Macroeconomic impacts of shale gas extraction in the EU

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Executive Summary

Commercial breakthroughs in hydrocarbon extraction technologies have led to a surge in shale gas production in the United States and Canada. This has opened up new prospects for the extensive global development of unconventional fossil fuels—in particular shale gas—and EU Member States have been keen to reproduce this development, but are cautious about the environmental impacts.

The Roadmap to a Resource Efficient Europe 2020 aims to create a framework for policies to support the shift towards a low-carbon economy and resource efficiency, while delivering smart, sustainable and inclusive growth (EC 2011a). The Energy Roadmap 2050 reports the decline in conventional gas production and foresees Europe's potential exploitation of indigenous shale gas (EC 2011b). Various Member States have engaged or plan to engage in exploration activities, with most drilling for shale gas thus far taking place in Poland, but other leasing and exploratory activity being carried out in other Member States. According to shale gas proponents, it would provide economic benefits, improve energy security and create employment during difficult economic times, while helping the EU's transition towards a low-carbon economy. On the other hand, shale gas exploration has raised serious questions about risks to the environment and human health. Such concerns have led to total or partial shale gas moratoria or bans on the use of hydraulic fracturing for hydrocarbons exploration and exploitation in place (e.g., France and Bulgaria).

This study is one of the studies commissioned by the European Commission (EC) to support an impact assessment pursuant to the EC initiative, 'Environmental, Climate and Energy Assessment Framework to Enable Safe and Secure Unconventional Hydrocarbon Extraction.' The overall aim of this study is to assess the impacts of different environmental risk management policies for shale gas on the energy system and the economy. More specifically, this study explores the macro-economic impacts of shale gas development under a base case scenario as well as two alternative policy scenarios to manage environmental risk (one more stringent than the other).[1]

In addition, a number of sensitivities are run to assess the macro-economic impacts of shale gas development under the more stringent environmental risk management policy scenario assuming (1) a high shale resource base scenario, (2) a low world economic growth scenario, and (3) a high economic growth scenario. These scenarios are summarised in the table below.

[1] As explained in Section 2.2, the base case assumes best estimates for EU shale gas resource base and world economic growth and GHG policies that are in line with the 2050 roadmap GHG reduction targets.

Table 1. Scenarios for modelling

Scenario No.	Shale Gas Risk Management Policy Option		Value Used for Key Sensitive Parameter		
	More Stringent[a]	Less Stringent[b]	Shale Gas Resource Base	World Economic Growth	GHG Policy
Base case			Best estimate	Best estimate	In line with 2050 roadmap GHG reduction
1	X		Best estimate	Best estimate	Same as in base case
2		X	Best estimate	Best estimate	Same as in base case
3	X		High	Best estimate	Same as in base case
4	X		Best estimate	High	Same as in base case
5	X		Best estimate	Low	Same as in base case

[a] This policy option is more stringent relative to the other policy option explored in this analysis; it includes the elaboration of stand-alone EU legislation for shale gas. See Section 2.2 for more details.

[b] This policy option is less stringent relative to the other policy option explored in this analysis; it includes promotion of an EU-level non-binding approach to minimise environmental risks (including industry standards, guidance, information exchange etc.). See Section 2.2 for more details.

The environmental risk management policy scenarios explored in this study are based on those developed under two parallel studies commissioned by the EC:

- ICF (2014). "Mitigation of climate impacts of possible future shale gas extraction in the EU: available technologies, best practices and options for policy makers", a study prepared for DG CLIMA; this study assessed the baseline and alternative policy measures for mitigating the GHG impacts of shale gas extraction in the EC and their associated costs.
- AMEC (2014). "Technical support for assessing the need for a risk management framework for unconventional gas extraction", a study prepared for DG ENV; this study assessed the baseline and alternative policy measures for mitigating environmental risks and impacts (i.e., to air, water, biodiversity, noise, seismicity, etc.) of shale gas extraction in the EC and their associated costs.

