6.7	47.6	6.6
Italy	IT	12.0	14.6	-2.3	18.3	7.5	16.2	58.2	11.0
Germany	DE	-0.4	0.8	-9.1	3.6	-4.5	1.1	53.1	-3.0
France	FR	-0.9	0.9	-5.8	-4.3	0.4	-10.3	39.4	4.1
Belgium	BE	7.9	7.0	12.6	13.8	3.7	11.2	52.0	0.1
UK	UK	-2.8	0.2	-17.6	5.2	-9.4	0.1	42.4	-5.7
Austria	AT	6.6	8.5	-4.1	12.5	3.2	9.8	58.2	5.5
Finland	FI	2.0	3.4	-5.1	10.2	-6.5	9.1	33.0	-7.1
Netherlands	NL	9.4	12.2	-4.1	22.5	-0.6	21.5	29.7	1.0
Sweden	SE	17.9	24.1	-5.3	38.4	7.4	37.5	45.4	13.4
Denmark	DK	-0.8	0.3	-4.7	1.4	-2.5	-2.1	34.4	-1.2
Ireland	IE	6.2	17.0	-14.5	23.3	-2.1	19.7	56.0	10.7
Luxembourg	LU	10.6	11.5	-3.3	13.7	9.4	4.5	32.3	10.6

For more details on the emission figures included in the PRIMES database for 2005 (as in end November 2007) and in the PRIMES Baseline scenario, see the tables shown in Appendix.

2.2 The GHG Target

The 20% EU target corresponds to maximum emissions of 4462 Mt of CO_2-equivalent in 2020, 18.8% down from business-as-usual[8] emissions in 2020 (5494 Mt). The target for 2020 corresponds to a 14.4% reduction of GHG emissions from 2005 levels, instead of an increase by 5.5% as projected under business-as-usual trends.

The choice of a single EU-wide cap on emissions by sectors subject to the ETS implies that the total emission reduction effort must be first divided between the ETS and the non-ETS at the EU-wide level. Enforcing an overall cap on ETS emissions in 2020 of e.g. 21% less than emissions in 2005,

[8] Business-as-usual refers to the 2007 Baseline scenario quantified by PRIMES model (Op. Cit.)

implies that the ETS sectors, excluding aviation, will have to decrease emissions by 460 Mt CO_2 in 2020 compared to 2005 emission levels or 606 Mt less than their business-as-usual emissions in 2020. This corresponds to an abatement effort of 25.9%.

Non-CO_2 GHG emissions are included in the non-ETS category and accounted for 33% of non-ETS emissions in 2005. The enforcement of the emissions cap on the EU-ETS keeping 21 % below 2005 levels together with a target for the aviation sector equal to their 2005 emission levels implies that the non-ETS sectors will have to emit maximally 2582 Mt of CO_2-equivalent in 2020. This corresponds to an abatement effort of 12.1% from business-as-usual emissions in 2020 (or 10.0% less emissions from 2005 levels).

The allocation of emission allowances is to be harmonised and the EU-ETS cap to be set at EU level. Therefore Member States cannot longer set themselves an emission cap for their ETS sectors.

By contrast, it is proposed that the emissions cap on non-ETS sectors has to be met by each Member-State, so specific caps have to be specified by Member-State.

Table 4: GHG Targets according to the EC proposal

Max allowed emissions in Mt CO2 equivalent in 2020 (EC proposal)		% change from Baseline
All GHGs	4462 = 20% less than 1990	-18.8
ETS without aviation	1732 = 21% less than 2005	-25.9
Aviation	147 = stable from 2005	-32.3
ETS sectors	1880 = Sum of ETS caps	-26.5
Non-ETS sectors	2582 = Diff. GHG - ETS	-12.1

In summarising, the emission reduction "effort sharing" problem can be translated in setting the following constraints:

a) Reduction of CO_2 emissions by EU-ETS sectors of the EU in 2020, compared to 2005.
b) Reduction of GHG emissions by non-ETS sectors of each Member-State in 2020, compared to 2005.

2.3 The RES Target

The EU used 123 Mtoe of renewable energy sources (RES) in 2005 to cover part of its primary energy requirements, accounting for 6.8% of total primary energy requirements in 2005.

Eurostat introduced a new indicator termed "share of renewables in Gross Final Energy Consumption", which is measured as a ratio of renewable energy consumed in all final demand sectors (including the part of electricity and heat generated by renewables) over final energy demand increased by distribution losses and self consumption of electricity and steam. In terms of final energy demand, the EU consumed (directly or indirectly) 104 Mtoe of RES in 2005, which accounted for 8.7% of Gross Final Energy Consumption in 2005, according to the new indicator of Eurostat, mentioned above, which is used to measure performance against the RES target.

Table 5: RES use – Baseline scenario - EU27

Renewable Energy Sources	1990	2000	2005	2020	2030
In Primary Energy (Mtoe)	74	101	123	197	237
In Final Energy Demand (Mtoe)		91	104	176	213
As % of Final Energy Demand		7.9	8.7	12.7	14.7

Under business-as-usual assumptions, the share of RES in Gross Final Energy Consumption is projected to rise to 12.7% in 2020, which is lower than the 20% required by the EU target. The development of RES is very unequal across the Member-States (see Table 6), since it depends on their RES potential and the policies in place. Thus, increasing RES deployment will also imply unequal relative efforts across the Member-States. Table 6 shows that gross final demand is projected to grow significantly more in Member-States with GDP/capita lower than the EU average. Increasing the RES ratio would imply higher relative effort, compared to Member-States with low increase of gross final energy demand.

Meeting the RES target will require increasing the use of RES or reducing final energy demand, or both. To quantify the additional amount of RES that the EU has to use by 2020 in order to meet the RES target, it is therefore necessary to also forecast final energy demand and its possible change under the new policy circumstances.

For this purpose, a prospective analysis, a scenario, is necessary. Such a scenario is even more necessary if it is required to set differentiated RES targets by Member-State, again because the targets are expressed as ratios of RES over final energy demand.

Table 6: RES per Member-State - Baseline scenario

	Observed - 2005			Baseline - 2020			% change or diff. from 2005		
	RES Mtoe	Gross Demand Mtoe	RES ratio in %	RES Mtoe	Gross Demand Mtoe	RES ratio in %	RES Mtoe	Gross Demand Mtoe	RES ratio in %
BG	1.2	10.4	11.3	1.4	13.6	10.0	15.6	31.0	-1.3
RO	5.1	26.1	19.7	7.1	37.3	18.9	37.4	42.8	-0.7
LV	1.8	4.2	42.2	2.2	6.3	35.3	24.8	49.0	-6.9
LT	0.7	4.8	15.0	1.2	6.6	17.7	60.5	35.8	2.7
PL	4.5	59.6	7.5	8.9	80.3	11.1	98.9	34.9	3.6
SK	0.8	11.1	6.9	1.1	14.0	7.6	40.4	26.2	0.8
EE	0.6	3.1	18.3	0.7	4.1	17.0	23.3	33.1	-1.3
HU	0.9	18.6	4.7	1.5	22.6	6.5	68.6	21.2	1.8
CZ	1.8	27.3	6.7	3.8	33.1	11.6	109.4	21.4	4.9
MT	0.0	0.6	0.0	0.0	0.7	3.1		29.1	3.1
SI	0.8	5.1	15.1	1.1	7.0	15.3	39.3	37.2	0.2
PT	3.3	19.2	17.0	5.7	24.0	23.9	75.8	25.3	6.9
EL	1.6	21.6	7.5	3.0	27.0	11.0	82.4	24.8	3.5
CY	0.1	1.7	3.0	0.2	2.2	7.5	221.3	26.5	4.6
ES	8.2	100.4	8.2	19.7	126.8	15.5	140.6	26.2	7.4
EU	104	1205	8.7	176	1391	12.7	68.9	15.4	4.0
IT	7.3	137.2	5.3	13.6	166.7	8.2	86.6	21.5	2.9
DE	13.2	224.7	5.9	25.7	236.6	10.9	94.7	5.3	5.0
FR	15.4	161.5	9.5	23.3	179.8	13.0	51.3	11.3	3.4
BE	0.9	37.1	2.4	3.2	40.5	7.8	249.3	9.1	5.4
UK	2.5	155.9	1.6	10.1	163.4	6.2	307.9	4.8	4.6
AT	6.8	28.0	24.2	8.4	32.4	26.1	24.4	15.6	1.8
FI	7.5	25.9	28.8	9.1	28.7	31.6	21.4	10.9	2.7
NL	1.8	52.9	3.5	4.1	59.2	6.9	124.3	11.8	3.5
SE	14.7	34.6	42.4	15.9	40.0	39.8	8.5	15.5	-2.6
DK	2.5	16.3	15.5	3.7	17.5	20.9	45.3	7.5	5.4
IE	0.4	12.7	3.0	1.2	15.5	7.5	204.7	22.3	4.5
LU	0.0	4.4	1.1	0.3	5.3	6.1	578.3	20.1	5.0

2.4 *Considering the two targets together*

The RES effort sharing problem cannot be examined without consideration of the emission reduction effort sharing and vice versa. Both the RES and the reduction of energy demand are among the options for meeting both the GHG and the RES targets. This is also ensured by following a model-based analysis.

2.5 *Additional policy issues*

The complexity of the analysis increases when considering the following additional issues:

a) It is recognised as possible to meet part of the emission reduction obligations outside the EU territory by means of the Clean Development Mechanisms (CDM), as defined within the Kyoto protocol.

b) The EU policy package extends the applicability of the guarantees of origin (GO) as a means for Member-States to comply with their individual RES target. The Member-States may trade RES for that purpose.

c) The biofuels target (10%) is enforced at the EU level and is not differentiated by Member-State. However, the biofuels are taken into account at the Member-State level for complying with the RES target.

3 Methodology

3.1 *Energy scenarios for effort sharing*

A large number of candidate effort sharing schemes were analysed by constructing a series of energy scenarios with the PRIMES energy model. Each PRIMES scenario corresponds to a specific effort sharing scheme. The model was not used to optimise the effort sharing scheme per Member State according to some distribution key but only to analyse the overall consequences of alternative schemes. These schemes were proposed by the EC.

3.2 *Modelling methodology*

In mathematical terms, the PRIMES energy model may be understood as a tool which determines energy quantities and energy prices that maximise the sum of consumer and producer surpluses[9]. The emission reduction and the RES targets are defined as constraints of this maximisation problem. The marginal values (dual variables of constraints) associated to these two constraints are termed “carbon value” and “RES value” respectively. The carbon value is the system-wide cost of the last ton of CO_2 abated in order to meet the emission reduction constraint. The RES value is the virtual system-wide unit cost

[9] In fact the PRIMES model has the equivalent mathematical form of a set of concatenated MCPs (Mixed Complementarities Problem), which correspond to the first-order conditions of a nonlinear optimization problem representative of an agent’s behavior, as well as demand-supply equilibrium conditions. Total energy system cost is calculated ex-post on the basis of model results and is not used as an overall objective function, as in traditional optimization models. The concatenation of MCPs and equilibrium conditions can be extended by adding overall constraints such as the emission cap and the RES deployment targets. The solution of the concatenated MCPs and equilibrium constraints is equivalent of maximizing social surplus (sum of consumer and producer surpluses). The computer implementation of PRIMES is more complex and the model is not solved as a single MCP.

from the last RES unit which is used in order to meet the RES constraint.

If both targets are sufficiently ambitious, both marginal values are different from zero. This means that the emission reduction target alone would not be enough to induce RES use that meets the ambitious RES target, and vice versa.

In any energy demand or supply sector, the unit cost of emission reduction increases with increasing total amount of emission abated. Similarly, the unit cost of RES increases with increasing total amount of RES used. The PRIMES model simulates in detail these relationships by representing energy technologies, substitution possibilities and potential resources.

The results of the model indicate the specific amounts of emission reduction and RES uses by sector and by Member-State which are associated with the overall energy market equilibrium, subject to the emission and the RES constraints.

3.3 The Cost-Efficiency solution

At a market equilibrium point, the amount of emission reduction by sector is such that the marginal emission reduction costs of all sectors are equal to the marginal value of the overall emission reduction target. Similarly, the amount of RES uses is such that marginal costs of RES uses in all sectors are equal to the marginal value of the RES constraint. The equality of marginal emission abatement costs across all sectors of the EU Member-States and the equality of the RES marginal values across all sectors ensure the lowest possible total cost for meeting the two targets.

The resulting energy scenario is termed “cost-efficiency scenario” and is used as a benchmark in the analysis of alternative effort sharing schemes.

3.4 Total Compliance Cost

Total compliance cost is defined as the additional direct and indirect energy-related costs, compared to business-as-usual, which correspond to the additional effort needed for meeting the emission reduction and the RES deployment targets.

From an economy-wide perspective, the total energy cost is the sum of all kinds of energy-related costs incurred by final energy demand sectors, namely households, services, agriculture, industry and transport. These costs include purchase of energy commodities, as well as cost associated with the purchase and use of end-use equipments, and the costs of any actions to improve energy efficiency and adapt energy consumption behaviour. Final demand sectors may also bear stranded costs, when for example energy equipment is prematurely replaced for economic reasons.

The prices of energy commodities, which are computed by the model, are such that all kinds of energy supply costs (investments, purchase of fuels, transportation-transmission etc.) plus profit are covered.

The PRIMES model implements a partial equilibrium, contrasting a general economic equilibrium that a model such as GEM-E3 implements. From this perspective, total compliance cost is exactly the incremental cost that the rest of the economic system would be required to pay in order to comply with the targets. In this sense, total compliance cost is a first order approximation of economic cost of the policy package.

3.5 Costs for non-CO_2 GHGs

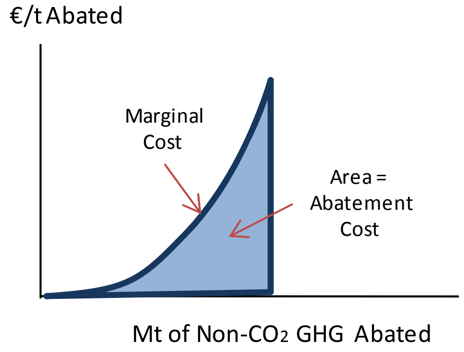
The PRIMES model covers the energy and process related emissions of CO_2. The non-CO_2 GHGs are modelled by using the GAINS model of IIASA. This model derives emissions of non-CO_2 GHGs from a series of activity indicators, referring among others to agriculture and to specific industrial processes.

Emission reduction possibilities are modelled through cost-abatement marginal curves which are identified per type of non-CO_2 GHG and per Member-State. These curves, along with CO_2 abatement possibilities quantified by using the PRIMES model, are combined for constructing GHG emission and RES scenarios, hence the effort sharing schemes.

Hereinafter, referring to effort sharing analysis with PRIMES is considered as inclusive of the marginal abatement curves of non-CO_2 GHGs from the GAINS model of IIASA[10].

[10] See http://www.iiasa.ac.at/rains/C&E_package.html?sb=19

Figure 1: Marginal Cost Curve and Abatement Cost



Compliance cost for non-CO_2 GHGs is the integral of the marginal abatement cost curves from zero up to the level of abatement required for non-CO_2 GHGs under a certain effort sharing scheme. (See Figure 1)

3.6 Distributional Equity

Although the cost-efficiency scenario is optimal in terms of total compliance cost, it is not necessarily acceptable from the perspective of distributional effects among the Member-States. This is simply because the cost-efficiency scenario does not consider distributional equity among the constraints of market equilibrium. In this scenario compliance costs per unit of GDP have substantial differences between the Member-States. A cost-effective distribution of the effort among the Member-States results in proportionally higher compliance costs for Member-States with lower GDP per capita. This result was considered by the EC as not consistent with equity and fairness criteria which have been set as basic policy principles by the EU.

The PRIMES model has also been used to evaluate distributional effects among the Member-States for different allocation scenarios. The evaluation was based on quantification of a set of distributional equity criteria using the results of the model. There has been no attempt to aggregate the criteria, as for example is common in multiple criteria decision-aid methods. The distributional criteria included the following:

i. Total compliance cost for a Member-State per unit of GDP.

ii. Change of GHG emissions of a Member-State from non-ETS sectors in 2020 compared to 2005.

iii. Total per capita emissions of a Member-State from non-ETS sectors in 2020.

Obviously these criteria are measures of distributional equity concerning the sharing of efforts among the Member-States. Enforcing one of these criteria is meant as seeking minimisation of variation of criterion value across the Member-States in addition to minimisation of total cost of compliance with the required targets. The inclusion of the additional criterion results into an energy scenario and a distribution of efforts that differ from the one corresponding to the cost-efficiency scenario. Total compliance cost corresponding to such a scenario is naturally higher than the cost associated with the cost-efficiency scenario, the difference representing the cost incurred for satisfying the distributional equity requirement.

The finally proposed target allocation by the EC was not based on a PRIMES model run that optimises targets according to a certain equity criteria such as for instance equal costs per GDP. But the policy making process did take into account the various PRIMES results for different target allocation keys, as proposed by the EC, and their impact on fairness, expressed as cost per GDP.

The model-based analysis of alternative effort sharing schemes based on the above mentioned distributional criteria are not presented in the present report, in order to avoid further complexity. The present report includes only the model-based results of scenarios that correspond to the eventual effort sharing schemes proposed by the Commission.

3.7 Energy Scenario Data Base

As mentioned above, the GHG emission reduction and the RES deployment are related to each other. The levels of the two targets as decided by the EU are ambitious. In fact, the results of the model indicate that the marginal values of both targets are different from zero at market equilibrium. In other words, meeting a single target is not enough to also meet the other target: additional policies and measures are required.

Due to the size of the model and computer limitations, solving the model simultaneously for all Member-States results in unacceptable large computing times. Therefore, enforcement of both EU targets simultaneously as explicit constraints is not possible.

It was thus chosen to run the model consecutively for each Member-State by varying the level of the marginal values associated with the two targets, namely the carbon value and the RES value, until both targets are met.

The model runs had also to accommodate the policy option to represent the EU ETS market at the EU level and the non-ETS sectors on a national basis with the possibility of varying carbon values, reflecting differentiated emission reduction targets by Member-State for the non-ETS sectors. Similarly, the model runs had to accommodate the policy option allowing for differentiated RES targets by Member-State and so the corresponding RES values could vary across the Member-States.

Consequently the domain of possible energy (effort sharing) scenarios is delimited by the Cartesian product of one carbon value for the EU-wide EU-ETS sector, 27 carbon values for the national non-ETS sectors[11] and 27 RES values also on a national basis. Only a sub-set of these combinations comprises of acceptable effort sharing schemes, having carbon values and RES values sufficiently high to induce meeting both targets.

Following this methodology approximately 150 complete energy scenarios with different carbon and RES values were investigated by using the PRIMES model for the period 2005-2030 and for all Member-States and the set of those that meet the two targets was identified. Each of these scenarios corresponds to a distinct effort sharing scheme which, on the basis of the model results, can be evaluated against its performance in terms of compliance cost (per Member-State and overall). The scenarios allow assessing usual energy policy appreciation criteria, such as security of energy supply, energy intensity indicators, etc.

By using the database of energy scenarios it is possible to construct multidimensional marginal abatement cost curves and marginal RES deployment cost curves, for each Member-State and for the EU. The multiple dimensions correspond to the 55 (1+27+27) different marginal values for carbon and the RES.

[11] The carbon values for the non-ETS sectors, which are defined on a national basis, were also used for the marginal abatement cost curves for the non CO_2 GHGs.

3.8 Auctioning vs. Grandfathering

In order to assess the implications of enforcing full auctioning versus grandfathering two series of the scenarios were implemented.

The full auctioning regime assumes that purchasing the emission allowances is a true cost element in power generation and so electricity prices are affected directly. Under the grandfathering regime, the degree of passing through to consumer prices the opportunity costs associated with the carbon price of the EU ETS depends on the market power of participants in the electricity market. In a well functioning market, as this assumed for the PRIMES model projections, power producers will mostly pass through to consumers true emission abatement costs induced by the scarcity of emission allowances and are less able to pass through the opportunity cost associated with grandfathered emission allowances. So the model simulates very different impacts on electricity prices of auctioning versus grandfathering regimes which consequently affects the demand for energy and the rest of the energy system.

On the contrary, the non-ETS carbon values and the RES values, although used in the model to influence decision makers' choices about fuel mix and energy efficiency, do not entail direct payments to the consumers or to energy producers, other than the costs that are involved indirectly in the changes of energy structures induced by these marginal values. There are no money transactions induced directly by these marginal values. They constitute therefore a measure of the intensiveness of policies and measures that would be implemented for inducing the corresponding energy system changes.

The auctioning regime will generate substantial revenues which will be recycled in the economy under the responsibility of the national states. It is assumed that they are not allowed, however, to recycle the revenues as subsidies to the purchasers of emission allowances in the ETS. From a macroeconomic perspective, the economic impact of revenue recycling, although depending on the concrete choices for recycling, will most likely have a positive impact on the economy. So the auctioning revenues are not included in the compliance cost. However, the consumer costs corresponding to the increased energy prices induced by the auctioning regime are included in the compliance cost.

3.9 Impact of CDM

All these scenarios have assumed that emission reduction takes place within the EU territory. As mentioned before, it is an option to get emission reduction credits through the CDM flexibility mechanisms. For this purpose a set of additional scenarios were built by using the PRIMES model that include access to CDM.

It is generally assumed that the marginal cost (i.e. the price if an organised market operates) of CDM emission credits at a global scale will be lower than the marginal cost of emission reduction within the EU territory, certainly in case of no new ambitious international agreement on post 2012 climate change policies. Therefore, providing for the possibility of using the CDM flexibility mechanism implies lower emission reduction efforts in the EU and lower carbon prices for the ETS as well as the non-ETS sectors at national level. This will further imply that the RES values must increase in order to meet the RES target, since the additional RES deployment induced by the carbon values will be lower. Generally, there will be weaker incentives for structural changes in the EU energy system, both in the demand and the supply sectors.

Hence, the choice of the reduction in marginal costs within the EU and thus carbon values in the EU due to access to CDM is a crucial assumption for the construction of the scenarios. Several scenarios were built to analyse the impact of reduced EU carbon values due to access to CDM emission credits.

It is however difficult to predict what will be the level of the marginal cost of emission credits at global scale because this will mainly depend on whether or not other world regions will undertake sufficient emission reduction commitments. If the EU acts unilaterally then the marginal cost of emission credits from CDM is likely to remain at low levels, which would require imposing upper limits to the access to CDM if substantial emission reductions need to be achieved within the EU.

3.10 RES trading

Trading of electricity of RES origin among Member-States is of course possible under the EU Internal Energy Market regulations. The PRIMES model simulates electricity trading irrespectively of electricity origin. Physical trading of electricity from RES is assumed not to imply any exchange of Guarantees of Origin (GO).

The proposed policy package analysed possible benefits from RES trading, which is meant to concern the exchange of GOs. Two cases have been examined by means of energy scenarios constructed with PRIMES:

a) No RES trading. The exchange of GOs among Member-States would not count towards the RES targets and the Member-States meet their RES targets domestically.

b) Full RES trading. The scope of GOs is extended adding all possible applications of RES, including outside the electricity sector. The exchange of GOs among Member-States count towards their individual RES targets.

According to the first case, the Member-States will implement strictly national policies to meet their RES target. As they may have different RES targets and because the marginal costs of RES deployment differ, both the costs of meeting the target and the RES values will differ by Member-State. Evidently the resulting distribution of RES uses does not correspond to a cost-effective exploitation of renewables potential of the EU and compliance costs would be raised.

According to the second case, the Member-States would be allowed to meet their targets by buying GOs for RES produced in other Member-States. The RES trading system may be applied in practice at the level of companies. In that case, RES-producing companies would be able to select between feed-in tariffs or other domestic support schemes or to sell the GO to a company in another Member-State who would have the obligation to hold GOs. It is difficult to model in PRIMES this complex economic mechanism, because PRIMES represent the national RES supporting schemes directly without possibility for arbitration among sub-models by Member-State. For this reason, it was assumed that the exchange of GOs is allowed only between Member-States irrespectively of possible differences in their national RES supporting schemes. Nevertheless, the possibility of trading the GOs among the Member-States facilitates reaching a cost-effective exploitation of the RES potential in the EU and leads to lower compliance cost and a lower RES value, compared to the non-trading case.

