Dialogue on a RES policy framework for 2030

towards2030

Background Report

(to Issue Paper No. 1)

How can renewables and energy efficiency improve gas security in selected Member States?

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About the project

The aim of **towards2030-*dialogue*** is to facilitate and guide the RES policy dialogue for the period towards 2030. This strategic initiative aims for an intense stakeholder dialogue that establishes a European vision of a joint future RES policy framework.

The dialogue process will be coupled with in-depth and continuous analysis of relevant topics that include RES in all energy sectors but with more detailed analyses for renewable electricity. The work will be based on results from the IEE project beyond 2020 (www.res-policy-beyond2020.eu), where policy pathways with different degrees of harmonisation have been analysed for the post 2020 period. **towards2030-*dialogue*** will directly build on these outcomes: complement, adapt and extend the assessment to the evolving policy process in Europe. The added value of **towards2030-*dialogue*** includes the analysis of alternative policy pathways for 2030, such as the (partial) opening of national support schemes, the clustering of regional support schemes as well as options to coordinate and align national schemes. Additionally, this project offers also an impact assessment of different target setting options for 2030, discussing advanced concepts for related effort sharing.

Who we are?

Vienna University of Technology, Energy Economics Group (EEG), Austria *(Project coordinator)*
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Consejo Superior de Investigagiones Cientificas (CSIC), Spain
Ecofys Netherlands and affiliates (Ecofys), Netherlands
REKK Energiapiaci Tanacsado Ltd (REKK ET), Hungary
European University Institute, Florence School of Regulation (EUI), Italy

Summary

In this paper the results of a coordinated modelling assessment are presented, where gas market impacts of European energy efficiency and renewable policies integrated with two possible gas market development scenarios are evaluated. The two energy efficiency and renewable scenarios were developed by Fraunhofer ISI and TU Vienna, while the gas market modelling was carried out by REKK. A detailed statistical coverage on the gas supply security situation of 12 selected Member States (12 MS), those most vulnerable to Russian gas supplies, was also provided by ECN.[1]

In this assessment two gas demand levels are analysed (Limited and Full cooperation scenarios) according to the stringency of renewable (RES) and energy efficiency (EE) policies bringing different level of gas demand reduction. These demand cases are investigated under a re-negotiation and a breaking-up gas market scenario. The re-negotiation scenario assumes that long term contract based imports are reduced in proportion to overall gas demand reduction due to the implementation of EE and RES policies. The breaking-up scenario assumes that Russian long term contracts are completely resolved and then Russian gas is purchased solely on a spot market basis.

Our main objective was to quantify the impacts these policies could bring jointly to improve the security of supply situation in Europe concerning its natural gas dependency from Russia. The detailed bottom up gas market model calculated the impacts of the policies on the ‘gas bills’ countries have to pay to satisfy the gas demand of their consumers. This assessment should be seen as a first approximation to assess the gas security of the European countries, further assessment and wider use of additional indicators could be elaborated in the near future.

The main findings of this assessment can be summarised as follows:

- In the reference case we can observe a price convergence of the European gas markets due to improved interconnections, mostly in Central Eastern Europe. The volume of Russian gas imports and Russian gas dependency increases towards 2030.
- A strong deployment of renewables as anticipated in the alternative policy scenarios (of limited / full RES cooperation) leads to increases in system costs and support expenditures at EU-28 level but for the assessed 12 Member States this may even lead to savings in support expenditures for renewables in range of € 2.0-2.1 billion per year in the period post 2020, which is mainly due to improved framework conditions (i.e. removal of non-economic barriers).
- The increase in renewables and energy efficiency comes along with benefits related to Europe’s trade balance due to a (significantly) decreased demand for fossil fuels and related imports from abroad. Thus, natural gas demand can be reduced by more than 20% in the assessed countries, if a 30% target for renewables and energy efficiency by 2030 is aimed for.
- When the re-negotiation scenario is applied in combination with enhanced energy efficiency and renewable energy policies, this results in a massive 148-155 TWh gas demand reduction on the EU level by 2020 compared to the reference scenario. Dependence on Russian gas under long term contracts reduces by 355 TWh in the re-negotiation scenarios by 2030. In both the limited and the full cooperation cases there is a price decrease in Europe, also reflected in a reduction of gas purchase cost to an aggregated savings at 12 MS level of € 2.8 billion by 2020 and € 4.9 billion by 2030 in the re-negotiation scenarios.

[1] 12 MS includes: Bulgaria, Croatia, Czech Republic, Estonia, Finland, Latvia, Lithuania, Hungary, Poland, Romania, Slovakia, Slovenia

- The same RE+EE scenario combined with a breaking up policy would, on a 2020 horizon lead to an increase in gas purchase related expenditures in 12 MS by € 318 million, which is the cost of eliminating all Russian contracts in 2020. By 2030 the breaking up policy would also bring benefits on the 12 MS and on the EU-28 levels compared to our base case scenario.
- It seems feasible to reduce Russian dependency on natural gas supply to a very low level without causing skyrocketing natural gas prices in any of the EU member countries. In the full cooperation scenario, assuming that Russian long-term contracts and the related take-or-pay obligations are cancelled, and Russian gas is purchased on a short term base competing with other sources, it is possible to reduce Russian gas imports down to 79 TWh/year, which is 6,5% of the present level. This could be achieved on a market basis, through better interconnectivity and energy efficiency and renewable energy driven gas demand reduction.

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1 Introduction

1.1 Background and aims

Against the backdrop of the recent geopolitical developments in Ukraine, security of energy supplies – foremost supply of natural gas – in the EU has regained top priority on the EU energy policy agenda. The political urgency of energy security against external supply vulnerabilities is notably generated by sudden upward price developments and (threats of) outright disruptions in energy supplies from dominant exporters. Cases in point are oil supplies from certain OPEC countries in 1973 and 1979 and gas supplies from Russia in 2006, 2009 and to date, 2014. This summer the European Commission has proposed an EU energy security strategy.[2] Member States in east and central Europe might be most vulnerable to (potential) disruptions of energy imports from Russia. Yet ENTSO-G analysis suggests that a protracted cut in Russian gas supply will propagate immediate gas supply problems to most of Europe (European Commission, 2014b).

This fact-finding paper seeks to identify recent trends in gas use and import dependencies in 12 quite vulnerable Member States and to analyse the potential to reduce insecurity of external gas supplies of these countries in the short and longer term up to 2030. In doing so, the potential contribution of renewables and energy efficiency to reduce gas import dependency will be assessed. Two reasons to focus in this first issue paper of the **towards2030**-***dialogue*** project on gas are that currently gas-based energy services play a very essential societal role in most of the focus countries, whilst the lion's share of their gas imports tend to be pipeline gas from Russia. At short notice, no easy alternatives are at hand rendering these countries vulnerable to serious gas supply risks.

1.2 Scope and approach

Focus countries of this paper are the following 12 EU Member States: Bulgaria (BG), Czech Republic (CZ), Estonia (EE), Croatia (HR), Latvia (LV), Lithuania (LT), Hungary (HU), Poland (PL), Romania (RO), Slovenia (SI), Slovakia (SK), and Finland (FI). These countries, all of which have to cope with sensitive vulnerabilities to the security of vital energy services, will henceforth be referred to as 12 MS (Member States). The 12 MS performance on distinct scores will be benchmarked against corresponding scores for the EU at large, i.e. EU-28 (or EU-27 when no information on the newest Member State, Croatia, is available). Furthermore, with a view to their important role in EU's gas demand, this paper focuses on three energy using sectors:

1. **Buildings:** emphasis on residential and, to a lesser extent, services
2. **Industry:** manufacturing, including non-energy feedstock
3. **The energy sector:** energy transformation with emphasis on the power generation

The paper presents results of retrospective statistical fact-finding and forward-looking analysis of relevant trends up to a 2030 time horizon. The prospective assessment provides an outlook towards 2030 on gas demand and supply, bringing together three distinct model-based assessments, one related to the role of energy efficiency (EE) and a complementary one to assess the contribution of renewable energies (RE) to reduce the demand for (imported) natural gas. Finally, applying REKK's European Gas Market Model (EGMM), a modelling approach is used to analyse the feasibility and impacts of assessed gas replacement options from a gas-market perspective, considering infrastructural specifics and prerequisites as well as complementary regulatory measures. Identified cost savings (on the gas import bill) are consequently compared with the cost related to

[2] See (European Commission, 2014a)

enhancing the targeted deployment of renewables and to trigger the identified energy savings. Recommendations are made on short- and mid-term security enhancing policies and measures.

Figure 1-1 provides an overview on the working steps taken and the corresponding scenarios derived within the prospective assessment. Please note that detailed description of the approach taken are provided for the reference trend, the renewables and energy efficiency part in subsection 3.2.1 and for the gas market modelling in subsection 3.3.1. Complementary to these detailed explanations the individual working steps are summarised briefly below:

- The starting point for the assessment of natural gas replacement through increasing the use of renewable energy sources (RES) and energy efficiency is to have a clear **reference trend on future supply and use of energy**, and specifically related to natural gas. As baseline projection we make use of (an adapted version of) the European Commission's latest reference scenario on EU energy, transport and GHG emissions trends to 2050 as derived by the PRIMES model (EC, 2013).
- Next, **energy efficiency** comes into play: The analysis underlying the assessment of energy efficiency policy options until 2030 is based on detailed modelling of the final energy demand in the different demand sectors. The Low Policy Initiative (LPI) scenario as used in this assessment has been conducted in the frame of a study evaluating the current energy efficiency policy framework in the EU and providing orientation on policy options for realising the cost-effective energy-efficiency/saving potential until 2020 and beyond, conducted on behalf of DG ENER by a consortium led by Fraunhofer ISI (Braungardt et al., 2014).
- As third pillar, an assessment of **renewable energy** options is undertaken: By use of a TU Vienna's specialised energy system model (Green-X) a quantitative analysis is conducted to assess feasible RES developments up to 2030 according to selected policy pathways, indicating RES deployment at MS and at EU-28 level as well as related impacts on costs, expenditures and benefits. Thus, three distinct scenarios (i.e. *baseline* and two alternative RES policy pathways of *limited* or *full (RES) cooperation* across Member States) are developed.
- The next step aims to bring together the outcomes of the assessments of increasing energy efficiency and renewables, **estimating the replacement effect** of both **on natural gas**. For doing so, we make use of PRIMES forecasts related to the conventional supply portfolio, i.e. the share of the different conventional conversion technologies in each sector at country-level. Sector- and country-specific conversion efficiencies derived on a yearly basis are consequently used to calculate the amount of avoided primary energy based on the renewable generation figures obtained. Assuming that the relative composition of the fossil fuel mix is unaffected, avoidance can be expressed in units of coal or gas replaced.
- Finally, applying REKK's European Gas Market Model (EGMM), a modelling approach is used to **analyse the feasibility and impacts of assessed gas replacement options from a gas-market perspective**, considering infrastructural specifics and prerequisites as well as complementary regulatory measures. Complementary to baseline, the two scenarios of reduced gas demand as derived above (i.e. limited and full (RES) cooperation, both combined with enhanced energy efficiency policies) are investigated through the application of EGMM under two distinct gas market scenarios (i.e. *re-negotiation* and a *breaking-up*).

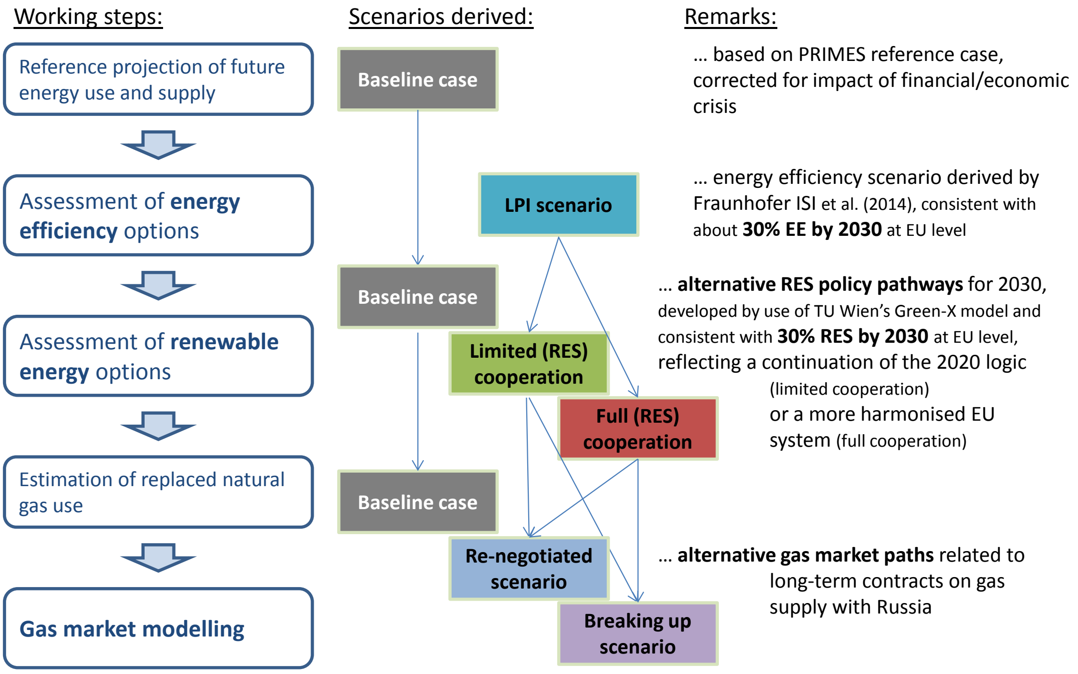

Figure 1-1. Approach taken for assessing the future contribution of renewables and energy efficiency to supply security in selected MSs

This paper focuses on short and medium-term energy security enhancing policies and measures targeted at reducing vulnerability to disruptions in imported gas supplies originating from Russia in timeframes up to 2030. These include supply diversification, investments in storage capacity, reverse-flow investments, interconnections, strategic reserves, strengthening intra-EU co-operation and emergency/solidarity mechanisms linked to obligations to draw up and implement Emergency Preparedness / Preventive Action Plans and Emergency Response Plans and functioning of reverse flow pipelines, regional and EU-level market integration. Issues of wider energy security concern are beyond the scope of this first paper.

The following key questions will be addressed:

1. What are the recent trends of energy import dependency with special reference to import dependency on Russian gas?
2. What is the potential for replacement of Russian gas in 2020 and 2030?
3. What are the main replacement options of Russian gas?
4. Which options are available in the short run and which ones on longer time frames?
5. What infrastructural and gas-regulatory measures are needed to realise this potential?
6. What role can renewable energies and energy efficiency play in fostering energy security?
7. What regulatory measures are needed to enable the targeted developments of renewable energies and energy efficiency?

1.3 Outline

Section 2 presents information on energy supply and demand trends in the 12 focus countries as compared to corresponding trends for the EU at large. External gas dependence with a focus on Russia as key supplier is covered as well. The core of the paper is in section 3 where the forward-looking analysis on gas demand and supply is presented. As a starting point, we introduce the approach and provide the outcomes of the assessment of gas replacement options, including energy efficiency measures to reduce overall energy consumption levels and the accelerated deployment of renewables as accompanying supply-side measure. The detailed gas-market modelling follows next and, finally, results and costs and benefits (in terms of savings) are compared and contrasted. Also main policy interventions warranted to realise the envisioned improvement in gas supply security are identified, related to enhancing renewable and energy efficiency developments as well as to gas supply infrastructure. The main conclusions of this paper are presented in section 4.

2 Energy use and import dependencies: current trends

2.1 Energy use and underlying trends

During the period 2000-2012 most of the 12 MS countries witnessed stagnating population numbers with negative growth in the Baltics, Bulgaria, Romania, Estonia and Hungary. Table 2-1 presents some details on this. During 2000-2008 by and large welfare levels in the focus countries improved much faster on average than in the EU, but during 2008-2012 the impact of the financial crisis tended to be more severe in these countries as well, when compared to the Union as a whole. Especially, but not only, Hungary, Romania, and Croatia were badly hit. Typically, countries that grow fast economically also show fast energy efficiency improvement (energy intensity reduction) whilst countries in economic stagnation also show poor performance in energy efficiency trends.

Table 2-1. Compound annual growth rates of population, GDP per capita, energy intensity and gross inland energy consumption in the 12 focus Member States and the EU, 2000-2012.

Country, region	Population			GDP p.c.			Energy intensity			GIEC		
	2000-2008	*2008-2012*	2000-2012	*2000-2008*	*2008-2012*	2000-2012	*2000-2008*	*2008-2012*	2000-2012	*2000-2008*	*2008-2012*	2000-2012
Bulgaria	*-1.1%*	*-0.6%*	**-0.9%**	*6.3%*	*0.9%*	**4.4%**	*-4.0%*	*-2.4%*	**-3.5%**	*0.9%*	*-2.2%*	**-0.1%**
Czech Republic	*0.1%*	*0.4%*	**0.2%**	*8.7%*	*-2.4%*	**4.9%**	*-7.0%*	*0.7%*	**-4.5%**	*1.2%*	*-1.4%*	**0.3%**
Estonia	*-0.6%*	*-0.2%*	**-0.5%**	*8.2%*	*-1.0%*	**5.1%**	*-5.0%*	*2.0%*	**-2.7%**	*2.3%*	*0.7%*	**1.7%**
Croatia	*-0.5%*	*-0.2%*	**-0.4%**	*6.4%*	*-4.1%*	**2.8%**	*-3.8%*	*1.7%*	**-2.0%**	*1.9%*	*-2.7%*	**0.3%**
Latvia	*-1.0%*	*-1.7%*	**-1.3%**	*7.5%*	*-1.1%*	**4.6%**	*-3.7%*	*2.0%*	**-1.9%**	*2.5%*	*-0.8%*	**1.3%**
Lithuania	*-1.1%*	*-1.7%*	**-1.3%**	*10.5%*	*-1.0%*	**6.5%**	*-5.4%*	*-3.9%*	**-4.9%**	*3.5%*	*-6.5%*	**0.0%**
Hungary	*-0.2%*	*-0.3%*	**-0.2%**	*3.8%*	*-6.1%*	**0.4%**	*-2.8%*	*3.6%*	**-0.7%**	*0.6%*	*-3.0%*	**-0.6%**
Poland	*0.0%*	*0.3%*	**0.1%**	*5.9%*	*-2.5%*	**3.0%**	*-4.4%*	*2.2%*	**-2.2%**	*1.2%*	*-0.1%*	**0.8%**
Romania	*-1.1%*	*-0.7%*	**-0.9%**	*3.7%*	*-5.8%*	**0.4%**	*-1.4%*	*3.4%*	**0.2%**	*1.2%*	*-3.2%*	**-0.3%**
Slovenia	*0.1%*	*0.6%*	**0.3%**	*1.9%*	*-3.8%*	**0.0%**	*0.3%*	*0.7%*	**0.4%**	*2.3%*	*-2.5%*	**0.7%**
Slovakia	*-0.1%*	*0.1%*	**0.0%**	*9.1%*	*0.0%*	**6.0%**	*-8.3%*	*-2.4%*	**-6.3%**	*0.0%*	*-2.3%*	**-0.8%**
Finland	*0.3%*	*0.5%*	**0.4%**	*2.3%*	*-2.0%*	**0.8%**	*-1.3%*	*0.2%*	**-0.8%**	*1.3%*	*-1.3%*	**0.4%**
12 MS	*-0.4%*	*-0.1%*	**-0.3%**	*5.4%*	*-2.8%*	**2.6%**	*-3.6%*	*1.3%*	**-2.0%**	*1.2%*	*-1.6%*	**0.3%**
EU28	*0.3%*	*0.3%*	**0.3%**	*0.9%*	*-1.6%*	**0.1%**	*-0.7%*	*-0.3%*	**-0.6%**	*0.5%*	*-1.6%*	**-0.2%**

Legend:
GDP p.c.: gross domestic product per capita
Energy intensity: Energy per unit of GDP at constant prices of year 2013
GIEC: gross inland energy consumption

Source: Eurostat

Population, income per capita and energy intensity trends together have their bearing on the growth of energy consumption in a country. Consider, for example, the 12 MS during the period 2000 to 2012. Their overall compound annual rates of change in population, GDP per capita and energy intensity during this period are -0.3%, 2.6%, and -2.0% respectively. These figures correspond approximately to an annual rate of change in gross inland energy consumption of 0.3%.[3] The evolution of energy demand cannot be assessed in isolation from demographics, economic growth and energy efficiency performance. Policies to contain the level of energy demand with given economic growth levels have to influence the economy-wide energy intensity one way or the other. On the one hand, energy efficiency performance for all economic activities and notably in the most energy-intensive energy conversion and energy end-use sectors would need to be targeted for improve-

[3] 100% * {(0.997 * 1.026 * 0.98) -1} = 0.246%, i.e. – due to rounding errors –approximately 0.3%.

ment. On the other, production and consumption structures need to be targeted to become less energy-intensive. For countries that are in a stage of economic development warranting heavy investment in physical infrastructures (e.g. Bulgaria) such structural changes in a less energy-intensive direction are much more challenging than for countries that have already embarked on a post-industrialization pathway (e.g. Finland). But the advantage is that economically emerging countries can benefit from technological leap-frogging, adopting state-of-the-art technologies from the economically most advanced countries.