To undertake the study, EU shale gas production potential and production costs were first assessed, and the impacts of shale gas development on energy mix and prices were then modelled using Enerdata's POLES model (described in Annex 1) under the base case and the two alternative policy scenarios. The impacts of the resulting energy mix and price changes on the economy were then modelled at a sectoral level using Cambridge Econometrics' E3ME model (described in Annex 2). The results of the analysis are summarised below, based on research and analysis primarily undertaken between January and July 2013.

EU shale gas resources

Building on an extensive literature review to estimate the extent of the EU-27 shale gas resource base conducted by ICF as part of this study and accounting for what is ultimately recoverable (based on technical considerations)[2] and accessible (based on land access considerations), estimates developed by ICF for the accessible ultimately recoverable resource (URR) base are shown in Table 2. The “mean” values were used in the base case as “best estimate”, while “max” values were used for the “high” shale gas resource base sensitivity parameter. These values are shown in yellow. The mean accessible resource base is estimated at 8,000 billion cubic meters (bcm), as compared to the technical recovery estimate of approximately 12,000 bcm.

Table 2. Estimated accessible[3] shale gas Ultimately Recoverable Resource (URR)

		Ultimately Recoverable Resource			Natura	Population	Accessible URR		
		Min	Mean	Max	Off Limits	Off Limits	Min	Mean	Max
Member State	Source	Bcm	Bcm	Bcm	Percent	Percent	Bcm	Bcm	Bcm
Austria	Thomson Reuters 2012	**159**	*200*	**241**	14.7%	14%	116	147	241
Bulgaria	Bloomberg 2012	**300**	*650*	**1,000**	33.9%	8%	183	395	1,000
Denmark	EIA 2013	*227*	**907**	*1,360*	8.9%	14%	178	710	1,360
Estonia	EIA 2011 play assessments/ICF allocations	3	**11**	*17*	17.8%	7%	2	9	17
France	EIA 2013	*970*	**3,881**	*5,822*	12.5%	17%	705	2,819	5,822
Germany	BGR 2012	**680**	**1,275**	**2,266**	15.4%	41%	339	636	2,266
Hungary	Veliciu and Popescu 2013	**399**	*700*	**1,000**	21.4%	14%	270	473	1,000
Ireland	Enegi Oil 2013	**42**	*76*	**109**	13.0%	6%	35	62	109
Latvia	EIA 2011 play assessments/ICF allocations	*4*	**17**	*25*	11.3%	5%	4	14	25
Lithuania	EIA 2013 for mean; EIA 2011 for maximum	0	**0**	**113**	12.1%	5%	0	0	113
Netherlands	EIA 2013	184	**737**	*1,105*	13.8%	74%	41	165	1,105
Poland	Polish Geological Institute 2012; EIA 2013 for max.	**346**	**558**	**4,193**	19.4%	16%	234	378	4,193
Romania	Veliciu and Popescu 2013; EIA 2013 for max.	*232*	**929**	**1,445**	17.9%	10%	172	687	1,445
Spain	ACIEP 2013 for mid; EIA 2013 for low	***227***	**1,977**	*2,966*	27.2%	15%	140	1,224	2,966
Sweden	EIA 2013	*71*	**283**	*425*	13.8%	7%	57	227	425
UK	UK DECC 2012; EIA 2013 for maximum	*38*	**150**	*737*	7.2%	49%	18	71	737
EU 27 Total		3,881	12,351	22,823			2,492	8,016	22,823

Notes:

Natura 2000 "off limits percent" is an assumption taken for modelling purposes.

Values in italics are ICF estimates to establish ranges. Published values are bolded.

Maximum access resource scenario assumes no access restrictions.

Minimum and maximum values are straight sums of each country's min/max values; they do not represent probability weighted values.

EU shale gas production costs

ICF estimated EU shale gas production costs by generating play level “supply curves” representing the resource cost versus cumulative resource for each play by Member State. Production costs for the base case and policy scenarios were estimated by first scaling U.S. costs (for which more robust data were available) for shale gas drilling, completion, and operation to the EU and then refining them based on the unique characteristics of EU shale gas plays (i.e., based on required drilling depths and gas

[2] The ultimately recoverable resource is that which could be produced through vertical or horizontal wells using existing technology without regard for economics.