3.11 Biofuels Target

The European Commission's proposal includes a target concerning renewables in transport separately from the RES target. It is expected that the bulk of this target will be achieved through the use of biofuels. The target is defined at the EU level, 10% of liquid fuels in transport, without differentiation by Member-State. Using biofuels counts towards the RES target for each Member-State.

The European Commission proposed a set of sustainability criteria referring to production of biofuels and clearly opted for the promotion of second-generation biofuels. The PRIMES model did not study the sustainability issue for biofuels, because the new specialised biomass model of PRIMES was not fully operational when the present study was carried out. However the PRIMES model took into consideration the potential of biomass and waste energy supply and the related cost curves.

The model simulated that production of biofuels domestically in the EU exhibits increasing marginal costs with increasing amounts of production, owing to decreasing marginal productivity of agricultural resources. The cost curves differ by Member-State and the model, which simulates a cost-effective exploitation of biomass resources, shows different levels of biofuels production per Member-State.

Exchanges of biofuels among the Member-States are assumed to take place and so the target can be met in a flexible way at the EU level. To ensure meeting the 10% target it is found that the marginal cost of biofuels at the EU level needs to be higher in certain scenarios than the RES value corresponding to the RES target. In other words meeting the target cannot derive from meeting the RES target alone: additional policies would be needed to promote the biofuels.

The modelling of the scenarios applies an iterative process varying the level of biofuels marginal cost until the target is reached. Since the biofuels are assumed to count towards meeting the RES target, the level of the RES value corresponding to the RES target is lower than without the biofuels.

3.12 Energy System Impacts

The Appendix includes a summary of the energy system projections per Member-State and for the period up to 2030, corresponding to a set of scenarios which have been retained as the basis of the policy making process. The PRIMES model projects in detail the energy balances, investment in energy demand and supply sectors, costs and prices by sector and commodity and emissions of CO_2. The GAINS model of IIASA also estimates air quality emissions (as derived from PRIMES projections) and the emission of non-CO_2 GHGs.

3.13 Definition of Scenarios

The scenarios shown in the Appendix are defined as follows:

i. **Baseline scenario (BL)**: the business-as-usual scenario of DG-TREN of end November 2007.

ii. **EC Proposal without RES trading (RSAT)**: scenario corresponding to the effort sharing scheme proposed by the European Commission which meets the target (see Table 1) separately in the EU (for the EU ETS, 27 Non ETS and 27 RES targets) and does not allow exchange of GOs among the Member-States.

iii. **EC Proposal with CDM without RES trading (RSAT-CDM)**: same as scenario RSAT, but part of emission reduction can be justified by emission reduction credits taken from the CDM mechanism lowering the carbon value to a uniform price of 30 €/tCO_2.

iv. **EC Proposal with RES trading (NSAT)**: same as scenario RSAT, but exchange of GOs among the Member-States is allowed, resulting in RES developing differently from RES obligations by Member-State but overall RES developing on a cost effective basis.

v. **EC Proposal with CDM and with RES trading (NSAT-CDM)**: same as NSAT, but with possibility to take emission credits from CDM lowering the carbon value to a uniform price of 30 €/tCO_2.

vi. **Cost-Efficiency Scenario (CES)**: meets the targets at least energy system cost by equalizing marginal costs of GHG emission reduction and marginal costs of RES deployment across all sectors and all Member-States.

vii. **Cost-Efficiency Scenario with CDM (CES-CDM)**: same as scenario CES, but with possibility to take emission credits from CDM at a price of 30 €/tCO_2.

viii. **High Oil & Gas prices Baseline (HOG-BL)**: Alternative business-as-usual projection assuming high import prices for oil and gas,

ix. **Cost Efficiency scenario with high prices (HOG-CES)**: same as scenario CES, but built on the basis of the high oil and gas prices Baseline scenario.

Except the two Baseline scenarios (BL with moderate world energy prices, and HOG-BL with high oil and gas prices), all policy scenarios involve meeting the overall GHG emission reduction target, the RES ratio and the biofuels targets. All policy scenarios assume full auctioning of emission allowances for the power generation sector (including CHP). A grandfathering regime is assumed for the rest of sectors covered by the EU-ETS.

All scenarios were quantified up to 2030 in order to analyse the long term consequences for the energy system. Neither specific emission reduction target nor RES targets were set for 2030. However, it was assumed that the carbon and RES values applied for 2020 will further increase in 2030 according to an extrapolation formula.

For comparison purposes, two extreme scenarios were also quantified: a) a "pure" carbon scenario which considers the GHG emission reduction target alone and finds a cost-effective solution at the EU level; b) a "pure" RES scenario which considers the RES target alone and finds a cost-effective solution at the EU level. The "pure" carbon scenario does not meet the RES target and the "pure" RES scenario does not meet the GHG emission reduction target.

4 Exploring the Scenario Database

As mentioned above, numerous energy scenarios were constructed with PRIMES by varying the levels of the carbon price of EU-ETS, the carbon value for non-ETS sectors and the RES value. This section summarises some interesting findings regarding the relationships between ETS, non-ETS and RES.

The analysis presented here refers to the year 2020 and to the EU as a whole. The CDM possibility is not taken into account in this analysis. Each point shown in the graphics of this section correspond to an energy scenario with PRIMES. In the analysis presented in this sub-section only CO_2 emissions from energy are considered. The rest of the GHGs (including non energy CO2) are not accounting against the reduction target. The carbon price (for the EU-ETS) and the carbon values (for the non-ETS) were varied in a range[12] from 25 €/tCO_2 up to 80 €/tCO_2 and the RES value varied between 0 and 75 €/MWh.

The relationships between EU-ETS and non-ETS can be explored by varying the carbon price of the EU-ETS and the carbon value for the non-ETS sectors, while keeping unchanged the level of the RES value. The relationship between EU-ETS and non-ETS is shown in Figure 2 first for a zero RES value and then for a high RES value (70 €/MWh). As expected, total GHG emissions decrease as the carbon values increase.

The rate of change of GHG emissions per unit of change of carbon values is higher when both EU-ETS and non-ETS face high levels of carbon values. In other words, there is clearly a synergy between EU-ETS and non-ETS in terms of effectiveness of carbon values in reducing emissions.

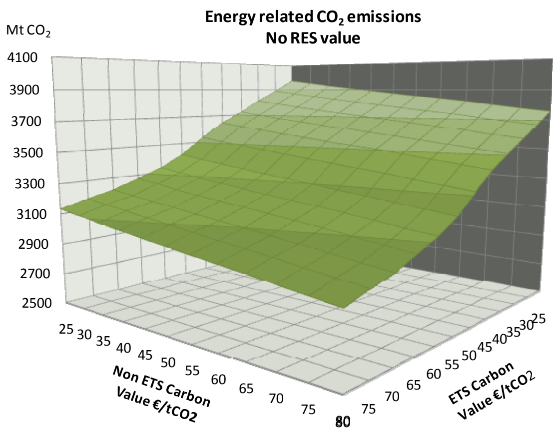
The effectiveness of the carbon values intensifies with increasing RES-values. In terms of effectiveness, there is a synergy between all the three domains: ETS, non-ETS and the RES.

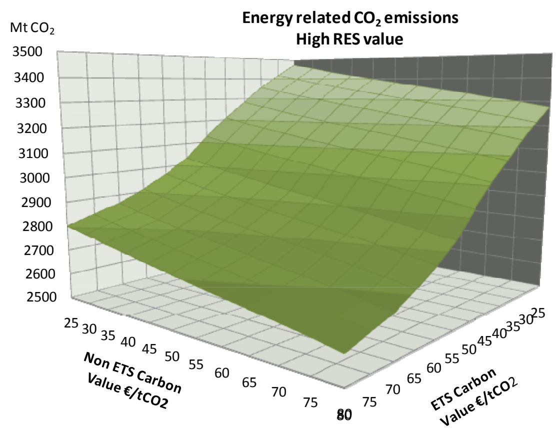
Figure 2 also shows that the relative effectiveness of the carbon values in terms of emission reduc-

[12] For comparison, the Baseline scenario assumes a carbon price of 22 €/tCO_2 applicable only for EU-ETS which is assumed to operate under a grandfathering regime.

tion is increasing up to a certain level (40-45 €/tCO_2) and is decreasing in marginal terms beyond that level, owing to a relative exhaustion of highly productive emission reduction options. This decreasing effectiveness is more pronounced when considering the carbon price of the EU-ETS alone, which can be attributed to the relative short horizon (2020) not allowing the deployment of carbon free options that need long lead times.

Figure 2: ETS vs. non-ETS



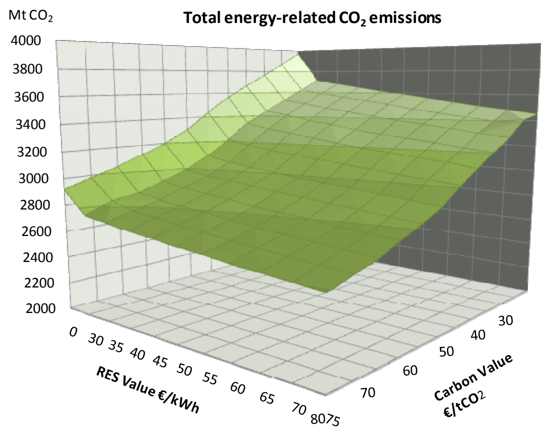


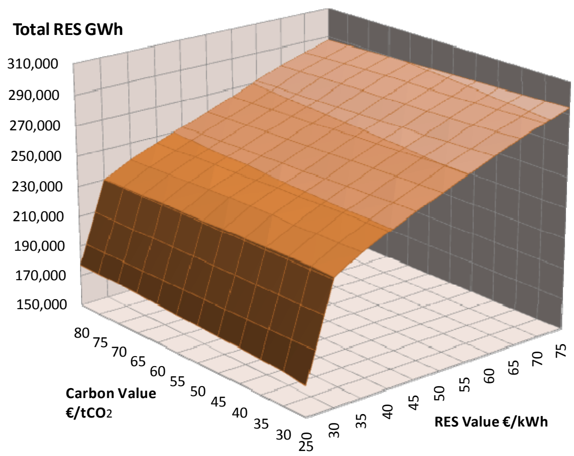
The relationships between the carbon values (taken equal for the EU-ETS and the non-ETS) and the RES values are shown in Figure 3. The first figure shows the effects on GHG emissions and the second shows the effects on total RES use.

The effectiveness of the RES value in reducing emissions and facilitating the deployment of RES is significantly high for a range of RES values up to 35-40 €/MWh. Beyond that level the effectiveness of the RES value is decreasing in marginal terms.

The effectiveness of the RES value is higher when the carbon value is at a high level and especially in a range between 35 and 50 €/tCO_2. In that range the model results show the maximum degree of synergy between the carbon values and the RES values in terms of their effectiveness in reducing emissions and deploying RES.

Figure 3: Carbon values and the RES value





However, for high levels of the carbon values the results show that some degree of antagonism exists between carbon values and RES: the change of emissions and RES per unit of change of the RES value is decreasing when the carbon value exceeds the level of roughly 55 €/tCO_2. At such a level of carbon value it seems more economic to start deploying other carbon free options (e.g. CCS which is expensive because it lacks sufficient maturity by 2020) rather than further increasing the RES.

Not all combinations of carbon values and RES values imply meeting the two targets. The feasible combinations are those that lead to at least 20% emission reduction from 1990 and to at least 20%

RES in gross final energy consumption. Moreover, a small subset of these feasible combinations meets exactly the two targets and from an economic perspective merit to be further considered in the policy analysis process. These combinations form the efficient frontier.

If the RES value is limited strictly below 40 €/MWh then, in order to meet the RES target, the carbon values needed are higher than those required to meet exactly a CO2 emission reduction of 20% (from 1990 and only for CO_2 from energy). If the RES value is above 60 €/MWh then the RES target is overshot for any carbon value higher than 25 €/tCO_2.

If the carbon values are kept strictly below 35 €/tCO_2 the reduction of CO2 emissions by 20% (achieved entirely through domestic measures) cannot be met for any RES value below 80 €/MWh. If the carbon values are higher than roughly 60 €/tCO_2, the reduction of CO2 emissions by 20% is overshot even if the RES value is zero. However, the RES value has to be at least equal to 35 €/MWh for meeting the RES target as well.

In Figure 4 the points lying on the floor of the 3d graph correspond to combinations of carbon values and RES values that exactly meet the 20% (energy related) CO_2 target, without overshooting this percentage reduction. Similarly, in Figure 5 the points lying on the floor of the graph are the combinations that meet exactly the RES target. Such combinations define the efficient frontier.

The efficient frontier ranges between 35 and 45 €/tCO_2 for the carbon values related to reduction of CO2 emissions from energy and between 40 and 55 €/MWh for the RES values.

Within such range there exist several combinations of carbon and RES values (see Figure 6) that lead to meeting exactly the two targets (-20% of CO2 emissions from energy and RES 20% in gross final energy demand) by 2020 without overshooting these percentage goals.

The range shown in Figure 6 corresponds to energy scenarios that reduce energy CO_2 by 20%, from 1990 and meet the 20% RES target.

Figure 4: Combinations that at least reduce energy-related CO2 emissions from 1990 by 20%

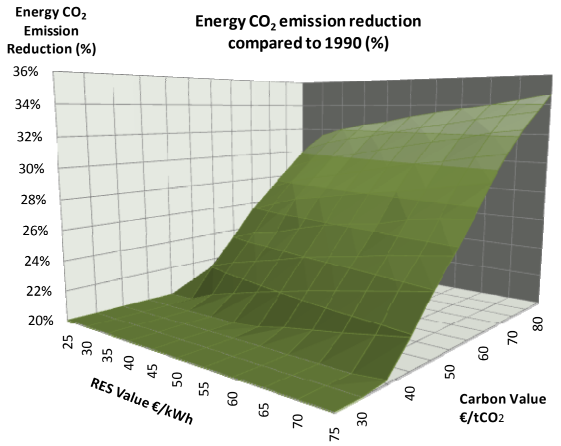


Figure 5: Combinations that at least meet the RES target

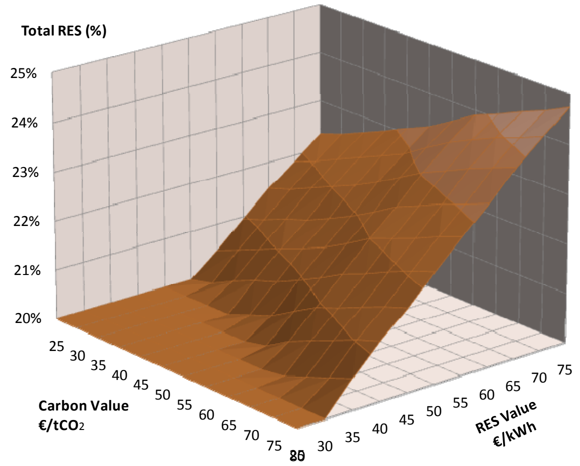
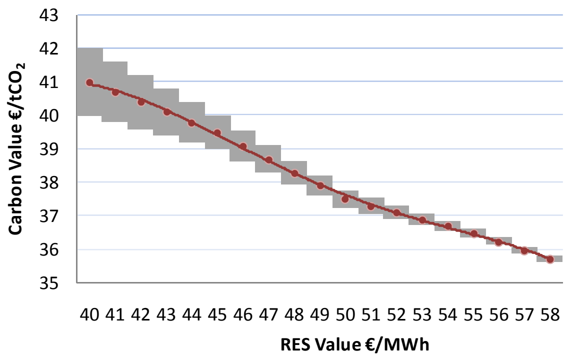


Figure 6: The Efficient Frontier



5 Overview of Scenario results

5.1 Summary of results

Table 7 provides a summary of model results by scenario. The abbreviations of scenario names are explained in section 3.13.

The "pure" carbon scenario (pure-GHG) needs the highest carbon value (assumed the same for the ETS and the non-ETS sectors to support cost-effectiveness) among the scenarios to achieve the GHG emission reduction target because there is no independent effort to reach the RES target which would facilitate reaching the GHG target. Similarly, the "pure" RES scenario (pure-RES) needs the highest RES value among the scenarios in order to reach the RES target, because there is no independent GHG emission reduction effort which would induce higher deployment of RES. The deployment of the RES under the pure-RES case leads to GHG emission reduction of 9.3% in 2020 from 1990, down from 1.5% in the Baseline scenario. Emission reduction under the pure-GHG case induces more RES leading to a RES share of 15.9% in 2020, up from 12.7% in the Baseline scenario.

Using the cost-efficient scenario as a reference, the consideration of both targets helps to reduce the carbon value by 9 €/tCO_2 and the RES value by 11 €/MWh, from their levels in the pure-GHG and the pure-RES cases, respectively.

Table 7: Summary of Scenario Results – EU27 - 2020

Scenarios	BL	RSAT	NSAT	CES
GHG compared to 1990 in %	-1.5	-20	-20	-20
RES Share in Gross Final Energy	12.7	20	20	20
Carbon Price EU-ETS €/tCO2	22.0	47.0	42.7	39.2
Carbon Value non-ETS €/tCO2	0	35.2	37.2	39.2
RES value - energy supply €/MWh	0	49.6	44.5	44.8
RES value - energy demand €/MWh	0	49.9	44.5	44.8
RES value - biofuels €/MWh	0	69.5	44.5	44.8
Scenarios		RSAT-CDM	NSAT-CDM	CES-CDM
GHG compared to 1990 in %		-14.8	-15.2	-16.8
RES Share in Gross Final Energy		20	20	20
Carbon Price EU-ETS €/tCO2		30.0	30.0	30.0
Carbon Value non-ETS €/tCO2		20.9	22.2	30.0
RES value - energy supply €/MWh		53.0	49.5	48.2
RES value - energy demand €/MWh		52.2	49.5	48.2
RES value - biofuels €/MWh		82.9	49.5	48.2
Sensitivity Analysis	pure-GHG	pure-RES	HOG-BL	HOG-CES
GHG compared to 1990 in %	-20	-9.3	-7.1	-20
RES Share in Gross Final Energy	15.9	20	14.9	20
Carbon Price EU-ETS €/tCO2	48.5	22.0	22.0	34.5
Carbon Value non-ETS €/tCO2	48.5	0	0	34.5
RES value - energy supply €/MWh	0	56.0	0	36.8
RES value - energy demand €/MWh	0	56.0	0	36.8
RES value - biofuels €/MWh	0	56.0	0	36.8

The effort sharing scheme proposed by the European Commission implies differentiation of carbon values between the ETS and the non-ETS sectors. It implies also differentiation of carbon values between the Member-States for the non-ETS sectors.

Assuming that RES trading among the Member-States is possible, the results (see case NSAT in Table 7) show that the deviation of this effort sharing scheme from the cost-efficiency case implies that the carbon price of the ETS needs to increase by 3.5 €/tCO_2 and the carbon value for the non-ETS sectors need to decrease by 2 €/tCO_2 from their values in the cost-efficiency scenario, in order to obtain the desired distributional equity and meet both targets.

If RES trading among the Member-States is not allowed, the marginal cost of RES deployment may reach high values in some Member- States and low ones in other. The resulting distribution of costs may deviate from the desired distributional equity. To re-establish such equity (see results for case RSAT in Table 7) it is necessary to further increase the carbon price of the ETS by 7.8 €/tCO_2 from its level in the cost-efficiency scenario and reduce the carbon value for non-ETS sectors by 4 €/tCO_2.

As expected, the absence of RES trading among the Member-States increases the average EU RES value, which needs to become more than 5 €/MWh higher than in the case of RES trading. The absence of RES trading implies difficulties in reaching the biofuels target at the EU level, which implies a RES value for biofuels significantly higher than the RES-value for the sectors other than transport (roughly 25 €/MWh higher compared to the RES trading case).

As also expected, access to CDM in the ETS and the non-ETS sectors decrease the carbon values. In the NSAT-CDM, the RSAT-CDM and the CES-CDM scenarios is it assumed that carbon values decrease and are limited to 30 €/tCO2.

Since the RES target remains to be met domestically, the RES value has to increase because the effect towards higher RES from GHG emission reduction domestically is weakened because of the emission credits from CDM. The new RES value is found 3.4 €/MWh higher than in the cost-efficiency case.

In the scenarios reflecting the effort sharing scheme proposed by the European Commission, some Member-States get GHG emission reduction targets which can be met domestically at carbon values lower than the marginal cost levels induced due to access to CDM (i.e. 30 €/tCO_2). So in scenarios reflecting the effort sharing scheme proposed by the European Commission with emission credits from the CDM, the average EU carbon value for the non-ETS sectors become lower than 30 €/tCO_2, whereas the carbon price of the ETS remains at 30 €/tCO_2. The domestic EU emission reduction relatively to the Baseline in 2020 is, in this case, between 25% and 28% down from cases performing emission reduction only domestically in the EU.

Under these circumstances, emission reduction as driver of RES deployment is weaker than in cases without CDM. Given also that the RES target has to be met domestically in the EU, the implied RES values have to increase compared to cases without CDM. They are found 5 €/MWh higher than in the case of reducing emissions fully within the EU. For the cases involving emission credits from CDM it is also found that the absence of RES trading among the Member-States further increases the difficulty in meeting the RES target and this adds roughly 3 €/MWh to the RES values. This situation also involves further difficulties in meeting the biofuels target which requires RES values much higher than for the rest of RES.

In the high oil and gas prices baseline scenario (HOG-BL) GHG emissions are lower than in the moderate prices Baseline scenario (BL) and RES deployment is higher. This is due to the effects of high prices but these are not sufficient to reach the two targets. A cost-effective emission reduction and RES deployment built on the basis of the high oil and gas prices baseline requires less effort to meet the two targets, compared to the moderate prices baseline. So under the assumption of high oil and gas prices, the carbon value is found 4.7 €/ tCO_2 lower and the RES value 11 €/MWh lower.

The table below shows the model-based evaluations of compliance costs, which represent all energy-related costs incurred by end-users of energy excluding revenues from auctioning of emission allowances. The compliance costs for the year 2020 range between 0.45 and 0.71% of EU's GDP, depending on the scenario.

Table 8: Compliance Costs – EU27 - 2020

Scenarios	*Name*	Compliance Cost (*) (billion €)	Compliance Cost as % of GDP	% change from Cost Efficiency (CES)
RSAT	EC Proposal without RES trading	111.2	0.71	22.5
RSAT-CDM	EC Proposal with CDM without RES trading	93.2	0.59	2.7
NSAT	EC Proposal with RES trading	94.1	0.60	3.7
NSAT-CDM	EC Proposal with CDM and with RES trading	70.1	0.45	-22.7
CES	Cost-Efficiency Scenario	90.8	0.58	
CES-CDM	Cost-Efficiency Scenario with CDM	75.2	0.48	-17.1
pure-GHG	Pure Carbon case	78.9	0.50	-13.0
pure-RES	Pure RES case	29.1	0.19	-67.9
HOG-BL	Baseline scenario with high oil & gas prices (**)	275.5	1.76	
HOG-CES	Cost Efficiency scenario with high prices (***)	59.8	0.38	

(*) Total energy system costs after payments for CDM (where applicable), net of payments to buy emission allowances in auctions

(**) For the HOG-BL cases the costs shown are not compliance costs but are additional energy systrem costs from Baseline with moderate prices reflecting the consequences of high prices

(***) For the HOG-CES scenario the costs shown are relative to the high oil and gas prices baseline scenario (the HOG-BL)

The cost-efficiency scenario ensures the lowest compliance costs among all scenarios in which emission reduction takes place entirely within the EU. The distributional equity criteria included in the EU proposal for effort sharing, assuming that RES trading is allowed, induce roughly 3.4 billion € additional compliance cost compared to the cost-efficiency case. This result is obtained for the NSAT case compared to the CES case.

Reducing emissions through CDM helps to decrease the total compliance cost, including payment for emission credits from CDM. The cost savings depend on the scenario and range between 15.6 (in the CES case) and 24 billion € (in the NSAT case), or between 0.10 and 0.15% of GDP. In terms of the compliance costs, the CES-CDM case is not directly comparable with the RSAT-CDM and the NSAT-CDM cases, as the CES-CDM assumes that a significantly smaller part of emission reduction obligation is fulfilled through the CDM emission credits. This is so because the CDM price is fixed at €30/t CO2 from the outset and not the volume of CDM credits.