2.2 Energy import dependencies

Energy supply security is a multi-facetted issue. Its connotation is inherently contextual and subjective (Jansen and Seebregts, 2010; Jewell et al, 2014). The present paper zooms in on gas security and considers how to reduce, in short-term and mid-term, in selected EU Member States the external dependency of gas supplies on a single, dominant, external supplier. The ongoing Russian-Ukrainian stand-off and its possible impact on energy supply security in the focus countries form the backdrop of this paper (See e.g. EurActiv, 2014 on Russia-EU gas flow reduction actions, recently undertaken on the part of Gazprom).

Ain principle, a wide range of proxies for economic vulnerabilities to energy imports can be used (See e.g. Percebois, 2006). The European Commission uses the so-called **energy dependency rate** as central indicator.[4] It shows the proportion of energy that an economy must import. It is defined as net energy imports divided by gross inland energy consumption plus fuel supplied to international maritime bunkers, expressed as a percentage. A negative dependency rate indicates a net exporter of energy while a dependency rate in excess of 100 % indicates that energy products have been stocked. For kicking off the analysis of energy supplies security, the energy (gas) dependency rate is a useful indicator to provide a first and preliminary litmus indication of the overall vulnerability of a country to sudden disruptions in external energy supplies. In fact, it is important to consider external energy security issues *by fuel* to gain a better understanding of the overall risk at stake (Le Coq and Palseva, 2009). Other aspects such as import sourcing and transport route concentration, ease of supplier and/or fuel substitution are relevant as well. The following supplementary information in (percentage points shares based on) volume terms will be used:

- The share of gas in gross inland energy consumption
- Gas dependency rate: the share of net gas imports in gross inland gas consumption
- The share of Russia in net gas imports
- The share of gas originating from Russia in gross inland gas consumption.

Table 2-2 gives an overview of total gas consumption, own production and imports of gas for the 12 MS. Romania and Croatia have a substantial own production (more than 50% of consumption) and four countries have no own production at all. Imports cover the difference between consumption and production. In some cases imports are somewhat higher than consumption, which can be due to storage or re-export. The column on the right shows that the share of gas in total energy consumption is relatively high (one-third to a quarter) in half of the countries and around 10% in four countries.

[4] See e.g. http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=Energy_production_and_imports&printable=yes

Table 2-2. Natural gas consumption, production and import in assessed 12 MS in 2012 (EUROSTAT, 2014)

	Gross inland natural gas consumption			inland natural gas production			total natural gas import			Share in Gross Inland Energy Consumption
	TJ	bcm*	TWh	TJ	bcm*	TWh	TJ	bcm*	TWh	%
Bulgaria	102625	2.68	28.51	12907	0.34	3.59	95029	2	26.39694	13%
Czech Republic	287051	7.55	79.74	8956	0.24	2.49	284123	7	78.92306	16%
Estonia	22835	0.60	6.34	0	0.00	0.00	25372	1	7.047778	9%
Croatia	101038	2.67	28.07	68445	1.81	19.01	51291	1	14.2475	30%
Latvia	50709	1.36	14.09	0	0.00	0.00	64115	2	17.80972	27%
Lithuania	111119	2.99	30.87	0	0.00	0.00	123540	3	34.31667	37%
Hungary	347753	9.06	96.60	74027	1.93	20.56	313776	8	87.16	35%
Poland	569447	15.06	158.18	160250	4.24	44.51	467218	12	129.7828	14%
Romania	452715	12.22	125.75	363527	9.81	100.98	106877	3	29.68806	31%
Slovenia	29730	0.78	8.26	72	0.00	0.02	32953	1	9.153611	10%
Slovakia	182767	4.76	50.77	5325	0.14	1.48	184190	5	51.16389	26%
Finland	125835	3.32	34.95	0	0.00	0.00	139801	4	38.83361	9%
Total (12 MS)	**2383624**	**63.05**	**662.12**	**693509**	**18.50**	**192.64**	**1888285**	**49.79**	**524.52**	
EU-28	16446001	432.79	4568.33	5574661	146.70	1548.52	16009329	421.30	4447.04	

Note: *we calculated with the GCV values given by EUROSTAT.

Source: Eurostat

The part of the imports from Russia is shown in Figure 2-1. For the period 2000-2012 a few corrections have been made because the Eurostat data do not show all imports of Russian gas. For instance, according to Eurostat Polish imports drop from more than 300 PJ to almost zero by 2010, while the import from not-specified countries increases with the same amount. Therefore, it has been assumed that actually the gas is still coming from Russia. Same, smaller, corrections have been made for Croatia and Romania.

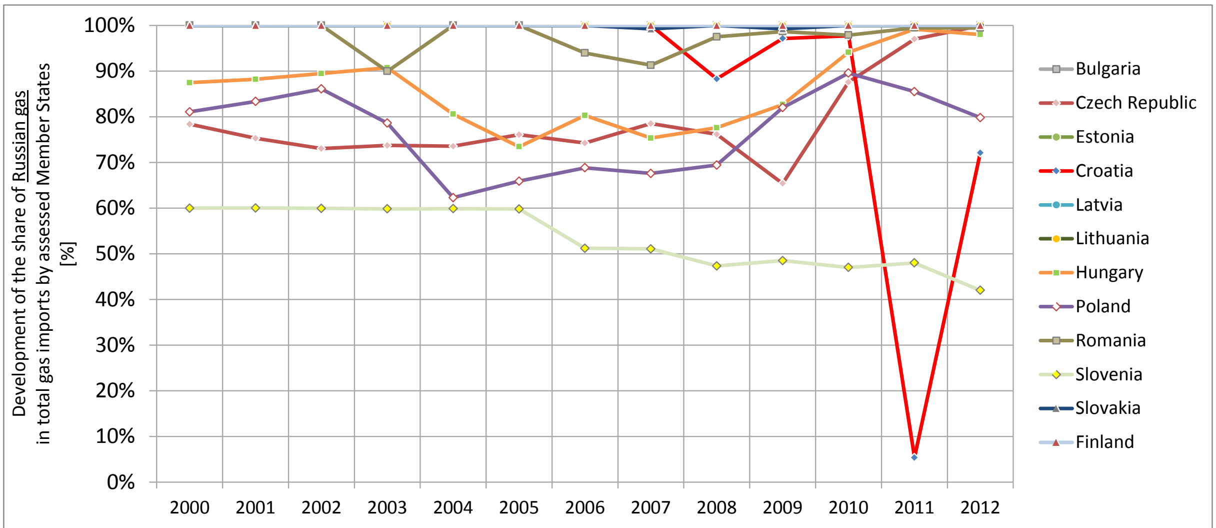

Figure 2-1. Trends for the fraction of Russian gas in total imports of 12 chosen countries

Source: Eurostat

The Baltic countries and Bulgaria, Slovakia and Finland are completely and continuously dependent on Russian gas. Only Slovenia managed to substantially limit the dependency by relying on gas from Algeria and, recently, western European countries. An interesting observation in the light of the subject of this paper is that the fraction of Russian gas has increased in recent years for the Czech Republic, Hungary and Romania.

A special case is Croatia that, in 2011 did not renew the previous long term contract with Russia, instead in an open call invited international suppliers – among them Gazprom - to supply households for a 3 year period. ENI (Italy) was the selected shipper. There are however smaller amounts imported on a commercial basis from Hungary, which is most probably Russian source gas, but it is no longer a Russian contract.

Total imported gas by the EU from Russia was around 108 bcm/year in 2012.[5] Out of this quantity 35 bcm/year is accounted for by the 12 focus countries.

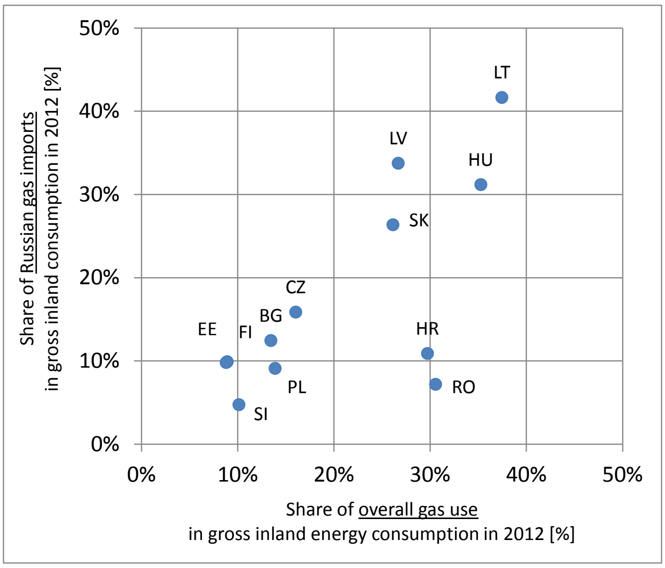

Figure 2-2. Fraction of gas consumption versus share of Russian gas import, both with respect to Gross Inland Energy Consumption (GIEC) in 2012

Source: Eurostat

In Figure 2-2, we combine this information together: in most of the countries the Russian gas represents almost 100% of the total import, but there are significant differences in the importance of gas among these countries. In general, we might assume that in case Russian gas provides more than 20% of total energy consumption (GIEC), a country is highly dependent on Russian import. Figure 2-2 brings out that four of the 12 focus countries face a material problem regarding Russian gas dependency.

Disaggregation by fuel and sector

Table 2-3 gives a country-by-country overview for year 2012 of gross inland energy consumption in the focus countries by fuel. Gross inland energy consumption (GIEC) in the focus countries totals 12.6 EJ or about 18% of the corresponding amount for the whole EU. Focus countries with gas shares in GIEC higher than 20% are Lithuania (37% of GIEC), Hungary (35%), Romania (31%), Croatia (30%), Latvia (27%) and Slovakia (26%). Positive (negative) amounts in the column 'Electrical energy' denote electricity imports (exports). Solid fuels (hard coal, lignite) use is remarkably high in Estonia and Poland in relative terms (60% and 52%), oil in Croatia (42%), Lithuania (35%) and Slovenia (35%). 7 out of the 12 focus countries have nuclear energy generating installations: Bulgaria, Czech Republic, Hungary, Romania, Slovenia, Slovakia and Finland. Frontrunners in renewable biomass energy in relative terms are Latvia and Finland with shares in gross inland energy consumption of 38% and 31% respectively.

[5] In 2013 EU imports from Russia reached a level of 126 bcm

Table 2-3. Breakdown of gross inland energy consumption in year 2012 into fuels used, 12 focus Member States and EU28.

Country	Gross inland consumption (in PJ) by fuel (in % points)								
	All products	Solid fuels	Total petroleum products	Gas	Nuclear heat	Derived heat	Renewable energies	Electrical energy	Waste (non-renewable)
BG	763	38%	21%	13%	22%	0%	9%	-4%	0%
CZ	1791	40%	21%	16%	18%	0%	8%	-3%	1%
EE	256	62%	18%	9%	0%	0%	14%	-3%	0%
HR	340	8%	42%	30%	0%	0%	12%	8%	0%
LV	190	2%	30%	27%	0%	0%	36%	3%	1%
LT	297	3%	35%	37%	0%	0%	16%	8%	0%
HU	986	11%	25%	35%	17%	0%	8%	3%	0%
PL	4102	52%	25%	14%	0%	0%	9%	0%	1%
RO	1481	21%	25%	31%	8%	0%	15%	0%	0%
SI	293	20%	35%	10%	20%	0%	15%	-1%	0%
SK	699	21%	20%	26%	24%	0%	8%	0%	0%
FI	1427	13%	26%	9%	17%	0%	29%	4%	1%
12 MS	12626	33%	25%	19%	10%	0%	12%	0%	0%
EU28	70485	17%	34%	23%	14%	0%	11%	0%	1%

Note: Derived heat and electrical energy (net electricity imports) have been excluded

Source: Eurostat

Regarding the electricity generating sector, it is notably of interest how gas is represented in the fuel mix in relation to other fuels. Table 2-4 provides details about the electricity production mix in the focus countries and EU-28 in 2012.Gas features prominently in the electricity fuel mix of Lithuania (57%), Latvia (33%), Hungary (27%) and Croatia (24%). However, being rather small countries as to electricity production, the effect of possible shifts away from gas will have limited effects on total gas consumption of the 12 countries together.

In Poland the primacy of coal (Poland: 83%) is striking, and oil shale and oil sands in Estonia (Other renewables, 86%). The share of nuclear in the electricity mix is lower for the 12 focus MS aggregated than for EU28, i.e. 22% against 27%. The same goes for wind power and solar power (PV, CSP), i.e. 2% and 1% against 7% and 2%. Finland and Estonia stand out in bio energy with shares of 16% and 8% respectively in the electricity mix. Lithuania is doing relatively well in wind power (11% in the gross electricity production mix), whilst among the focus countries Czech Republic and Bulgaria solar is poised to take off (2%).

Table 2-4. Gross electricity production by fuel in 2012.

Country	Gross electricity production (in GWh) by fuel (in % of total)											
	Total	Coal	Natu-ral gas	Oil	Nuclear	Other non-renew-able	Hydro	Bio energy	Solar	Wind	Geo ther-mal	Tidal, wave, ocean ener-gy,
BG	47329	47%	**5%**	0%	33%	1%	8%	0%	2%	3%	0%	0%
CZ	87573	51%	**1%**	0%	35%	3%	3%	4%	2%	0%	0%	0%
EE	11967	0%	**1%**	0%	0%	86%	0%	8%	0%	4%	0%	0%
HR	10557	21%	**24%**	6%	0%	0%	45%	1%	0%	3%	0%	0%
LV	6168	0%	**33%**	0%	0%	0%	60%	5%	0%	2%	0%	0%
LT	5043	0%	**57%**	5%	0%	5%	19%	4%	0%	11%	0%	0%
HU	34590	18%	**27%**	1%	46%	1%	1%	5%	0%	2%	0%	0%
PL	162139	83%	**4%**	1%	0%	1%	2%	6%	0%	3%	0%	0%
RO	59045	39%	**15%**	1%	19%	0%	21%	0%	0%	4%	0%	0%
SI	15729	33%	**3%**	0%	35%	0%	26%	2%	1%	0%	0%	0%
SK	28664	12%	**10%**	2%	54%	2%	15%	3%	1%	0%	0%	0%
FI	70323	10%	**10%**	0%	33%	7%	24%	16%	0%	1%	0%	0%
12 MS	539127	46%	**8%**	1%	22%	4%	11%	5%	1%	2%	0%	0%
EU28	3295170	27%	**18%**	2%	27%	2%	11%	5%	2%	6%	0%	0%

Source: Eurostat

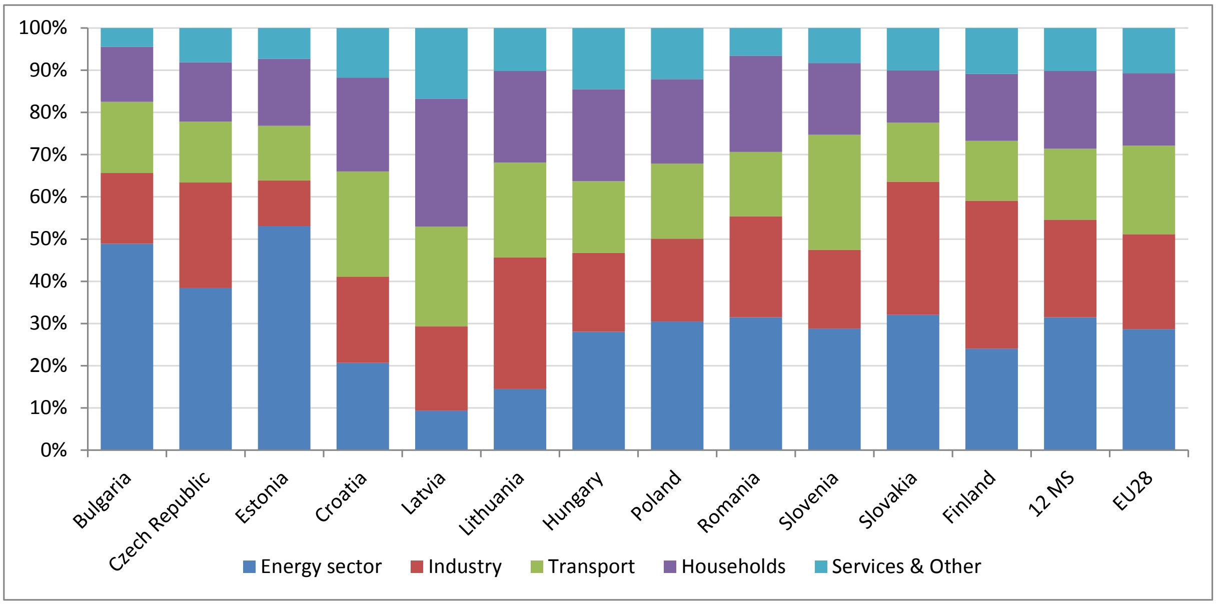

Figure 2-3. Breakdown of gross inland energy consumption in the year 2012 into energy conversion sector and four end-use sectors, assessed 12 MS and EU-28.

Source: Eurostat

General background information on the sectorial breakdown of overall energy consumption per country/region is presented in Figure 2-3. On aggregate, the sectorial breakdown of gross inland energy consumption of the 12 focus countries together is broadly comparable with the corresponding EU28 breakdown, but this hides nota-ble country-by-country differences. In Estonia and Bulgaria the energy conversion sector, account for roughly half of total energy use. In notably net electricity importers Finland, Slovakia and Lithuania, industry is a large energy user accounting for roughly a third of total energy use. Households assume a 20% + share in total energy use in Latvia, Romania, Croatia, Lithuania, Hungary and Poland, which makes these countries rather vulnerable to supply disruptions.