[3] According to EU legislation, if a foreseen project may affect in a significant manner Natura 2000 sites, a prior appropriate assessment is required under the Habitats Directive (92/43/EC). The project can be authorised if it is ascertained that the project will not adversely affect the integrity of the site concerned, based on reliable supporting evidence. If the conclusion of the appropriate assessment is that the project will have a negative impact on the Natura 2000 site and there is no alternative solution, the project may still be authorised for an imperative reason of overriding public interest. In this case, appropriate compensatory measures must be taken.

and liquids[4] recovery per well distribution within each play). Costs associated with environmental risk mitigation measures in the base case and across policy scenarios were also considered.

Energy impacts of shale gas extraction based on POLES modelling

The POLES model is used in this project to model EU shale gas production and gas prices under different policy scenarios. For this study, the POLES model was updated per the Member State shale gas resource base assumptions and associated production costs estimated by ICF (as described above and in more detail in Sections 3.1 and 3.2). The model is also used to simulate the effect of any policy barriers (moratoria or bans) on extracting shale gas in the base case scenario.

The POLES model simulates demand and supply dynamically and gas prices are an endogenous result of the annual demand/supply equilibrium. As a result, a study of shale gas production and production costs will result in different gas prices overall; in turn, this will change the competitiveness of gas as a fuel to energy consumers. Thus, forecasts of shale gas production levels associated with variants on technology costs or policies in producing countries will also be associated with corresponding forecasts of gas prices and gas demand levels by sectors in consuming countries.

Based on POLES modelling, the energy system impacts of the shale gas resource and policy scenarios explored in this analysis can be summarised as follows:

- Production of shale gas starts with over 1 bcm in 2015 and ramps up gradually to between about 30 bcm (low economic growth) and about 130 bcm (high resources) in 2030, with development trends pointing to higher volumes expected after 2030 for all scenarios.
- Production levels differ relatively little between risk management policy options (-8% with the more stringent policy option explored compared to the base case).
- Conventional gas production is largely not impacted between scenarios assumptions, due to uniformly geologically depleting resources in the EU and to similar gas prices between scenarios.
- In all scenarios, including the sensitivity run with high domestic shale gas production (with the more stringent policy scenario), the exposition of the EU to international markets is such that the differences in domestic shale gas production have little effect on global supply and thus on international gas prices. As a result, prices between scenarios are largely similar, and we observe essentially a trade-off between domestic shale gas production and imports in all scenarios defined by internal EU factors (i.e. risk management policies and domestic shale gas resources).
- In all cases, the contribution of shale gas to domestic gas consumption gradually reaches around 10% in 2030, i.e. 15 years after start of production (except in the "high resources" scenario, which does not take into account any possible access restrictions due to Natura 2000 areas or population density, where it reaches 25%).
- With gas prices being significantly similar between scenarios, the only differentiating factor between scenarios for total gas demand and total CO_2 emissions in the EU is economic growth.

[4] The study included estimations of both the gas and the liquids content of shale gas. Liquids can have a large positive impact on shale gas economics. Natural gas liquids include lease condensate, ethane, propane, butane and pentanes-plus.

Economic impacts of shale gas extraction based on E3ME modelling

Impacts on competitiveness and employment are based on the results of the market impact analysis from the POLES model. The E3ME macroeconomic model was used to convert key outputs from the POLES model—i.e., energy consumption (by fuel and sector), source of energy (domestic or imported), energy prices (by fuel) and investment by the energy sector—into impacts on: GDP, employment by sector, unemployment, other macroeconomic indicators (e.g., household incomes by income group, consumption, investment, government expenditure, inflation), and sectoral indicators (output, exports, imports and prices). The E3ME model is based on Eurostat data, with a historical database covering the period 1970-2010 (1995-2010 for CEE countries). Energy balances are obtained from the IEA (2012). As macroeconomic models require a complete data set, gaps in the data have been estimated using customised software algorithms. To ensure that the analysis is carried out on a consistent basis, E3ME was calibrated to the same baseline forecast as the POLES model. The labour market baseline forecast in E3ME was calibrated to be consistent with the most recent version of the EU projections published by CEDEFOP.