The difference in compliance costs between the case with RES trading (NSAT case) and the case without RES trading (RSAT case) is calculated as the difference of the total cost between the RSAT and the NSAT cases. Thus it includes direct as well as indirect impacts on compliance costs from the absence of RES trading.

The direct impacts come from the fact that some Member-States deploy RES in the case without RES trade more than what cost-effectiveness would suggest and thus face high nonlinear costs which would be avoided if RES trading takes place. The indirect effects come from the change in carbon values induced by the non cost-effective RES production in the case of no RES trade.

Recall that the RES target is a ratio and carbon values influence both the RES deployment and the energy demand, so given the simultaneity of RES and carbon values it is logical that carbon values also change consequently. Accounting for their impact on cost is necessary from the perspective of energy system analysis.

The direct effects of the absence of RES trading were estimated by using the PRIMES model: a cost differential of 9.9 billion € was found for the EU. This cost corresponds to a scenario in which all Member-States develop at least a 10% share of biofuels in road transportation. Of course biofuels can be traded among the Member-States, in physical terms. By assuming in the PRIMES model that biofuels are traded, the cost estimation of the direct effects of the absence of RES trading among the rest of the sectors (i.e. power generation, heating, etc.) amount to only 2.6 billion € in 2020. The analysis about direct costs of the absence of RES trading was carried out for separate scenarios that do not involve specific ETS and non-ETS targets.

The cost difference between the RSAT and the NSAT scenarios cannot be totally attributed to the absence of RES trading per se (which is estimated to be 2.6 billion €, as mentioned above) but is related to the indirect effects of specific target assumptions as modelled in the RSAT scenario.

The cost differential between the RSAT and the NSAT cases can be also attributed to the following factors:

1. The RSAT case has been designed so that all Member-States meet exactly their individual RES targets through domestic actions. Overshooting the targets was not allowed in model simulation. This implies that the Member-States that may have a cost-effective RES potential higher than the assigned target are not allowed, under the RSAT assumptions, to develop more RES in order to meet their GHG targets in a more cost effective way. This leads to overall higher compliance cost for meeting both GHG and RES targets (e.g. Spain, the Baltic countries, Czech Republic, Denmark and others).

2. Some Member-States getting ambitious RES targets that have to be met domestically are, under the assumptions of the RSAT scenario, simulated to develop more biofuels than the 10% share targeted for the EU as a whole, in order to meet their individual RES targets. As a result they bear high marginal costs. So, despite the possibility to trade biofuels, in physical terms, there is an additional compliance cost in the RSAT. This is the case for France, Germany, Italy and the UK. As a result the share of biofuels at the EU level attains 11.8% in 2020 under the assumptions of the RSAT case.

3. Some Member-States get smaller RES targets than the cost-effective deployment of RES over the entire EU would suggest and would not gain in terms of compliance cost if they developed more RES in the RSAT case, although they do develop more RES in the NSAT case. By undertaking a limited RES deployment effort domestically, higher carbon values are needed so as to comply with the GHG targets.

4. Finally, the low RES values in some Member-States under the assumptions of the RSAT case (without RES trading) imply lower contribution of RES in power generation and so the ETS sector at the

EU level needs higher carbon prices to comply with the EU ETS target.

The above reasons explain why higher costs are induced in the RSAT case compared to the NSAT.

An important finding of the model-based analysis is that the compliance cost for meeting the GHG emission reduction target but ignoring the RES target is lower than meeting both targets: 9.1 billion € or 0.06% of GDP. The compliance cost of meeting the RES target alone amounts to 29.1 billion € (0.19% of GDP). However, meeting both targets induces lower compliance cost than the sum of compliance costs of meeting the two targets separately. The gain from the synergy between the two targets amounts to 17.3 billion € (0.11% of GDP).

The baseline scenario with high oil and gas prices increases considerably the total cost of energy, compared to the baseline with moderate prices. The additional energy-related cost incurred for end-users of energy amounts to 275.5 billion € (1.76% of GDP). Meeting the two targets in the presence of high oil and gas prices implies relatively lower compliance cost compared to the cost-efficient scenario under moderate prices. The gain is significant: 31 billion € (0.2% of GDP, from 0.58 down to 0.38%).

5.2 *GHG Effort Sharing*

The cost-efficiency scenario, seeking a least-cost solution for meeting the two targets, ignores distributional effects, which measured as compliance costs per unit of GDP are higher for Member-States with lower GDP per capita. This is shown in Table 9, which also shows the emission reduction effort and the RES deployment under the assumptions of the cost-efficiency case compared to the Baseline scenario for the year 2020.

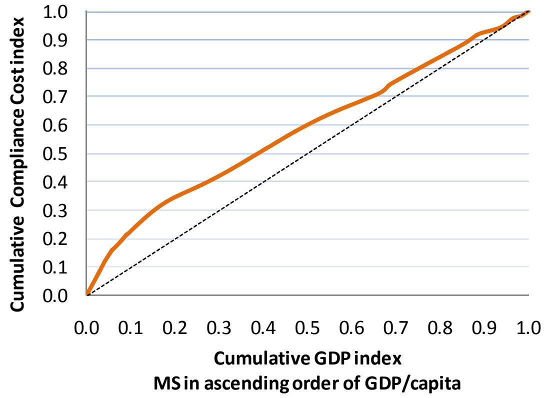
Table 10 shows the same information for the NSAT scenario which involves differentiated targets for GHG emission reduction and performs RES development in a cost effective way. In this scenario, the specified RES targets by Member-State differing from actual developments in NSAT provide opportunity for RES trading among the Member-States.

The Member-States are shown in Table 9 and in Table 10 in ascending order of GDP per capita, as in 2005. There is obvious dissimilarity in the results of the cost-efficiency scenario (CES case, see Table 9) between the distribution of GDP among the Member-States and the distribution of compliance costs.

Table 9: Distributional Effects of Cost Efficiency scenario (CES) in 2020

		Cost Efficiency Scenario				
	GDP/cap k€ in 2005	Compliance Cost in 2020 (% GDP)	% change or % Diff. from Baseline			
			GHG	GHG ETS	GHG non-ETS	% RES/Gross Demand
Bulgaria	2.8	2.16	-28.4	-35.4	-16.1	12.7
Romania	3.7	0.95	-21.4	-23.1	-19.7	7.5
Latvia	5.6	1.10	-27.9	-45.4	-20.0	15.5
Lithuania	6.0	1.02	-28.2	-45.6	-17.9	18.5
Poland	6.4	1.24	-21.1	-27.1	-13.4	7.6
Slovakia	7.1	1.17	-19.2	-23.7	-13.5	10.8
Estonia	8.2	1.59	-34.2	-43.5	-14.8	21.9
Hungary	8.8	1.22	-25.2	-40.0	-16.7	13.9
Czech Rep.	9.8	1.12	-20.4	-27.7	-11.8	8.2
Malta	11.3	0.31	-17.3	-26.3	-9.7	3.1
Slovenia	13.8	0.86	-24.2	-38.3	-14.4	8.8
Portugal	14.0	0.87	-26.8	-41.3	-12.2	10.8
Greece	16.3	0.97	-27.2	-38.5	-15.6	7.9
Cyprus	18.2	0.09	-18.0	-23.2	-12.7	3.7
Spain	21.0	0.70	-19.1	-26.3	-13.1	8.9
EU27	22.4	0.58	-18.9	-24.7	-13.8	7.5
Italy	24.2	0.49	-14.5	-19.6	-10.7	5.8
Germany	27.2	0.57	-13.9	-14.0	-13.9	5.8
France	28.2	0.39	-18.4	-28.0	-15.0	6.4
Belgium	28.6	0.76	-15.4	-13.3	-17.1	5.1
UK	29.8	0.49	-20.1	-27.8	-12.7	6.9
Austria	29.9	0.66	-22.7	-35.3	-14.8	12.9
Finland	30.1	0.47	-28.5	-38.5	-16.4	12.2
Netherlands	31.0	0.28	-19.4	-25.6	-13.7	6.2
Sweden	31.9	0.66	-21.7	-33.5	-13.8	8.1
Denmark	38.5	0.29	-23.0	-36.7	-11.5	12.2
Ireland	39.2	0.47	-21.5	-31.8	-15.2	9.5
Luxembourg	64.6	0.54	-14.8	-13.7	-15.2	3.0

Figure 7: Distribution of costs for the Cost-Efficiency scenario –2020



This is further illustrated in Figure 7 which shows that the distribution differs substantially from the equality line and more for Member-States with lower GDP per capita. This figure shows that the low GDP-capita Member-States, for example those that represent the first 30% percentile of cumulative GDP bear the first 45% percentile of cumulative compliance costs.

The effort sharing scheme of the NSAT scenario leads to a substantial reduction of compliance costs of low GDP/capita Member-States compared to the cost-efficiency scenario (CET). Table 10 shows that the differentiation of targets, as assumed in the NSAT case, improves distributional equity (compare to Table 9).

Table 10: Distributional Effects of the NSAT scheme with and without RES trading

	EC Proposal with RES trading (NSAT)					
			% change or % Diff. from Baseline			
	Compliance Cost (% GDP) before RES trading	Compliance Cost (% GDP) after RES trading	GHG	GHG ETS	GHG non-ETS	% RES/Gross Demand
Bulgaria	1.09	0.00	-25.6	-41.6	2.9	14.2
Romania	0.38	0.20	-13.0	-23.0	-3.3	7.3
Latvia	1.56	0.68	-32.5	-50.4	-24.4	17.0
Lithuania	0.52	-0.32	-17.0	-39.9	-3.5	17.1
Poland	0.48	0.21	-13.2	-22.7	-1.1	7.3
Slovakia	0.77	0.46	-14.7	-25.3	-1.4	10.1
Estonia	1.10	0.15	-28.4	-40.7	-2.7	19.6
Hungary	0.46	-0.04	-17.2	-41.9	-3.0	13.3
Czech Rep.	0.49	-0.07	-14.1	-26.5	0.6	7.7
Malta	0.17	0.36	-13.8	-23.1	-5.9	3.0
Slovenia	1.08	1.15	-26.8	-41.5	-16.5	9.1
Portugal	0.48	0.42	-14.0	-25.6	-2.3	8.6
Greece	0.74	0.72	-24.3	-38.0	-10.3	7.6
Cyprus	0.07	0.16	-14.9	-19.4	-10.5	3.6
Spain	1.20	0.99	-29.0	-41.6	-18.7	10.0
EU27	0.60	0.60	-18.8	-26.6	-12.0	7.6
Italy	0.96	1.05	-23.2	-28.4	-19.1	6.8
Germany	0.47	0.54	-11.9	-13.6	-10.0	5.6
France	0.39	0.53	-18.1	-28.3	-14.3	6.3
Belgium	0.86	0.88	-16.6	-14.7	-18.0	5.1
UK	0.36	0.44	-17.6	-28.3	-7.4	6.4
Austria	0.86	0.61	-27.9	-42.7	-18.6	14.2
Finland	0.53	0.29	-22.2	-32.0	-10.2	10.9
Netherlands	0.34	0.37	-21.2	-27.2	-15.5	6.4
Sweden	0.70	0.76	-27.9	-35.7	-22.7	8.4
Denmark	0.56	0.43	-29.3	-43.1	-17.9	14.2
Ireland	0.62	0.59	-24.5	-34.6	-18.3	10.0
Luxembourg	0.88	0.95	-24.3	-17.9	-26.9	3.4

To change this cost distribution so as to become inversely proportional to GDP per capita per Member-State, it is necessary to differentiate the targets. At the same time, cost efficient policy instruments will be needed to ensure total costs for the whole EU don't increase disproportionate.

The EC proposal corrected the undesirable distributional effects of the cost-efficiency scenario by introducing a stepwise approach. The proposal includes differentiated targets to increase the fairness of distributional effects and instruments that ensure that the outcome does not deviate too much from the cost effective outcome. The stepwise approach is as follows:

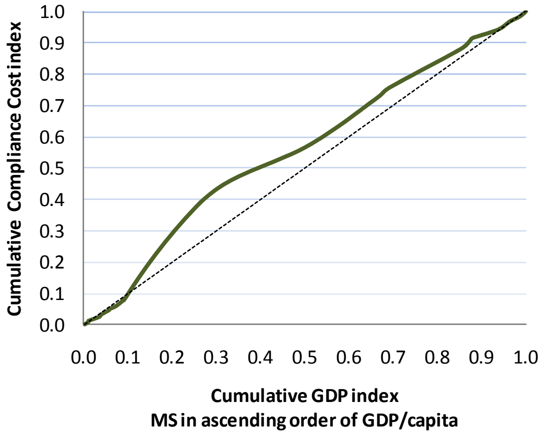
1. ETS and Non-ETS get separate targets.
2. Non ETS targets are distributed among Member States taking into account a GDP/capita criterion. No trade in emission rights is foreseen between member States for the Non ETS sectors.
3. RES targets distributed among Member States taking into account a GDP/capita criterion
4. Member States have the option to participate in RES trading.
5. Both the ETS and Non-ETS sectors can continue to use CDM. This lowers the carbon price in the ETS in all Member States and in the Non ETS in those Member States with targets that lead to higher carbon values if achieved internally
6. The amount of allowances that can be auctioned by a Member State is distributed among Member States taking into account a GDP/capita criteria

Differentiating the GHG emission reduction target in the non-ETS sectors by Member-State, displaces emission reduction effort in non-ETS sectors from low GDP/capita Member-States to those with high GDP/capita and as such decreases the costs for low GDP/capita Member-States and increases those for high GDP/capita Member States. This may result into very high marginal abatement cost in the latter. This is due to the high nonlinear steepness of the marginal abatement curve in non-ETS sectors, which include sectors with lower responsiveness to prices, such as the buildings and transportation. This impact can be reduced by allowing for access to CDM.

Similarly, differentiating RES targets by Member States could lead to the displacement of investments in RES towards Member States where higher incentives will be required to achieve the targets shifting costs away from low GDP/capita Member-States and increasing those for high GDP/capita Member States.

Figure 8 illustrates the impacts of a separate ETS and Non ETS target with differentiated targets per Member State in the Non ETS and for the RES target (this corresponds to steps 1, 2 and 3 shown above). Figure 8 assumes that the targets are met without access to RES trading, and without access to CDM (the RSAT case). The distributional impacts decrease for low GDP/capita Member-States, compared to the CES case, shown in Table 10 but the distribution still differs from the equality line.

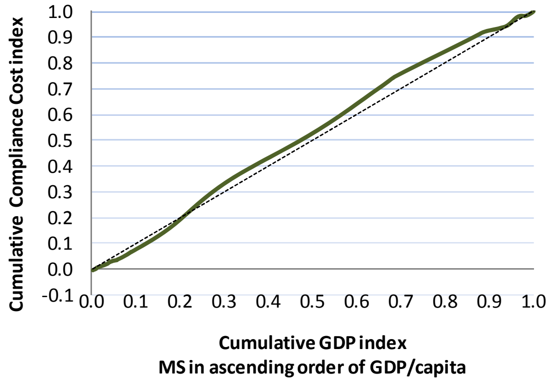
Figure 8: Distribution of costs for the RSAT case – 2020



Allowing for access to CDM (this corresponds to step 5 of the EC stepwise approach shown above) will result into overall lower costs. In order to further remove distributional inequalities, the EC proposal included redistribution of part (10%) of auctioning[13] rights of emission allowances for the ETS to the low GDP/capita Member-States (this corresponds to step 6). Figure 9 is similar to Figure 8 but it includes in addition CDM access and redistribution of 10% of auctioning rights redistributed among Member States (covering as such the steps 1, 2, 3, 5 and 6).

In Figure 9, the compliance cost per Member-State includes the energy system costs (corresponding to the differentiated RES and Non ETS targets across the Member-States taking into account access to CDM), the net financial flows due to ETS auctioning (because of the 10% redistribution) and the payments to purchase CDM emission credits.

Figure 9: Distribution of costs for the RSAT-CDM case, including effects from auctioning redistribution – 2020



The distribution of costs shown in Figure 9 is sufficiently aligned to the equality line. There is a small undershoot of costs for Member-States with low GDP per capita and a small overshoot for Member-States with high GDP per capita.

Finally, Figure 10 illustrates the distributional effects when also including step 4 which allows for RES trading among the Member-States (so all 6 steps are included). This effort sharing scheme removes inequality for high GDP/capita Member-States and further favours some of the low GDP/capita Member-States.

Figure 10: Distribution of costs for the NSAT-CDM case, including effects from auctioning redistribution – 2020

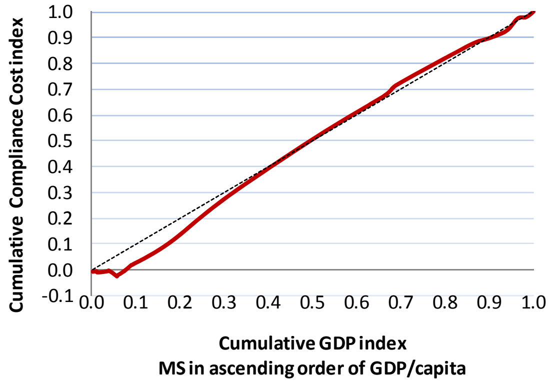


Table 11 summarises the effects on compliance costs by Member-State following the stepwise approach proposed by the European Commission.

[13] In order to calculate the revenue for Member States from auctioning, it is assumed that all sectors participate in auctioning. The Primes scenario only represented auctioning in the power generation sector.

Table 11: Compliance costs of effort sharing schemes

	Compliance Cost as % of GDP in 2020				
	NSAT without flows from RES trading	NSAT with auction rights redistributed and without RES trading	Same as previous, but in addition RES trading	NSAT-CDM but auction rights redistributed	Same as previous, but in addition RES trading
Bulgaria	1.09	-0.35	-1.44	0.14	-1.22
Romania	0.38	0.30	0.12	0.29	0.06
Latvia	1.56	1.47	0.59	1.02	-0.01
Lithuania	0.52	0.36	-0.48	0.43	-0.70
Poland	0.48	0.32	0.05	0.38	0.06
Slovakia	0.77	0.72	0.40	0.60	0.29
Estonia	1.10	0.43	-0.52	0.59	-0.53
Hungary	0.46	0.29	-0.21	0.36	-0.39
Czech Rep.	0.49	0.03	-0.53	0.20	-0.50
Malta	0.17	-0.36	-0.17	-0.21	0.01
Slovenia	1.08	0.92	0.99	0.74	0.81
Portugal	0.48	0.54	0.49	0.57	0.48
Greece	0.74	0.53	0.52	0.60	0.59
Cyprus	0.07	-0.04	0.05	-0.03	0.07
Spain	1.20	1.07	0.86	0.62	0.41
EU27	0.60	0.60	0.60	0.45	0.45
Italy	0.96	1.02	1.11	0.51	0.66
Germany	0.47	0.60	0.67	0.49	0.56
France	0.39	0.37	0.51	0.32	0.47
Belgium	0.86	0.97	0.98	0.69	0.70
UK	0.36	0.36	0.43	0.34	0.42
Austria	0.86	0.82	0.57	0.58	0.34
Finland	0.53	0.56	0.32	0.52	0.19
Netherlands	0.34	0.43	0.46	0.28	0.32
Sweden	0.70	0.72	0.78	0.74	0.81
Denmark	0.56	0.48	0.36	0.22	0.13
Ireland	0.62	0.64	0.61	0.47	0.45
Luxembourg	0.88	0.90	0.97	0.59	0.70

Table 12: GHG Emissions in different scenarios in 2020

	RSAT scenario			NSAT scenario			NSAT-CDM scenario		
	All GHGs	ETS (CO2)	non-ETS (GHGs	All GHGs	ETS (CO2)	non-ETS (GHGs	All GHGs	ETS (CO2)	non-ETS (GHGs
BG	56.1	30.5	25.6	50.9	25.5	25.4	51.7	26.4	25.4
RO	165.8	72.7	93.1	165.2	72.1	93.1	169.4	76.2	93.2
LV	13.4	4.2	9.2	12.0	2.7	9.2	13.1	2.8	10.2
LT	21.5	7.2	14.3	19.5	5.2	14.3	19.3	5.1	14.2
PL	387.1	202.1	184.9	367.2	184.1	183.1	377.2	194.6	182.6
SK	51.6	25.0	26.5	51.8	25.3	26.6	53.9	27.3	26.6
EE	17.2	10.4	6.8	15.6	8.8	6.8	16.5	9.7	6.8
HU	78.6	22.6	56.0	75.2	19.2	56.0	74.6	18.7	55.9
CZ	127.9	61.8	66.2	122.7	57.0	65.7	125.2	59.2	66.0
MT	2.4	0.9	1.5	2.5	1.0	1.5	2.6	1.2	1.4
SI	16.7	5.2	11.4	17.0	5.6	11.4	18.3	6.2	12.0
PT	84.7	37.1	47.6	83.7	36.2	47.5	83.9	36.5	47.4
EL	103.3	42.6	60.6	103.5	42.8	60.7	106.6	46.1	60.5
CY	7.2	3.4	3.8	7.3	3.5	3.8	7.4	3.6	3.8
ES	366.3	146.5	219.7	349.3	129.5	219.7	425.8	185.2	240.5
EU	4465	1875	2590	4464	1876	2588	4727	2049	2679
IT	487.5	192.8	294.7	495.4	200.6	294.8	564.2	232.2	332.0
DE	857.0	432.6	424.4	880.6	456.3	424.4	903.3	479.9	423.4
FR	445.1	96.1	348.9	455.3	106.4	348.9	466.6	110.3	356.3
BE	125.5	55.5	69.9	127.2	57.3	69.9	132.7	59.6	73.1
UK	542.0	219.7	322.3	563.6	241.3	322.3	576.4	254.8	321.7
AT	79.8	27.6	52.2	75.2	23.0	52.2	83.3	27.3	56.0
FI	58.3	29.8	28.5	54.9	26.4	28.5	55.2	26.7	28.5
NL	188.3	82.9	105.4	190.3	84.9	105.4	200.5	89.4	111.0
SE	59.6	21.2	38.4	59.6	21.2	38.4	67.5	23.4	44.1
DK	49.8	20.4	29.4	46.3	16.9	29.4	52.1	19.9	32.3
IE	61.5	20.7	40.8	60.9	20.1	40.8	66.5	22.8	43.7
LU	11.6	3.6	8.0	11.6	3.6	8.0	13.6	4.0	9.5

5.3 RES Effort Sharing

As mentioned before, meeting the RES-target in a cost-effective way (least cost for the EU taken as a whole) requires equality of RES-values across all sectors and Member-States. This is reflected onto scenario CES, which however leads to undesirable distributional effects.

The EC proposal includes differentiated RES targets by Member-State and assumes that it is possible to trade the guarantees of origin (GO) among the Member-States. This proposal involves specific RES targets per Member-State that differ from the distribution reflecting cost-effective RES effort. The reason for this difference is the aim to reduce compliance costs, owing to RES, in particular for Member-States with low GDP/capita.

The calculations shown in Table 13 attempt to mimic the way the RES targets were revised and distributed among the Member-States. The calculations are based on the PRIMES model database and projections and so in numerical terms they do not necessarily coincide with the EC proposal.

The RES share, in terms of percentage of gross final energy consumption in 2005, being 8.6% at the EU level, needs to increase by 11.4 percentage points in order to meet the RES target for 2020. Half of this increase (roughly 5.5 percentage points) is assumed to be distributed equally to all Member-State irrespectively of their GDP per capita. The remaining distance from the RES target (in terms of toe) is distributed so as to obtain additional RES deployment effort inversely proportional to GDP per capita of the Member-States. The resulting RES targets differ from those obtained by the cost-effectiveness solution, and are generally higher for high GDP/capita Member-States.

Figure 11 show the additional RES deployment effort in 2020 compared to 2005, as required by the EC effort sharing proposal. The RES ratio figures for 2005 correspond to PRIMES data for 2005. The best-fit line showed in this graphic has an increasing slope in relation to GDP/capita of the Member-States.

It is not possible to isolate the additional cost implied by the proposed RES effort sharing compared to the cost-efficiency scenario, because of the simultaneous effects from GHG emission reduction and RES deployment.

As mentioned before, the RES target is expressed as a percentage of RES over gross final energy consumption. So the amount of RES deployed in each scenario depends also on gross final energy consumption which decreases as the intensity of GHG emission reduction increases.