In the focus countries, most of available gas tends to be used in industry, i.e. 35% as weighted average with industry shares topping 50% in Slovenia, Lithuania and Estonia in year 2012 in Table 2-5. On aggregate, the energy (power) sector is the next most important, accounting for 29% of total gas use. Especially in Finland, Lithuania and Estonia gas use in the energy sector accounts for more than 50% of total gas use. These figures need to be seen in perspective: for example, gas accounts for a modest share in the energy mix in Finland. On aggregate, less of available gas is used in households in the selected Member States (22% in 2012) as compared to EU28 (29%). In Hungary, Czech Republic, Poland and Slovakia households account for at least 25% of available gas. Further below information on most important household uses for gas is given.

Table 2-5. Breakdown of gross inland gas consumption in the year 2012 into energy conversion sector and four end-use sectors in total and relative numbers for 12 focus Member States and EU28.

Country	Gross inland gas consumption: energy sector and four end-use sectors											
	Level [TJ]						Share in gross inland energy consumption [%]					
	Energy	Industry	Transport	Housholds	Services	Total	Energy	Industry	Transport	Housholds	Services	Total
BG	44,743	39,399	11,232	2,237	4,361	101,972	44%	39%	11%	2%	4%	100%
CZ	35,571	106,286	1,789	84,713	58,707	287,066	12%	37%	1%	30%	20%	100%
EE	13,258	5,432	0	2,317	1,828	22,835	58%	24%	0%	10%	8%	100%
HR	40,303	32,966	34	21,490	6,244	101,037	40%	33%	0%	21%	6%	100%
LV	33,863	7,600	0	4,472	4,774	50,709	67%	15%	0%	9%	9%	100%
LT	43,403	56,912	1,329	5,670	3,805	111,119	39%	51%	1%	5%	3%	100%
HU	112,528	59,382	47	113,212	62,035	347,204	32%	17%	0%	33%	18%	100%
PL	104,073	238,899	10,806	141,437	79,171	574,386	18%	42%	2%	25%	14%	100%
RO	153,510	154,654	399	106,498	35,123	450,184	34%	34%	0%	24%	8%	100%
SI	6,634	17,607	29	4,907	553	29,730	22%	59%	0%	17%	2%	100%
SK	26,805	73,855	8,419	45,377	28,311	182,767	15%	40%	5%	25%	15%	100%
FI	86,332	35,973	548	1,390	1,591	125,834	69%	29%	0%	1%	1%	100%
12 MS	701,023	828,965	34,632	533,720	286,503	2,384,843	29%	35%	1%	22%	12%	100%
EU28	5,302,425	4,300,002	117,206	4,531,036	2,188,474	16,439,143	32%	26%	1%	28%	13%	100%

Source: Eurostat

On aggregate, in assessed 12 MS household energy use is 2326 PJ in total. The share of electricity in this use is appreciably lower than in the EU at large, i.e. 18% against 25%. Yet in Bulgaria (39%), Finland (35%) and Hungary (31%) the electricity share is rather high. Also gas use in the households sector is much less in the 12 MS than in EU-28, i.e.23% against 37%. Yet in Hungarian households gas accounts for 53% of total energy use. Biomass use in households is quite high in Latvia, Slovenia, Romania, Estonia and Lithuania with biomass shares topping 30%.

In all 12 MS together, electricity (37%), gas (21%) and oil products (18%) take up the largest shares in energy use in the services sector, good for a 1335 PJ volume in total. Gas accounts for at least one third of energy use in services in Hungary, Slovakia, Czech Republic and Romania.

Industrial energy use for energy purposes in the 12 MS reaches a total level of 2298 PJ. Quite a bit of electricity (27%), gas (26%) and solid fuels (18%) for these purposes is used in assessed focus countries. Gas shares topping 30% are reported for Romania, Slovenia, Hungary, Slovakia and Czech Republic.

The level of energy use for non-energy purposes in the 12 focus countries is relatively modest, amounting to 649 PJ in total. Oil products (61%) and gas (36%) cover most of it. Quite high gas shares have been recorded in Lithuania (87%), Hungary (75%), Romania (53%), Poland (43%) and Bulgaria (40%).

3 Reducing gas import dependencies towards 2030: scenarios on potentials and costs

3.1 Options to reduce Russian gas import dependency

Various options are available to replace imported natural gas. These include, apart from enhanced renewables deployment and energy efficiency improvement, enhanced exploration and development of domestic conventional and shale gas reserves (with or without carbon capture and storage (CCS) as well as fuel switch to nuclear or coal (the latter with or without carbon capture and storage). This paper will focus on the energy efficiency and renewable energy options, as they shape the core policies in EU climate and energy strategy .As will be set out in this section, enhanced deployment of renewables and energy efficiency raising options will have a negative impact on gas consumption. In this respect, enhanced REEE options would result from RES and EE policy intensification due to the recently implemented Energy Efficiency Directive, compared to policies already in place in the Member States, partly due to existing EU legislation.

3.1.1 Energy efficiency

In this paper enhanced energy efficiency is interpreted as reaching given levels of macroeconomic activity (say GDP) with less energy than would be the case under baseline conditions, that is under the Reference Scenario. Broadly, the following main "options" are available for policy intensification to reach enhanced energy efficiency levels:

- Introduction and adoption of stricter energy consumption standards and norms for new buildings
- Introduction and adoption of stricter requirements on energy-efficient renovation of existing building stock
- Introduction and adoption of stricter standards for energy-using consumer goods
- Intensification of awareness raising and promotion of low-energy lifestyles and consumption portfolios
- Elimination of market failures such as split incentives
- Faster roll-out of smart metering for individual dwellings and small businesses
- Enhanced application of cutting-edge production technology in industry, including incremental good housekeeping, improved process integration, and radical process and IT innovations
- Enhanced application of cutting-edge electricity generation, transmission and distribution as well as other energy conversion technology (e.g. oil refinery) in the energy sector, including incremental good housekeeping, improved process integration, and radical process and IT innovations
- Adoption of ever more strict standards for cars
- Shift to transport modes that use less energy per passenger-km
- Improved spatial planning with smart clustering of industrial activities and residential areas, ensuring improved access to mass-transit amenities and low-energy bulk transport corridors.
- Improved access to innovative REEE financing instruments
- Last but not least, intensification of RD&D efforts to bring about enhanced outward shifts of energy-efficiency frontiers and enable strengthening comparative advantages and employment at Member State and Union level in REEE-related activities

- Elaboration of these broad options - beyond the scope of the present paper – is available in recent documents downloadable at websites of the Commission and the IEA.[6]

3.1.2 Renewable energies

The following main technologies/options are available for enhanced deployment of renewables:

- **Bio-SNG.** When substituting natural gas by bio-SNG the infrastructure and home equipment can remain unaltered. This up-stream technology is theoretically able to provide all gas demand, but realistically it is constrained strongly by the available potential of biomass input. When conversion stations are being erected close to existing infrastructure and with at the same time a lot of input of biogene origin the logistical challenge might be manageable. This option applies to the residential sector, to industry and to the power sector and does not have any downstream integration issues, which makes this route an interesting alternative. The electrification through biogas use is also a route that is relatively easy to integrate into the energy system.
- **Bioliquids** is another energy carrier that can be integrated relatively easy to substitute for oil products. This fuel can be deployed in all sectors without much hassle: residential, industry and power sector.
- **Solid biomass**. This fuel can be using on a stand-alone basis to provide heat at high temperature levels and may be used in a co-firing setting with coal. It applies to the residential sector, to industry and to the power sector
- **Aquifer Thermal Energy Storage (ATES).** ATES is balancing out heat demand in winter against cooling demand in summer: a mature technology which can typically be found in the service sector. The bottleneck in some geographical areas is that for the residential sector regeneration of the underground energy storage is more difficult through the lack of cooling demand. Additional complication is that the system operates best with a low-temperature heat distribution system, thus requiring additional investments. In new buildings such low-temperature distribution system is more easy to implement. This technology is an interesting option when combined with far-reaching energy efficiency measures like increased insulation.
- **District heating systems driven by large-scale renewable sources.** These include deep geothermal, biomass and large solar thermal plants. Deep geothermal and solar thermal require considerable investments but have only few operational costs. For biomass-based heating plants the fuels costs are considerable. An alternative system layout is to benefit from other heat sources such as conventional and nuclear power plant residual heat.
- **Heat pumps.** Like ATES, also heat pumps require a low temperature heating system. Thermal energy can be obtained from three different bodies: water, ambient air or shallow geothermal ground-coupled systems. Heat pumps may be considered in a collective or an individual system layout.
- **Solar thermal collectors**. Can be used for hot sanitary water and for space heating, commonly in an individual layout but likewise in collective systems or in district heating systems.
- **Increased (renewable) electrification.** Increasing the renewable energy share by increased electrification, where the electricity is generated by renewable energy, substituting gas-fuelled power options. This is, like bio-SNG, an up-stream technology. Contrary to bio-SNG, consumers have to purchase different equipment. All renewable electricity technologies can be used up-stream: wind power, solar (PV and CSP), electricity from deep geothermal energy and biomass.
- **Financing.** Improved access to innovative REEE financing instruments.
- **RD&D.** Last but not least, intensification of RD&D efforts to bring about cost-reducing innovations in renewable energy technologies and enable strengthening comparative advantages and employment at Member State and Union level in REEE-related activities.

[6] For example: European Commission, 2014c)

3.1.3 Other fuel switch

3.1.4 Natural gas infrastructure development

The 2009 Russian –Ukrainian gas dispute has led to a 3 week crisis in Europe, where the EU experienced 5 bcm loss of Russian gas supply, and the Ukraine about 2 bcm. This crisis has been analysed in detail[7] and the findings materialized in a security of supply regulation[8] and an infrastructure regulation[9]. The main instruments to enhance security of gas supplies were defined as: more interconnectivity, more source diversification, more flexibility on the supply and demand side as well. The most vulnerable EU member states have answered the call, and have already invested into gas infrastructure: several new interconnectors, reverse flows were commissioned and two LNG terminals are under construction in the region. Besides the interconnectors listed in Table 3-1 there were commercial storage investments (in the Czech Republic, Hungary and in Slovakia) and even a strategic storage site has been built in Hungary to increase responsiveness of the gas system to supply disruptions. The European Commission has defined in a transparent selection process the most important Projects of Common Interest (PCI), that have to be built in the short and mid-term, and PCIs are supported by a Connecting Europe Facility financial scheme[10]. Several Member States introduced internal measures to increase storage stock by placing obligation on different market players to inject gas.

Table 3-1. New investments in the MS 12 that support security of supply in GWh/day

FROM	TO	capacity	reverse flow	Date of commissioning
New interconnectors				
Hungary	Croatia	76	0	2010
Hungary	Romania	51	3	2010
Slovakia	Hungary	127	51	under construction
Bulgaria	Romania	46	28	2014
Reverse flow				
Austria	Slovakia		423	2010
Czech Republic	Slovakia		696	2010-2014
Germany	Poland		118	2014
LNG				
Poland		134		under construction
Lithuania		55		under construction

Large new gas transmission pipeline investments have not been materialized so far, except for the North Stream. Nabucco, the European initiative failed in the competition for the Southern Corridor to ship Azeri gas to Europe, and the wining consortia of TAP seems to be coming online around 2020. The 12 MS will benefit of

[7] The January 2009 Gas Supply Disruption to the EU: An Assessment http://ec.europa.eu/energy/strategies/2009/doc/sec_2009_0977.pdf

Lessons from the 2009 January gas crisis for Central and South East Europe, In: Security of energy supply in Central and South-East Europe, REKK 2009

http://www.rekk.eu/index.php?option=com_content&view=article&id=241&Itemid=176&lang=hu&14c7e2ee2520855d5ac98ec049c29945=80f5b4f47d9133cc2a1daea9f46763f5

[8] REGULATION (EU) No 994/2010 concerning measures to safeguard security of gas supply

[9] REGULATION (EU) No 347/2013 on guidelines for trans-European energy infrastructure

[10] An amount of € 5.85 billion will be made available for improving the trans-European energy infrastructure for the period 2014 to 2020. For the details see: REGULATION (EU) No 1316/2013 establishing the Connecting Europe Facility,

this project only if further PCIs are built. South Stream, the Gazprom initiative to bypass Ukraine is proceeding however that brings no source diversification to Europe.

3.2 Renewables and energy efficiency replacing natural gas: Scenarios on future developments up to 2030

Despite various options are available to replace imported natural gas, this assessment focuses on energy efficiency and renewable energy options, as they are the core policies at EU level that also have significant impact on gas consumption. Thus, this section is dedicated to present the approach taken for and the outcomes derived from the quantitative assessment of replacing natural gas use in selected Member States by increased energy efficiency and renewable energy deployment. Next we introduce the methodology applied and the assumptions taken, followed by an illustration of the results derived. Approach and outcomes are shown in topical order, firstly, identifying the role of energy efficiency, followed by renewables, and finally the replacement effect of both on natural gas will be estimated.

3.2.1 Method of approach and key assumptions

Reference projection of future energy use and supply

The starting point for the assessment of natural gas replacement through increasing RES and energy efficiency is to have a clear reference trend on future energy, and specifically gas use. As reference projection we make use of the European Commission's latest reference scenario on EU energy, transport and GHG emissions trends to 2050 as derived by the PRIMES model (EC, 2013b). This scenario provides a detailed projection of energy supply and use at Member State level, offering details and insights by sector at technology and at fuel level - and specifically also for natural gas consumption – for the period up to 2050. Thus, expectations on future energy demand are taken from this projection but have been compared with actual data for the status quo (2011 and 2012) and corrected, respectively.[11] This modified reference scenario of future EU energy use and supply serves as basis for the follow-up analysis.

Assessment of energy efficiency options – the *Low Policy Initiative (LPI)* scenario

Next, energy efficiency comes into play: The analysis underlying the assessment of energy efficiency policy options until 2030 is based on detailed modelling of the final energy demand in the different demand sectors using the following modeling tools:

- The INVERT/EE-Lab model (run by TU Wien) for residential and non-residential buildings
- The FORECAST platform (run by Fraunhofer ISI), including an industrial model as well as the electricity uses in the residential and service sector
- The ASTRA model (run by Fraunhofer ISI) providing potentials for the transport sector

These models were used both to evaluate policy impacts up to 2020 as well as to evaluate in a detailed manner energy efficiency potentials up to 2030.

[11] Demand projections provided by PRIMES modelling appeared to reflect latest developments generally more adequate than alternative data sources. A correction and validation process at MS level in order to reflect recent changes in energy consumption, i.e. incorporating the impact of the financial/economic crisis that was significant in magnitude in parts of Europe, was however indispensable for being capable to provide suitable short- and mid-term projections. Thus, demand data at sector level by country that originally stemmed from PRIMES scenario was replaced by actual data for the years 2011 and 2012. For the follow-up period until 2030 and beyond it was assumed that the demand collapse occurring until 2012 has a permanent impact on forthcoming years. More precisely, for the years after 2012 the yearly change in demand was assumed to follow the trend underlying the PRIMES reference case but the gap that has risen until 2012 would consequently permanently remain.

The *low policy intensity (LPI)* scenario includes all policy measures that are currently implemented as well as their upcoming revisions and a selection of new policy measures. For each sector, the policy measures that are taken into account are described in the following.

Buildings

The scenario includes policy measures that were adopted until 2014 as well as revisions of the implementation of the directives (EED and EPBD) that are due in 2014/2015. However, it is assumed that a large majority of Member States does not adopt ambitious Nearly Zero Energy Buildings targets and that the uptake of renovation activities is slower due to barriers and lack of information and related policy support.

Residential electricity use

The scenario includes all adopted implementing measures of the Ecodesign Directive and Energy Labelling for all products covered so far Furthermore, it includes the revisions of implementing directives that are due in 2014/2015, the recast of the Labelling scheme due in 2015 and a moderate adoption of new implementing measures. Until 2020, the additional estimated saving potential of such new implementing measures is mainly driven by the current efforts to include a system approach for lighting and cooling within the current policy framework. The 2030 saving potential further assumes the adoption of implementing measures from 2020 for products which are currently not covered by Ecodesign.

Transport

The scenario considers all currently implemented major policy measures as well as the following additional measures:

- A road charge of 6 €ct per vehicle-km driven on motorways for passenger cars is implemented starting in 2014. The charge is assumed to substitute existing charges in case that the existing charge is lower than the new one.
- The promotion of energy efficient public commercial vehicles in the EU will be implemented from 2014 on.
- A stimulus programme is assumed providing owners of cars older than 10 years a rebate of € 2000 for buying a more efficient new car. The programme starts in 2014 and initiates a higher scrapping ratio of cars older than 10 years.
- A "feebate" system is implemented for all Member States in 2014 assuming a rebate or a fee for buying a new car depending on the CO_2 emission per vehicle-km of the car.
- The intensive promotion and teaching of eco-driving in all MS. Eco-driving measures will be implemented in all countries which have not yet considered it in their NEEAPs.
- New registered LDVs are supposed to emit on average 110 gramme CO_2 per vehicle-km in 2030. As for heavy duty vehicles, the scenario considers a reduction of average fuel consumption of 23% from 2014 until 2030.

Industry

The scenario considers all current policies including the EPBD, the Ecodesign Directive, changes in taxes and a number of information-based policies. It further includes the revisions of implementing directives for the Ecodesign Directive that are due in 2014/2015 and the full implementation of the EPBD (recast) on member state level for which we assume an ambitious implementation for industrial premises particularly improving compliance with standards.

In the frame of the Ecodesign Directive, a number of regulations were adopted until 2013 that substantially affect electricity demand in industry. Among them are the regulations addressing electric motors, circulation pumps, fans, water pumps and boilers. The LPI scenario further assumes an extension to LEDs (2018), MEPS based on least-lifecycle costs for compressors (2016) and machine tools (2016), and MEPS based on Best Available Technology (BAT) for fans (2018), ventilation and air-conditioning > 12 kW (2018), circulators (2018), fans (2018) and water pumps (2018).

This scenario also includes the structural reform proposed by the Commission to repair the ETS presented under the previous scenario. We do include the impacts by keeping the carbon price at the levels proposed by PRIMES (2013) up to 2030, resulting in an EUA price of about 35 €/t CO_2 in 2030.

Furthermore, the LPI scenario assumes that close to 50% of all companies invest in energy efficiency measures with a payback time of up to 2 years.