Table 3 provides a summary of key economic indicators of the risk management options in 2030 for the EU27, as percentage difference from the base case. The table illustrates the policy options represented by Scenario 1 and Scenario 2 have a negligible economic impact compared to the base case. At all levels the results for these scenarios are negligible because the policies have almost no impact on energy production, energy prices or energy demand (and therefore, no impact on the economy is observed). The sectors that benefit the most in the scenario are those that supply the gas extraction sector; although there may be some uncertainty in the magnitude of the effects, it is unlikely that this would not be the case.

Table 3. EU-27 Summary of impacts of economic and social impacts of risk management policy scenarios (% difference from base case) in 2030

	Base Case	More Stringent Policy Scenario	Less Stringent Policy Scenario	High Resources Sensitivity with More Stringent Policy Scenario
GDP	0	-0.02	-0.01	0.34
Employment	0	0	0	0.15
Extra-EU Export	0	0	0	0.02
Extra-EU Import	0	0.07	0.04	-1.22
Household Consumption	0	0	0	0.12
Investment	0	-0.01	-0.01	0.44
Unemployment	0	0.02	0.02	-0.53

The direction of results and the qualitative conclusions can be considered robust, given the model inputs used from POLES.

1 Introduction

1.1 Background

Commercial breakthroughs in hydrocarbon extraction technologies have led to a surge in shale gas production in the United States and Canada. This has opened up new prospects for the extensive global development of unconventional fossil fuels—in particular shale gas—and some EU Member States have been keen to reproduce this development, but some are also cautious about the environmental impacts.

The Energy Roadmap 2050 reports the decline in conventional gas production and foresees Europe's potential exploitation of indigenous shale gas (EC 2011b). Various Member States have engaged or plan to engage in exploration activities, with most drilling for shale gas thus far taking place in Poland, but other leasing and exploratory activity being carried out in other Member States.

According to shale gas proponents, it would provide economic benefits, improve energy security and create employment during difficult economic times, while helping the EU's transition towards a low-carbon economy. On the other hand, shale gas exploration has raised serious questions about risks to the environment and human health. Such concerns have led to total or partial shale gas moratoria or bans on the use of hydraulic fracturing for hydrocarbons exploration and exploitation in place, e.g., in France and Bulgaria.

In response to calls from stakeholders, Member States and the European Parliament, the European Commission has recently completed a number of studies to investigate the impact of shale gas developments on climate, environment and energy markets.[5]

1.2 Purpose

This study is one of the studies commissioned by the European Commission to support an impact assessment pursuant to the EC initiative, 'Environmental, Climate and Energy Assessment Framework to Enable Safe and Secure Unconventional Hydrocarbon Extraction.' The overall aim of this study is to assess the impacts of different environmental risk management policies for shale gas on the energy system and the economy. More specifically, this study explores the macro-economic impacts of shale gas development under a variety of environmental risk management policy scenarios—namely, one more stringent scenario that can involve legislation, and one less stringent scenario that can involve simply guidance—assuming best estimates for shale gas resource base, world economic growth, and GHG policies (which are assumed to be in line with the 2050 roadmap GHG reduction targets).[6] In defining these two policy scenarios, this study borrowed from two studies commissioned in parallel by DG ENV[7] and DG CLIMA.[8] The study also explores the impacts of adopting the more stringent policy scenario under several sensitivities: (1) with a high shale gas resource base, (2) with low world economic growth, and (3) with high economic growth. The research and analysis in this study was primarily undertaken between January and July 2013.

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5 See: http://ec.europa.eu/environment/integration/energy/uff_studies_en.htm.

6 See Section 2.2 for more detail.

7 "Technical support for assessing the need for a risk management framework for unconventional gas extraction", a study prepared by AMEC. This study assessed the baseline and alternative policy measures for mitigating environmental risks impacts (i.e., to air, water, biodiversity, noise, seismicity, etc.) of shale gas extraction in the EC and their associated costs.

8 "Mitigation of climate impacts of possible future shale gas extraction in the EU: available technologies, best practices and options for policy makers", prepared by ICF International. This study assessed the baseline and alternative policy measures for mitigating the GHG impacts of shale gas extraction in the EC and their associated costs.