Table 13: RES Target, determination of Effort Sharing

	Observed		RES Burden sharing proposal				Cost Efficiency	
	RES % in 2005	RES Mtoe - 2005	RES % after flat increase 5.5%	add. RES (toe) per capita	RES Mtoe - 2020	RES % in 2020	RES % in 2020	Diff % from EC Proposal
Bulgaria	11.3	1.2	14.9	0.022	2.0	16	22.7	6.6
Romania	19.7	5.1	22.0	0.027	8.2	24	26.4	2.9
Latvia	42.2	1.8	40.4	0.043	2.5	42	50.9	9.0
Lithuania	15.0	0.7	20.5	0.044	1.4	23	36.3	13.5
Poland	7.5	4.5	12.7	0.046	11.0	15	18.7	3.7
Slovakia	6.9	0.8	12.2	0.049	1.8	14	18.5	4.3
Estonia	18.3	0.6	22.6	0.064	0.9	25	38.9	14.1
Hungary	4.7	0.9	9.8	0.063	2.6	13	20.4	7.6
Czech Rep.	6.7	1.8	10.5	0.070	3.9	13	19.8	7.1
Malta	0.0	0.0	5.5	0.066	0.1	10	6.1	-3.8
Slovenia	15.1	0.8	21.5	0.094	1.6	25	24.1	-0.7
Portugal	17.0	3.3	26.0	0.096	6.7	31	34.7	3.9
Greece	7.5	1.6	12.4	0.120	4.4	18	18.9	0.9
Cyprus	3.0	0.1	8.4	0.104	0.3	13	11.2	-1.8
Spain	8.2	8.2	14.2	0.137	22.8	20	24.5	4.9
EU27	8.6	104.2	14	0.151	255.6	20	20	0
Italy	5.3	7.3	10.7	0.169	26.3	17	14.0	-3.1
Germany	5.9	13.2	11.3	0.188	40.0	18	16.7	-1.8
France	9.5	15.4	15.8	0.186	37.7	23	19.3	-3.7
Belgium	2.4	0.9	7.7	0.193	5.0	13	12.9	-0.4
UK	1.6	2.5	6.8	0.198	22.6	15	13.1	-2.1
Austria	24.2	6.8	28.8	0.200	10.3	34	39.0	4.5
Finland	28.8	7.5	34.0	0.202	10.1	38	43.8	5.7
Netherlands	3.4	1.8	7.9	0.205	7.7	14	13.1	-1.1
Sweden	42.4	14.7	44.4	0.212	18.4	49	47.9	-1.5
Denmark	15.5	2.5	20.9	0.261	4.7	30	33.1	3.1
Ireland	3.0	0.4	8.6	0.233	2.3	16	17.0	0.6
Luxembourg	1.1	0.0	6.4	0.384	0.5	11	9.1	-1.5

Figure 11: RES Effort following the EC Proposal

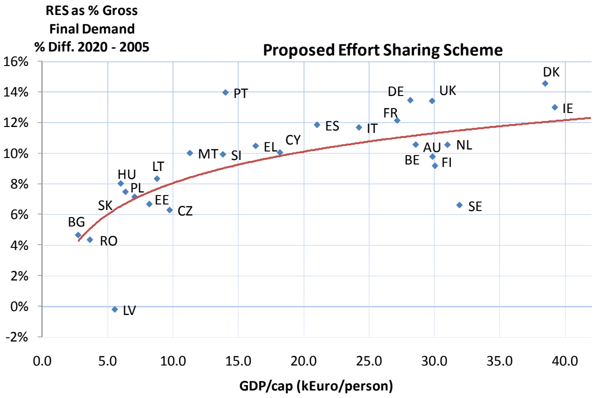


Figure 12: RES deployment by scenario - EU27 – 2020

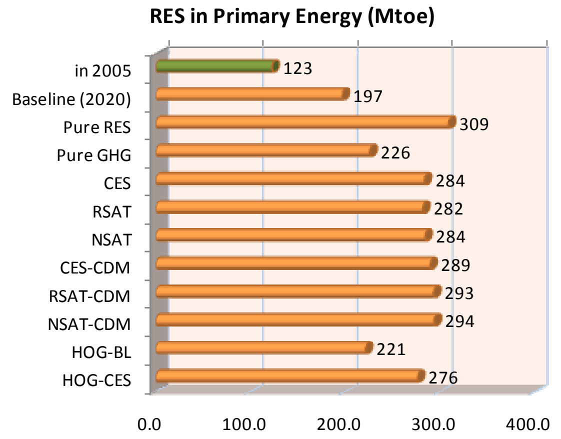


Figure 12 shows that the total amount of RES is higher in the pure-RES scenario because energy consumption is higher as there is no specific target towards lower GHG emissions. The scenarios involving CDM develop slightly more RES than the corresponding scenarios without CDM just because the former perform lower emission reduction domestically in the EU.

5.4 *The auction revenues from the power generation sector*

The scenarios involving GHG emission reduction assume that the power generation sector will be obliged in 2020 to buy all emission allowances from the EU-wide ETS. Assuming that both the auctions and the ETS spot market are perfect and that arbitraging between possible parallel emission allowances markets is also perfect, the model finds a single ETS carbon price at the EU level for each scenario and calculates auction payments and revenues at that level of that carbon price. It is also assumed that the auction revenues are returned as public revenue to the Member-States according to the emission allowances purchased per Member-State for emissions from power generation in their territory.

The model does not assume auctions by Member-State and so, as far as the modeling exercise is concerned, there was no need to assume any prior allocation of emission allowances[14] to the Member-States.

[14] As mentioned in the previous sub-section, the EC proposal includes redistribution of part of auctioning revenues to Member-States with lower GDP per capita. This redistribution is not taken into account in this sub-section.

Table 14: Summary of Auction Revenues – EU27 -2020

Scenarios	CES	RSAT	NSAT	CES-CDM	RSAT-CDM	NSAT-CDM	HOG-CES
ETS Carbon Price (€/tCO2)	39.2	47.0	42.7	30.0	30.0	30.0	34.5
Auction Revenues (bill. €)	38.8	44.6	40.3	32.3	33.9	32.7	39.3
Avoided auction payments relative to Baseline scenario							
Total	22.0	28.2	25.9	14.2	12.6	13.8	14.2
- from carbon intensity	16.1	20.1	19.1	10.5	9.0	10.3	9.8
- from lower electricity demand	5.9	8.1	6.9	3.7	3.6	3.5	4.4

As shown in Table 14 the auction revenues paid by the power generation sector range between 32 and 45 billion €, which accounts for less than 1% of public revenues in 2005 of the EU27. The revenues are assumed not to be recycled as subsidies to energy supply companies or as subsidies to consumers for energy purposes.

If electricity demand and the carbon intensity of power generation remained frozen at the level projected in the Baseline scenario for 2020, the payments of the sector for purchasing emission allowances would be 60 to 45 % higher than the figures shown in Table 14. The carbon intensity changes as a result of substitutions driven by the carbon values and the RES values. Electricity prices increase inducing reduction in electricity demand. Table 14 shows the effects from these changes in lowering auctioning payments by power generation. Allowing access to CDM emission credits implies lower auction payments by power generation (17 to 24% compared to cases without CDM).

5.5 *The Effects from CDM*

As mentioned before, it is assumed that emission credits from CDM cost 30 €/tCO_2 and can be purchased by ETS as well as by non-ETS sectors under the same conditions.

The direct effect of CDM on the ETS market, which clears at the EU-level, is a reduction in the carbon price. The effort sharing scheme proposed by the EC includes differentiated carbon values for the non-ETS sectors of the Member-States.

Those Member-States that can (according to the model results) meet their individual non-ETS emission reduction target domestically at a carbon value lower than 30 €/tCO_2 do not benefit from CDM, contrasting other Member-States which need carbon values higher than 30 €/tCO_2 to meet their non-ETS targets domestically (see Table 15).

Table 15: Effects from CDM – 2020

Difference of NSAT-CDM from the NSAT case (CDM at 30 €/tCO_2)					
	Carbon value - ETS (€/ tCO_2)	Carbon value - non ETS (€/ tCO_2)	Renew-ables value (€/ MWh)	Comp-liance Cost as % of GDP	GHG Emission Reduction Domesti-cally in MtCO_2 eq.
Bulgaria	-13	0	5	-0.53	-1
Romania	-13	0	5	-0.10	-4
Latvia	-13	-31	5	-0.77	-1
Lithuania	-13	0	5	-0.40	0
Poland	-13	0	5	-0.17	-10
Slovakia	-13	0	5	-0.12	-2
Estonia	-13	0	5	-0.41	-1
Hungary	-13	0	5	-0.30	1
Czech Rep.	-13	0	5	-0.18	-3
Malta	-13	0	5	0.07	0
Slovenia	-13	-19	5	-0.21	-1
Portugal	-13	0	5	0.00	0
Greece	-13	0	5	0.02	-3
Cyprus	-13	-1	5	0.01	0
Spain	-13	-42	5	-0.52	-77
EU27	-13	-15	5	-0.15	-263
Italy	-13	-62	5	-0.42	-69
Germany	-13	0	5	-0.05	-23
France	-13	-7	5	-0.03	-11
Belgium	-13	-12	5	-0.23	-5
UK	-13	0	5	0.01	-13
Austria	-13	-32	5	-0.28	-8
Finland	-13	0	5	-0.16	0
Netherlands	-13	-17	5	-0.10	-10
Sweden	-13	-57	5	0.03	-8
Denmark	-13	-50	5	-0.29	-6
Ireland	-13	-26	5	-0.16	-6
Luxembourg	-13	-57	5	-0.25	-2

The former category of Member-States (with lower than €30/tCO2) comprises of mainly those with low GDP/capita, because the proposed effort sharing scheme by the EC assigned to them lower emission reduction targets for non-ETS sector in order to reduce compliance costs.

Consequently, the Member-States with high GDP/capita benefit more than others from the CDM and so they reduce their domestic emission reduction effort, compared to non CDM cases, more than the low GDP/capita Member-States.

There are some exceptions according to the model results: Latvia and Slovenia among the low GDP Member-States benefit from CDM in their non-ETS sectors and Germany, UK and Finland among the high GDP Member-States do not benefit.

Since the ETS carbon price decreases as a consequence of CDM, all Member-States undertake lower domestic emission reduction effort compared to the cases not involving CDM. This further implies that the RES value needs to increase in order to meet the RES targets.

Table 16: Comparison of cases with CDM for 2020

Differences from Baseline for 2020	Cases with CDM		
	NSAT-CDM	RSAT-CDM	CES-CDM
GHG Emission Reduction	1032	1031	1037
- domestically	769	743	856
- CDM	263	288	180
(% reduction abroad)	*26%*	*28%*	*17%*
- Additional RES compared to the non JI/CDM cases (Mtoe)	9.6	11.4	5.9

Total emission credits from CDM (as shown in Table 17) represent 6% of GHG emissions by the EU in 2005.

Table 17: CDM emission credits by Member-State

Comparison of 2020 results to 2005 emissions	Emission Reduction from 2005 (Mt CO2 eq.)					
	NSAT case			RSAT case		
	Without CDM	With CDM	CDM credits	Without CDM	With CDM	CDM credits
Bulgaria	14	13	1	9	6	3
Romania	-16	-20	4	-16	-21	5
Latvia	-1	-2	1	-2	-4	1
Lithuania	0	0	0	-2	-3	0
Poland	6	-4	10	-14	-22	8
Slovakia	-1	-3	2	-1	-4	3
Estonia	3	2	1	2	0	2
Hungary	4	4	0	0	-1	1
Czech Rep.	23	20	3	17	9	8
Malta	1	1	0	1	1	0
Slovenia	3	2	1	3	2	1
Portugal	4	3	0	3	3	0
Greece	28	25	3	29	25	3
Cyprus	1	1	0	1	1	0
Spain	100	24	77	83	5	78
EU27	747	484	263	746	458	288
Italy	80	12	69	88	27	61
Germany	123	100	23	146	113	33
France	106	94	11	116	112	4
Belgium	14	9	5	16	9	7
UK	140	127	13	162	136	26
Austria	23	15	8	18	8	10
Finland	14	14	0	11	9	1
Netherlands	30	20	10	33	22	11
Sweden	10	3	8	11	3	8
Denmark	20	14	6	16	11	5
Ireland	15	9	6	14	9	5
Luxembourg	2	0	2	2	1	2

The compliance costs[15] decreases as a result of lower carbon values and increases as a result of higher RES values (to meet the RES targets). As a result some countries might have slightly higher compliance costs with CDM (Malta, Greece, Cyprus and Sweden e.g.). The model results show that the effect from the lower carbon values dominate and so the compliance costs are found generally lower compared to the cases not involving CDM (see fourth column in Table 15).

[15] Excluding auctioning revenues and the flows derived from redistribution of auction revenues among the Member-States.

For the EU as a whole, the net benefit in terms of compliance costs due to CDM amounts to 24 billion € (0.15% of the EU GDP) for the effort sharing proposal of the EC which involves RES trading (the NSAT case). The benefits from CDM are smaller (18 bill. €) in the case of the effort sharing proposal that does not involve RES trading (RSAT) because this case generally leads to higher RES values, hence to more emission reduction undertaken domestically. The table above summarises the effects of CDM, showing that emission reduction abroad ranges between 17 and 28% of total reduction.

5.6 *The Effects from RES trading*

As mentioned before, the effort sharing RES targets per Member-State do not coincide with a cost-effective RES deployment in the EU which would be based on equality of RES values between the Member-States and the sectors. The targets differ in order to reflect a more equitable distribution of compliance costs in terms of GDP/capita of the Member-States.

This implies that Member-States with high GDP/capita and expensive RES potential would have interest to buy guarantees of origin (GOs) from Member-States with low GDP/capita and less expensive RES potential. Allowing RES trading among the Member-States would provide additional revenue to some of the low GDP/capita Member-States which would further contribute to a more equitable distribution of compliance costs.

This option is analysed in the NSAT case which includes the EC proposal for effort sharing both for GHG emission reduction and the RES and in addition allows for RES trading among the Member-States. The trade is assumed to be perfect; hence a single RES value clears the GO market (equal to 44.5 €/MWh as shown in Table 18). The cost-effective RES deployment (as % of gross final energy consumption) shown in the third column of this table corresponds to the assumptions of the NSAT case about distribution of targets and not to the CES case (which involves cost-effectiveness for both GHG and RES).

The results show that the majority of the new Member-States benefit from RES trading and become net sellers, whereas several of the high GDP/capita Member-States are net buyers of GOs. While for the latter the additional cost is a small fraction of GDP, for the former the additional revenues account for up to 1% of GDP for some Member-States with low GDP/capita. This is shown by the last column of Table 18.

Table 18: Effects from RES trading – 2020

Clearing Price of GOs = 44.5 €/MWh	RES Target (%)	Cost-Effec-tive RES - % (NSAT)	Purchase (-) or Sale (+) of GOs in TWh	Cost (-) or Revenue (+) from GOs in bill. €	Gain (+) or Loss (-) as % of GDP
Bulgaria	16	24	12.1	0.5	1.1
Romania	24	26	7.5	0.3	0.2
Latvia	42	52	6.3	0.3	0.9
Lithuania	23	35	8.5	0.4	0.8
Poland	15	18	28.7	1.3	0.3
Slovakia	14	18	5.5	0.2	0.3
Estonia	25	37	5.0	0.2	1.0
Hungary	13	20	16.5	0.7	0.5
Czech Rep.	13	19	22.7	1.0	0.6
Malta	10	6	-0.3	0.0	-0.2
Slovenia	25	24	-0.7	0.0	-0.1
Portugal	31	32	2.6	0.1	0.1
Greece	18	19	0.9	0.0	0.0
Cyprus	13	11	-0.5	0.0	-0.1
Spain	20	26	66.0	2.9	0.2
EU27	20	20	0.0	0.0	0.0
Italy	17	15	-37.2	-1.7	-0.1
Germany	18	16	-47.8	-2.1	-0.1
France	23	19	-76.8	-3.4	-0.1
Belgium	13	13	-1.0	0.0	0.0
UK	15	13	-45.8	-2.0	-0.1
Austria	34	40	18.7	0.8	0.2
Finland	38	42	12.0	0.5	0.2
Netherlands	14	13	-5.5	-0.2	0.0
Sweden	49	48	-6.2	-0.3	-0.1
Denmark	30	35	7.7	0.3	0.1
Ireland	16	18	1.9	0.1	0.0
Luxembourg	11	10	-0.8	0.0	-0.1

RES trading implies that physical production by RES is allocated among the Member-States in a more cost-effective way. This of course implies lower overall compliance cost.

The loss in cost-effectiveness, estimated as difference of the NSAT scenario results from the RSAT scenario, implies that the ETS clearing carbon price increases: it is found 4.3 €/tCO_2 up from the cost-effective case. The average RES value increases as well, compared to the cost-effective RES deployment: 5 €/MWh higher.

5.7 *The Effects from high oil and gas prices*

The sensitivity analysis that was carried out by using the PRIMES model included also scenarios that assume soaring oil and gas prices, as a result of world energy market trends (see Table 19).

These assumptions were first used to build an alternative baseline scenario (HOG-BL case) which was used as reference to assess the impacts of the GHG and RES targets in the context of high oil and gas prices. For analysis purposes it was also assumed that the targets would be met in a fully cost-effective way (HOG-CES case). The analysis draws conclusions by comparing the differences of the HOG-CES from the HOG-BL to the differences of the Baseline scenario (with moderate prices) from the CES case.

High oil and gas prices imply a general rise of consumer energy prices. They imply also a significant loss of competitiveness of gas vis-à-vis coal the price of which increases much less than that of gas. High prices induce more energy efficiency compared to moderate prices baseline and also more use of indigenous energy resources, other than oil and gas.

Renewables and nuclear provide higher contribution to primary energy compared to the moderate prices baseline. These effects, lower energy demand and more carbon free resources, act towards lower CO_2 emissions. However, in power generation coal (and lignite) is substituting for gas and emissions increase.

The modeling results show that the net effect is towards lower emissions and also higher RES. The resulting figures are far lower than the targets involved in the EC package.

The high oil and gas prices imply considerable additional costs for energy consumers in the Baseline scenarios. Compared to the moderate prices baseline, the additional total energy system cost, in the HOG-BL case, amounts to 1.76% of the EU GDP in 2020, or 275.5 billion € in 2020. This is three times higher than the cost for complying with the GHG and the RES targets.

Table 19: Assumptions about world energy prices, in €'2005 per barrel of oil equivalent

	1990	2000	2005	2010	2020	2030
BL case: Baseline scenario with moderate world prices						
Oil	28.2	34.5	43.6	45.4	53.0	56.7
Gas	18.5	21.7	32.1	36.1	42.4	46.7
Coal	13.4	9.5	11.9	11.5	12.7	13.4
HOG-BL case: Baseline with high oil and high gas world prices						
Oil	28.2	34.3	43.4	55.7	82.5	102.9
Gas	18.5	21.6	32.1	40.3	62.9	82.5
Coal	13.4	9.5	11.8	13.0	18.0	21.7
% change from Baseline (BL)						
Oil				22.5	55.5	81.63
Gas				11.5	48.3	76.49
Coal				13.5	41.4	61.44

The impact of high oil and gas prices on total energy system costs, hence on consumer prices, is much larger than the cost for meeting the two targets. However, the increased prices owing to world energy prices cannot alone meet the targets. Carbon prices and RES values need to be raised.

Since the distance from the targets is partly covered as a result of high oil and gas prices, the remaining distance can be covered at lower total cost, compared to starting from the moderate prices baseline. With reference to the CES scenarios, starting from the HOG-BL scenario implies that the ETS clearing carbon price is 5 €/tCO_2 lower than starting from the BL scenario.

A similar comparison shows that the RES values are also lower (by 11.4 €/MWh). The compliance cost, with reference to the HOG-BL scenario, amounts to o.38% of the EU GDP, down from 0.58% in the CES scenario which compares with the BL scenario (see Table 20).

Further sensitivity analysis has shown that if gas prices were not linked with oil prices and thus increase less relative to oil prices, the tendency to shift power generation towards coal would be weaker but the effect towards more energy efficiency driven by high prices would also be weaker.

Keeping gas prices low, relative to oil prices, would be important for consumer prices because of the role of gas in power generation and in final energy consumption (other than transportation). However, this is not a decisive factor from the point of view of emission reduction and the RES development.

Table 20: Effects from high oil and gas prices

	Diff. in GHG HOG-BL vs. BL (%)	Diff. in RES percentage HOG-BL vs. BL (%)	Additional energy cost HOG-BL vs. BL (% of GDP)	Compliance cost HOG-CES vs. HOG-BL (% of GDP)	Compliance cost CES vs. BL (% of GDP)
Bulgaria	3.3	0.8	3.84	1.89	2.16
Romania	-5.6	2.0	3.40	0.75	0.95
Latvia	-8.3	4.2	2.77	0.59	1.10
Lithuania	-13.5	4.0	2.98	0.64	1.02
Poland	-8.9	3.0	2.90	1.19	1.24
Slovakia	-7.8	0.7	3.23	0.64	1.17
Estonia	-2.5	3.4	2.28	1.04	1.59
Hungary	-5.5	1.6	3.22	0.88	1.22
Czech Rep.	-8.1	2.3	3.31	0.68	1.12
Malta	-14.9	1.7	2.20	0.34	0.31
Slovenia	-2.9	1.7	2.57	0.86	0.86
Portugal	-4.9	2.8	2.27	0.63	0.87
Greece	-0.8	2.3	2.00	0.45	0.97
Cyprus	-4.4	1.5	2.25	0.02	0.09
Spain	-2.6	2.5	1.89	0.34	0.70
EU27	-5.8	2.3	1.76	0.38	0.58
Italy	-6.0	1.8	2.13	0.42	0.49
Germany	-4.5	1.8	1.81	0.35	0.57
France	-11.1	1.9	1.10	0.27	0.39
Belgium	-2.8	1.8	2.11	0.54	0.76
UK	-5.2	2.9	1.31	0.32	0.49
Austria	-8.0	4.3	1.81	0.28	0.66
Finland	-7.6	1.2	1.59	0.10	0.47
Netherlands	-5.0	1.8	2.17	0.15	0.28
Sweden	-6.7	2.7	1.08	0.37	0.66
Denmark	-3.2	2.0	1.08	0.13	0.29
Ireland	-5.6	3.5	1.22	0.34	0.47
Luxembourg	-8.3	2.1	2.09	0.29	0.54

6 Energy System Implications

6.1 Methodological remarks

6.1.1 Introduction

As mentioned in a previous section, the two targets (GHG and RES) are conceived as constraints which are imposed to influence the energy markets equilibrium. The energy system has to comply with the constraints, thus all individual decisions of the agents (demanders and suppliers of energy) are influenced and so are the energy market prices. This is simulated with the PRIMES model.

The changes are driven by the dual variables (shadow prices) associated with the GHG and the RES constraints, termed as carbon values and RES values respectively. They feed into the decision making modules, increasing the perceived costs (for GHG) and the revenues (for the RES) associated with the use of the different energy forms. The resulting energy market equilibrium is compared to the baseline market equilibrium in order to draw conclusions about impacts.

6.1.2 How the carbon values act

The carbon values increase the perceived cost of using fossil fuels proportionally to their carbon intensity. They differ from energy taxation because they do not imply money transfer from energy consumers or producers to the government. Nevertheless, the carbon values change the relative unit costs of energy forms, thus carbon intensive fuels become more expensive. Consequently, substitutions take place favouring the less (or zero) carbon intensive energy forms. Since such substitutions cannot be perfect, a positive cost associated with energy use arises. Hence, substitutions in favour of non energy goods and services are induced, including investment (in buildings and in new equipment) enabling energy savings.

Also the process of capital replacement changes with preferences shifting towards less energy consuming equipment. Thus, energy efficiency gains are achieved both in the short and the long term.

Producers of secondary energy, such as electricity and heat/steam, are affected by carbon values and tend to undertake substitutions among energy forms used as inputs in their production. They decrease the use of carbon intensive fuels. Substitutions being imperfect, positive costs arise which are passed through to consumer prices. Better energy efficiency in production is also motivated.

Electricity and heat/steam are used by consumers as energy carriers and do not emit carbon dioxide at their end-use. However, their prices reflect the degree of carbon intensiveness of their production. Substitutions between energy carriers and fuels used directly at the end-user level are possible and are also driven by relative prices. If emission reduction is relatively less expensive in the production of energy carriers, a final consumer would benefit from increasing demand for these carriers. He would be obliged to undertake more emission reduction by himself if emission reduction in the production of energy carriers is relatively more expensive.