Assessment of renewable energy options – Green-X scenarios on future RES developments

By use of a specialised energy system model (Green-X) a quantitative analysis was conducted to assess feasible RES developments up to 2030 according to selected policy pathways, indicating RES deployment at MS and at EU-28 level as well as related impacts on costs and benefits. The core strength of TU Wien's Green-X model lies on the detailed RES resource and technology representation accompanied by a thorough energy policy description, which allows assessing the impact of various policy options in a detailed manner.[12]

Overview on assessed cases

Since the RES policy framework is a key input to this analysis different scenarios have been defined for the deployment and support of RES technologies in the assessed countries as well as for the EU as a whole:

- **Baseline case**: In this case the assumption is taken that RES policies are applied as currently implemented (without any adaptation) until 2020, while for the post-2020 timeframe a gradual phase-out of RES support is presumed. Following the concept of a reference case that serves as benchmark for alternative RES and energy efficiency policy interventions, energy demand projections are also taken from the (modified) PRIMES reference case as discussed above.
- Alternative policy pathways of **limited** and/or **full RES cooperation**: While the RES policy pathway for the years up to 2020 appears well defined given the EU RES directive 2009/28/EC and the corresponding national 2020 RES targets and related national renewable energy action plans, exploring RES development beyond 2020 means entering a terrain characterized by a higher level of uncertainty – both with respect to the policy pathway and the ambition level aimed for concerning RES deployment. The alternative RES policy scenarios analysed in this brief analysis reflect a higher level of ambition as anticipated under baseline conditions in order to explore the capability of RES in reducing fossil fuel use, and in particular gas use. Thus, at EU level a RES share of about 30% by 2030 (as share in gross final energy demand) was anticipated as target level in both assessed cases.[13] With respect to the underlying policy concepts the following assumptions are taken:
  - Similar to baseline both alternative policy cases assume a continuation of currently implemented RES policies for the period up to 2020. In contrast to above, improvements are however assumed concerning non-economic barriers (e.g. administrative barriers, constraints related to grid access). Thus, the assumption is taken that all countries follow an best-practice approach concerning permission procedures and gird access, leading to a mitigation of non-economic barriers across the EU from 2015 onwards.

[12] For details on the model and its database we refer to www.green-x.at.

[13] In its communication "A policy framework for climate and energy in the period from 2020 to 2030" (COM(2014) 15 final) in January 2014, the European Commission proposed targets for 2030 of reducing greenhouse gas emissions by 40% and achieving a 27% share of renewable energy in gross final consumption. In the accompanying impact assessment (SWD(2014) 15), further scenarios were analysed with respect to RES deployment and climate mitigation, characterised by RES shares of 30% and 35% by 2030, respectively. Thus, the alternative scenarios defined for this study are aligned to the impact assessment scenario following a moderate RES target for 2030.

- In the case of **limited (RES) cooperation**, a continuation of the current policy framework with national RES targets (for 2030) is assumed. Each country uses national (in most cases technology-specific) support schemes in the electricity sector to meet its own target, complemented by RES cooperation between Member States (and with the EU's neighbors) in the case of insufficient or comparatively expensive domestic renewable sources. In this case support levels are generally based on technology specific generation costs per country.
- In the case **full (RES) cooperation** the assumption was taken that the 2030 RES target is only set at EU level. For reaching this a harmonised support scheme for RES in the electricity sector comes into play: a quota system that does not differentiate between different technologies. In this case the marginal technology to meet the EU RES-target sets the price for the overall portfolio of RES technologies in the electricity sector. The policy costs, i.e. support expenditures, occurring in the quota system can be calculated as the certificate price multiplied by the RES generation under the quota system. These costs are then distributed in a harmonized way across the EU so that each type of consumer pays the same (virtual) surcharge per unit of electricity consumed.

Overview on key parameters

In order to ensure maximum consistency with existing EU scenarios and projections various input parameters of the renewable scenarios conducted with Green-X are derived from PRIMES modelling. More precisely, the PRIMES scenario used is the PRIMES *reference scenario* as of 2013 (EC, 2013). The main data source for RES-specific parameter is the Green-X database – this concerns for example information on the status quo of RES deployment, future RES potentials and related costs as well as other country-specific parameter concerning non-economic barriers that limit an accelerated uptake of RES. As discussed above (see overview on assessed cases) the policy framework for RES is specifically defined for this assessment and for consistency future energy demand developments are aligned to the reference projection and/or the assessment of energy efficiency options, respectively. Table 3-2 shows which parameters are based on PRIMES, on the Green-X database and which have been defined for this assessment.

Table 3-2: Main input sources for scenario parameters

Based on PRIMES	Based on Green-X database	Defined for this assessment
Primary energy prices	RES cost (investment, fuel, O&M)	RES policy framework
Conventional supply portfolio and conversion efficiencies	RES potential	Reference electricity prices
(CO_2 intensity of sectors)	Biomass trade specification	Energy demand by sector*
	Technology diffusion / Non-economic barriers	
	Learning rates	

Note: *Reference demand data is originally taken from PRIMES (reference case) but modified (see previous explanations on reference projections on energy supply and use). Demand data for the alternative energy efficiency scenario reflects the changes in energy consumption pattern according to the LPI scenario (see previous description of the assessment of energy efficiency options).

Estimation of replaced natural gas use

The final step aims to bring together the outcomes of the assessments of increasing energy efficiency and renewables, estimating the replacement effect of both on natural gas. For doing so, we make use of PRIMES forecasts related to the conventional supply portfolio, i.e. the share of the different conventional conversion technologies in each sector at country-level. As it is beyond the scope of this brief assessment to analyse in detail which conventional power plants would actually be replaced, for instance, by a wind farm installed in the year 2023 in a certain country (i.e. either a less efficient existing coal-fired plant or possibly a new highly-efficient combined cycle gas turbine), the following assumptions are made: Bearing in mind that fossil energy represents the marginal generation option that determines the prices on energy markets, it was decided to stick to the sector-specific conventional supply portfolio projections on a country level provided by PRIMES. Sector- as well as country-specific conversion efficiencies derived on a yearly basis are consequently used to calculate the amount of avoided primary energy based on the renewable generation figures obtained. Assuming that the fuel mix is unaffected, avoidance can be expressed in units of coal or gas replaced.

In the following, the derived data on aggregated conventional conversion efficiencies characterising the conventional reference system (excl. nuclear energy) is presented. Figure 3-1 shows the dynamic development of the average conversion efficiencies as projected by PRIMES for conventional electricity generation as well as for grid-connected heat production. This is done at EU-28 level and for the aggregate (12 MS) of assessed selected Member States. Error bars indicate the range of country-specific average efficiencies among assessed Member States. For the transport sector, where efficiencies are not explicitly expressed in PRIMES' results, the average efficiency of the refinery process used to derive fossil diesel and gasoline was assumed to be 95%.

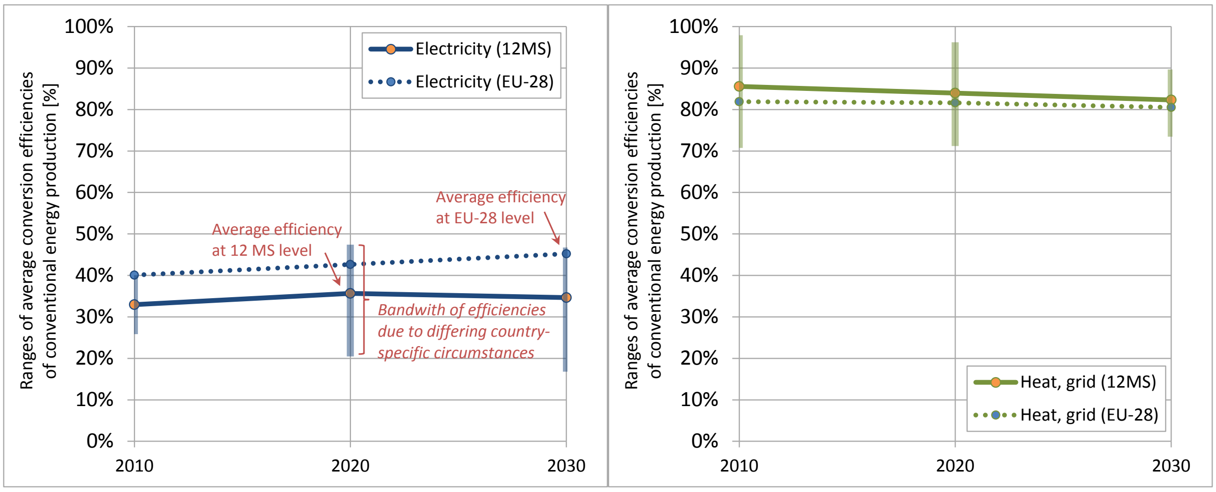

Figure 3-1: Country-specific average conversion efficiencies of conventional (fossil-based) electricity (left) and grid-connected heat production (right) in the assessed 12 Member States (and at EU-28 level)

Source: PRIMES scenarios

Complementary to above Figure 3-2 shows the projected share of natural gas in conventional fossil-fuel supply, both for the 12 MS as well as for the EU-28 at aggregated level. It can be seen that at present the share of gas in both electricity and heat supply is lower in the 12 MS compared to the EU-28 in total. For grid-connected heat supply this is however expected to change in future years where gas is expected to achieve shares larger than 60% (of total fossil-based fuel supply) while at aggregated EU-28 level the opposite trend can be seen. In the electricity sector a growing share of gas-based supply is projected both at 12 MS as well as at EU-28 level.

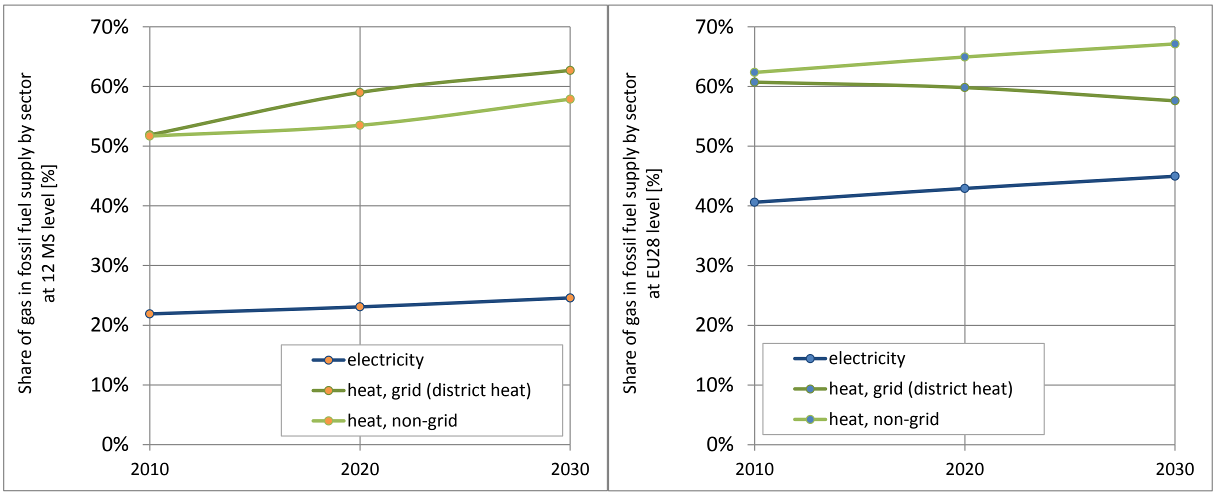

Figure 3-2: **Projected future share of natural gas in conventional (fossil-based) electricity and heat supply in the assessed 12 Member States (left) and at EU-28 level (right)**

Source: PRIMES scenarios

3.2.2 Modelling results

Figure 3-3 shows the development of the gross final energy demand up to 2030 at 12 MS and EU-28 level. The graphs show the effect of the corrections which were made based on actual data for the years 2011 and 2012. According to these projections gross final energy demand will still grow in the 12 MS, whereas it will decrease on an EU-28 level. The blue lines indicate the impact of the outcome of the energy efficiency analysis if moderate energy efficiency policies are implemented as assumed in the LPI scenario. By 2030 savings in energy demand of 219 TWh can be achieved with respect to the baseline for the 12 countries that are assessed.

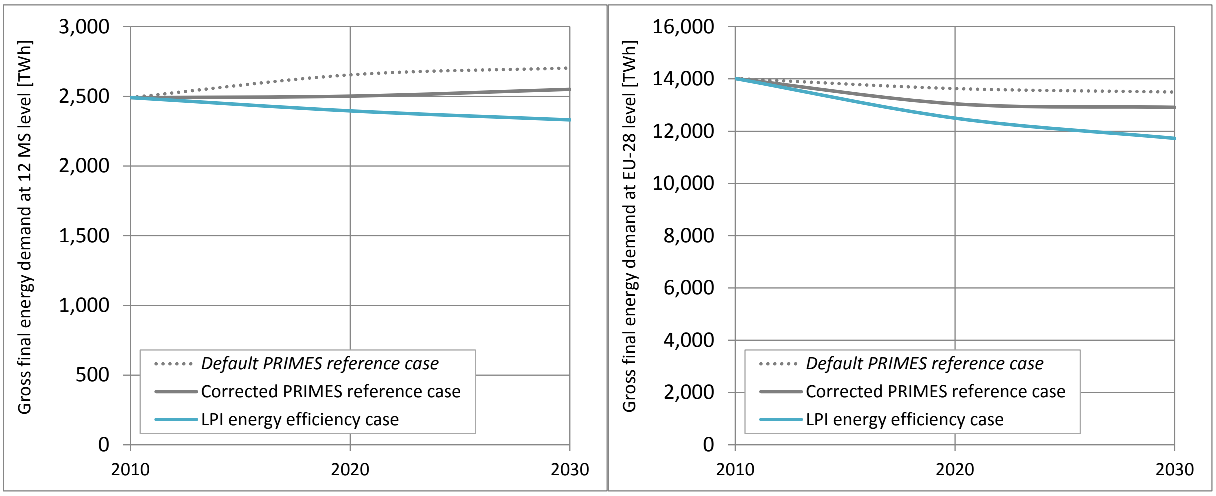

Figure 3-3: **Development of gross final energy demand at 12 MS (left) and at EU-28 level (right) according to assessed scenarios (i.e. default and corrected PRIMES reference and LPI)**

Assessment of energy efficiency options – the *Low Policy Initiative (LPI)* scenario

The cost-benefit estimates on energy efficiency are derived from the bottom-up modelling approach, in which the adoption of individual energy efficiency technologies is projected based on the policy scenarios. For each technology, the total cost of ownership is calculated taking into account the investment and maintenance cost as well as the energy costs, where learning curves are applied to project future investment costs. The program costs of the policy measures are not explicitly taken into account, as they are typically negligible compared to the investment costs. The cost-benefit analysis is based on a comparison of the cumulated total cost of ownership between the different scenarios.

The breakdown of the resulting total final energy demand in the assessed 12 Member States and the EU-28 at large based on the LPI scenario as introduced in the previous subchapter is shown in Figure 3-4. The pie charts show that the demand share of the industry sector is significant higher in the 12 MS than at the EU-28 level.

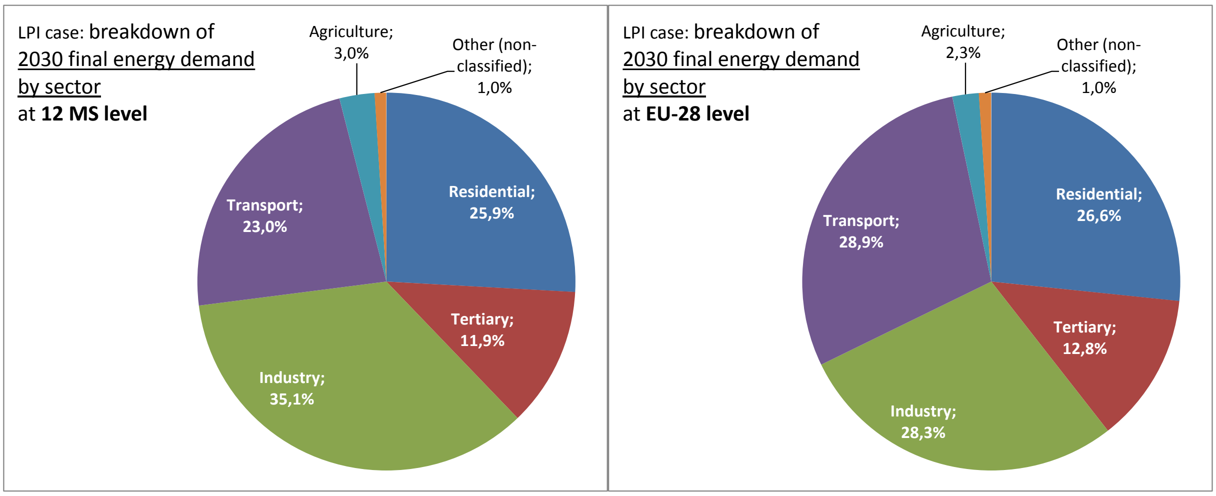

Figure 3-4: Breakdown of final energy demand at 12 MS and EU-28 level in 2030 by sector

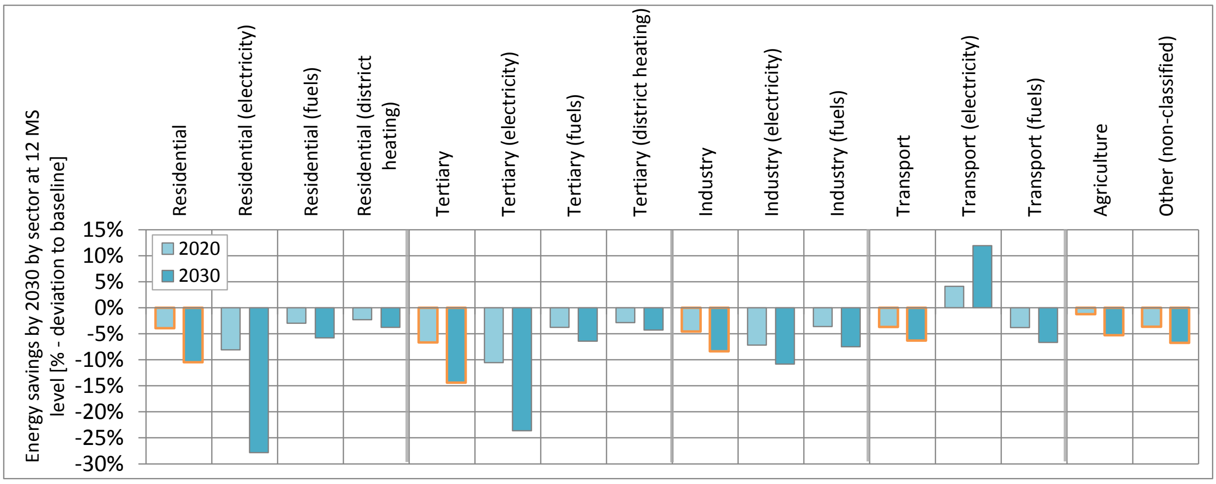

Figure 3-5: Energy savings (compared to reference) by sector including sub-sectors in 2020 and in 2030 at 12 MS level according to the LPI scenario

Figure 3-5 above shows the potential energy demand reductions compared to the reference scenario split by energy sectors, whereas Figure 3-6 shows the saving potential split by the 12 MSs. The overall reduction of demand amounts to about 11% between 2012 and 2030. The strongest savings can be realized in the residential building sector and in the tertiary sector. There is an increase of energy demand in the sub sector Transport (electricity) which comes from a switch from fuel based transport to electricity based transport. Nevertheless the total energy demand of the transport sector decreases as well.