2 Methodology

2.1 Overview

The overall approach used to undertake this study is summarised below:

- ICF assessed the accessible shale gas resource base in each Member State for high, mean, and low resource base estimates.
- ICF developed supply curves to model the costs for shale gas extraction in the EU, considering the unique characteristics of EU shale gas plays and uptake levels of environmental risk mitigation measures under baseline and two environmental risk management policy scenarios (based on ICF [2014] and AMEC [2014]).
- Enerdata's POLES model (described in Annex 1) was used to model EU shale gas production and gas prices under the base case and different policy scenarios for years 2020 and 2030. In particular, POLES was used to model impacts of policy scenarios and sensitivities on EU energy consumption, sources of energy, energy prices and investment by the energy sector.
- Using Cambridge Econometric's E3ME model (described in Annex 2), the economic impacts of shale gas production were explored. The analysis is carried out at a sectoral level, recognising that there could be quite important distributional effects as well as macro-level impacts.

These steps are described in further detail in the sections below. The GHG impacts of shale gas development in the base case and under the two alternative policy scenarios were also explored under the parallel study conducted by ICF (2014).

2.2 Policy modelling scenarios

The following scenarios have been modelled in this study:

- **Base Case** conditions, with best estimates applied for the EU-27 shale gas resource base, world economic growth, and GHG policy;
- **Scenario 1 (more stringent policy option compared to Scenario 2):** adoption of new shale gas risk management policies—e.g., elaboration of stand-alone EU legislation for shale gas — with the same estimates applied for the EU shale gas resource base, world economic growth, and GHG policy as in the base case; and
- **Scenario 2 (less stringent policy option compared to Scenario 1, but more stringent than compared to the base case):** adoption of new shale gas risk management policies—e.g., promotion of an EU-level voluntary approach to minimise environmental risks (e.g., industry standards, guidance, information exchange etc.)—with the same estimates applied for the EU shale gas resource base, world economic growth, and GHG policy as in the base case.

The level of uptake of the environmental risk management measures assumed in the base case and alternative policy scenarios, as well as their assumed costs, are based on ICF (2014) and AMEC (2014) with input from ICF experts under this study. More specifically:

- ICF (2014) assessed 10 broad types of policy options for reducing fugitive emissions from shale gas production; of these, the more stringent policy option was defined as the elaboration of specific EU legislation for shale gas (which could take the form of a Regulation, Directive, Recommendation, Opinion, etc.) or an amendment to the Industrial Emissions Directive (IIED); the less stringent policy option was defined as the promotion of an EU-level voluntary approach to minimise environmental risks (e.g., industry standards, guidance, information exchange, etc.) or an amendment to the Environmental Impact Assessment (EIA) Directive. The specific mitigation options

applied in each of these policy scenarios, as well as their assumed costs and baseline level of market adoption assumed in this analysis, are described in the report.
- AMEC (2014) assessed five broad types of policy options for reducing environmental risks apart from non-fugitive emissions;[9] of these options, policy option 1 (guidance) was used to define the "less stringent" policy option (i.e., guidance only) explored in this analysis, while policy option 4 (dedicated legislation + guidance) was used to define the "more stringent" policy option. The specific mitigation options applied in each of these policy scenarios, as well as their assumed costs and baseline level of market adoption assumed in this analysis, are described in the AMEC report.

The following sensitivities were run with Scenario 1, the more stringent of the shale gas risk management policy scenarios explored in this analysis:

- **High shale gas resource base**, with best estimates applied for world economic growth and GHG policy;
- **High world economic growth**, with best estimates applied for shale gas resource base and GHG policy;
- **Low world economic growth**, with best estimates applied for shale gas resource base and GHG policy.

A summary of the scenarios and sensitivity model runs conducted in this study is illustrated in Table 4.