Carbon values act as taxation of emissions from fossil fuel combustion when the corresponding amounts of money are actually paid by consumers or producers of energy and are not given back to the energy agents. For example, when power generation has to acquire the emission allowances from a public auction (clearing at a single carbon price) without recycling of public revenue back to power generation companies, then the purchase cost of allowances corresponds to an actual direct cost which adds to indirect costs. The latter incur as a result of substitutions and energy efficiency gains. The total additional cost is reflected onto consumer prices and the relative competitiveness of electricity deteriorates at the level of the final consumer.

Generally, the increase in electricity prices under an auctioning regime reflects true costs of the power generating companies, whereas under a grandfathering regime the increase reflects opportunity costs, given that part of the allowances are given for granted. In the latter case, the increase in electricity prices depends on the degree of passing through of opportunity costs associated with the free allowances, which depending on market conditions may be lower than 100%.

The increase in electricity prices due to emission costs reduces the attractiveness of electricity in substituting for fossil fuels at the end-user level. Replacement of fossil fuels at the end-use level by electricity hinges upon the capability of power generation to develop substantial emission reduction at an affordable cost, so as to overcome the effect of carbon prices on electricity prices. This might be challenging until 2020, given the long lead times that the power generation needs to develop carbon free resources such as nuclear, CCS and large scale RES. Moreover, it would require considerable investments and would entail significant costs arising from stranded investments.

Distributed heat and steam may also have difficulties in delivering affordable and low carbon intensive services. Cogeneration depends on power generation and is also subject to carbon payments through the auctions. It also needs long lead time to reduce emissions having biomass as the single carbon-free option. Biomass is also the only essential possibility for distributed heat industry to deliver low carbon intensive services. But development on a large scale of biomass and waste also needs long lead times and it is difficult to make large inroads in the short term.

Under these circumstances, substitution possibilities to induce large emission reduction are rather limited in the medium term, contrary to the long term. This is for two reasons: firstly it is not attractive economically to shift final consumption from direct fossil fuels to energy carriers in the short/medium term, such as electricity and distributed heat/steam; secondly, substitutions among fossil fuels are limited (because natural gas has already penetrated massively in most of the final demand sectors of the EU, except transportation). However, renewables will strongly penetrate encouraged by policy and thereby decrease considerably the carbon intensity of power generation. In addition, final energy consumers have to improve energy efficiency by undertaking investment and by purchasing new advanced energy equipment. They can also increase the direct uses of renewable energies (e.g. solar thermal).

In the long term however, towards 2030 and beyond, the power sector will have more possibilities to develop carbon free options at costs that would render electricity (and CHP) more attractive to final consumers, who then may shift their consumption in favour of electricity.

Energy saving dominates substitution in favour of electricity in the short and medium term, so electricity demand decreases. The power sector also uses more renewables since it has access to a larger cost-effective potential than other sectors. Therefore, emission reduction in absolute terms takes place more in the ETS sector, rather than in the non ETS.

6.1.3 How energy efficiency progress is modelled

Engineering-oriented analysis points to the existence of energy saving potentials that may be achieved without extra cost to the energy system, or even at negative costs. However, there is evidence from statistics that consumers do not act as expected by engineering-oriented analysis.

The PRIMES model takes the view that in reality “hidden” costs explain why consumers do not exploit this so-called no-cost energy saving potential. They have to be motivated by some price signal or by command-and-control policies. Factors such as lack of information, risk associated with the adoption of new technologies (such as possible lack of maintenance or lower technical reliability), market barriers (associated with the effort of equipment sellers to keep selling the old inefficient equipment), disutility (less comfort) and lack of appropriate standards bring about true costs for the consumer and explain the observed behaviour.

Any energy efficiency investment involves higher expenditure for investment cost (purchase of more efficient equipments and appliances or works for insulating buildings and houses) and lower expenditure for operation because of fuel savings. The pay-back period depends on the discount rate. Engineering-oriented analyses adopt rather low discount rates. However, statistical studies have shown that the discount rates used by consumers are much higher, reflecting lack of sufficient wealth (or cash) or high preference for holding savings in cash form. These high rates are often called subjective discount rates as opposed to business discount rates.

The PRIMES model represents the hidden costs associated with the choice of new equipments as perceived costs that differ from engineering costs. In addition, the model uses subjective discount rates, which vary between 12 and 20% depending on the size of the consumer, contrasting for example 8 – 9% rates that are used for utilities.

The model takes the view that energy efficiency investments which are included in the Baseline scenario are driven by market forces. Consequently, for scenarios that include emission or similar constraints which drive energy efficiency investments further, the model evaluates positive (and not zero or negative) additional costs.

Another explanation of positive costs of energy efficiency is the so-called rebound effect. A rebound effect, i.e. more consumption of energy than expected by engineering analysis of energy savings, occurs when energy efficiency improves. If energy efficiency improvement saves money for the consumer, he or she may increase consumption, including energy. The net effect cancels part of the energy savings. The associated additional cost is sometimes neglected in engineering analyses. The PRIMES model formulates a structural microeconomic decision for each consumer-type (as a detailed budget allocation problem), thus it simulates the rebound effect.

Within the context of a scenario involving emission reduction effort, which drives energy efficiency improvement, it should be expected that both public policy and the suppliers of equipment react by removing part of the factors that entail hidden costs associated with energy efficiency investment.

For example, public authorities undertake information campaigns and adopt standards, while suppliers promote new, more advanced, equipment and improve the maintenance services. Consequently, the perceived costs of energy efficiency actions decrease, compared to baseline, and the related investments become more attractive.

The PRIMES model formulates non linear cost-supply curves with increasing slope, in which the perceived cost are an increasing function of the energy efficiency potential by end-use type. Therefore cumulative energy efficiency actions (e.g. savings, insulation, adoption of more advanced equipment vintages, etc.) induce proportionally higher unit costs for the consumer. This relationship is modelled for each of the categories included at the bottom level of the decision tree corresponding to each consumer type.

It is assumed that in the context of an emission reduction scenario the cost-supply curves shift to the right making the potential of energy efficiency gains more attractive economically. This shift is calibrated so as to be proportional to the magnitude of the price signal, which in the case of emission reduction is represented by the carbon value. The shift represents proactive policies (public and private) that facilitate energy efficiency improvement. The price signal (carbon value) is used as a proxy to measure the intensity of these policy actions.

The assumed shift of perceived cost curves entail positive costs incurred by public policy and private equipment suppliers. It is further assumed that they pass through to consumers the additional costs. Thus consumers bear costs owing to the shift of cost-supply curves of energy efficiency driven by the carbon values. These costs are included in the calculation of compliance cost. Their magnitude is computed by the model by calculating the area below the curve of marginal costs of energy efficiency gains per type of consumer and type of energy use. They are added to other direct and indirect costs which result from the emission reduction effort.

6.1.4 How the RES values act

Instead of imposing directly an overall target for renewables, it is assumed that a certain positive monetary value is associated with any unit of energy produced by a renewable energy source. Such a monetary value does not involve payments but its presence alters the economic optimality of calculations of the agents (either demanders or producers of energy). This monetary value could be interpreted as a “virtual” subsidy and enters in the model calculations as a negative unit cost (a benefit), which is called a “RES value”. Being a virtual subsidy, the renewables value does not make energy cheaper but just influences the optimal fuel mix as considered by each economic agent.

In power generation, these values impact on investment and dispatching decisions as they are virtually subtracted from costs for investment, thus leading to higher renewables investment and dispatching. The "RES value" being only a virtual subsidy, the accounting costs for electricity and heat production are calculated on the basis of true capital costs, O&M costs, fuel costs, etc. and these calculations are used to determine consumer prices.

However, because the RES value drives deviation from baseline optimality, the accounting costs for electricity and heat production increase. Thus, electricity and heat/steam prices increase and influence changes of consumption behaviour.

The RES target adopted by the EU is expressed as a ratio of renewable energy over gross final energy consumption. So to meet this target it is possible to act either by increasing the use of RES, or by decreasing energy consumption or both. The RES values drive higher RES consumption through substitution between energy forms. They also induce higher prices and costs of energy, compared to baseline, and so they drive energy efficiency progress, which reduces energy consumption. The carbon values act in a similar way: they drive substitutions in favour of RES and they drive more energy efficiency progress. Thus, both terms of the ratio expressing the RES target change in opposite directions.

The PRIMES model assumes cost-supply curves for virtually all energy forms, including the renewable sources (e.g. biomass, waste, hydro, wind, etc.). A cost-supply curve represents the unit cost of an energy form (or the unit cost of investment in capacity producing the energy form) as an increasing function of the potential for this energy form (or the potential sites for developing capacity for this energy form). So, cumulative volume of consumption of the energy form (or cumulative volume of capacity investment for this energy form, respectively) induces higher unit costs. The cost-supply curves have an increasing slope reflecting exhaustion of a fuel resource or exhaustion of a RES potential or increasing difficulty of finding new construction sites and supply contracts (in case of imported energy forms).

For the renewable energy sources, the cost-supply curves represent cost increases associated with developing new sites (applicable to intermittent and hydro resources), or fuel supply cost curves (applicable to biomass and waste exhaustible potential).

The fact that the cost-supply curves are upward sloping implies that in a scenario involving high RES-values the marginal cost of RES deployment will be higher than in a baseline scenario.

However, high RES-values will also drive development of infrastructure that will further facilitate the exploitation of the RES potential. Examples of infrastructure include the grids in remote areas to exploit wind power, the facilities for collection and conditioning of biomass and waste at a large scale, the network systems enabling PV applications, etc. High RES-values also reflects better public acceptance of RES deployment, which contribute towards lower unit development costs.

These changes are represented in the model by shifting the cost-supply curves of RES potential to the right, rendering the exploitation of the RES potential less expensive. The shifting is assumed proportional to the magnitude of the driver, i.e. the RES-value.

It should be stressed that despite using a price signal, such as the RES-value, the true drivers are the public (and private) actions which concern the development of appropriate infrastructure and other facilitations. All these actions enable the deployment of higher RES potential at lower marginal cost.

The shifts of RES cost-supply curves are assumed to act in addition to the effects from learning-by-doing, which concern the unit overnight cost of capital equipment of RES. The model includes learning curves for all technologies. To the time horizon of 2020, however, the effects from learning-by-doing are rather small, except for few RES technologies, such as solar photovoltaic, solar thermal, tidal and offshore wind power.

High development of power generation from intermittent renewables entails additional costs for the reinforcement of power grids (and for new grid devices) and for backup power with flexible thermal units. These costs are calculated in detail by the PRIMES model and are included in the compliance costs. The additional costs are reflected also into consumer prices.

6.2 Decomposition of Emission Reduction

To get more insight about the restructuring of the energy demand and supply system needed to meet the targets, the amount of emission reduction from the Baseline scenario is decomposed by type of change.

The decomposition is quantified by processing ex-post the results of the PRIMES model for a scenario expressed as differences from the Baseline scenario.

A simple accounting model, which calculates an energy balance, is first quantified on the basis of model results. In this simple model, energy consumption by sector is related to activity through an energy intensity ratio. Total energy consumption is split in consumption by fuel by using share parameters referring to the fuel mix by sector. Finally, CO2 emissions are derived from fuel use by applying standard emission factors. The average carbon intensity of electricity and heat/steam distributed to final consumers is associated with the structure of energy production, and is also decomposed by using energy efficiency ratios, fuel mix shares and emission factors.

The parameters, i.e. the ratios, shares and emission factors, are taken from the results of the model by scenario for the year 2020.

The decomposition method is illustrated by the following formula:

$$CO_2 = \left(\frac{Energy}{Activity}\right) \times \left(\frac{Fossil\ Fuels}{Energy}\right) \times \left(\frac{CO_2}{Fossil\ Fuels}\right) \times Activity$$

The ratios in parentheses correspond to energy intensity, share of fossil fuels (one minus the share of carbon free sources) and average emission factor for fossils, respectively.

The above formula is quantified by energy consumption sector. Emissions in production of electricity and steam are also decomposed by using a similar formula. If the combined share of a electricity and steam increases in final demand, emissions in final demand decrease, all other things being equal, but emissions in the production of the secondary form may increase. This is explicitly expressed in the accounting model.

To compare two scenarios the accounting model equations are transformed into linear expression involving rates of change. To illustrate this procedure, consider the above simple formula which is first transformed by applying a logarithm in both sides. Then it is expressed in terms of differences between a scenario and the Baseline. The "ΔLog" are approximately percentage rates of change, so the final formula is as follows:

$$\frac{\Delta CO_2}{CO_2} = \frac{\Delta\left(\frac{Energy}{Activity}\right)}{\left(\frac{Energy}{Activity}\right)} + \frac{\Delta\left(\frac{Fossil\ Fuels}{Energy}\right)}{\left(\frac{Fossil\ Fuels}{Energy}\right)} + \frac{\Delta\left(\frac{CO_2}{Fossil\ Fuels}\right)}{\left(\frac{CO_2}{Fossil\ Fuels}\right)} + \frac{\Delta Activity}{Activity}$$

The symbol Δ indicates differences of a scenario from the Baseline and the denominator of the above ratios refer to the Baseline scenario. The last formula provides the decomposition information.

The four components appearing in the above decomposition formula are interpreted as follows:

a) A reduction of the ratio of energy over activity corresponds to energy savings and to the use of more energy efficient equipments; this is termed "energy efficiency" effect.

b) A reduction of the ratio of fossil fuels over energy corresponds to higher use of carbon free energy resources, such as RES, nuclear or CCS; this is termed "use of carbon free energy" effect.

c) A reduction of the rate CO2 over fossil fuels corresponds to substitutions within the mix of fossil fuels, for example natural gas substituting for coal; this is terms "fossil fuel mix" effect.

d) A reduction in activity corresponds to lower room temperatures, lower transportation activity or to lower production of energy intensive materials; this is termed "activity" effect.

To decompose emission changes for final energy demand sectors the formula finally used also includes the ratio of secondary energy form use (e.g. electricity and distributed heat/steam) over energy consumption. The changes of the value of this ratio between two scenarios may have positive or negative impacts on CO2 emissions, depending on the average emission factor of production of the secondary energy form relative to the average emission factor of direct consumption of energy forms by final consumers.

By including emissions from production of the secondary energy form, the decomposition of emission changes for a final energy demand sector refers to system-wide effects.

This is termed "shift to electricity and steam" effect and expresses the net impact on emissions from increasing consumption of electricity and heat/steam to the detriment of direct uses of energy forms by final consumers.

Table 21 shows the decomposition of energy-related emission reduction by scenarios relative to the Baseline.

The table shows the contribution of five emission reduction means in percentage terms. The figures refer to the entire energy system of EU27 as projected by scenario for 2020. The table also includes the high oil and high gas baseline scenario which does not include GHG or RES targets.

Table 21: Decomposition in % of Reduction of CO2 Emissions from energy in the whole system, EU27 - 2020

Scenarios	Activity	Energy Effici-ency	Use of Carbon Free Energy	Fossil Fuel Mix	Shift to Electri-city/ Steam	SUM
RSAT	5.9	40.7	45.7	0.4	7.3	100
NSAT	4.7	36.1	49.4	4.9	5.0	100
RSAT-CDM	3.8	27.0	58.1	6.6	4.4	100
NSAT-CDM	3.9	30.9	58.6	1.5	5.1	100
CES	4.7	37.5	50.4	3.8	3.6	100
CES-CDM	4.2	34.9	55.5	1.6	3.9	100
Pure-GHG	5.6	47.7	35.6	10.6	0.6	100
Pure-RES	1.6	8.3	82.1	-2.4	10.4	100
HOG-BL	11.5	47.6	72.5	-14.1	-17.5	100
HOG-CES	6.6	45.8	58.3	-6.7	-4.0	100

The decomposition shows that the use of carbon free energy resources is the main option for emission reduction, followed by energy efficiency improvement. In 2020 there exist few possibilities for deploying carbon free resources other than RES (nuclear, CCS) at a significant scale. So, the carbon free effect mainly consists in deploying RES. The “pure-GHG” scenario, which seeks to meet the GHG target without having a RES target, is the only scenario in which energy efficiency effect dominates over the carbon free effect. All other scenarios involve the RES target and deploy more RES than the pure-GHG case. So, the RES target plays an important role on its own within the proposed policy package in promoting RES deployment.

The fossil fuel mix effect is small in all scenarios except in the pure-GHG one. This means that gas substituting for coal is not among the main means of the energy system for emission reduction because of the coexistence of the RES target. The negative sign of this effect in the scenarios with high oil and high gas prices signifies that the resulting substitution of gas by coal plays a negative role within the effort for reducing emissions. Consequently, in these scenarios shifting final demand towards more electricity and steam has negative impacts on emission reduction. This shift has a positive but small contribution to emission reduction in all other scenarios and takes the highest value in the pure-RES scenario which ignores the GHG target.

Energy efficiency improvement has considerable contribution to emission reduction, in all scenarios except in the pure-RES scenario. However, it is the dominant option only in the pure-GHG scenario. The limited possibility to shift final demand towards electricity and steam and so to rely more on power and steam production for emission reduction explains why energy efficiency improvement is so important for emission reduction in 2020. Its importance reduces when emission credits can be taken from CDM. This leads to lower carbon values and higher RES values, as it was explained in a previous section. So part of the contribution from energy efficiency is replaced by more contribution from carbon free resources.

Table 22 shows decomposition of emission reduction in final energy demand consumers. The calculation and the percentages shown refer to the whole energy system, thus taking into account the indirect emissions corresponding to secondary energy forms, such as electricity and distributed heat/steam. The table shows the part of emission reduction which is attributable to final consumers.

Table 22: Decomposition in % of Reduction of CO2 Emissions from energy due to final energy consumers, EU27 – 2020

	Final Energy Demand Sectors				
Scenarios	Activity	Energy Effici-ency	Use of Carbon Free Energy	Fossil Fuel Mix	SUM (% of total emission reduction)
RSAT	5.9	36.3	12.2	-0.1	54.3
NSAT	4.7	29.9	10.1	0.6	45.2
RSAT-CDM	3.8	20.5	15.1	0.7	40.1
NSAT-CDM	3.9	25.1	16.1	0.0	45.0
CES	4.7	32.0	11.7	0.6	49.0
CES-CDM	4.2	29.6	15.5	0.1	49.5
Pure-GHG	5.6	42.7	2.2	1.3	51.7
Pure-RES	1.6	0.7	24.7	-1.3	25.7
HOG-BL	11.5	47.4	31.1	-0.5	89.5
HOG-CES	6.6	45.0	19.2	0.1	70.9

Energy efficiency improvement dominates the response of final consumers to the targets, representing two thirds of their contribution. It is small only in the pure-RES case. Energy efficiency gains are driven by higher consumer prices of energy. This is confirmed by the HOG-BL scenario for which energy efficiency improvement is directly attributable to high oil and gas prices.

The substitution effect in favour of carbon free resources is also important. The changes in fossil fuel mix have a very small contribution to emission reduction. Activity reduction has a positive but small contribution: roughly 10% of contribution by final consumers. It is higher in the HOG-BL case and is attributable to the high prices of energy.

Table 23: Decomposition in % of Reduction of CO2 Emissions from energy due to power generation, EU27 – 2020

	Power Generation				
Scenarios	Shift to Electricity	Energy Efficiency	Use of Carbon Free Energy	Fossil Fuel Mix	SUM (% of total emission reduction)
RSAT	7.5	3.8	33.1	0.3	44.8
NSAT	5.1	5.4	39.0	4.4	53.8
RSAT-CDM	4.5	5.5	42.7	5.8	58.4
NSAT-CDM	5.1	5.1	42.1	1.6	54.0
CES	3.3	5.1	38.2	3.4	49.9
CES-CDM	3.6	4.9	39.4	1.5	49.4
Pure-GHG	0.4	5.0	33.3	9.2	47.9
Pure-RES	10.4	6.3	56.3	-0.9	72.1
HOG-BL	-17.3	0.8	40.6	-13.1	11.0
HOG-CES	-3.7	0.6	38.3	-6.6	28.7

Contrasting the final demand sectors, in power and steam production the substitution effects dominate the response of these sectors to the targets. The use of carbon free resources (mainly RES by 2020) in power generation, replacing fossil fuels, represents roughly 80% of sector's contribution to emission reduction (see Table 23).

The shift of final consumption towards more electricity contributes by roughly 10% in emission reduction attributable to power generation. It is higher in the pure-RES case, but it has a negative impact in scenarios with high oil and gas prices, obviously because coal is favoured in these scenarios.

The scenarios results show that shift to electricity effect is more important in the long term, towards 2030, just because that horizon is long enough to allow power generation developing carbon free resources (in addition to RES) that would render emission reduction in power generation more beneficial for the system.

Gas substituting for coal in power generation has a small contribution, except in the pure-GHG case. This confirm again the importance of the coexistence of the RES target which helps avoiding increase of gas imports, hence aggravating security of energy supply concerns, as a response to GHG targets.

Energy efficiency effects in power sector are attributed to the use of more efficient plants and represents roughly 10% of emission reduction by the sector.

Table 24: Decomposition in % of Reduction of CO2 Emissions from energy due to production of distributed heat/steam, EU27 – 2020

	Steam / Heat Production					
Scenarios	Shift to Steam	Energy Efficiency	Use of Carbon Free Energy	Fossil Fuel Mix	More steam from CHP	SUM (% of total emission reduction)
RSAT	-0.3	0.0	0.4	0.1	0.6	0.9
NSAT	-0.1	0.0	0.4	-0.1	0.7	0.9
RSAT-CDM	-0.1	0.0	0.4	0.1	1.0	1.4
NSAT-CDM	0.0	0.0	0.5	-0.1	0.7	1.0
CES	0.2	0.0	0.5	-0.1	0.4	1.0
CES-CDM	0.3	0.0	0.6	-0.1	0.3	1.1
Pure-GHG	0.1	0.0	0.2	0.1	-0.1	0.4
Pure-RES	0.0	0.1	1.1	-0.2	1.2	2.3
HOG-BL	-0.2	0.0	0.8	-0.4	-0.7	-0.5
HOG-CES	-0.3	0.0	0.7	-0.2	0.2	0.4

Table 24 shows a similar decomposition for heat and steam production. The use of carbon free resources (biomass and waste) represents roughly half of sector's contribution to overall emission reduction the other half being attributed to CHP. Generally the role of this sector in overall emission reduction is small.

Table 25 summarises the relative contribution of the sectors to overall emission reduction. Generally the power sector has a slightly higher contribution than the final demand sectors.

The high RES values in the RSAT case, which imply high consumer prices, explain why in RSAT consumers contribute more than power generation. A similar explanation (high consumer prices) holds for the high oil and gas prices scenarios.

Table 25: Decomposition in % of Reduction of CO2 Emissions from energy between demand and supply sectors, EU27 – 2020

Scenarios	Final Energy Demand Sectors	Power Generation	Steam / Heat Production	SUM
RSAT	54.3	44.8	0.9	100
NSAT	45.2	53.8	0.9	100
RSAT-CDM	40.1	58.4	1.4	100
NSAT-CDM	45.0	54.0	1.0	100
CES	49.0	49.9	1.0	100
CES-CDM	49.5	49.4	1.1	100
Pure-GHG	51.7	47.9	0.4	100
Pure-RES	25.7	72.1	2.3	100
HOG-BL	89.5	11.0	-0.5	100
HOG-CES	70.9	28.7	0.4	100

6.3 Assumptions for dynamic scenarios with PRIMES up to 2030

The PRIMES model simulates dynamic scenarios of the energy system and involves anticipations in the decision making by energy consumers and producers.

The simulations were made for the time period 2005 to 2030 assuming that the results for 2005 are fixed to statistical data.

To quantify a dynamic policy scenario with the model it is not enough to fix a GHG or RES target for 2020 but one also needs to assume targets for the whole projection period, starting from 2010. Since such targets are not set for years other than 2020, it was instead assumed for the scenario design certain carbon values and RES values for the years other than 2020.