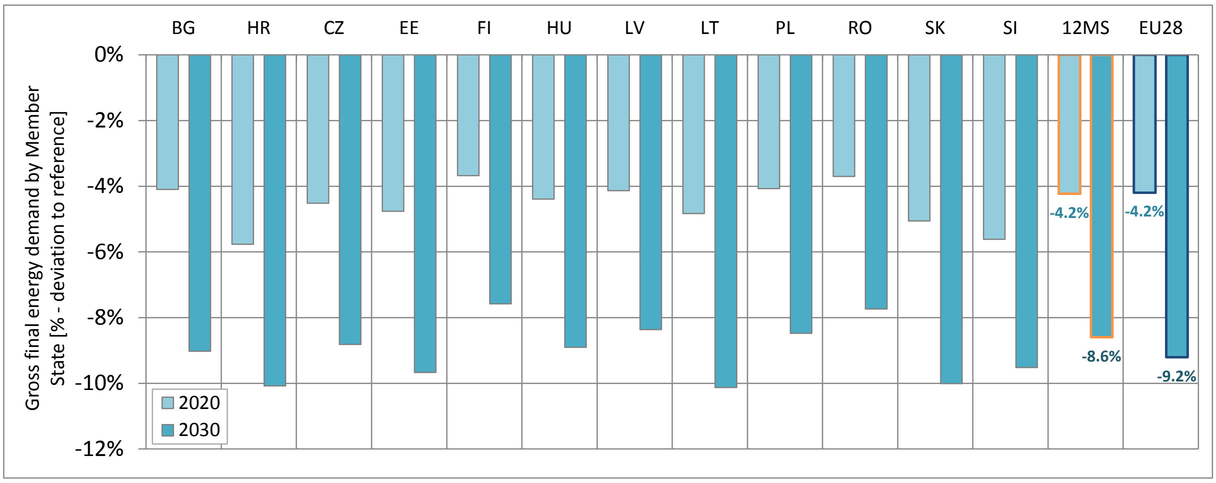

Figure 3-6: Energy savings (compared to reference) by MS in 2020 and in 2030 according to the LPI scenario

The annual average of the total cost impact (net savings) of energy efficiency options for the period (2021-2030) is shown for the 12 MS in Figure 3-7 below. The total annual savings in the 12 Member States amount to € 3.5 billion on average over the considered period.

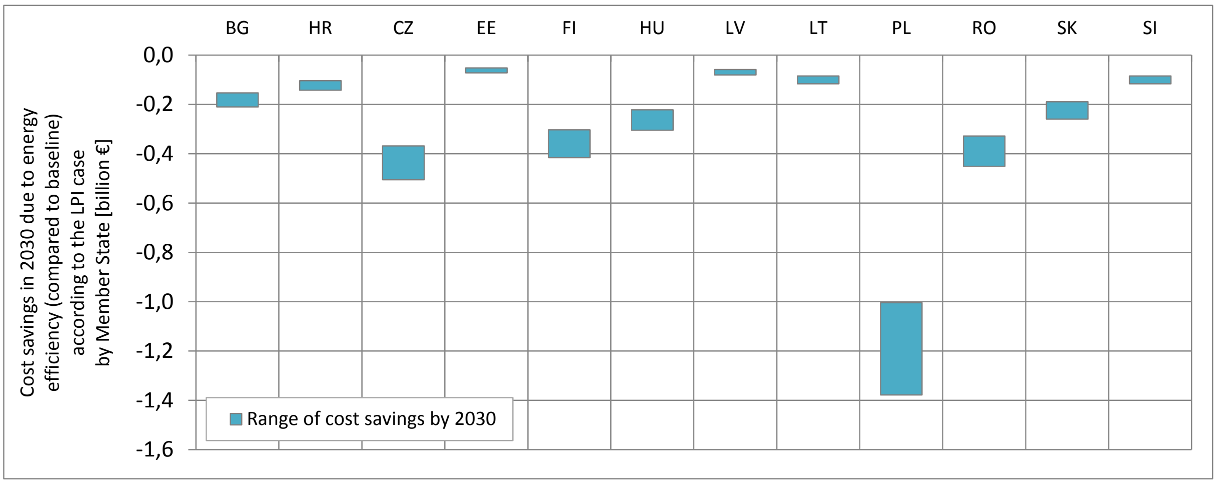

Figure 3-7: Range of cost savings by 2030 due to energy efficiency in the assessed 12 Member States based on the LPI scenario

Assessment of renewable energy options – Green-X scenarios on future RES developments

Results on RES deployment

We start with an analysis of RES deployment according to Green-X scenarios conducted on the basis of corresponding demand scenarios that have been derived within this project and discussed previously. More precisely, Figure 3-8 below shows the development of RES generation according to the different Green-X scenarios assessed at the level of the aggregate of all assessed 12 Member States (left) as well as at EU-28 level (right). For comparison the graphs also contains default projections of RES deployment from the PRIMES reference case. Comparing baseline with alternative policy scenarios of limited and full (RES) cooperation at 12 MS level, on average an increase of 108.9-114.5 TWh is observable by 2030. RES developments under different scenarios at 12 MS and at EU-28 level have similar trends - but the difference between baseline and alternative policy paths is less pronounced for assessed 12 MSs than at EU-28 level, compare for example also Figure 3-10.

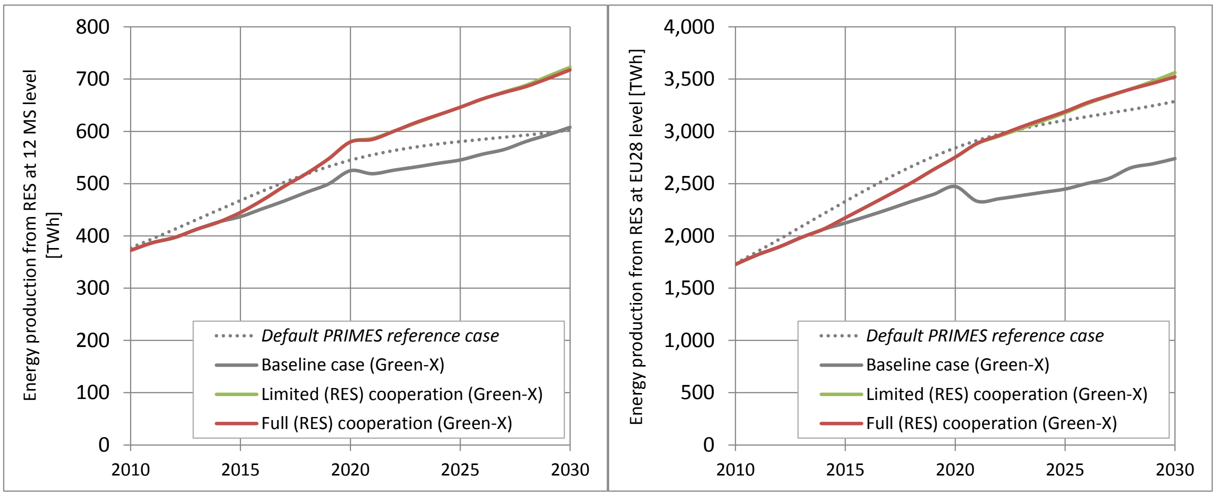

Figure 3-8: **Development of energy production from RES at12 MS (left) and at EU-28 level (right) according to assessed Green-X scenarios**

Further insights on the sector-specific RES deployment is presented in Figure 3-9, indicating RES shares in corresponding (sector-specific) demand at 12 MS level by 2020 and 2030 for all assessed RES-related scenarios (i.e. baseline (left) and alternative policy paths of full and limited (RES) cooperation (right). Since the underlying policy concepts on RES cooperation differ only in the period post 2020 both alternative paths show an identical RES deployment in 2020. Furthermore, at aggregated 12 MS level the difference between both alternative policy cases in sector-specific RES deployment is also comparatively small in 2030. Comparing baseline and policy cases differences in RES deployment are highest for biofuels in transport, followed by RES in the electricity sector, but also RES in heating and cooling show a significant increase in the case of ambitious RES targets and dedicated moderate to strong RES support as preconditioned in the policy variants.

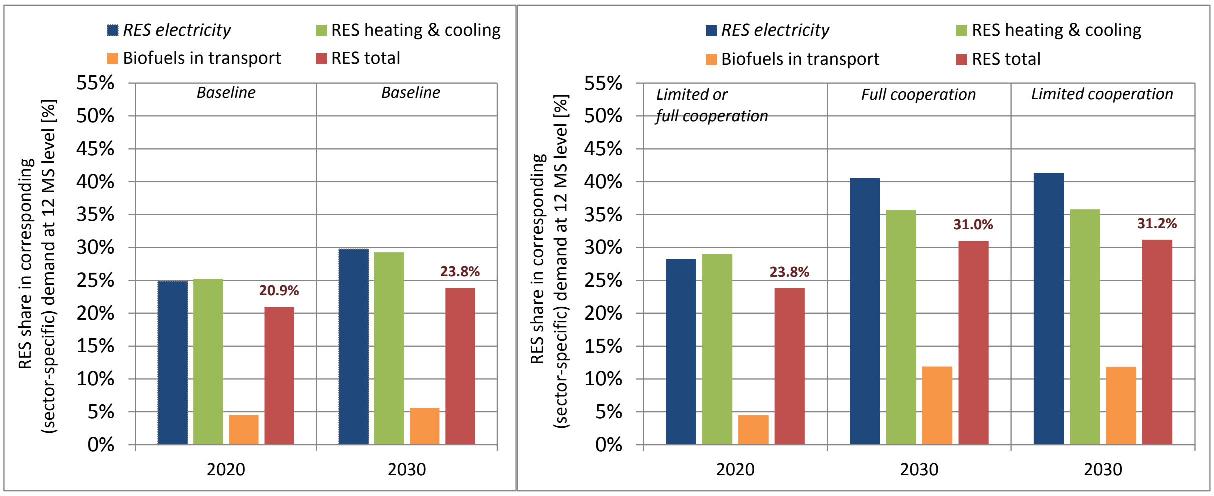

Figure 3-9: **RES share in corresponding (sector-specific) demand at12 MS level in 2020 and in 2030 according to the baseline case (left) and for alternative policy paths (of full and/or limited cooperation)**

Figure 3-10 shows the changes in RES generation by Member State in 2030 compared to the baseline case if alternative policy concepts are followed, i.e. in the case of limited (RES) cooperation across Member States or in the case of full (RES) cooperation. On average at 12 MS level an increase by 18.1-18.9% is observable by 2030 while the spread of country-specific changes is significantly broader, ranging from about 7% (Hungary) to 47% (Bulgaria) in the case of full cooperation. As discussed above, differences to baseline are more pronounced at aggregated EU-28 level than in the assessed group of countries.

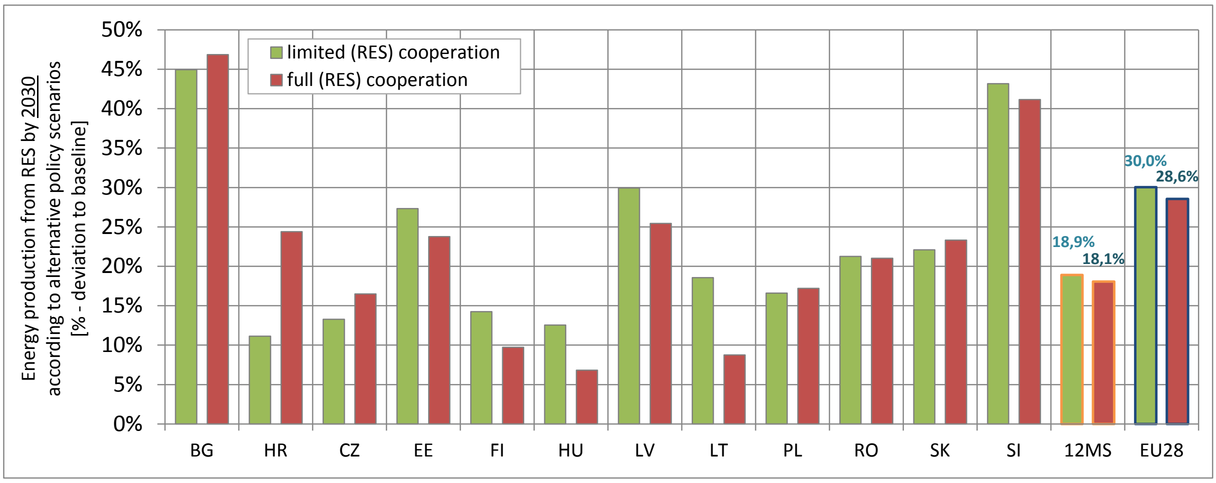

Figure 3-10: Change in RES generation by 2030 at MS level according to alternative policy paths of limited and full cooperation

Results on cost impacts

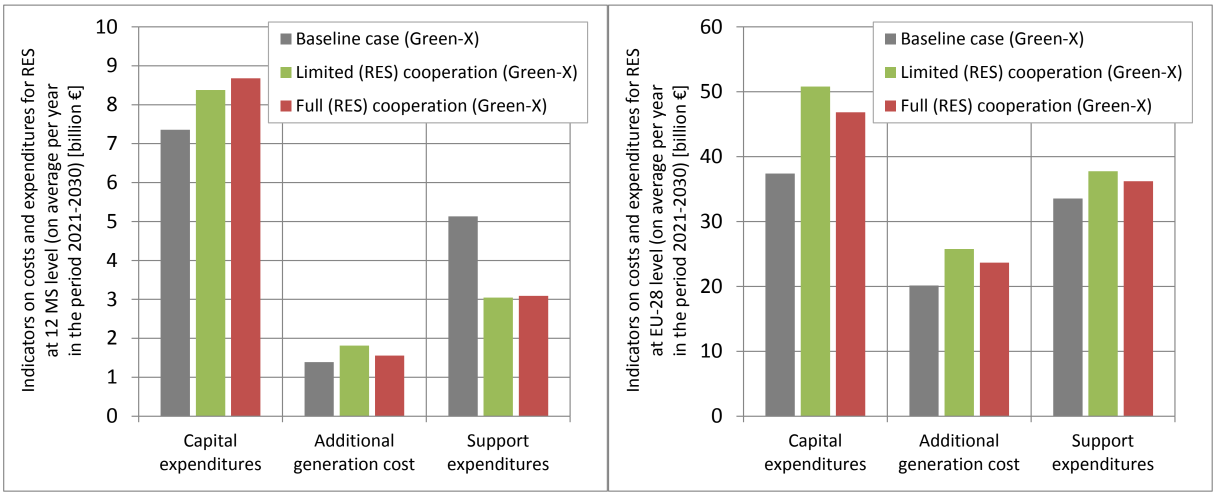

Figure 3-11: Indicators on costs and expenditures for RES at12 MS (left) and at EU-28 level (right) according to assessed Green-X scenarios

Figure 3-11 illustrates direct economic impacts of increasing RES deployment. While benefits in terms of fossil fuel (and specifically gas) replacement are discussed later, above we focus on direct costs and expenditures that come along with an enhanced RES deployment both from a system perspective (i.e. additional generation costs for RES compared to the reference scenario based on conventional power sources) as well as when looking at distributional effects among different actors (i.e. support expenditures for RES that are transferred from energy consumer to RES producer). Thus, Figure 3-11 provides a summary of both and offers also an illustration of the necessary investments into RES. Scenario-specific results are shown at 12 MS level and for comparison also for the EU in total (EU-28). Not surprisingly, increasing RES deployment as assumed in the alternative policy cases requires additional investments: on average throughout the period 2021 to 2030 yearly capital expenditures increase by 14-18% compared to baseline according to the derived alternative policy scenarios.

Figure 3-12 and Figure 3-13 show those capital expenditures and the change of these capital expenditures compared to the Baseline case at MS level.

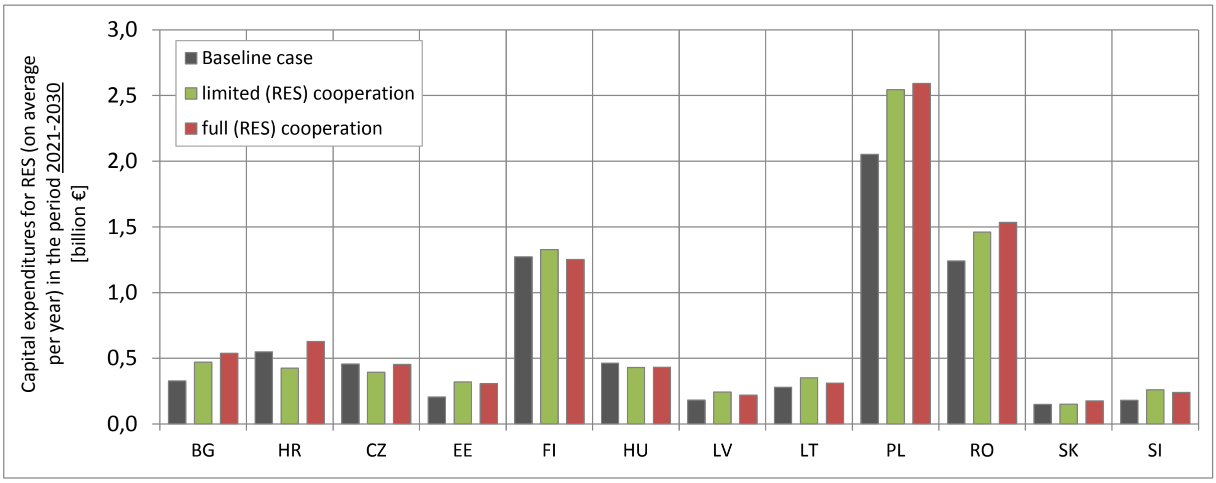

Figure 3-12: Average yearly capital expenditures for RES in the period 2021 to 2030 at MS level

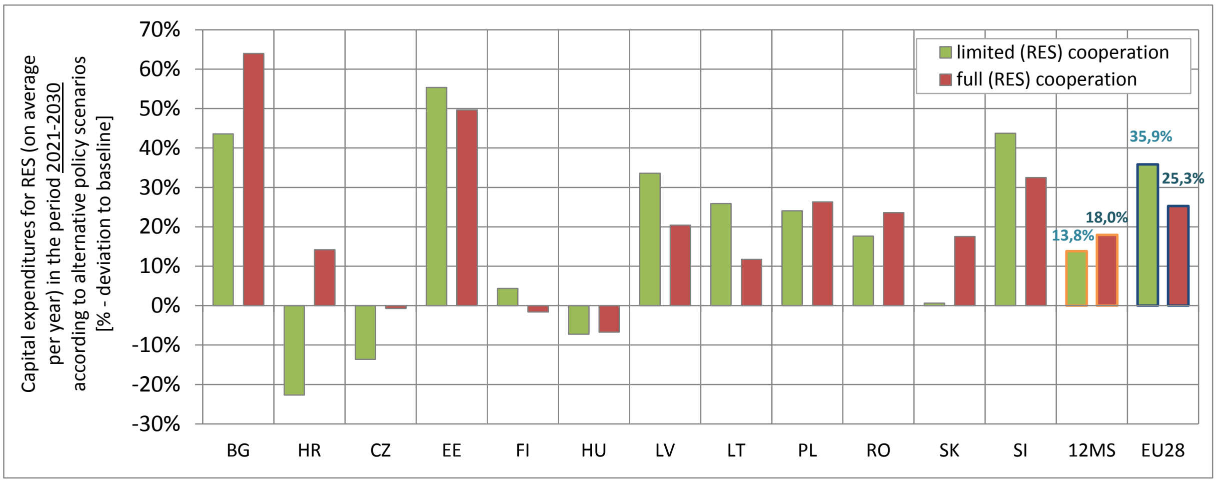

Figure 3-13: Change in average yearly capital expenditures for RES compared to the Baseline case in the period 2021 to 2030 at MS level

This comes along with an increase in system costs – i.e. additional generation costs rise by 12-30%, corresponding to additional costs in range of € 0.2-0.4 billion on average per year at 12 MS level. The increase in system costs is more pronounced if national RES policies remain the key driver for investments and, in turn, RES cooperation across the EU is limited as assumed in the case of limited (RES) cooperation. Contrarily, under a more harmonised policy framework (i.e. full (RES) cooperation), where resource allocation across countries follows a least-cost approach, the increase in generation costs can be classified as moderate.