Table 4. Scenarios and sensitivities for modelling

Scenario No.	Shale Gas Risk Management Policy Scenarios		Value Used for Key Sensitive Parameters (with More Stringent Policy Scenario)		
	More Stringent[a]	Less Stringent[b]	Shale Gas Resource Base	World Economic Growth	GHG Policy
Base case			Best estimate	Best estimate	In line with 2050 roadmap GHG reduction
1	X		Best estimate	Best estimate	Same as in base case
2		X	Best estimate	Best estimate	Same as in base case
3	X		High	Best estimate	Same as in base case
4	X		Best estimate	High	Same as in base case
5	X		Best estimate	Low	Same as in base case

9 The broad policy options assessed by AMEC (2014) include: 1) Guidance; 2) Amendment of existing EU legislation + Guidance; 3) Dedicated legislation (Directive) + Guidance; and 4) Dedicated legislation (Regulation) + Guidance.

3 Energy Modelling

To model the impacts of shale gas on the EU energy system under different policy and economic growth scenarios using the POLES model, it was necessary to first quantify the accessible EU shale gas resource base and shale gas production costs. The methodology for estimating the resource base, production costs, and energy system impacts determined by the POLES model are described below, as are the results.

3.1 EU shale gas resource base

Building on an extensive literature review conducted by ICF as part of this study, ICF developed country level assessments of ultimately recoverable (based on technical considerations) shale gas resources for the EU-27.[10] Further, some assumptions were made on the land access, incorporating the Natura 2000 natural resource areas and evaluating the distribution of population density to estimate the impact of possible access restrictions on shale gas development. The methodology and results are described below.

3.1.1 Ultimately recoverable shale gas resources

The ultimately recoverable resource is that which could be produced through vertical or horizontal wells using existing technology without regard for economics. Numerous sources of information were used to compile the table, in the following order of prioritisation:

- Government agency assessments, as available;
- Country specific assessments provided in EIA (2013) and EIA (2011), as available;
- Academic sources including presentations;
- Producing industry association assessments; and
- Industry estimates from specific operators (if considered comprehensive).

Specifically, the following sources were used:

- Government agency assessments were used for the UK (DECC 2012), Poland (PGI 2012), and Germany (BGR 2012). It should be noted that the Poland government mean assessment of 558 bcm[11] is much lower than the 2011 EIA assessment of 5,297 bcm, the 2013 EIA assessment of 5,224 bcm, and the JRC (2012) assessment of 4,306 bcm.
- For Romania and Hungary, a 2013 assessment study prepared by the International Centre for Green Energy Information (Veliciu and Popescu 2013) was used.
- For Ireland, Austria, and Bulgaria, industry estimates were obtained from corporate presentations and business news articles (Enegi 2013, Thomson Reuters 2012, Bloomberg 2012).
- For Spain, a 2013 gas industry association (ACIEP) assessment was used.
- For all other countries, EIA (2013) estimates were used. Exceptions were Latvia and Estonia, for which EIA (2011) was used, as there was no assessment in EIA (2013).

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[10] The ultimately recoverable resource is that which could be produced through vertical or horizontal wells using existing technology without regard for economics.

[11] The report from the Polish Geological Institute includes a "risked" recoverable range of 346 to 768 bcm and an "unconstrained" (i.e., unrisked) 1920 bcm. This analysis calculates the mean or "best" estimate as the mid-value between these two estimates (of 346 and 768 bcm).

For modelling purposes, for each Member State, ICF created a low, mid, and high ("min/mean/max") resource assessment based on what is ultimately recoverable (or technically recoverable)—i.e., the volume of gas that can potentially be recovered through existing and future wells regardless of economics, as summarised in Table 5. For some countries, published data included both a mean and a range of uncertainty, in which case, the range was used for the maximum and minimum resource cases. For government assessments that provide a range but for which the minimum or maximum values are not as low or high, respectively, as the EIA estimates, the EIA values were used.[12] Where only one value was reported in the literature across (as with the EIA assessment and several other sources), ICF treated that value as the mean and developed estimates for the high and low cases. Specifically, where needed, it was assumed that low cases are equivalent to 25% of the mean, whereas high values are 150% of the mean. This range was selected to represent the significant level of uncertainty associated with current assessments. The selected range of 25% to 150% of the mean, although somewhat arbitrary, is an approximation of a log-normal probability distribution in which the high estimate should be farther from the mean than the minimum. In Table 5, the published assessment values are shown in bold, while the values that are ICF derived estimates are shown in italics.