The carbon values for the year 2010 were fixed at 20 €/tCO2 for the ETS and zero for the non-ETS, as it was also assumed in the Baseline scenario. The RES values for 2010 were assumed equal to zero. The carbon values and the RES values for 2015 were estimated as a result of interpolation between values of 2010 and 2020, assuming that 0.79% of the values of 2020 apply for 2015. For the years beyond 2020, the carbon and RES values were obtained through extrapolation, assuming 6.8% increase of values in 2025 from 2020 and 13.5% increase in 2030 from 2020. Both interpolations and extrapolations were made specifically for each scenario (see Table 26).

Table 26: Carbon and RES Value assumed for scenarios, EU27

		2010	2015	2020	2025	2030
Carbon value €/tCO2	NSAT	20	33.8	42.7	45.6	48.5
	NSAT-CDM	20	23.7	30.0	32.0	34.1
	CES	20	31.0	39.2	41.9	44.5
RES value €/MWh	NSAT	0	35.1	44.5	47.5	50.5
	NSAT-CDM	0	39.1	49.5	52.9	56.2
	CES	0	35.4	44.8	47.8	50.8

It is clear that the carbon values and the RES values drive GHG emission reduction and more RES development beyond the year 2020. The results obtained do not constitute official EC targets but have been quantified only for the purpose of energy system analysis.

6.4 Reduction of Energy Consumption

As mentioned previously, the imposition of the GHG and the RES targets implies that all energy consumers and producers bear a cost for CO2 emissions and enjoy a virtual subsidy for the use of RES. These induce substitutions but since they cannot be perfect, energy input cost rises in all sectors. This induces reduction of energy inputs per unit of activity, as a result of energy savings and the increased use of more efficient energy technologies.

Focusing on the NSAT scenario, which leads to 42.7 €/tCO2 carbon value in ETS, 37.2 €/tCO2 EU average carbon value in non-ETS and 44.5 €/MWh RES value in all sectors, the model results confirm that significant reduction of energy inputs per unit of activity takes place.

Total primary energy requirements of the EU (termed Gross Inland Consumption by EUROSTAT) is found lower in NSAT by roughly 10% relative to the Baseline throughout the period 2020-2030. Final energy consumption is also lower in NSAT, compared to the Baseline, in a range between 8.5 and 10% during the same period.

The energy intensity of GDP, which is projected to decrease by 1.7% per year on average between 2005 and 2030 in the Baseline scenario, is decreasing by 2.1% per year in the NSAT scenario.

The model results (see Table 27) show that reduction of energy consumption is larger in the tertiary sector (between 16.5 and 19% from Baseline during 2020-2030), followed by transportation (between 9 and 12%) and the residential sector (7.5 – 10.5%).

Energy savings are found much lower for industry, ranging between 3.5% and 5,5% relative to the Baseline. These differences reflect different energy saving potentials by sector: energy consumption in industry seems to be more optimized already in the Baseline scenario than in other sectors.

The substitution effects are rather small in final energy demand sectors. This is inferred from the shares of energy forms within each sector's total energy consumption, which change little when comparing NSAT with Baseline. The main change of shares in NSAT corresponds to the increase of RES, driven directly by the RES target and indirectly by the GHG target. As a result, the shares of fossil fuels decrease but the mix of fossil fuels seems largely unchanged from the Baseline.

Table 27: Energy Consumption in the NSAT, EU27

NSAT Scenario	% Change of Consumption from Baseline		% Diff. of shares from Baseline	
	2020	2030	2020	2030
Gross Inland Consumption	-9.94	-10.18		
Solids	-36.60	-37.33	-5.1	-5.1
Oil	-11.12	-14.80	-0.5	-1.8
Natural gas	-15.25	-19.92	-1.5	-2.8
Nuclear	-1.30	0.11	1.1	1.2
Renewables	44.50	54.16	6.0	8.5
Final Energy Consumption	-8.21	-10.58		
Energy Intensive Industry	-3.18	-4.22	0.9	1.2
Other Industries	-4.36	-5.34	0.4	0.6
Residential	-7.41	-10.38	0.2	0.1
Tertiary	-16.33	-18.95	-1.3	-1.4
Transport	-8.88	-11.83	-0.2	-0.5
Final Energy Consumption	-8.21	-10.58		
Solids	-7.19	-12.83	0.0	-0.1
Oil	-11.58	-16.41	-1.5	-2.5
Gas	-11.72	-22.57	-0.9	-3.1
Electricity	-12.90	-2.99	-1.1	2.0
Steam Distrib.	-9.16	-9.64	0.0	0.0
Renewables	40.33	35.06	3.5	3.7

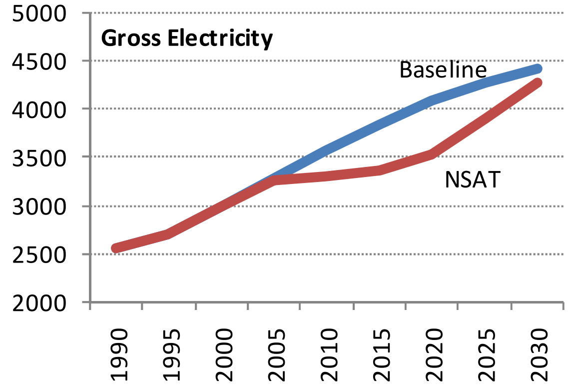
The limited substitutions among the fossil fuels is due to the fact that they are mostly used in specific energy uses, as for example oil in transportation, gas in residential uses and coal in specific industrial processes. It would be very costly for example to use gas in coal-using processes as a means for reducing CO2 emissions.

An important issue is whether or not substitution towards more electricity within final demand is used as a means of reducing overall emissions at lower total cost. Such a substitution would be a result of energy market equilibrium if the marginal abatement cost in electricity remains lower than that in final demand sectors after shifting part of final energy demand towards electricity.

The results suggest a negative answer for 2020 but a positive answer for 2030. The share of electricity in total energy consumption in 2020 decreases by 1 percentage point relative to Baseline but it increases by 2 percentage points in 2030. This result reflects the fact that 2020 is rather short for the power sector to develop low cost carbon-free generation (in addition to the RES) at a sufficiently large scale, whereas 2030 is not.

By 2030, nuclear may develop and CCS is expected to become mature. In fact, since the NSAT scenario keeps unchanged the rather pessimistic assumptions about nuclear development even for 2030 (such as the phase out in some Member-States and the non extension of lifetimes of existing plants), it is the development of CCS which explains the attractiveness of electricity close to 2030. The share of nuclear energy in Gross Inland Consumption in NSAT is 1.1 percentage points higher than in the Baseline in 2020 (1.2 percentage points in 2030).

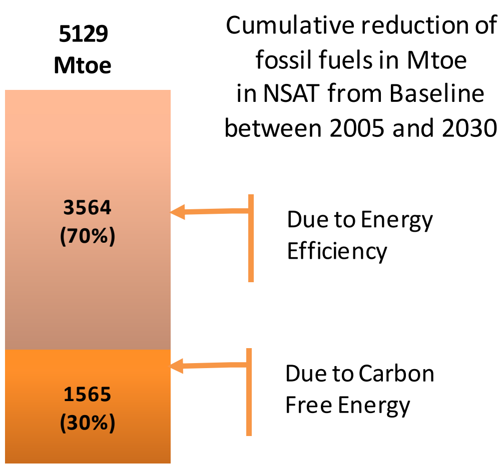
Figure 13: Gross Electricity Demand (TWh) in the NSAT relative to the Baseline - EU27



	Cumulative thousand TWh generated	Annual growth rate of electricity demand	
	2005-2030	2005-2020	2020-2030
NSAT	89510	0.51	1.92
Baseline	98003	1.47	0.78

The role of electricity in emission reduction, as discussed above, can be further illustrated by considering the graphic and the table above. NSAT projects a slower pace of electricity demand growth than the Baseline in the medium term, but a faster pace in the long term. However, cumulative electricity production between 2005 and 2030 is lower in NSAT by 8.7% relative to the Baseline.

Figure 14: Cumulative changes in fossil fuel use in the NSAT scenario - EU27

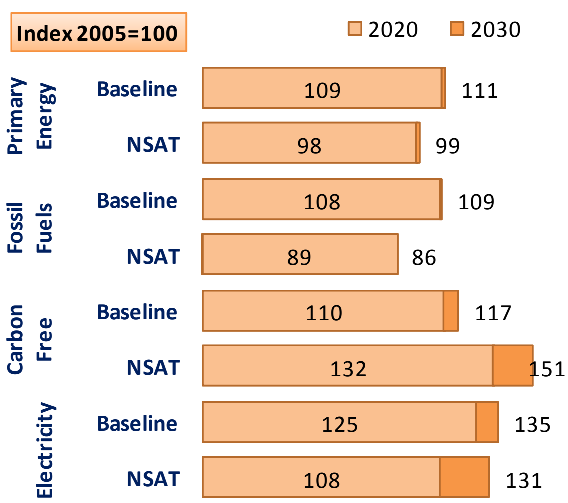


The NSAT scenario involves considerable reduction of fossil fuel consumption. Compared to the Baseline, the NSAT reduces cumulative consumption of fossil fuels between 2005 and 2030 by 13.5%. It also increases the use of carbon-free energy: 15.1% up from Baseline in cumulative terms over the same time period. Energy efficiency improvement in cumulative terms, measured at the level of Gross Inland Consumption, explains 70% of the drop of cumulative consumption of fossil fuels, the rest (30%) being attributed to the carbon free resources.

The figures below further illustrate the importance of energy efficiency within the NSAT scenario, which involves meeting the GHG target domestically in the EU.

As expected, getting part of the emission credits from abroad, like in the NSAT-CDM scenario, implies lower energy consumption reduction in the EU. Regarding energy efficiency, the model results for the NSAT-CDM scenario show similar trends as for the NSAT scenario but numerically the magnitude of changes is generally smaller.

Figure 15: Indicators for scenario NSAT relative to the Baseline, EU27



The overall energy intensity of GDP needs, in the NSAT-CDM, to improve by 2% per year on average, instead of 2.1% per year.

Compared to the Baseline, total energy consumption in the NSAT-CDM is reduced by roughly 7% (2020-2030), instead of roughly 10% in the NSAT. In terms of final energy consumption, energy savings in the NSAT-CDM in 2020 are 5% on average, instead of 8.2% in the NSAT.

The cumulative savings of fossil fuels (2005-2030) from the Baseline are in the NSAT-CDM 10.9%, instead of 13.5% in the NSAT. Energy efficiency improvement explains 60% of these savings in the NSAT-CDM (70% in the NSAT).

Figure 16: Gross Inland Consumption in NSAT scenario relative to the Baseline - Mtoe - EU27

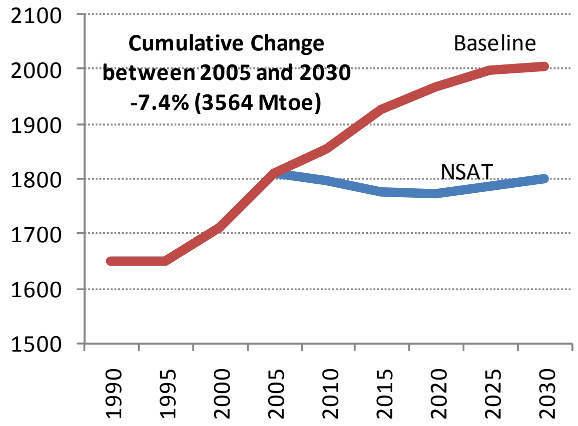


Table 28: Energy Consumption in the NSAT-CDM, EU27

NSAT-CDM Scenario	% Change of Consumption from Baseline		% Diff. of shares from Baseline	
	2020	2030	2020	2030
Gross Inland Consumption	-6.42	-7.31		
Solids	-24.81	-27.14	-3.4	-3.6
Oil	-8.43	-12.11	-0.8	-1.8
Natural gas	-14.84	-20.11	-2.3	-3.6
Nuclear	-2.01	-2.83	0.5	0.5
Renewables	49.36	58.93	6.0	8.5
Final Energy Consumption	-5.07	-7.50		
Energy Intensive Industry	-1.48	-2.49	0.6	0.9
Other Industries	-3.16	-4.36	0.2	0.4
Residential	-3.94	-7.21	0.3	0.1
Tertiary	-11.54	-14.60	-1.0	-1.2
Transport	-5.40	-8.04	-0.1	-0.2
Final Energy Consumption	-5.07	-7.50		
Solids	-1.71	-4.66	0.1	0.1
Oil	-8.48	-13.07	-1.4	-2.4
Gas	-10.79	-20.92	-1.4	-3.4
Electricity	-8.75	0.80	-0.9	2.1
Steam Distrib.	-6.20	-7.54	0.0	0.0
Renewables	46.76	36.94	3.6	3.5

As already mentioned, the contribution of RES is higher in the NSAT-CDM than in the NSAT, in relative terms.

The NSAT-CDM shows very small substitutions in the fossil fuel mix, as it was also the case in the NSAT. As regards the relative energy saving efforts by final demand sector, the results for the NSAT-CDM confirm that the tertiary sector seems to have the largest potential, followed by the residential sector and transportation. However, under the conditions of the NSAT-CDM, i.e. an average carbon value for non-ETS of 22.2 €/tCO2, the results show significantly less savings in 2020 than in 2030.

Figure 17: Cumulative changes in fossil fuel use in the NSAT-CDM scenario - EU27

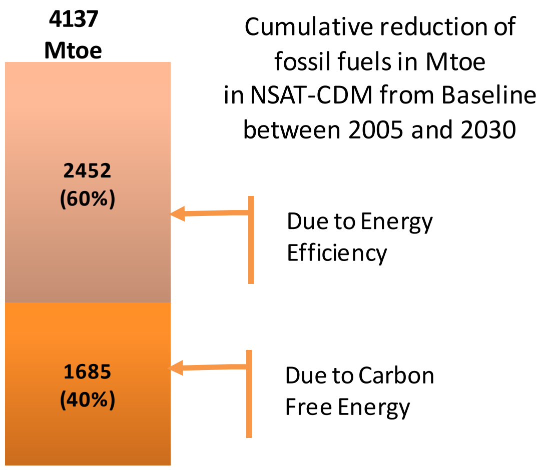
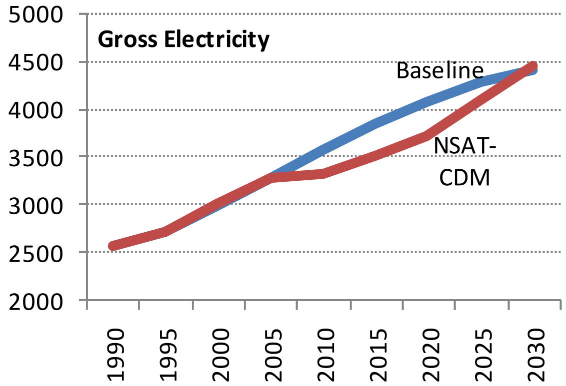


Figure 18: Gross Electricity Demand (TWh) in the NSAT-CDM relative to the Baseline - EU27



	Cumulative thousand TWh generated	Annual growth rate of electricity demand	
	2005-2030	2005-2020	2020-2030
nsatl	92390	0.84	1.81
Baseline	98003	1.47	0.78

Electricity demand in the NSAT-CDM is less affected than in the NSAT in the medium term and is more favoured in the long term. Cumulative gross electricity generation in the NSAT-CDM (2005-2030) decreases by 5.7% from the Baseline, instead for 8.7% in the NSAT. By 2030, electricity demand in NSAT-CDM becomes higher than in the Baseline, in absolute terms, highlighting the long term role of electricity in the reduction of emissions.

6.5 Development of RES

As expected, the RES target drives considerable development of renewable energy applications in all sectors. The coexistence of the GHG target also drives energy savings and, since the RES target is expressed as a ratio of RES over energy demand, total RES developed is lower in absolute terms than when considering the RES target alone. Nevertheless, in all cases that meet both targets, energy from RES increases considerably from the Baseline scenario.

The NSAT scenario assumes that the RES target is met in a cost-effective way, which means that the RES potentials of the Member-States are exploited according to a uniform RES value, which is determined in the NSAT scenario endogenously. The RES value in this scenario was found equal to 44.5 €/MWh. The RES supportive instruments, such as feed-in tariffs, investment subsidies, green certificates, etc., are assumed to remain unchanged from the Baseline scenario. These instruments are represented specifically for each Member-State and their cost is recovered through the consumer price of energy. The model converts these instruments into an equivalent investment incentive for RES; judging from their numerical values, as calibrated and extrapolated to the future under the assumptions of the Baseline scenario, the incentives are rather small in magnitude. The RES value of 44.5 €/MWh acting on top of existing incentives is in absolute terms a significant push to the RES development.

In fact, the NSAT scenario results show that the combined targets induce between 45% and 55% higher RES use in primary energy terms during 2020-2030, than in the Baseline scenario. In particular the RES target is instrumental for this increase, while the GHG target plays a supportive role.

In the NSAT scenario, the share of RES in total primary energy requirements in the EU in 2020 amounts to 16% (up from 10% in the Baseline) and further grows to 20% in 2030 (11.8% in the Baseline).

The share of RES in terms of gross final energy consumption, i.e. the indicator in which the RES target is expressed reaches 20% in 2020 and grows to 25% in 2030, more than 10 percentage points up from the Baseline. Details by sector are shown in Table 29.

Referring to Table 29, in the NSAT scenario, 51.5% of the RES in 2020 is used in energy production, the rest being consumed in direct uses at the final consumer level. In 2030, the share of energy production increases to 58%. The incremental development of RES in the NSAT, compared to the Baseline, in 2020 is 56% for energy production increasing to 69% in 2030.

RES in power generation is by far the largest part of RES applications, followed by direct uses of biomass and waste energy by final energy consumers. The direct uses of biomass increase less than other types in the NSAT if compared with the Baseline. However, the use of biomass in power generation and in the production of steam/heat increases substantially more than its direct uses in the NSAT scenario. Solar energy and geothermal energy used directly by final consumers exhibit high growth in the NSAT but remain small in shares.

Table 29: RES measured at Gross Final Energy Consumption, NSAT - EU27

	NSAT (Mtoe)		% Change from Baseline	
RES in Gross Final Energy Consumption	2020	2030	2020	2030
	257.3	331.2	46.2	55.3
Electricity Generation	93.2	132.3	37.3	61.0
Heat/Steam Production	39.3	59.9	104.1	112.2
Biomass direct use	72.1	77.4	26.4	26.4
Solar energy direct use	19.0	22.9	263.8	234.5
Geothermal heat direct use	1.7	1.6	131.3	133.3
Biofuels in Transport	32.0	37.2	23.5	8.9
RES in Primary Energy	284.2	365.8	44.5	54.2

Table 30: Shares of RES in final energy demand (direct uses only), NSAT - EU27

	Shares in the NSAT (%)		% Diff. from Baseline	
Direct RES in Final Energy Demand (as in the Energy Balances)	2020	2030	2020	2030
	10.1	11.1	3.5	3.7
Industry	8.0	10.1	3.2	4.5
Residential	16.5	16.1	5.0	4.7
Tertiary	7.6	8.6	4.4	5.0
Transport	8.0	9.1	2.1	1.7

The contribution of biofuels, which constitute the only RES possibility for transportation, is equal to the biofuels target in 2020 and is projected to increase slowly towards 2030. Their contribution to total RES use is roughly 12%.

The direct uses of RES by final consumption sectors are shown in Table 30. In the NSAT scenarios, the shares range between 8 and 16%, 2 to 5 percentage points up from the Baseline. The highest shares are projected for the residential sector.

The largest deployment of RES is projected to take place in the power generation sector, according to the NST scenario. To put this in a perspective, the NSAT scenario projects that approximately one third of kWh produced in the EU will be generated by using renewable energy sources. This percentage grows to 38.4% by 2030, 15.6 percentage points up from the Baseline scenario. The RES power generation industry is thus becoming almost twice larger than the nuclear industry (21% in 2030 in the NSAT).

The largest contribution in incremental terms relative to the Baseline is provided by biomass/waste and by wind power. These two energy forms would produce roughly three quarter of electricity generated by RES in 2030 in the NSAT scenario. In 2000, the largest power producing RES was by far the hydroelectric energy source, which because of lack of additional potential grows at a slow pace. Solar photovoltaic and other RES for power generation are projected to grow at a fast pace and more than triple from the Baseline, but their share in power generation remain low in the NSAT scenario.

Table 31: RES in energy production, NSAT - EU27

	NSAT (TWh)		% Change from Baseline	
Electricity Generation (net) from RES	2020	2030	2020	2030
	1146.7	1643.4	39.2	63.5
Hydro	346.3	352.2	2.9	0.4
Wind	372.3	595.5	37.3	74.0
Solar, tidal etc.	26.5	71.8	125.2	239.0
Biomass & waste	392.9	614.9	100.0	118.2
Geothermal heat	8.9	8.9	8.5	0.0
	Shares in the NSAT (%)		% Diff. from Baseline	
	2020	2030	2020	2030
RES % in Power Generation	32.4	38.4	12.2	15.6
RES % in Steam Boilers	22.7	26.4	8.6	12.0

The share of biomass in total inputs to steam and heat boilers is also projected to increase substantially in the NSAT scenario. By 2020, the share of biomass/waste reaches 22.7%, 8.6 percentage points up from the Baseline. Total biomass/waste resources in primary energy terms are projected in the NSAT to be roughly 30% higher than in the Baseline during the period 2020-2030. The biomass/waste resources used for energy purposes in the NSAT scenario in 2030 are projected to be 2.5 times higher than they were in 2005.

Wind power, including onshore and offshore wind, is also projected to rise considerably, increasing by 8.5 times between 2005 and 2030 in the NSAT scenario, 74% up from the Baseline in 2030. Offshore wind is projected to represent roughly 30% of total wind generation by 2030, up from less than 20% in 2020.

The NSAT-CDM scenario involves slightly more RES development than the NSAT scenario. This is so, because the lower carbon values in the NSAT-CDM case induce less energy savings than in the NSAT case and so to meet the RES target the RES value has to increase (49 .5 €/MWh in the NSAT-CDM) inducing higher development of RES. The difference from the NSAT is nevertheless small in magnitude.

Table 32: RES measured at Gross Final Energy Consumption, NSAT-CDM - EU27

	NSAT-CDM (Mtoe)		% Change from Baseline	
RES in Gross Final Energy Consumption	2020	2030	2020	2030
	266.1	339.9	51.1	59.4
Electricity Generation	94.3	136.2	39.1	65.7
Heat/Steam Production	41.1	62.8	113.5	122.6
Biomass direct use	76.2	77.1	33.5	26.0
Solar energy direct use	19.5	23.5	272.2	242.4
Geothermal heat direct use	1.7	1.6	130.6	136.5
Biofuels in Transport	33.3	38.8	28.3	13.7
RES in Primary Energy	293.8	377.1	49.4	58.9

Table 33: RES in the power sector, NSAT-CDM - EU27

	NSAT-CDM (TWh)		% Change from Baseline	
Electricity Generation (net) from RES	2020	2030	2020	2030
	1162.2	1688.7	41.1	68.0
Hydro	347.4	352.4	3.3	0.4
Wind	375.5	601.5	38.5	75.7
Solar, tidal etc.	24.3	70.0	106.2	230.3
Biomass & waste	406.1	656.0	106.8	132.7
Geothermal heat	8.9	8.9	9.3	0.0

Figure 19 compares power generation from RES to power from other sources in the NSAT and the NSAT-CDM cases.

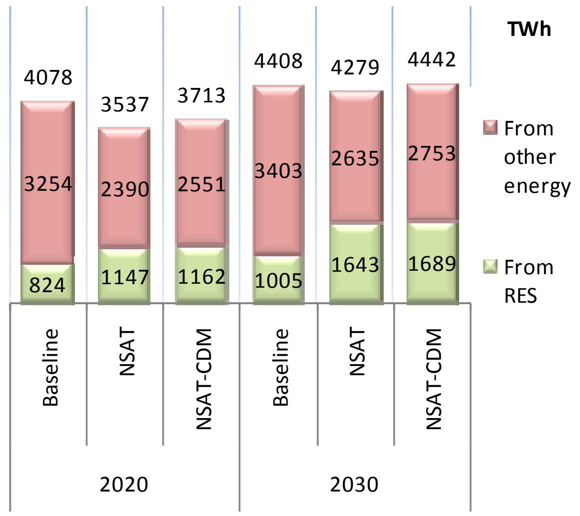
As also shown in Table 31 and in Table 33, roughly one third of electricity is produced from renewables in the NSAT and in the NSAT-CDM scenarios (similar results are obtained for all scenarios that meet the two targets).