Figure 3-14 shows the above explained additional generation costs at MS level and Figure 3-15 shows the change in additional generation costs compared the to the Baseline case. Hungary would have the most significant rise in additional generation costs, whereas Romania could even face a reduction until 2030.

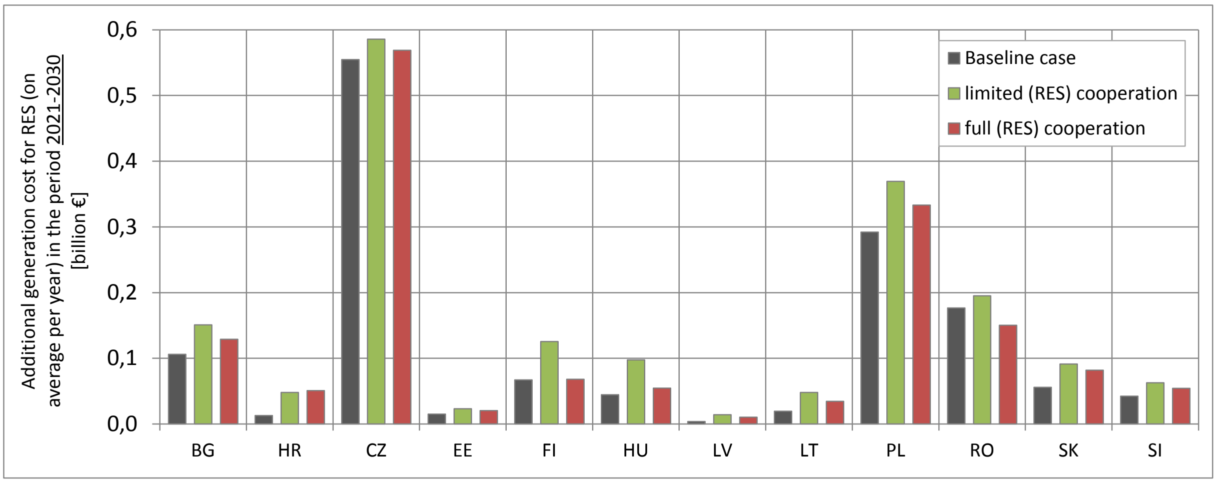

Figure 3-14: Average yearly additional generation costs for RES in the period 2021 to 2030 at MS level

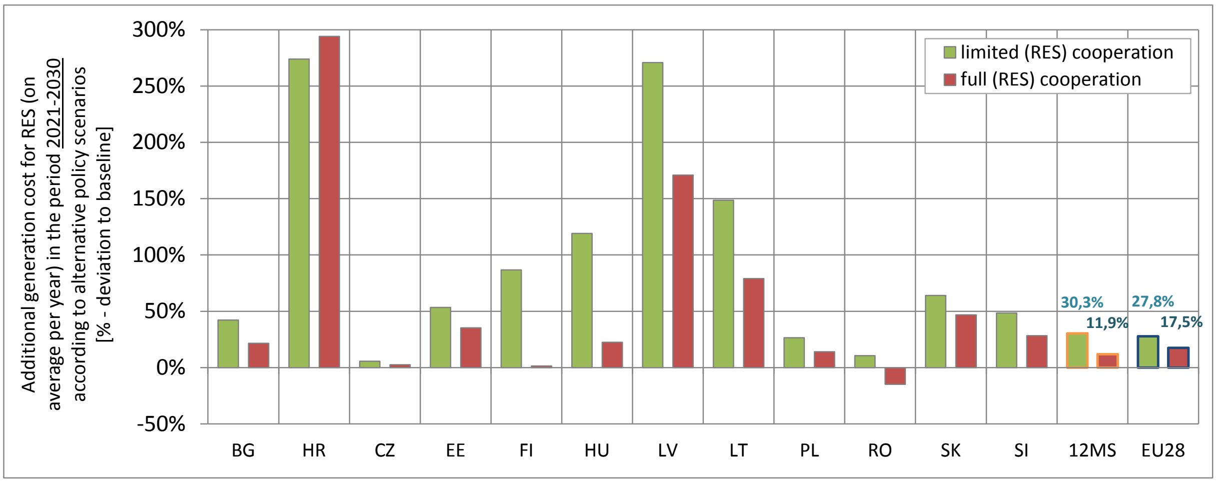

Figure 3-15: Change in average yearly additional generation costs for RES compared to Baseline case in the period 2021 to 2030 at MS level

Support expenditures for RES, generally named as "policy cost", show a different pattern. Remarkably, at the aggregate of our 12 focus countries (12 MS) savings in terms of support expenditures can be identified compared to baseline, partly of significant magnitude: according to our assessment € 2-2.1 billion (or 40-41%) can be saved compared to baseline on average per year in the period 2021 to 2030 if alternative policy pathways are pursued. This is a consequence of improved framework conditions (i.e. removal of non-economic barriers) and, in turn, an increased deployment of cheap to moderate RES potentials that would otherwise remain untapped. In Figure 3-16 the total support expenditures for RES is shown on MS level and in Figure 3-17 the change compared to the Baseline case. The change of the support expenditures in the assessed scenarios is very different among the 12 MS and also between the group of 12 MS at large and the EU-28 at large. While there is an increase in support expenditures on the EU-28 level, there is a significant decrease on the 12 MS level.

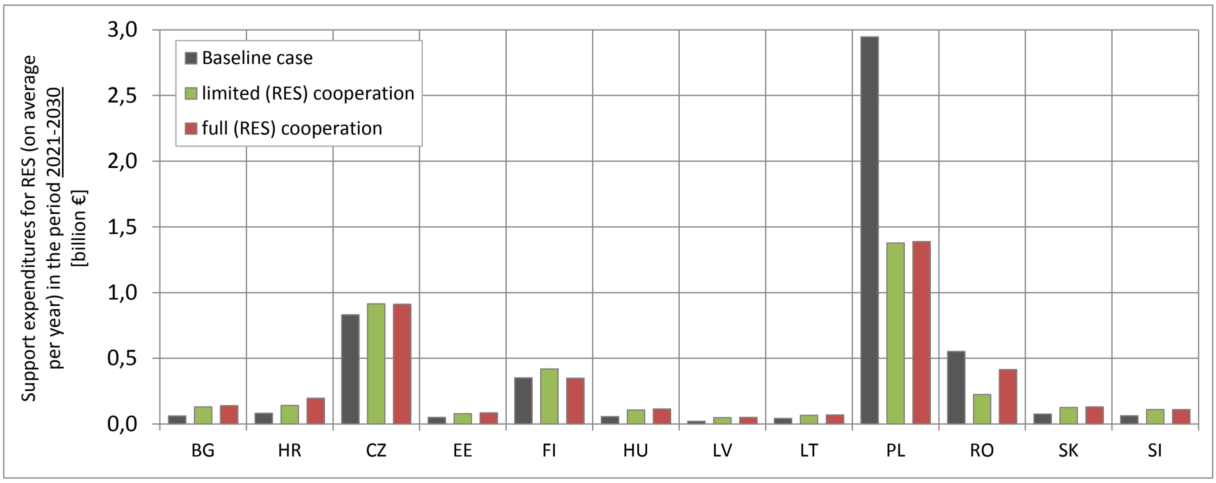

Figure 3-16: Average yearly support expenditures for RES in the period 2021 to 2030 at MS level

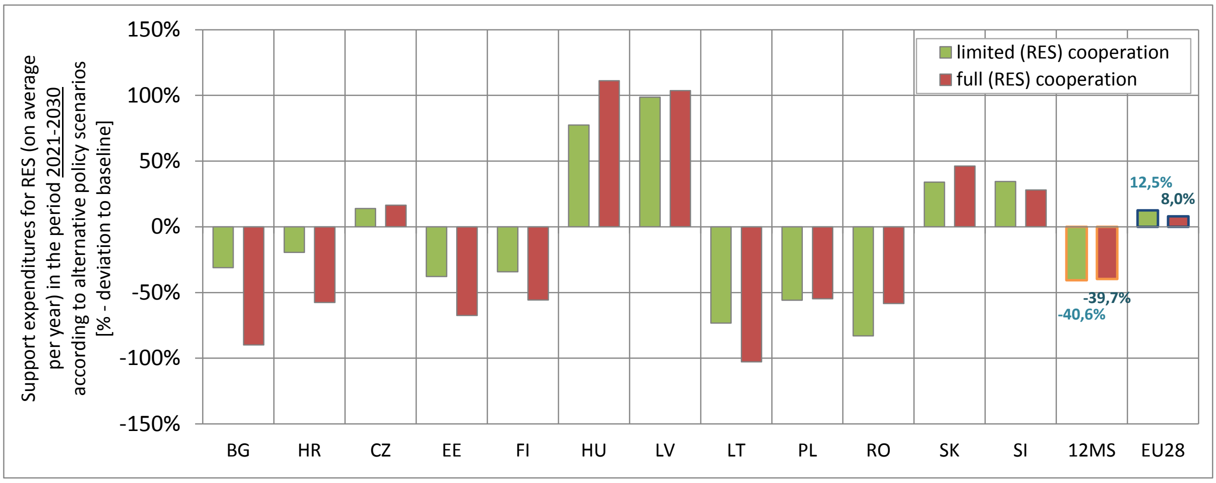

Figure 3-17: Change in average yearly support expenditures for RES compared to Baseline case in the period 2021 to 2030 at MS level

Note, however, that the post-2020 EU-wide RES policy framework, in particular the effort sharing across Member States of a (possible) European 2030 RES target, has a significant impact on the magnitude of savings: if RES-related support expenditures have to be borne by the country where deployment takes place, cost savings are somewhat smaller for the 12 MSs, i.e. ranging from 23-27% (compared to baseline). In our assessment, in both alternative policy paths, the final allocation of policy costs across countries follows however again the logic of national RES targets that similar to 2020 consider the economic wealth of countries. This leads to a moderate monetary redistribution from "West to East" and from "North to South", causing the increase in savings.

3.2.3 Summary of results

Finally, Table 3-3 provides a summary of the impacts of alternative policy scenarios for renewables and energy efficiency at 12 MS level, expressing the demand reduction due to energy efficiency and the increase in RES deployment as well as accompanying direct economic impacts. Complementary to that, Figure 3-18 shows the resulting reduction in demand for fossil energy in general, and for gas in particular.

Table 3-3. Summary of impacts of alternative policy scenarios for renewables and energy efficiency at 12 MS level

Impact of alternative policy scenarios for renewables & energy efficiency at 12 MS level - indicating the change compared to baseline			
Energy efficiency:	Unit	Low Policy Initiatives (LPI) case	
Gross final energy demand 2030	TWh	-219.3	
Net cost of energy efficiency measures	billion € (on average per year (21-30))	-3.5	
		Alternative policy cases	
Renewables:	Unit	Limited (RES) cooperation	Full (RES) cooperation
RES generation 2030	TWh	114.9	109.8
Additional generation cost (for RES)	billion € (on average per year (21-30))	0.4	0.2
Support expenditures (for RES)	billion € (on average per year (21-30))	-2.1	-2.0

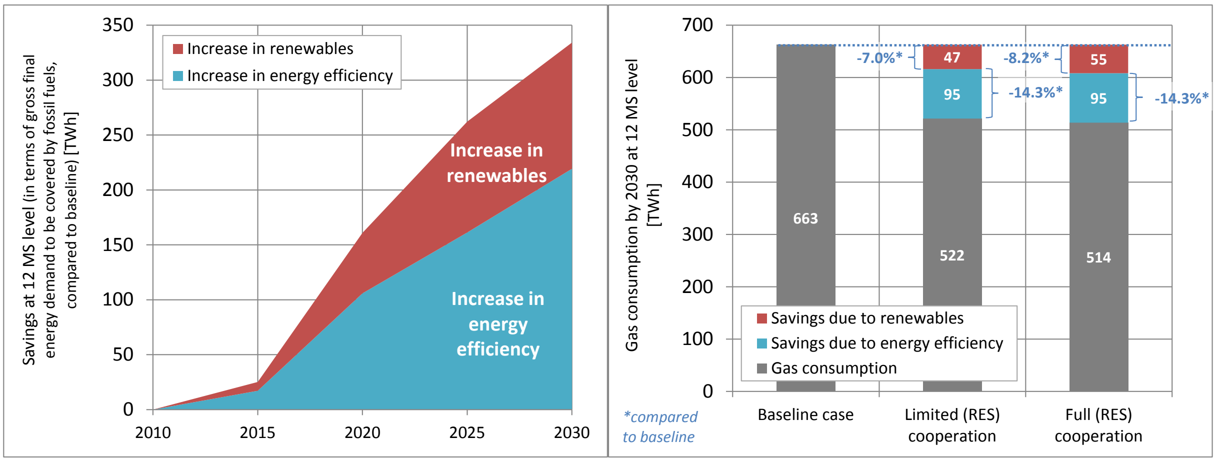

Figure 3-18: Reduction of fossil energy (left) and gas consumption (right) under two alternative renewables and energy efficiency policy scenarios in the assessed 12 Member States

3.3 Gas-marked modelling: Assessing the impacts of reduced gas demand on gas supply security

This section is dedicated to the gas market impacts of the previously described renewable and energy efficiency policies. As these policies have inter alia impacts on the gas demand of the various Member states, they also help to ease the gas dependency of Europe. Although it is a frequently mentioned positive side effect of these policies, quantifying their impact on the gas market from energy security point of view is a complex task, as it requires a harmonised assessment of both these policies as well as the gas market developments in the longer term future. This interaction in the timeframe of 2030 can only be captured with a detailed modelling exercise, where all the three areas: energy efficiency policies, renewable policies and gas market specific policies are handled in an integrated manner. This work is carried out here, where a detailed gas market model is applied to assess the gas market impact of the previously described policies. Although full blown energy models - having all sectors integrated in their model - could do similar job, we see a real value added in this work. The gas model applied has a most up-to-date and detailed infrastructural and contractual description of the European markets, which are in other integrated models are rather superficial. In addition the model includes the Energy Community members in full details – having important trade relations with many of the 12 MS countries, which is expected to grow in the long term – so this way we could also capture their impact on gas markets of the focus countries.

In order to capture the full potential, what the renewable and efficiency polices could bring to Europe, two gas market scenarios are investigated in this chapter differing in the treatment of the Russian gas contacts of the Member States: a more realistic re-negotiation scenario, and a compete breaking up scenario of the Russian long term contacts. These scenarios are introduced in details later. Our objective with the two alternative scenarios is to introduce the impacts of a more realistic (re-negotiation) scenario, as well as a scenario with an extreme commitment from the EU side to terminate with the long term gas contracts. This assessment is carried out with fully integrating the impacts on gas demands of the energy efficiency and renewable scenarios elaborated by Fraunhofer ISI and TU Vienna.

We measure gas market impacts with the price effects of the abovementioned assumptions, and as the gas model provides with the demanded quantities in each Member States it enables us to also calculate the 'gas bill' of the countries in the various scenarios. By this way we quantify the impacts of the described policies, if they are applied in an integrated manner.

In the following chapter the main assumption behind the gas market scenarios (on the infrastructure development, on the contracting terms) and the impacts on prices and on the gas cost of the various Member States will be introduced. The chapter will focus on the 12 Member States that are most exposed and vulnerable to the long term gas contracts, but also result on the EU 28 will be presented.

3.3.1 Method of approach and key assumptions

REKK's European Gas Market Model has been developed to simulate the operation of an international wholesale natural gas market in whole Europe. The geographical scope of the model is the EU countries (without Cyprus and Malta) and the Energy Community countries, including Ukraine. For each country the demand and supply side of the local market, as well as gas storages are explicitly included. Large external markets, such as Russia, Turkey, Libya, Algeria and LNG exporters are represented by exogenously assumed market prices, long-term supply contracts and physical connections to Europe.

For our reference scenario, which has to represent the European market as of today (2013-14), we used the infrastructure setting as of July 2014, based on Gas Infrastructure Europe data on pipelines, LNG and storages. The tariff fees are 2014 tariffs calculated for each border point for a standard firm capacity product assuming a 80% load factor. Storage fees are calculated for a one year storage contract and are uniform for all storage facilities in a country. LNG shipping costs are dependent on the length of the shipping route between the import and export points. Long term pipeline contract prices are the last available data from open sources, while LNG prices are calculated as the Japanese LNG price (in the reference 40 €/MWh) corrected by the shipping cost of LNG to the European LNG terminals.

The yearly marginal gas price and consumption of each country at that price are outputs of our model. The product of these two is the yearly gas purchase cost for each country. Our aim is to calculate this yearly gas purchase cost for each analysed country (12 MS) and for the EU-28 for 2020 and for 2030 under different scenarios of gas demand, as a result of distinct European policy scenarios related to energy efficiency and renewables (see section 3.2). We assume, as shown in Table 3-4, that short term key infrastructure projects will be built by 2020 and mid-term key PCI projects will be built by 2030. The infrastructure setup is the same for all scenarios to allow a useful comparison of the results.

Table 3-4. Infrastructure assumptions for the 2020 and 2030 modelling years

PCI projects	Short-term (2020)	Mid-term (2030)
interconnectors	SK-HU, GR-BG, RS-BG	PL-LT, FR-ES, PL-SK, PL-CZ, EE-FI, LV-LT
reverse flows	RO-HU, HR-HU, HU-UA, SK-UA	
LNG	Poland, Lithuania	Croatia, Estonia, Greece
storage	upgrade in Bulgaria	
international trans-mission		TAP/TANAP

In the **base case**, where we use gas demand forecast for 2020 and 2030 in a business as usual case, and we assume that no change in the Russian contract structure occurs. From this scenario we expect to learn about the gas cost of the region under present market conditions and without any additional effort to decrease gas consumption.

The two RE+EE policy scenarios of EGMM modelling (**limited and full cooperation**) differ only in the gas demand figures, that are output of the detailed assessment of enhanced renewable energy and energy efficiency policy interventions presented in section 3.2 of this paper.

The rationale behind RE+EE investments from a gas market energy security point of view is that reduced demand will reduce import dependency, and hence decrease the vulnerability of the analysed countries against one single gas supplier (Russia). It is important to keep in mind that the present market structure is frozen with long term (take-or-pay) contracts between Russia and the analysed countries or their former incumbent company. Without any change in the contractual situation, any RE+EE related gas demand decrease would increase the Russian imports share in the total consumption, given that take or pay obligations force buyers to use Russian gas in the first place, so alternative sources or domestic production would lose their shares.