The results of this assessment are presented in Table 5. As shown, the estimate of ultimately recoverable resources (URR) in the EU-27 is 12,351 bcm. Table 6 compares the assessment made in this study to that of the EIA (2011) and EIA (2013) studies and to the Joint Research Centre European shale gas report (JRC 2012).

12 For Lithuania, EIA (2011) is used as the maximum, since EIA (2013) assessment reported no resource base (i.e., 0 trillion cubic feet (tcf)).

Table 5. EU-27 shale gas resource assessment conducted by ICF

Member State	Source	Basins and Units Assessed	Ultimately Recoverable Resources		
			Min Bcm	Mean Bcm	Max Bcm
Austria	Thomson Reuters 2012	Not specified	**159**	*200*	**241**
Bulgaria	Bloomberg 2012	Carpathian-Balkanian Basin (Silurian)	**300**	*650*	**1,000**
Denmark	EIA 2013	Scandanavia Region (Ordovician)	*227*	**907**	*1,360*
Estonia	EIA 2011 play assessments/ICF allocations	Baltic Basin (Silurian)	*3*	**11**	*17*
France	EIA 2013	Southeast Basin (Upper and Lower Jurassic)	*970*	**3,881**	*5,822*
Germany	BGR 2012	North Sea-German Basin (Lower Carb., J, Lower K); Paris Basin (Carb.)	**680**	**1,275**	**2,266**
Hungary	Veliciu and Popescu 2013	Not specified	**399**	*700*	**1,000**
Ireland	Enegi Oil 2013	Clare Basin (Carboniferous Clare Shale)	**42**	*76*	**109**
Latvia	EIA 2011 play assessments/ICF allocations	Baltic Basin (Silurian)	*4*	**17**	*25*
Lithuania	EIA 2013 for mean; EIA 2011 for maximum	Baltic Basin (Silurian)	*0*	**0**	**113**
Netherlands	EIA 2013	North Sea-German Basin (Carboniferous)	184	**737**	*1,105*
Poland	Polish Geological Institute 2012; EIA 2013 for max.	Baltic-Podlasie-Lublin Basins (Lower Paleozoic)	**346**	**558**	**4,193**
Romania	Veliciu and Popescu 2013; EIA 2013 for max.	Moldavian Platform (Sil.-Ord.); Scythian Platform (Dev-Sil-Ord)	*232*	**929**	**1,445**
Spain	ACIEP 2013 for mid; EIA 2013 for low	Cantabrian Basin, multiple other basins	**227**	**1,977**	*2,966*
Sweden	EIA 2013	Scandanavia Region (Ordovician)	*71*	**283**	*425*
UK	UK DECC 2012; EIA 2013 for maximum	Weald and Wessex (Jurassic); Pennine Basin (Carb.); Midland (Cambrian)	*38*	**150**	**737**
EU 27 Total			3,881	12,351	22,823

Notes:

Values in italics are ICF estimates to establish ranges. Published values are bolded.

Maximum access resource scenario assumes no access restrictions.

Minimum and maximum values are straight sums of each country's min/max values; they do not represent probability weighted values.

Table 6. Comparison of EU-27 shale assessment in this study with other assessments