Since large hydro has little potential to develop on top of the Baseline projection, a significant part of power will be generated by intermittent and decentralized power units.

This implies that flexible thermal units ensuring reserve power and ancillary services will have to be used much more than in the Baseline. Also, the power grids will have to be reinforced and extended to absorb the increasing power from RES under reliable conditions.

The corresponding investments are simulated by the power sector sub-model of PRIMES and are taken into account on cost calculations.

Figure 19: Electricity from RES compared to electricity from other sources - EU27



6.6 Power Sector Restructuring

The power generation sector undergoes significant changes relative to the Baseline as a result of the carbon price and the RES values. It is also affected by the reduction of electricity demand, especially in 2020, as part of energy efficiency gains by final consumers.

The carbon prices change to some degree the merit order of unit commitment[16]: highly efficient gas plants displace the less efficient solid fuel plants in the merit order. The carbon prices also modify the investment schedules, favouring more efficient plants, including advanced coal plants in

[16] The electricity sub-model of PRIMES includes a very detailed representation of power plant technologies, keeps track of power plant vintages and simulates least cost unit commitment and perfect foresight power expansion subject to fuel supply cost curves and a DC-linear operation of the EU interconnecting grid.

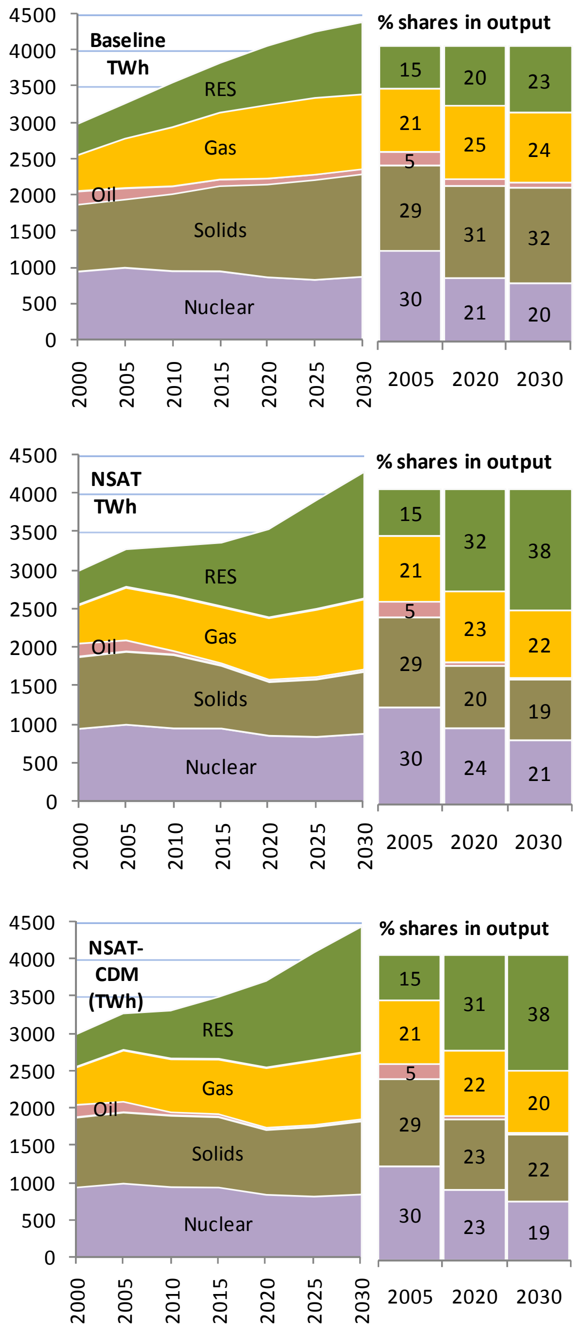
the long term. However, the cost-effective substitutions among the fossil fuel plants are rather limited when imposing also RES targets because these targets induce high penetration of RES generation to the detriment of other means for CO2 reduction. The main effect comes from the additional RES power units which reduce both coal and gas power generation and investment. Nevertheless gas-fired power is less reduced than coal-fired, because of the carbon prices but also because part of the RES power requires extensive support by flexible reserve power, which is supplied mainly by gas units.

Nuclear energy increases only marginally compared to the Baseline scenario, because all scenarios assume that Baseline nuclear policies remain unchanged despite the presence of the GHG emission targets. For example, the nuclear phase out policies in some Member-States, the non consideration of the nuclear option in other Member-States and the non extension of the lifetime of old nuclear plants are assumed to hold true in all scenarios. In any case the modest expansion of nuclear energy, in the EU as a whole, takes place beyond 2020 because of long lead times of nuclear development.

Figure 20 shows the structure of gross power generation by fuel in three scenarios. The shape of total power generation in the NSAT and the NSAT-CDM cases changes from the Baseline: power generation is lower in the medium-term, but recovers in the long term driven by final demand. The RES produces almost one third of electricity in the NSAT and the NSAT-CDM cases in 2020 and this percentage goes up to 38% by 2030. The share of gas-fired generation decreases slightly from the Baseline, contrasting a more significant drop of the share of coal-fired[17] generation. The re-emergence of coal generation in the long term as projected in the Baseline does not take place under the assumptions of the NSAT or the NSAT-CDM scenarios. Oil-fired generation vanishes in the NSAT and the NSAT-CDM cases and nuclear is rather stable, increasing slightly above its level in the Baseline by 2030.

Conventional coal plants are used in the NSAT scenario 20-25% less than in the Baseline scenario. Coal plants with advanced technology, being more efficient, remain in base-load generation in the NSAT scenario despite the higher carbon prices. The average yearly operating hours of combined cycle plants do not change from the Baseline. However, the rate of use of open cycle gas and oil plants drops considerably in the NSAT scenario compared to the Baseline.

Figure 20: Gross Power Generation by fuel type - EU27



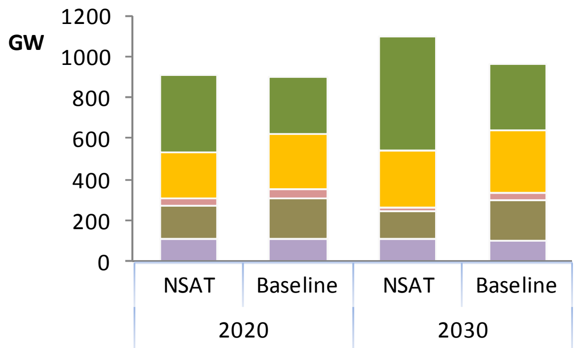
Generally, the thermal power plants (except biomass plants) produce less electricity per unit of installed capacity in the NSAT and the NSAT-CDM scenarios, compared to the Baseline. Power generation from fossil fuels accounts for roughly

[17] Coal-fired generation includes power production from coal, lignite, peat, blast furnace gas and coke-oven gas.

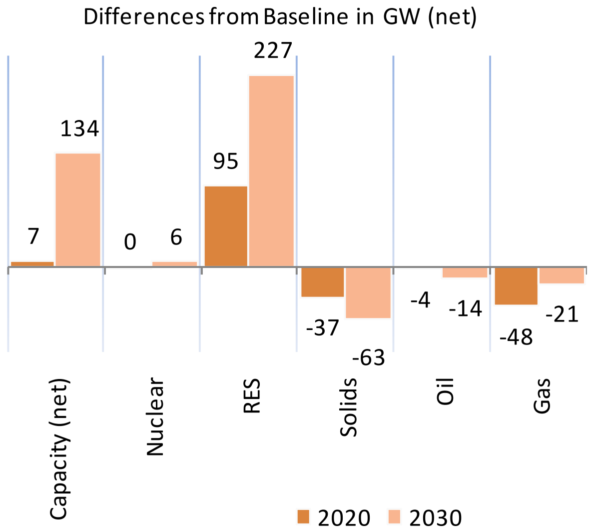
43% of total generation in 2020 in the NSAT scenario, which is significantly lower from their share (59%) in the Baseline scenario. A similar change is projected for 2030 (41% instead of 57.4%).

Total installed power capacity increases in the NSAT and the NSAT-CDM scenarios relative to the Baseline (see Figure 21). The increase is more significant towards 2030, but it is also true, albeit small in magnitude, for 2020 despite the significant decrease in power demand compared to the Baseline. The increase is related to the high development of RES power units which generally have a smaller capacity factor than the thermal power units. A small part of the increase is due to the replacement of old inefficient thermal plants with investment in more efficient units.

Figure 21: Net Power Capacity, NSAT scenario - EU27



	2020 NSAT	2020 Baseline	2030 NSAT	2030 Baseline
RES	377	282	558	331
Gas	224	271	284	305
Oil	34	38	16	31
Solids	160	197	134	197
Nuclear	113	113	108	102



Total installed capacity of solid-fired power plants, which remains rather stable over time in the Baseline scenario, reduces considerable in the NSAT scenario: 19% lower than the Baseline in 2020 and 32% lower in 2030.

Gas-fired capacity, which is increasing over time in the Baseline scenario, reduces by 18% in 2020 in the NSAT scenario, compared to Baseline, but the reduction is much smaller in 2030 (7%), contrasting the high reduction of solid-fired capacities by the same year.

Nuclear capacity in 2030 in the NSAT scenario is 6 GW up from the Baseline.

Figure 22 shows the average load factor of aggregated plant types in the NSAT versus the Baseline scenario. It shows clearly that the changes in the merit order induced in the NSAT scenario, relative to the Baseline, affects mainly the conventional coal and the open cycle oil and gas plants which are underutilised in the NSAT scenario.

The gas combined cycle plants are used in the NSAT almost as much as they are used in the Baseline scenario, whereas only the advanced coal plants (primarily advanced supercritical coal plants and secondarily IGCC plants), among the solid-fired plants, maintain their position in base load generation. Biomass plants, which are often cogeneration plants, are used in the NSAT slightly more than in the Baseline. The changes in the merit order of unit commitment are illustrated in Figure 22.

Figure 22: Avg. Load Factor of Thermal Plants, EU27

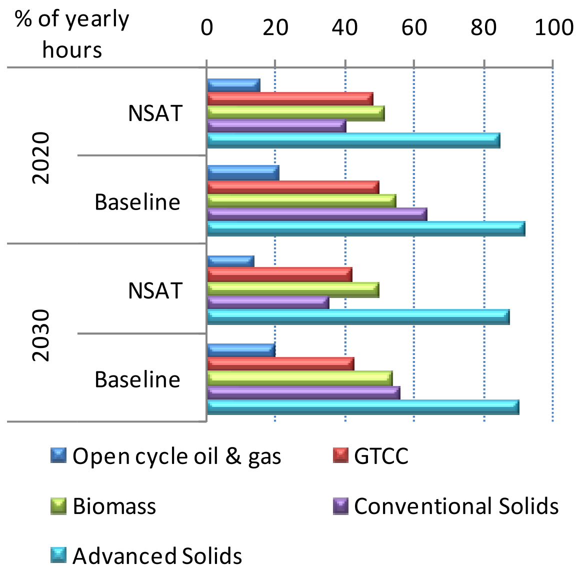


Table 34: Power Generation Investment, EU27

2006 - 2030 in GW (net)	NSAT	Baseline	Difference
Total Investment	794	666	127
Nuclear	61	56	6
RES	442	214	228
Solids	106	171	-64
Oil	7	23	-16
Gas	177	203	-26
2015-2030, GW (net)	**NSAT**	**Baseline**	**Difference**
Open cycle oil & gas	25	21	4
GTCC	99	123	-24
Conventional Solids	2	9	-7
Advanced Solids	64	115	-51
Biomass	113	34	79
Other RES	270	136	134

Power Capacity Expansion GW (net)	2010-2020		2020-2030	
	NSAT	Baseline	NSAT	Baseline
Solids	39.6	72.7	49.6	75.8
Oil	3.3	4.1	1.6	13.4
Gas	35.9	73.8	91.5	69.3
Nuclear	6.7	6.7	54.0	48.4
RES	160.7	80.5	222.8	90.6
Total	246.1	237.8	419.5	297.6

Concerning capacity expansion investment (see Table 34), the dominant effect is the development of RES: in the NSAT scenario half of all new MW to be constructed between 2006 and 2030 are RES power units (it is less than one third in the Baseline scenario). Investment in thermal power plants that use fossil fuels is lower in the NSAT scenario, compared to the Baseline. Concerning gas-fired plants the decrease in investment is lower than for plants using other fossil fuels. Between 2015 and 2030 investment in open cycle oil and gas units in the NSAT scenario is higher than the Baseline, as these units serve as back-up power to the intermittent RES units. Investment in solid-fired power plants decreases considerably in the NSAT scenario, compared to the Baseline.

However, the investment in advanced coal technologies in the period after 2020 (and close to 2030) in the NSAT scenario focuses on different technologies than in the Baseline[18], as Carbon Capture and Storage power plants using coal and lignite develop. Their capacity reaches 27.4 GW (net) by 2030 in the NSAT scenario. CCS represents roughly 20% of total coal power capacity that is in operation in 2030 in the NSAT scenario. Almost all new coal plants commissioned between 2020 and 2030 are projected to be equipped with CCS in the NSAT scenario. However a small part of the CCS capacity is commissioned around 2020 (1.7 GW), the bulk being commissioned close to 2030.

In the NSAT-CDM scenario, in which the ETS carbon price is 30 €/tCO2, investment in CCS is much smaller than in the NSAT scenario (carbon price 42.7 €/tCO2 in 2020): only 8 GW of coal plants with CCS are constructed and are not commissioned before 2030.

The NSAT-CDM scenario differs from the NSAT scenario also regarding the development of nuclear capacity. In the NSAT-CDM the additional nuclear capacity relative to the Baseline is 2.5 GW, instead of 6 GW in the NSAT scenario.

In the NSAT-CDM scenario investment in RES units is higher than in the NSAT (10 more GW in total), because the RES value is higher.

The development of power from RES in the scenarios that meet both the GHG and the RES targets is dominated primarily by wind power and secondarily by biomass-fired power technologies.

Table 35: Power capacity and investment in RES for power generation, EU27

NSAT: Net Power Capacity (GW)	2005	2015	2020	2030	Diff. from Baseline 2020	Diff. from Baseline 2030
Total RES	168.1	284.7	377.5	557.9	95.4	226.7
Hydro	109.3	113.1	114.4	115.6	0.1	0.1
Wind	40.8	117.4	161.4	259.0	41.0	113.0
- onshore	40.3	103.3	132.1	188.0	20.4	59.1
- offshore	0.5	14.1	29.3	70.9	20.7	53.9
Solar	1.8	6.3	14.9	44.7	5.9	29.3
Geothermal, etc.	1.0	2.5	5.1	7.3	2.9	3.6
Biomass	15.2	45.4	81.6	131.4	45.4	80.7

NSAT: Net Power Investment (GW)	00-05(*)	11-20	21-30	06-30	Diff. from Baseline 11-20	Diff. from Baseline 21-30
Total RES	36.2	160.7	222.8	441.7	80.1	132.2
Hydro	2.0	2.7	1.3	6.0	0.0	0.0
Wind	28.0	84.2	134.2	261.9	28.8	72.0
- onshore	27.5	62.4	92.1	190.9	11.9	38.8
- offshore	0.5	21.9	42.1	70.9	16.9	33.2
Solar	1.6	11.1	29.8	42.9	5.9	23.4
Geothermal, etc.	0.2	3.8	2.3	6.4	2.9	0.7
Biomass	4.4	58.8	55.2	124.4	42.5	36.2

NSAT-CDM: Net Power Investment (GW)	11-20	21-30	06-30	Diff. from Baseline 11-20	Diff. from Baseline 21-30
Total RES	163.0	228.5	450.3	82.4	138.0
Hydro	2.7	1.3	6.1	0.0	0.0
Wind	84.3	136.3	264.7	28.8	74.0
- onshore	61.9	94.0	193.2	11.5	40.6
- offshore	22.3	42.3	71.6	17.4	33.4
Solar	9.7	30.1	41.8	4.5	23.6
Geothermal, etc.	3.8	2.3	6.5	2.9	0.7
Biomass	62.4	58.6	131.3	46.2	39.6

(*) Investment up to 2005 corresponds to observed data

[18] There is no CCS in the Baseline scenario.

The installed power capacity of wind is projected to account for 46% of total capacity of power from RES in the NSAT scenario in 2030, more than 20 percentage points up from 2005. Electricity produced by biomass is projected to reach 24% of total power from RES in the NSAT scenario in 2030, up from 9% in 2005. The projections assume that for various reasons there is little possibility for developing hydroelectric power above its level in the Baseline scenario. Solar energy for power generation has a considerable potential but entails high costs. Facilitated by an important learning by doing potential, solar power develops in the NSAT scenario and reaches a total installed capacity of 45 GW in 2030, up from a mere 1.8 GW in 2005. Despite its impressive development, solar power represents a rather small share in the electricity balance by 2030. Electricity from geothermal, tidal and wave energy resources also develop in the NSAT scenario, albeit at a slower pace. Offshore wind develops with some delay, compared to onshore wind, but attains an installed capacity of 71 GW in the NSAT scenario in 2030, starting from only pilot applications in 2005. Offshore wind represents 27% of total installed wind power in the NSAT scenario by 2030.

In terms of total investment in RES MW for power generation, wind power accounts for roughly 57% and biomass 30%, the rest being mainly solar power. Total investment in RES electricity between 2006 and 2030 is projected for the NSAT scenario to amount to 383.5 GW, 132.2 GW up from the projection for the Baseline scenario. The largest part of additional investment in RES for power generation in the NSAT-CDM scenario, compared to the NSAT scenario, concerns biomass technologies (7 out of 10 GW additional investments in RES plants between 2006 and 2030).

The part of electricity generated from cogeneration (CHP) plants increases in the NSAT scenario, compared to the Baseline scenario, since a cogeneration plant has total thermal conversion efficiency higher than conversion that produces electricity and steam from separate plants.

Natural gas CHP plants are usually considered as more attractive than other technologies because of their lower capital cost and also because their implementation is easier in industrial areas, where the steam can be effectively consumed. However, imposing the RES target, together with the GHG target, implies that biomass-fired CHP plants are more interesting to develop than the gas-fired CHP.

But the biomass-fired CHP plants are more expensive to build and access to biomass resources competes with other energy-related applications of biomass, which limits potential penetration of cogeneration applications in the market. As expected, cogeneration applications that correspond to coal- or oil-fired plants decrease as a result of the carbon values.

Another factor limiting cogeneration development is electricity demand which decreases in the NSAT scenario by 2020, compared to the Baseline scenario. Electricity demand is among the main drivers of cogeneration development, as steam output is a by-product which alone would not easily justify investment in cogeneration.

By 2030, both the NSAT and the NSAT-CDM scenarios project a level of electricity demand which is similar to that in the Baseline scenario. So cogeneration develops less than expected in the NSAT (or the NSAT-CDM) scenario in 2020 but significantly more than in the Baseline in 2030.

Table 36: Cogeneration development - EU27

NSAT scenario	2005	2020	2030	Diff. from Baseline 2020	Diff. from Baseline 2030
Electricity from CHP (TWh - el.)	390	735	903	-30	44
- as % of total electricity	12.6	21.7	22.2	2.0	1.7
Steam/heat from CHP (TWh - th.)	837	1055	1235	-5	97
- as % of total steam/heat	49.4	56.4	64.1	3.2	9.5
Shares in CHP electricity					
Solids	46.4	24.4	14.0	-5.9	-9.8
Oil	9.0	3.1	1.4	-43.0	-44.8
Gas	41.6	27.1	25.2	21.6	20.2
Biomass	10.8	45.4	59.4	27.3	34.4

As shown in Table 36, by 2020, cogeneration produces less energy in absolute terms in the NSAT scenario, compared to the Baseline, but has a higher share in both the electricity and steam/heat markets. By 2030, cogeneration produces more energy in the NSAT than in the Baseline.

The share of CHP electricity from solid-fired and oil-fired plants decreases considerably in the

NSAT compared to the Baseline scenario. This contrasts high development of CHP from biomass-fired plants and secondarily of CHP from gas-fired plants in the NSAT scenario.

The restructuring of power generation induced by the carbon and RES values have important implications on fuel consumption in power generation.

Table 37: Fuel Consumption in Power Generation - EU27

NSAT scenario	2005	2020	2030	% change from Baseline 2020	2030
Inputs to Thermal Power (Mtoe)					
Total	*464*	*386*	*450*	-24.7	-14.2
Coal	155	90	91	-51.7	-51.6
Lignite	78	52	55	-32.2	-25.1
Oil	42	7	6	-62.8	-58.4
Gas and der. Gasses	154	146	156	-21.1	-14.3
Biomass and Waste	36	91	142	91.8	114

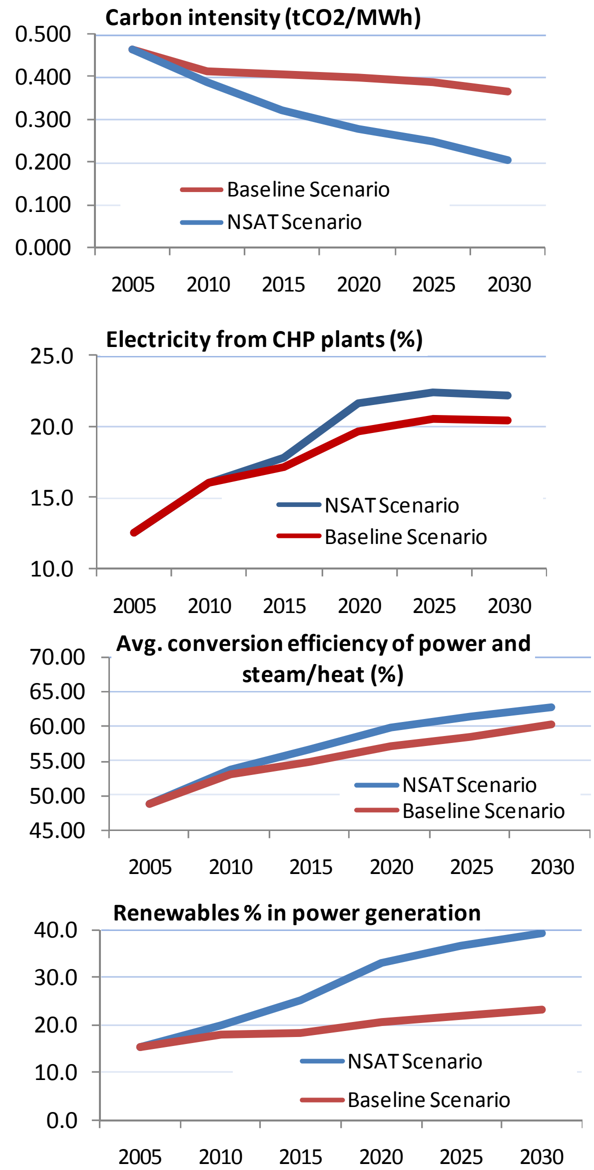
Table 38: Carbon intensity of power generation (tCO2/MWh net) - EU27

	2005	2020	2025	2030
Baseline	0.465	0.398	0.389	0.365
NSAT		0.278	0.249	0.204
NSAT-CDM		0.307	0.283	0.246
RSAT		0.282	0.252	0.182
RSAT-CDM		0.319	0.297	0.262
CES		0.288	0.253	0.220
CES-CDM		0.305	0.282	0.245
pure-GHG		0.292	0.258	0.195
pure-RES		0.326	0.301	0.269
HOG-BL		0.378	0.351	0.322
HOG-CES		0.323	0.280	0.241

The policies included in the NSAT scenario induce halving of coal consumption for power generation, compared to the Baseline, over the period 2020-2030. Consumption of lignite reduces in the NSAT scenario between 25 and 32% from the Baseline. Oil consumption for power generation is limited to specific applications in the NSAT scenario (islands, remote areas).

An important finding is that consumption of gas for power generation also decreases in the NSAT, compared to the Baseline (21% in 2020 and 14% in 2030), despite the advantage of gas vis-à-vis coal in terms of CO2 emissions. This result is attributed to the presence of the RES target. In fact, in the pure-GHG scenario, which meets the GHG target but is not subject to a RES target, gas consumption for power generation is much higher than in the NSAT scenario and in volume terms it is similar to the Baseline scenario in 2020 and 6% higher than the Baseline scenario in 2030. Thus, the coexistence of the GHG with the RES targets does not imply increasing dependence of power generation on gas. In this case (for example in the NSAT scenario), biomass and waste consumption for power generation is twice as high as in the Baseline during the period 2020-2030.