Long term take-or-pay contracts by nature do not adapt to changing market conditions fast. However re-negotiations are not unprecedented; demand has also dropped due to the economic crisis that created over-supply on the European market in the last few years due to substantial amount of take-or-pay in the long term supply contracts of the region with Russia. The European contract parties re-negotiated the contract terms with Russia, with smaller annual contract quantities and decreased prices. To reflect the potential changes of long term contracts in the modelling scenarios, we used two different sub-scenarios

a.) **Re-negotiation scenario**: We assume that the demand reduction of the analysed countries due to energy efficiency investments will reduce the Russian long term contract's annual contract quantity proportional[14]. This can be done through re-negotiations of contract quantity with Russia, where price of the individual contracts remains as they are in 2014 (between 28 and 37 €/MWh).

b.) **Breaking up scenario**: We assume that Russian long term contracts are completely resolved. This does not mean that Russian gas cannot be purchased in the analysed countries, but Russian gas will be purchased on a one year or shorter contract base and on a higher Russian gas price (37.2 €/MWh).

[14] For the other long-term contracts we also apply the proportionate reduction on the annual contract quantity. For the LNG contracts a cargo-diversion was already visible in the last few years: where market demand dropped and prices were low, parties agreed to send some cargos to the Asian market where much higher profits could be obtained.

3.3.2 Modelling results

Base case scenario

Yearly average gas prices of the analysed countries vary in the range of 28-37 €/MWh in 2012. Due to better interconnectivity through realization of key PCI investments will result in a price convergence, where all prices are in the range of 29-36 €/MWh. In 2030 prices converge again, and regional differences grow again. Prices vary between 12 and 33 €/MWh. Baltic countries experience a low price due to investment into LNG infrastructure, and hence to oversupply of the market. The Russian LTC contracts have to be taken, and take-or pay obligation will create losses for the incumbent companies that own the contract. Balkan countries benefit from new gas source delivered through TAP, but there might also be a tension because of take-or pay obligation towards Russia. Visegrad countries converge even more than in 2020, due to better interconnectivity through finalization of the North-South corridor.

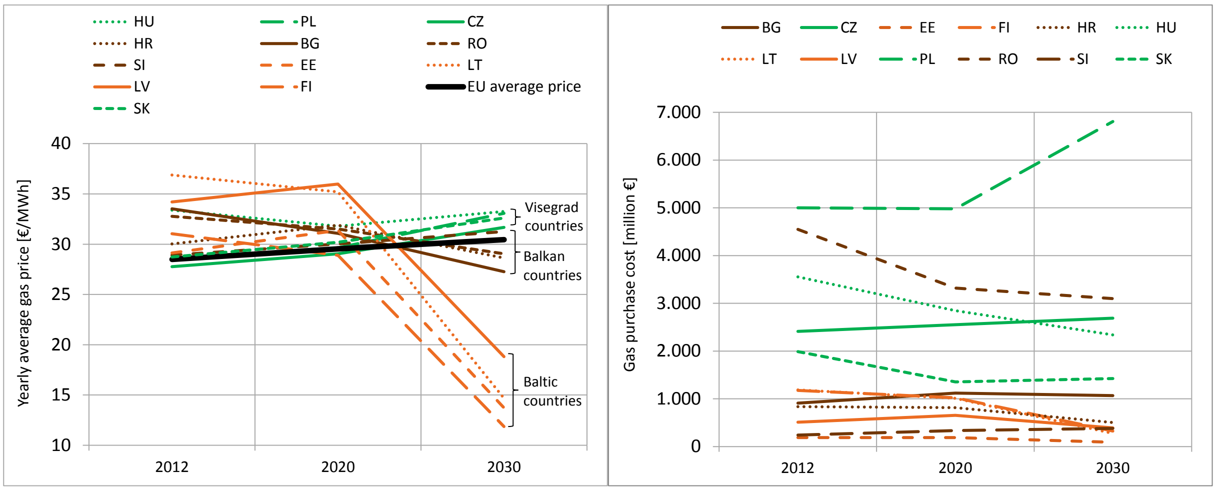

Figure 3-19. On the left: Yearly average gas price in €/MWh, On the right: Gas purchase cost of the analysed countries in the base case (million €). Source: REKK modelling

Message: investing only to gas infrastructure would create a price convergence on the short term (2020), but on the mid-term time horizon (2030) regional markets would re-emerge.

Gas purchase cost is reducing already in the base case, due to price decrease and to stagnating (or even decreasing) gas consumption. The only exception is Poland where gas consumption is expected to increase heavily by 2030 (see Figure 3-19).

Re-negotiation scenario

This scenario is the closest to reality, because it does not neglect the present contractual limits of the region, but allows for a slow adjustment to new market conditions. RE+EE policies combined with infrastructure investment do not materialize in rapid price decrease, however by 2030 a massive price reduction can be achieved, especially in the countries that have access to LNG (see Figure 3-20).

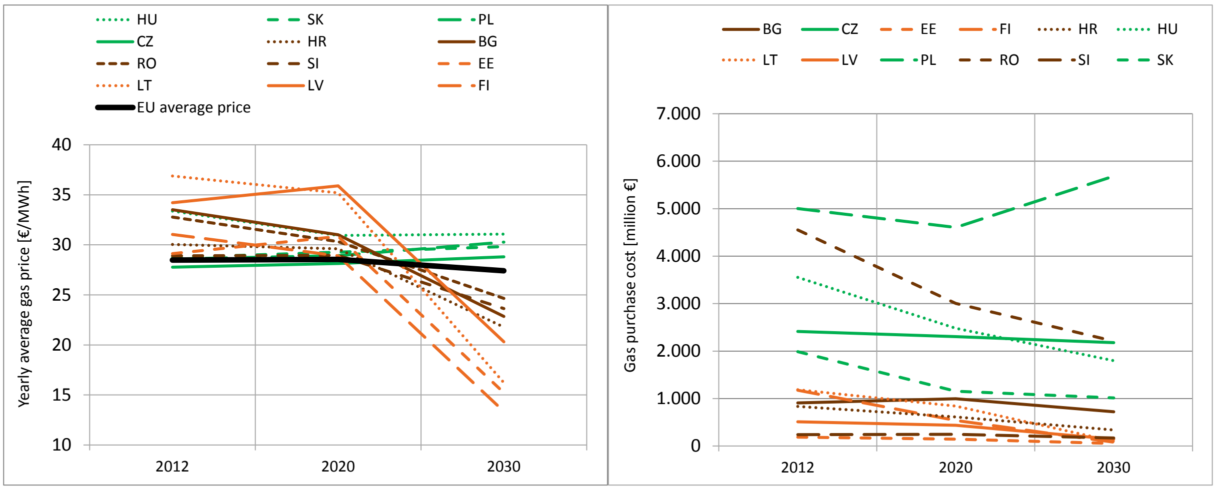

Figure 3-20. On the left: Yearly average gas price in €/MWh, On the right: Gas purchase cost of the analysed countries in the limited cooperation & re-negotiation of contracts case (million €). Source: REKK modelling

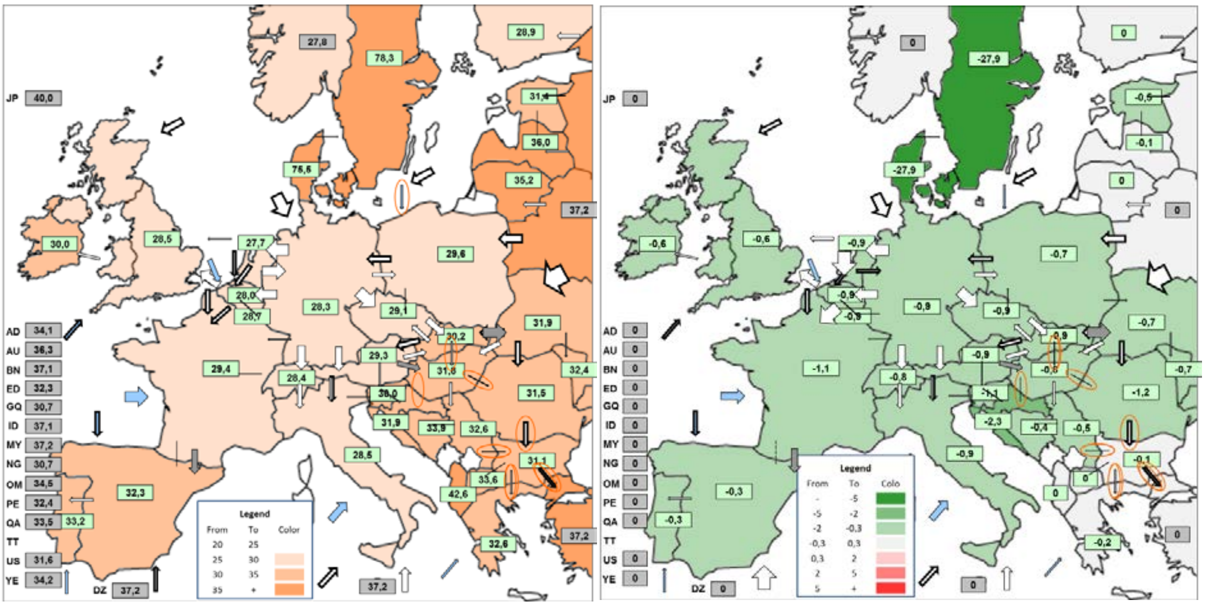

Figure 3-21. On the left: yearly average prices (€/MWh) in the base case 2020, On the right: yearly average prices €/MWh) in the limited &re-negotiation scenario 2020*. Source: REKK modelling

Blue arrows: LNG flows, white arrows: modelled gas flow on interconnectors, congested when coloured; Grey boxes: outside market prices. Colouring of countries: in the reference base case darker orange where prices are higher; in the analysed scenario (limited energy efficiency & renegotiation) green for those that experience a price decrease compared to reference, red for countries that experience a price increase compared to reference

***Sweden and Denmark have very high prices in the base case due to decrease in the Danish local production, and lack of interconnectivity with Europe**

Figure 3-21 visualize the effect of the limited energy efficiency scenario on average yearly natural gas prices, On the left the base case 2020 gas prices are indicated in the boxes for each modelled country. On the left all countries turn green, meaning that by 2020 an RE+EE policy driven gas consumption decrease, combined with renegotiation of long term contracts annual contract quantity results in a drop of natural gas prices (the difference to prices in the base case is indicated in the green boxes). For the full cooperation scenario the same pattern applies.

Breaking up scenario

In the limited cooperation scenario reduced gas demand in 2020 cannot compensate for the lack of Russian long term contracts in the region. The Russian gas, that has to be purchased on a short term basis and on higher price than the previous long term contract price leads to a general price increase for the analysed countries. In 2030 price increase does not continue, except for Romania, where domestic production has to be substituted by imported gas. Slovenia and Croatia experience the lowest prices being a relative small market with good interconnectivity and by 2030 the Croatian LNG being in place. They are fine without any Russian gas deliveries in 2030. The rest of the analysed countries are well above the EU average price (see). The existing interconnectors from Western Europe are fully utilized in 2030, and being congested they cannot transfer the Western European gas sources to this region. Gas purchase cost of the region is reducing, in all countries, except for Poland where it is stagnating after a sharp increase in 2020. In both the limited and in the full cooperation scenario the same pattern is visible (see Figure 3-21).

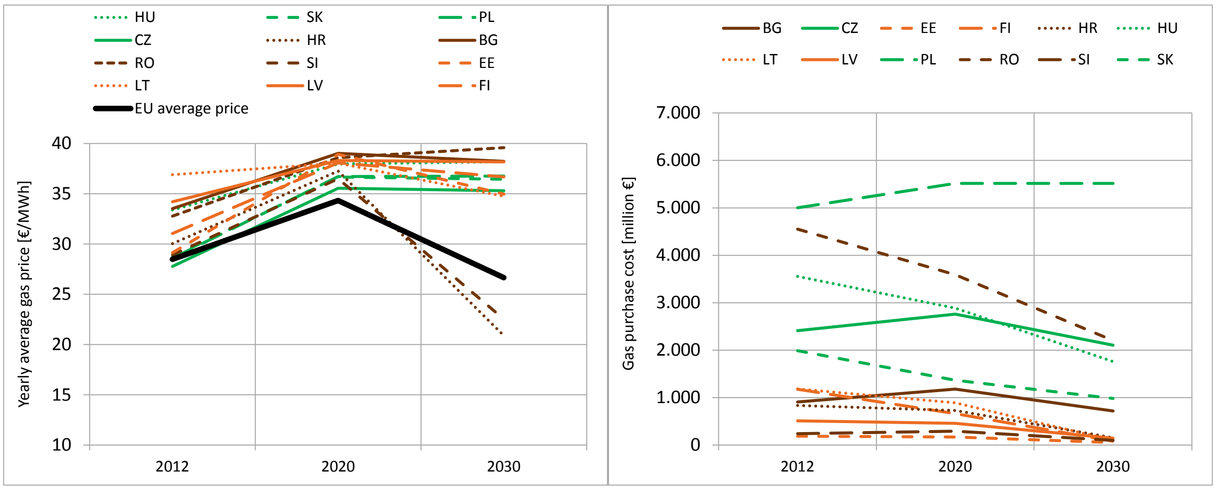

Figure 3-22. On the left: Yearly average gas price (€/MWh) On the right: Gas purchase cost (million €) in the analysed countries in the limited cooperation (breaking up) scenario. Source: REKK modelling

3.3.3 Summary of results

We modelled three gas policy options for Europe, and analysed their effect on gas prices and gas purchasing cost on those countries where Russian imported gas is the dominant source of supply:

1.) Base case, assuming that in the next 15 years a business as usual way in the European gas market context will prevail.
2.) Re-negotiation scenario: where there is a mutual cooperation on both sides (Russia and the EU member counterpart) to keep Russian gas business going on, but as an exchange for that Russia is willing to deliver gas according to the needs of the countries and renegotiate contract volumes (or in other words eliminates the take-or-pay obligation).
3.) Breaking up scenario: in this scenario we assume that Russian contracts are denounced, with the aim to measure to what extend Russian gas can be substituted on a market base in Europe.

Main findings of the modelling work (see Table 3-5) can be summarized as follows:

Modelling suggests that demand reduction through renewable energy and energy efficiency policies alone cannot allow for this region to fully abandon Russian supplies. If the goal would be to replace Russian import fully, more investment into the congested EU network would be needed.

In the base case the price difference that we observed in the last years between Western Europe and the analysed Russian gas dependent countries is eliminated due to better interconnectivity of the European gas markets. Even in the base case EU gas purchase cost is decreasing from 2012 to 2020 and 2030, but the volume of Russian gas and the Russian gas dependency is increasing.

The re-negotiation scenario is applied only in combination with enhanced energy efficiency and renewable energy policies which result in massive gas demand reduction on an EU level, about 80 TWh reduction by 2020 and about 148-155 TWh reduction by 2030 compared to the base case scenario. In both the limited and in the full cooperation case there is a price decrease on EU-28 and 12 MS level as well, that is reflected in a reduction of gas purchase cost, on the level of assessed 12 MS as an aggregate savings amount to € 2.8 billion by 2020 and € 4.9 billion by 2030, respectively.

The same RE+EE scenario combined with a breaking up policy would on a 2020 horizon lead to an increase gas-related expenditures of € 318 million, which is the cost of eliminating all Russian contracts in 2020. Interesting to note is that by 2030 the breaking up policy would bring benefits on a 12 MS level compared to our base case scenario.

Eliminating Russian dependency on natural gas supply to a very low level is possible (i.e. 79 TWh/year gas imports from Russia in the full cooperation scenario, assuming that Russian long-term contracts and the related take-or-pay obligations are cancelled, and Russian gas is purchased on a short term base competing with other sources. without Russian contract). None of the analysed countries would experience skyrocketing natural gas prices. This could be achieved on a market basis, through better interconnectivity and energy efficiency and renewable energy driven gas demand reduction.

Table 3-5. Summary of results

	Base scenario			Limited scenario				Full scenario	
				2020		2030		2030	
	2012	2020	2030	Renegotiation scenario	Breaking up scenario	Renegotiation scenario	Breaking up scenario	Renegotiation scenario	Breaking up scenario
Gas demand saving in 12 MS (TWh)					79.3		147.6		155.6
Average price in EU 28 (€/MWh)	28.5	29.5	30.4	28.5	34.3	27.4	26.7	27.5	25.3
Average price change in EU28				-1.0	4.8	-3.0	-3.8	-3.0	-5.2
Average price in 12 MS (€/MWh)	30.8	30.8	29.7	29.9	37.3	27.8	36.5	27.7	36.5
Average price change in 12 MS				-0.8	6.6	-1.9	6.8	-1.9	6.8
Gas purchase cost in 12 MS (m €)	22547.4	20190.6	19389.3	17366.7	20508.6	14492.0	17866.2	14253.4	17596.8
Gas cost savings in 12 MS (m €)				-2824.0	318.0	-4897.3	-1523.0	-5135.9	-1792.5
Russian gas in EU 28 (TWh)	1227.5	1244.7	1272.7	1058.0	112.7	918.0	133.9	893.0	78.9
Russian gas decrease in EU28 (TWh)				-186.7	-1132.1	-354.7	-1138.8	-379.7	-1193.7

To highlight the most important results for the EU 28 and the 12 MS, they are also presented in the following three graphs in a more clear-cut manner. They highlight the quantity of natural gas purchased from Russia, and the gas cost saving resulting in the modelled scenarios.

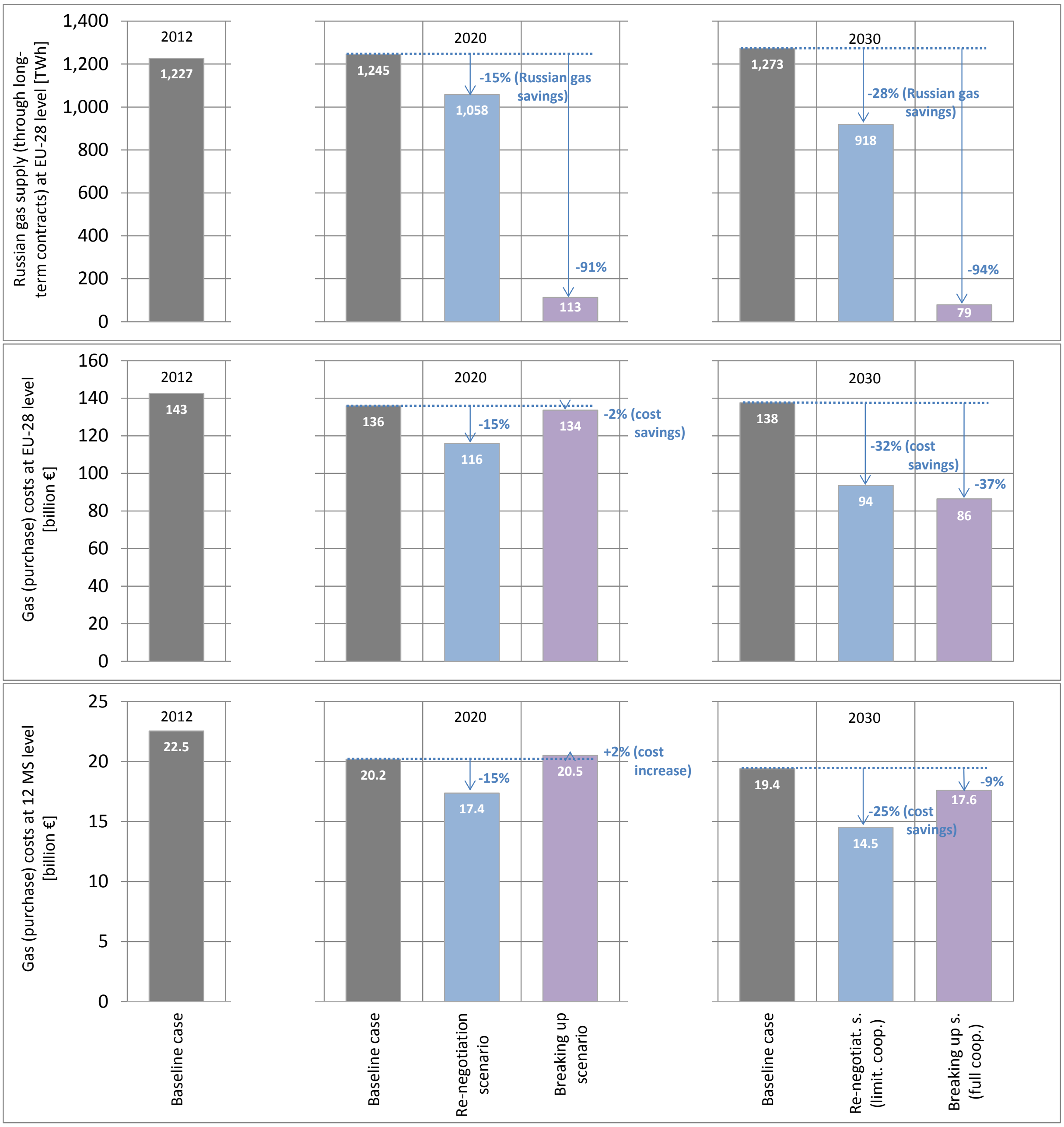

Figure 3-23. Key results from the gas market assessment for 2012, 2020 and 2030 according to (selected) assessed scenarios: Russian gas supply at EU-28 level (top), Gas purchase cost at EU-28 level (middle) and at 12 MS level (bottom)

Figure 3-23 shed light on an additional important impact of the assumed scenarios. While we were focusing on the 12 MS most affected by the present gas market situation due to the Ukrainian-Russian conflict, the figure illustrate that the impacts of the modelled policies – renewable, energy efficiency and gas market interventions – would bring significant benefits not only for the 12 MS but also for the whole Europe as well. What we can observe is that cost savings are in a range of 10-25 % for the 12 MS and 30-37 % for the EU28 by 2030 in the modelled scenarios.