Figure 23: Indicators for Power Generation, EU27



From the perspective of energy efficiency and climate change mitigation, all indicators (see Figure 23) improve in the NSAT scenario compared to the Baseline: electricity from RES increases substantially as already mentioned; the average conversion efficiency of power and steam/heat production improves by roughly 2.5 percentage points in the NSAT scenario between 2020 and 2030, compared to the Baseline; electricity from CHP is also increasing, as mentioned earlier.

As a result of the above changes, the average carbon intensity of power generation (tCO2/MWh net) drops impressively in the NSAT scenario, compared to the Baseline. By 2030, the average carbon intensity of power generation in the EU decreases by 44% in the NSAT scenario compared to the Baseline in 2030 (it decreases by 56% in the NSAT relative to 2005).

The scenarios involving emission credits from CDM entail less emission reduction domestically and thereby the carbon intensity of power generation is higher than in scenarios without CDM. The difference in terms of carbon intensity, when comparing the NSAT with the NSAT-CDM, reaches 20% in 2030.

The carbon intensity of power and steam/heat production (aggregating over power plants, CHP, district heating and industrial boilers) also reduces considerably from the Baseline. The reduction reaches 43% in the NSAT scenario in 2030 from the Baseline (53% down from 2005 in the NSAT scenario).

6.7 Costs and Prices of Energy

As already mentioned, meeting the two targets implies additional cost for energy and energy-related expenses, compared to the Baseline scenario.

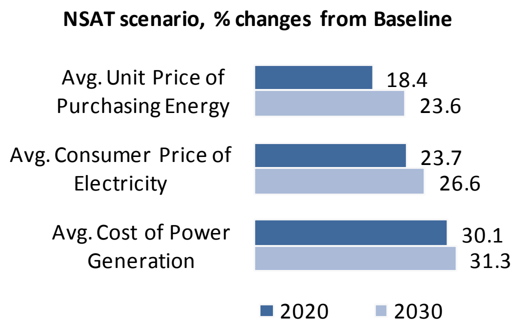
The power sector, belonging to the ETS, faces higher carbon prices than in the Baseline. The sector is also influenced by the RES values. As shown in the previous section, the sector performs restructuring consisting in investing in low carbon intensity power generation and in changing the fuel mix. As a result, power generation costs increase, compared to the Baseline. In addition, electricity prices also increase compared to the Baseline, since they are assumed to incorporate the increase in the ETS carbon prices.

Steam and heat production costs also increase compared to the Baseline, as a result of restructuring towards lower emissions and higher use of RES. The prices of distributed heat and steam increase consequently. The refinery costs also increase, as a result of the ETS and other costs associated with carbon emission reduction. Biofuels get a higher share in transport fuels, compared to the Baseline, and average prices of gasoline, diesel and other oil fuel blends increase, compared to the Baseline, because of the increased production costs. Unit supply costs, hence the prices, of biomass products and waste energy forms increase, driven by higher demand for these products given that their cost-supply curves are assumed to exhibit increasing slopes. Finally, prices and costs associated with primary production of coal and lignite and with imports of coal, gas and oil are assumed to remain unchanged from the Baseline scenario. All these changes in the costs and prices of energy fuel supply imply higher consumer prices of energy in the scenarios that meet the two targets, compared to the Baseline.

The final consumers (industry, tertiary, residential, etc.) decrease their energy consumption, relative to the Baseline, as a result of energy efficiency progress. The energy purchasing bill, consisting of payments to buy energy commodities, may decrease in some cases, if marginal energy savings are higher than the energy price differential. Otherwise, the energy purchasing bill increases relative to the Baseline.

In both cases, however, the energy efficiency progress entail higher expenses (investment) in purchasing new energy equipment, new durable goods, insulating the houses and the buildings, etc. Energy savings also entail disutility costs, at least for some energy uses. All these additional costs, incurred by final energy consumers, are considered to be related with energy use and are included in total energy system costs. In annual terms, the investment cost associated with energy savings is accounted for as annuity payments.

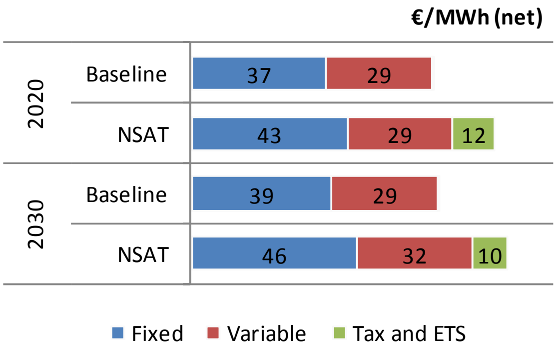
Figure 24: Impacts on energy prices and costs, EU27



Purchasing energy commodities by final consumers is projected in the NSAT scenario to cost per unit of energy in 2020 some 18.4% (23.6% in 2030) more than in the Baseline scenario. For the NSAT scenario, the average consumer price of electricity in 2020 is 23.7% (26.6% in 2030) higher relative to the Baseline.

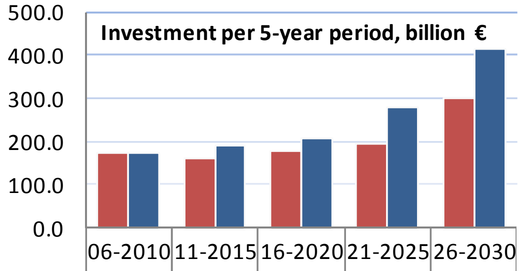
It should be noted that the Baseline scenario assumes an EU ETS system based on a "grandfathering" scheme (emission allowances are allocated for free to installations). The Baseline scenario also assumes that a well functioning market will reduce the degree of passing through to consumer prices the opportunity costs associated with the carbon price of the EU ETS. Hence, power producers will mostly pass through to consumers true emission abatement costs induced by the scarcity of emission allowances and are less able to pass through the opportunity cost associated with grandfathered emission allowances. As such, "windfall" profits are limited in the model results under baseline assumptions. On the contrary, under the assumptions of policy scenarios, such as the NSAT, payments for purchasing the emission allowances applies for the entire amount of carbon emissions from power generation. Thereby power produces face true costs associated with the emission allowances and pass through these costs to consumers. The power producers change the fuel-mix of power generation and emit less carbon than in the Baseline scenario; hence, total payment for emission allowances is less than it would had been if the fuel mix remained unchanged from the Baseline.

Figure 25: Cost structure of power generation, EU25



The cost structure of power generation becomes more capital intensive in the NSAT scenario: the part of generation cost corresponding to fixed cost increases in the NSAT by roughly 3 percent points, relative to the Baseline. Variable operating costs in power generation in the NSAT do not change in 2020, relative to the Baseline and slightly increase in 2030. The net effect of the increase in ETS carbon prices on power generation costs is estimated to be 12 €/MWh (net) in 2020 and 10 €/MWh (net) in 2030.

Figure 26: Power generation and transmission investment, EU27



	06-2010	11-2015	16-2020	21-2025	26-2030
Baseline	174.0	159.8	179.1	192.4	300.2
NSAT	174.0	188.3	205.1	279.5	414.0
% change	0.0	17.8	14.5	45.3	37.9

Total investment expenditure in power generation and in power transmission between 2006 and 2030 approaches 1250 billion €'2005, 26% up from the Baseline scenario. Despite lower demand for electricity in the NSAT scenario, investment in transmission grids increases by roughly 25% in the NSAT scenario over the projection period, relative to the Baseline.

At the level of final energy demand consumers, it is necessary to account for all kind of costs associated with the use of energy in order to assess the impacts of meeting the two targets. The model results indicate that total energy-related costs increase in the NSAT scenario, relative to the Baseline, for all categories of final consumers. However, the rates of change differ by sector. Cost increases incurred by the tertiary sectors are lower compared to other sectors, because the model-based analysis has identified for that sector an important energy saving potential.

A similar conclusion is drawn for the residential sector, but to a smaller degree: energy-related expenses per household are estimated to reach 2500 €/year in 2020 in the NSAT scenario, 6.2% up from the Baseline. They would be 10.7% higher in 2030 than in the Baseline.

Differential costs incurred by industry are higher than by other sectors (roughly 13.5% up from the Baseline), reflecting the rather low possibilities of the sector for achieving additional energy savings from the Baseline.

Fuel input costs per unit of activity for transportation increase in the NSAT scenario between 15 and 16% annually, relative to the Baseline.

Figure 27: Energy Expenses by Final Consumers, EU27

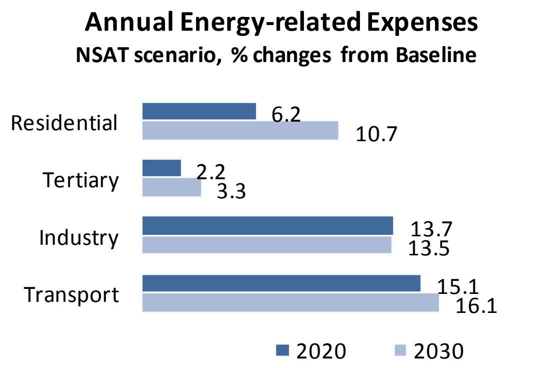
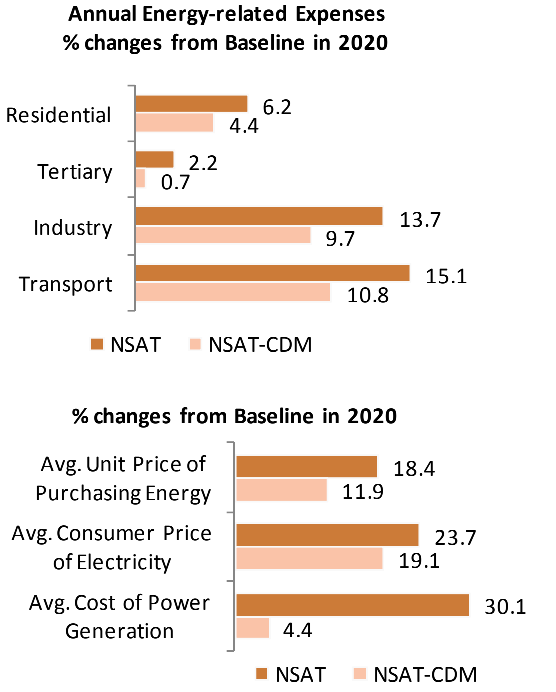


Figure 28: Comparison of the NSAT with the NSAT-CDM scenarios in terms of prices and costs of energy, EU27



Meeting part of the GHG target via emission credits from the CDM, as for example in the NSAT-CDM scenario, implies a smaller impact on energy prices and costs, compared to the NSAT scenario. In terms of rate of change from the Baseline scenario in 2020, the NSAT-CDM implies 4.5 percentage points lower increase in electricity prices, compared to the NSAT scenario, and 6.5 percentage points less increase in the average price of energy. Consequently, the energy related-expenses increase less in the NSAT-CDM from the Baseline, compared to the NSAT case, as shown in Figure 28.

6.8 Consequences for Dependence on Energy Imports

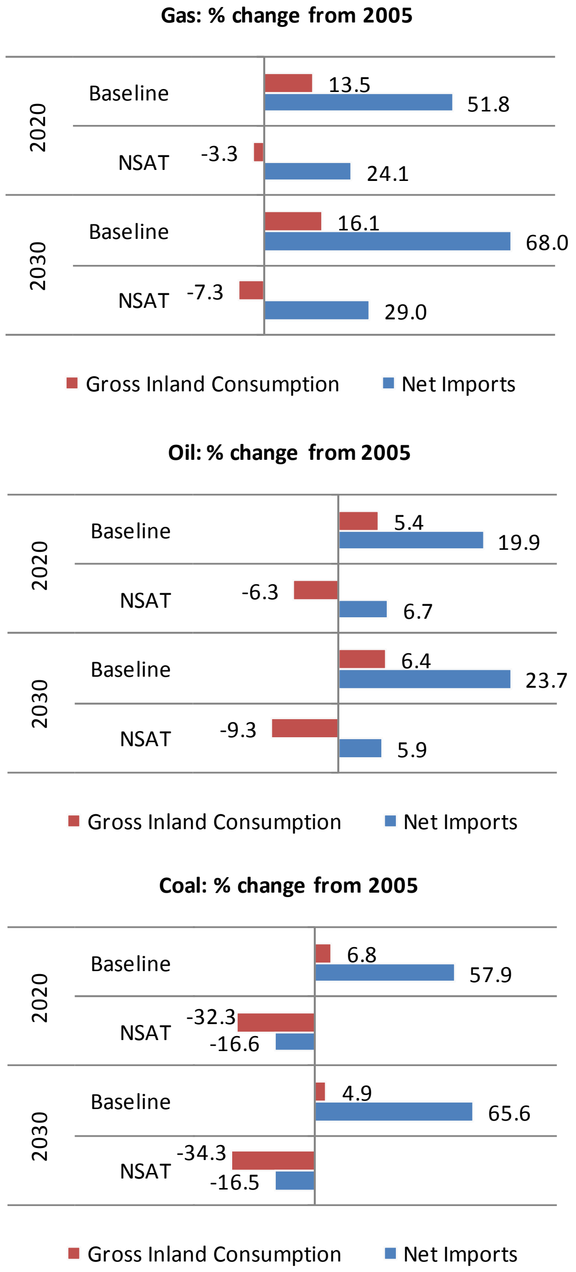
The outlook of primary energy production in the EU, according to the Baseline scenario, clearly shows a strong decline of indigenous production of fossil fuels: oil and gas production in the EU has already peaked around 2002; imported coal is expected to outpass domestic coal production before 2012 and domestic production of lignite, peat and oil shale will remain rather stable in the future. Under the Baseline scenario assumptions, primary production of RES is projected to increase substantially, relative to the past, but not sufficiently to compensate for the declining indigenous production of fossil fuels.

Consequently, the Baseline scenario projects a considerable increase of dependency on energy imports, which in percentage terms reaches 67% in 2030, as opposed to 52.4% in 2005. Gas import dependence in the Baseline projection raises concerns, as it increases by 25 percentage points from 2005: the EU will need in 2030 to import 431.4 Mtoe of natural gas, 174.6 Mtoe more than gas imported in 2005.

The imposition of the GHG and the RES targets induce energy efficiency gains in all sectors and thereby energy demand decreases from the Baseline. The effect on energy demand prevails against substitution effects among the fossil fuels. The imposition of the RES target prevents gas demand from increasing as a substitute for coal in power and steam generation. Thus, the results for all scenarios involving both targets show clearly that both total demand and imports of all fossil fuels, including natural gas, decrease relative to the Baseline, throughout the projection period. This is an important finding of the model-based analysis, which is different from older results that emphasised the possible adverse effects of climate change actions on gas import dependence.

The analysis presented in this report shows that by meeting the GHG and the RES targets, the EU will require less gas in all years until 2030 compared to gas needs in 2005. In the same context, the EU will need less oil until 2030, than in 2005, and considerably less solid fuels compared to consumption in 2005.

Figure 29: Changes in total fossil fuel consumption and in net imports of the EU27



The results for the NSAT-CDM scenario are not significantly different than for the NSAT, despite the decrease of the carbon values in the former scenario. If no explicit RES target was imposed, the energy system would use more gas as a substitute to coal and thereby total gas consumption would increase in 2020 and in 2030 compared to 2005, contrasting the decrease obtained for the NSAT scenario. Gross inland consumption (total primary energy requirements, according to Eurostat definitions) of the EU in various scenarios are shown in Table 39. In this table net imports of electricity are not shown.

Table 39: Gross Inland Consumption - EU27

Baseline	Mtoe		% structure		% change pa	
	2020	2030	2020	2030	05-2020	20-2030
Solids	341.9	335.6	17.4	16.7	0.44	-0.18
Oil	701.6	708.2	35.7	35.3	0.35	0.09
Natural Gas	504.9	516.2	25.7	25.7	0.85	0.22
Nuclear Energy	221.5	206.4	11.3	10.3	-1.00	-0.70
RES	196.7	237.3	10.0	11.8	3.20	1.89
Total Primary Energy	1967.6	2004.7	100.0	100.0	0.55	0.19
NSAT	**Mtoe**		**% structure**		**% from Baseline**	
	2020	2030	2020	2030	2020	2030
Solids	216.7	210.4	12.2	11.7	-36.6	-37.3
Oil	623.5	603.5	35.2	33.5	-11.1	-14.8
Natural Gas	427.9	413.4	24.1	23.0	-15.2	-19.9
Nuclear Energy	218.6	206.6	12.3	11.5	-1.3	0.1
RES	284.2	365.8	16.0	20.3	44.5	54.2
Total Primary Energy	1772.0	1800.6	100.0	100.0	-9.9	-10.2
NSAT-CDM	**Mtoe**		**% structure**		**% from Baseline**	
	2020	2030	2020	2030	2020	2030
Solids	257.1	244.6	14.0	13.2	-24.8	-27.1
Oil	642.4	622.5	34.9	33.5	-8.4	-12.1
Natural Gas	430.0	412.4	23.4	22.2	-14.8	-20.1
Nuclear Energy	217.0	200.6	11.8	10.8	-2.0	-2.8
RES	293.8	377.1	16.0	20.3	49.4	58.9
Total Primary Energy	1841.3	1858.1	100.0	100.0	-6.4	-7.3
RSAT	**Mtoe**		**% structure**		**% from Baseline**	
	2020	2030	2020	2030	2020	2030
Solids	215.3	218.4	12.2	12.1	-37.0	-34.9
Oil	617.3	601.5	34.8	33.2	-12.0	-15.1
Natural Gas	438.0	423.0	24.7	23.4	-13.3	-18.1
Nuclear Energy	218.8	212.0	12.3	11.7	-1.2	2.7
RES	281.9	355.0	15.9	19.6	43.3	49.6
Total Primary Energy	1772.2	1810.9	100.0	100.0	-9.9	-9.7
RSAT-CDM	**Mtoe**		**% structure**		**% from Baseline**	
	2020	2030	2020	2030	2020	2030
Solids	267.7	259.5	14.5	13.9	-21.7	-22.7
Oil	633.3	619.7	34.3	33.2	-9.7	-12.5
Natural Gas	433.3	421.6	23.5	22.6	-14.2	-18.3
Nuclear Energy	217.0	194.9	11.8	10.4	-2.0	-5.6
RES	293.3	369.3	15.9	19.8	49.1	55.6
Total Primary Energy	1845.6	1866.0	100.0	100.0	-6.2	-6.9
CES	**Mtoe**		**% structure**		**% from Baseline**	
	2020	2030	2020	2030	2020	2030
Solids	228.3	216.3	12.8	12.1	-33.2	-35.5
Oil	625.4	599.3	35.2	33.5	-10.9	-15.4
Natural Gas	420.9	403.0	23.7	22.5	-16.6	-21.9
Nuclear Energy	218.9	208.0	12.3	11.6	-1.2	0.8
RES	283.6	363.4	15.9	20.3	44.2	53.1
Total Primary Energy	1778.0	1790.9	100.0	100.0	-9.6	-10.7
CES-CDM	**Mtoe**		**% structure**		**% from Baseline**	
	2020	2030	2020	2030	2020	2030
Solids	253.8	242.6	13.9	13.2	-25.8	-27.7
Oil	635.7	613.8	34.9	33.4	-9.4	-13.3
Natural Gas	422.7	404.9	23.2	22.0	-16.3	-21.6
Nuclear Energy	217.4	202.7	11.9	11.0	-1.8	-1.8
RES	289.5	371.6	15.9	20.2	47.2	56.6
Total Primary Energy	1820.1	1836.5	100.0	100.0	-7.5	-8.4
HOG-BL	**Mtoe**		**% structure**		**% from Baseline**	
	2020	2030	2020	2030	2020	2030
Solids	340.4	328.5	17.9	17.0	-0.4	-2.1
Oil	648.1	626.7	34.1	32.5	-7.6	-11.5
Natural Gas	442.5	416.8	23.3	21.6	-12.3	-19.3
Nuclear Energy	249.2	280.2	13.1	14.5	12.5	35.7
RES	221.3	275.3	11.6	14.3	12.5	16.0
Total Primary Energy	1902.5	1928.4	100.0	100.0	-3.3	-3.8
HOG-CES	**Mtoe**		**% structure**		**% from HOG-BL**	
	2020	2030	2020	2030	2020	2030
Solids	285.1	261.6	16.2	14.7	-16.3	-20.4
Oil	588.9	558.7	33.4	31.3	-9.1	-10.9
Natural Gas	362.5	325.3	20.6	18.3	-18.1	-21.9
Nuclear Energy	246.8	285.3	14.0	16.0	-1.0	1.8
RES	276.3	350.4	15.7	19.7	24.9	27.3
Total Primary Energy	1760.6	1782.3	100.0	100.0	-7.5	-7.6

7 Concluding Remarks

The model-based analysis of the Climate Change Action and Renewables policy package proposed by the European Commission on January 23, 2008 was based on a set of energy system scenarios quantified by using the PRIMES model. The GAINS model complemented the analysis by quantifying the possibilities for reduction of non CO2 greenhouse gases.

The analysis used the DG TREN Baseline scenario completed in November 2007 as a reference, against which the policy scenarios were compared.

All policy scenarios included the GHG emission reduction target (-20% in 2020 from 1990) and the RES deployment target (20% of gross final energy consumption in 2020) as mandatory constraints. The scenarios differed from each other regarding the policy assumptions about the sharing of GHG emission reduction and RES development effort among the Member-States and between ETS and non-ETS sectors. They also differed regarding the possibility to use emission reduction credits from the CDM and regarding the possibility of trading RES guarantees of origin among the Member-States.

A series of scenario variants were also quantified for the purpose of sensitivity analysis. Some of them are included in the present report, as for example the scenarios that assumed high world oil and gas prices and the scenarios that addressed the GHG and the RES targets separately.

It was clear from the model-based analysis that the Climate Change Action and Renewables policy package is feasible despite targeting for the year 2020 which leaves less than 12 years from now for adaptation of the energy system. The model-based analysis extended simulations up to year 2030, by assuming extrapolation of carbon and RES related policy drivers, in order to assess long term implications. The results for 2030 show that beyond 2020 the adaptation possibility is higher and more stringent targets can be met.

Meeting the targets in the EU is an ambitious effort and requires considerable adjustments in how energy is consumed and produced. Energy efficiency improvement in all sectors is clearly the most cost-effective way for meeting the targets and must be the main driver of changes. Using less energy in all sectors per unit of activity is certainly motivated by price signals, such as higher energy prices induced by the emission reduction and the RES development constraints. But price signals alone are not enough. A multitude of policies promoting energy efficiency would need to accompany the imposition of the targets, including legislation for insulation of buildings, command and control policies promoting new equipment in all sectors enabling advanced energy technology, information campaigns, etc. These policies reduce the cost of energy efficiency actions via learning-by-doing and economies of scale, and also reduce the risk as perceived by consumers; thereby they facilitate exploiting the energy efficiency potential at lower price signals.

The coexistence of the RES target is found to play an important role within the policy package. The renewable sources are free of carbon emissions but also are indigenous resources. The RES target prevents using more gas as substitute for coal, as a response to the GHG emission reduction target, and hence it prevents for exposing the EU to an eventual higher risk in terms of security of energy supply. The inclusion of an explicit RES target is also important for enabling learning-by-doing and economy to scale effects to take place dynamically; this facilitates the deployment of the RES technologies, reduces the unit cost of RES at high levels of development and thereby allows for higher exploitation of the RES potential with a lower price signal.

The above mentioned accompanying policies, namely for energy efficiency and for the RES, are taken into account in the model-based analysis and influence the compliance costs. In the presence of the two targets, the EU economy will have to bear a higher cost, compared to the Baseline, in order to purchase energy commodities and invest in energy equipment and in energy savings. The compliance cost, including all sorts of costs associated with the energy use by final consumers, is estimated to be in a range between 0.4 and 0.7 % of GDP of the EU in 2020, depending on the scenario. Paying for the compliance cost involves less money transfer abroad to pay for energy imports, than in the Baseline, and significantly more expenses in goods and services produced domestically in the EU to support the restructuring of the energy system.

8 Appendix with detailed results by scenario and Member-State