Interesting to see that the breaking up scenarios does still bring benefits in the long term (by 2030), although there are costs in the beginning of the period (in 2020). While the break up scenario would significantly reduce Russian gas brought to the EU markets under long term contracts, substitution of long-term contracted Russian gas does not need significant extra costs neither for the 12 MS nor for the EU 28 gas consumers when compared to the re-negotiation results.

4 Conclusions

The main findings of this assessment can be summarised as follows:

- Energy efficiency measures can reduce the gas demand of the assessed Member States on the eastern border of the EU by 14 % while resulting in average net savings of € 3.5 billion per year. For doing so, according to the detailed study on energy efficiency policies in the EU led by Fraunhofer ISI (Braungardt et al., 2014) only a moderate policy intervention is required, meaning that all policy measures currently implemented as well as their upcoming revisions are enforced and a selection of new policy measures is introduced.
- A strong deployment of renewables as anticipated in the alternative policy scenarios (of limited / full RES cooperation) leads to increases in system costs and support expenditures at EU-28 level but for the assessed 12 Member States this may even lead to savings in support expenditures for renewables in range of € 2.0-2.1 billion per year in the period post 2020, which is mainly due to improved framework conditions (i.e. removal of non-economic barriers).
- The increase in renewables and energy efficiency comes along with benefits related to Europe's trade balance due to a (significantly) decreased demand for fossil fuels and related imports from abroad. Thus, natural gas demand can be reduced by more than 20% in the assessed countries, if a 30% target for renewables and energy efficiency by 2030 is aimed for.
- From the detailed gas market modelling we can conclude that it seems feasible to reduce Russian dependency on natural gas supply to a very low level without causing skyrocketing natural gas prices in any of the EU member countries. As most extreme case we analysed the scenario of increased renewables and energy efficiency combined with a "breaking up" policy of long-term gas contracts, assuming that Russian long-term contracts and the related take-or-pay obligations are cancelled, and Russian gas is purchased on a short term base competing with other sources. In this scenario it is possible to reduce Russian gas imports to 79 TWh/year, which is 6.5% of the present level. This can be achieved on a market basis, through better interconnectivity and energy efficiency and renewable energy driven gas demand reduction.
- Security of supply benefits of the EU renewable and energy efficiency policies can only be achieved, if the infrastructure development policy of the EU is realised in a consistent manner – this concerns in particular the gas infrastructure but also the power grid.
- From a gas market perspective this means that the selected infrastructural projects of common interest as well as the decisions on the reverse flow upgrades on the selected EU interconnectors must be enforced, their accomplishment is a key factor in achieving the benefits quantified in this paper.
- There are important impacts not only on the 12 Member States as results show, but also on the whole EU. This means that there are important drivers for a general EU involvement, opening up opportunities to achieve a win-win situation for all European countries in the case of a coordinated intervention.

5 References

European Commission. 2013a. GREEN PAPER. A 2030 framework for climate and energy policies. COM(2013) 169 final. Brussels, 3 March 2013

European Commission, 2014a. European Energy Security Strategy. Com(2014) 330 final. Brussels, 2 July 2014

European Commission, 2014b. In-depth study of European Energy Security. SWD(2014) 330 final/3. Brussels, 2 July 2014

European Commission. 2014c. A policy framework for climate and energy in the period from 2020 to 2030. COM (2014) 15 final. Brussels, 22 January 2014

Jansen, J.C., Seebregts, A.J., 2010. Long-term energy services security: What is it and how can it be measured and valued? Energy Policy, 38(2010), 1654-1664.

Jewell, J., Cherp, A., Riahi, K.. 2014. Energy security under de-carbo ization scenarios: An assessment framwe-work and evaluation under different technology and policy choices. Energy Policy, 65(2014), 743-760.

Le Coq, C., Paltseva, E., 2009. Measuring the security of external energy supply in the European Union. Energy Policy 37(2009). 4474-4481

Percebois, J., 2006. Dependance et vulnerabilité: deux façons connexes mais differantes d'aborder les risques énergétiques. Cahier no. 06.03.64. CREDEN Cahiers de recherche. Université de Montpellier

6 Annex: Technology-specific RES deployment by 2030 at Member State level according to Green-X scenarios

Table 6-1: Technology-specific RES deployment by 2030 at MS level according to the Green-X baseline scenario

General legend	[Unit]	EU28	Bulgaria	Croatia	Czech Republic	Estonia	Finland	Hungary	Latvia	Lithuania	Poland	Romania	Slovakia	Slovenia	12MS
Country comparison		**EU28**	**BG**	**HR**	**CZ**	**EE**	**FI**	**HU**	**LV**	**LT**	**PL**	**RO**	**SK**	**SI**	**12MS**
Energy production from RES in 2030 (national deployment)															
RES-E - Energy output															
Biogas	TWh	54.6	0.1	0.1	1.0	0.1	0.4	0.7	0.1	0.1	1.5	0.3	0.1	0.5	5.0
Solid biomass	TWh	150.1	0.9	0.4	4.6	1.1	16.1	3.0	0.1	0.3	21.3	1.2	2.6	0.9	52.7
Biowaste	TWh	32.3	0.2	0.0	0.1	0.1	0.6	0.6	0.0	0.0	1.2	0.5	0.1	0.2	3.6
Geothermal electricity	TWh	12.2	0.1	0.1	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.8	0.0	0.1	1.9
Hydro large-scale	TWh	329.5	4.2	7.4	1.1	0.0	12.9	0.4	3.6	0.4	1.4	18.9	4.8	4.9	59.9
Hydro small-scale	TWh	57.0	1.8	0.6	1.4	0.0	1.7	0.1	0.2	0.2	1.4	1.3	1.3	0.8	10.7
Photovoltaics	TWh	124.8	0.5	0.1	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.2	3.5
Solar thermal electricity	TWh	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tide & wave	TWh	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind onshore	TWh	485.2	1.0	5.1	1.5	1.8	1.0	2.3	0.4	3.3	31.8	6.3	0.1	0.2	54.7
Wind offshore	TWh	17.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
RES-E total	TWh	1,268.6	8.7	13.8	12.1	3.0	32.7	8.0	4.4	4.3	58.6	29.4	9.3	7.7	192.1
RES-E CHP	TWh	188.2	1.0	0.3	4.2	0.9	17.1	3.4	0.2	0.3	11.5	1.4	2.0	0.9	43.3
Decentralised PV	TWh	57.5	0.2	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	1.6
RES-H - Energy output															
Biogas (grid)	TWh	27.9	0.0	0.0	0.7	0.0	0.3	0.1	0.1	0.0	0.5	0.0	0.1	0.1	2.0
Solid biomass (grid)	TWh	226.5	3.7	1.4	8.1	3.2	31.0	4.4	4.1	4.1	17.0	6.2	5.7	0.7	89.7
Biowaste (grid)	TWh	50.8	0.3	0.1	0.1	0.1	1.4	1.0	0.0	0.1	2.0	0.8	0.2	0.3	6.3
Geothermal heat (grid)	TWh	19.1	0.6	0.2	0.1	0.0	0.0	2.7	0.0	0.0	1.0	1.0	0.9	0.2	6.8
Solid biomass (non-grid)	TWh	855.8	11.4	10.2	20.7	8.0	59.2	11.3	10.0	9.9	62.3	48.4	6.5	6.1	264.3
Solar thermal heating and hot water	TWh	40.5	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.9	0.0	0.2	3.0
Heat pumps	TWh	167.0	0.0	1.0	0.6	0.1	9.1	0.0	0.0	0.0	2.7	0.0	0.0	0.1	13.7
RES-H total	TWh	1,387.4	16.3	13.1	30.3	11.5	101.1	19.6	14.3	14.2	85.9	58.3	13.4	7.7	385.8
RES-H CHP	TWh	198.4	1.1	0.3	4.8	1.1	22.1	2.4	0.3	0.4	15.4	1.6	2.1	0.8	52.4
RES-H district heating	TWh	125.8	3.4	1.3	4.2	2.2	10.7	5.8	3.9	3.9	5.2	6.4	4.9	0.5	52.3
RES-H non-grid	TWh	1,063.2	11.8	11.5	21.3	8.1	68.4	11.3	10.0	10.0	65.3	50.3	6.5	6.4	281.0
RES-T (biofuels) - Energy consumption															
RES-T total	TWh	83.7	0.0	0.0	1.3	0.4	0.7	2.8	0.2	2.5	19.2	2.0	0.6	0.4	30.1

Table 6-2: Technology-specific RES deployment by 2030 at MS level according to the Green-X scenario of limited RES cooperation

General legend	[Unit]	EU28	Bulgaria	Croatia	Czech Republic	Estonia	Finland	Hungary	Latvia	Lithuania	Poland	Romania	Slovakia	Slovenia	12MS
Country comparison		**EU28**	**BG**	**HR**	**CZ**	**EE**	**FI**	**HU**	**LV**	**LT**	**PL**	**RO**	**SK**	**SI**	**12MS**
Energy production from RES (ALL) in 2030 (national deployment)															
RES-E - Energy output															
Biogas	TWh	76.4	0.5	0.4	1.3	0.2	0.7	1.3	0.2	0.3	4.1	1.8	0.4	0.5	11.8
Solid biomass	TWh	218.4	2.5	0.8	5.9	1.1	18.5	4.2	0.8	1.1	21.4	4.5	3.5	1.2	65.6
Biowaste	TWh	40.1	0.3	0.1	0.4	0.1	0.6	0.9	0.0	0.1	1.9	1.1	0.1	0.2	5.7
Geothermal electricity	TWh	21.0	1.4	0.1	0.1	0.0	0.0	0.8	0.0	0.0	0.5	1.8	0.1	0.2	5.1
Hydro large-scale	TWh	326.4	4.0	7.2	1.1	0.0	12.3	0.7	3.6	0.4	1.4	18.3	4.7	5.2	58.9
Hydro small-scale	TWh	55.4	1.8	0.5	1.3	0.0	1.8	0.1	0.2	0.2	1.9	1.1	1.3	0.7	11.0
Photovoltaics	TWh	210.6	0.9	0.7	2.4	0.0	0.0	0.1	0.0	0.0	0.0	0.5	0.3	0.5	5.4
Solar thermal electricity	TWh	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tide & wave	TWh	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind onshore	TWh	509.6	0.5	2.9	2.7	4.2	1.1	1.5	1.3	4.6	41.7	3.4	0.2	0.1	64.3
Wind offshore	TWh	95.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES-E total	TWh	1,565.4	12.0	12.6	15.3	5.6	35.0	9.6	6.2	6.8	72.9	32.5	10.7	8.8	227.8
RES-E CHP	TWh	280.3	2.7	0.8	6.6	1.1	19.4	5.7	1.1	1.3	17.6	6.4	3.2	1.3	67.1
Decentralised PV	TWh	84.0	0.4	0.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	2.3
RES-H - Energy output															
Biogas (grid)	TWh	38.1	0.2	0.1	0.9	0.1	0.4	0.3	0.2	0.2	1.9	0.5	0.2	0.2	5.2
Solid biomass (grid)	TWh	346.8	5.7	1.5	12.5	3.7	35.5	8.2	4.9	5.8	28.5	11.2	8.9	1.3	127.8
Biowaste (grid)	TWh	63.6	0.4	0.1	0.7	0.1	1.4	1.4	0.0	0.1	3.2	1.6	0.2	0.3	9.8
Geothermal heat (grid)	TWh	19.3	0.6	0.2	0.1	0.0	0.0	2.7	0.0	0.0	1.0	1.0	0.9	0.2	6.8
Solid biomass (non-grid)	TWh	921.7	14.2	12.3	12.9	8.6	67.3	8.1	12.1	10.5	58.3	50.2	4.6	9.1	268.2
Solar thermal heating and hot water	TWh	78.2	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.8	2.3	0.0	0.3	5.2
Heat pumps	TWh	197.9	0.2	0.7	0.8	0.2	9.8	0.0	0.2	0.3	3.6	2.1	0.1	0.2	18.2
RES-H total	TWh	1,665.6	21.7	15.3	28.0	12.8	114.4	20.8	17.3	16.8	98.4	68.9	15.1	11.6	441.2
RES-H CHP	TWh	289.1	2.9	0.7	7.8	1.3	24.8	4.5	1.2	1.5	21.2	6.7	3.2	1.2	77.0
RES-H district heating	TWh	178.7	3.9	1.2	6.5	2.7	12.5	8.2	3.9	4.6	13.5	7.6	7.2	0.8	72.6
RES-H non-grid	TWh	1,197.8	14.9	13.3	13.7	8.8	77.1	8.1	12.2	10.7	63.7	54.6	4.8	9.6	291.6
RES-T (biofuels) - Energy consumption															
RES-T total	TWh	330.4	2.7	2.1	6.2	0.6	4.3	3.7	1.0	1.3	19.5	7.3	2.7	2.2	53.8

Table 6-3: Technology-specific RES deployment by 2030 at MS level according to the Green-X scenario of full RES cooperation

General legend	[Unit]	EU28	Bulgaria	Croatia	Czech Republic	Estonia	Finland	Hungary	Latvia	Lithuania	Poland	Romania	Slovakia	Slovenia	12MS
Country comparison		**EU28**	**BG**	**HR**	**CZ**	**EE**	**FI**	**HU**	**LV**	**LT**	**PL**	**RO**	**SK**	**SI**	**12MS**
Energy production from RES (ALL) in 2030 (national deployment)															
RES-E - Energy output															
Biogas	TWh	69.7	0.5	0.3	1.1	0.1	0.7	1.3	0.2	0.2	3.3	1.5	0.4	0.5	10.0
Solid biomass	TWh	193.0	1.7	0.9	4.7	0.9	14.4	2.7	0.5	0.3	19.3	3.5	3.2	1.2	53.3
Biowaste	TWh	40.4	0.3	0.1	0.4	0.1	0.6	0.9	0.0	0.1	1.9	1.1	0.1	0.2	5.7
Geothermal electricity	TWh	19.9	1.1	0.1	0.0	0.0	0.0	0.8	0.0	0.0	0.0	1.8	0.0	0.2	4.0
Hydro large-scale	TWh	333.4	4.5	7.2	1.1	0.0	12.9	0.9	3.6	0.4	1.4	19.5	4.8	5.2	61.4
Hydro small-scale	TWh	58.2	1.9	0.6	1.4	0.0	1.8	0.1	0.3	0.2	1.9	1.3	1.3	0.8	11.6
Photovoltaics	TWh	153.1	0.5	0.4	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.2	4.0
Solar thermal electricity	TWh	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tide & wave	TWh	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind onshore	TWh	607.4	2.4	6.7	2.7	4.2	2.0	2.3	1.3	4.6	41.7	4.5	0.9	0.2	73.6
Wind offshore	TWh	32.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES-E total	TWh	1,512.1	12.9	16.2	13.7	5.3	32.3	9.0	5.8	5.8	69.4	33.4	11.0	8.6	223.6
RES-E CHP	TWh	231.6	1.7	0.7	5.1	0.8	15.2	3.9	0.7	0.4	13.8	4.2	2.5	1.0	49.9
Decentralised PV	TWh	65.5	0.2	0.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	1.8
RES-H - Energy output															
Biogas (grid)	TWh	32.3	0.1	0.1	0.7	0.0	0.4	0.3	0.1	0.1	1.1	0.2	0.2	0.1	3.4
Solid biomass (grid)	TWh	311.9	4.7	1.5	11.7	3.5	31.3	6.4	4.5	4.6	27.4	9.4	8.3	1.1	114.3
Biowaste (grid)	TWh	62.8	0.4	0.1	0.7	0.1	1.4	1.4	0.0	0.1	3.2	1.6	0.2	0.3	9.8
Geothermal heat (grid)	TWh	19.5	0.6	0.2	0.1	0.0	0.0	2.7	0.0	0.0	1.0	1.0	0.9	0.2	6.8
Solid biomass (non-grid)	TWh	976.2	14.8	12.4	16.9	8.6	68.1	9.0	12.0	10.6	64.7	51.1	5.2	9.2	282.7
Solar thermal heating and hot water	TWh	78.3	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.8	2.4	0.0	0.3	5.3
Heat pumps	TWh	197.9	0.2	0.7	0.8	0.2	9.8	0.0	0.2	0.3	3.6	2.1	0.1	0.2	18.2
RES-H total	TWh	1,678.9	21.3	15.3	30.9	12.5	111.0	19.7	16.8	15.7	102.8	67.8	15.1	11.5	440.4
RES-H CHP	TWh	240.1	1.9	0.6	6.2	1.0	19.9	2.8	0.8	0.4	17.4	4.6	2.5	1.0	59.2
RES-H district heating	TWh	186.4	3.9	1.2	7.0	2.7	13.2	7.9	3.9	4.4	15.4	7.6	7.2	0.8	75.1
RES-H non-grid	TWh	1,252.4	15.5	13.4	17.7	8.8	77.9	9.0	12.2	10.9	70.1	55.6	5.4	9.7	306.1
RES-T (biofuels) - Energy consumption															
RES-T total	TWh	329.9	2.7	2.1	6.2	0.6	4.3	3.7	1.0	1.3	19.5	7.3	2.7	2.2	53.7