		Ultimately Recoverable Resources					
Member State	Source	Min Bcm	ICF Mean Bcm	Max Bcm	EIA 2011 Bcm	EIA 2013 Bcm	JRC 2012 Bcm
Austria	Thomson Reuters 2012	**159**	*200*	**241**	NA	NA	not reported
Bulgaria	Bloomberg 2012	**300**	650	**1,000**	aggregated	482	not reported
Denmark	EIA 2013	*227*	**907**	*1,360*	652	907	not reported
Estonia	EIA 2011 play assessments/ICF allocations	3	**11**	*17*	NA	NA	not reported
France	EIA 2013	*970*	**3,881**	*5,822*	5,099	3,881	not reported
Germany	BGR 2012	**680**	**1,275**	**2,266**	227	482	not reported
Hungary	Veliciu and Popescu 2013	**399**	*700*	**1,000**	aggregated	0	not reported
Ireland	Enegi Oil 2013	**42**	*76*	**109**	NA	NA	not reported
Latvia	EIA 2011 play assessments/ICF allocations	*4*	**17**	25	NA	NA	not reported
Lithuania	EIA 2013 for mean; EIA 2011 for maximum	0	**0**	**113**	113	0	not reported
Netherlands	EIA 2013	*184*	**737**	*1,105*	482	737	not reported
Poland	Polish Geological Institute 2012; EIA 2013 for max.	**346**	**558**	**4,193**	5,297	4,193	4,306
Romania	Veliciu and Popescu 2013; EIA 2013 for max.	*232*	**929**	**1,445**	aggregated	1,445	not reported
Spain	ACIEP 2013 for mid; EIA 2013 for low	**227**	**1,977**	*2,966*	NA	227	not reported
Sweden	EIA 2013	*71*	**283**	*425*	1,161	283	not reported
UK	UK DECC 2012; EIA 2013 for maximum	*38*	**150**	**737**	567	737	not reported
Romania, Hungary, Bulgaria	EIA 2011				538		
Western Europe Total	JRC 2012						11,586
EU 27 Total		**3,881**	**12,351**	**22,823**	**13,598**	**13,371**	**15,892**

3.1.2 Access by member state

The above discussion relates to the ultimately recoverable resource. Not all of this resource is expected to be accessible for shale gas development. An effort was made to estimate the volume of shale gas in each Member State that could be considered accessible for future drilling activity. As a proxy, the approach involved evaluating Natura 2000 areas and population density statistics from Eurostat.

The analysis undertaken for this study relies on a statistical access approach and does not incorporate the detailed mapped distribution of shale gas plays and restriction areas. Such a GIS approach would be possible in areas for which shale gas play boundary maps are available, which are few, and this was beyond the scope of the current study.

The Natura 2000 website reports the onshore percentage of each Member State that is encompassed by Natura 2000 areas (Natura 2000, 2010). Natura designations are either Special Protection Areas (SPAs) for birds or Special Areas of Conservation (SACs) for habitat protection. About 20% of Europe territory falls under these designations. Both onshore and offshore areas have Natura designations but ICF evaluated only the onshore areas. ICF considered Natura areas to be potentially off limits for modelling purposes, although this is not necessarily the case, and some access to these areas may be expected, subject to an appropriate assessment[13] (see Table 7). Therefore, the resources estimates used for the mean estimates are rather conservative.

[13] According to EU legislation, if a foreseen project may affect in a significant manner Natura 2000 sites, a prior appropriate assessment is required under the Habitats Directive (92/43/EC). The project can be authorised if it is ascertained that the project will not adversely affect the integrity of the site concerned, based on reliable supporting evidence. If the conclusion of the appropriate assessment is that the project will have a negative impact on the Natura 2000 site and there is no alternative solution, the project may still be authorised for an imperative reason of overriding public interest. In this case, appropriate compensatory measures must be taken.

Table 7. Natura 2000 (2010) areas by member state

	National land area Th. sq. km	Natura land area Th. sq. km	Natura %
Austria	84	12	14.7%
Belgium	31	4	12.7%
Bulgaria	111	38	33.9%
Cyprus	6	2	28.4%
Czech Republic	79	11	14.0%
Denmark	43	4	8.9%
Estonia	45	8	17.8%
Finland	338	49	14.4%
France	549	69	12.5%
Germany	357	55	15.4%
Greece	132	36	27.1%
Hungary	93	20	21.4%
Ireland	70	9	13.0%
Italy	301	58	19.2%
Latvia	65	7	11.3%
Lithuania	65	8	12.1%
Luxembourg	3	0	18.1%
Malta	0	0	12.8%
Netherlands	42	6	13.8%
Norway	n/a	n/a	n/a
Poland	313	61	19.4%
Portugal	92	19	20.9%
Romania	238	43	17.9%
Slovakia	49	14	28.9%
Slovenia	20	7	35.5%
Spain	505	137	27.2%
Sweden	415	57	13.8%
UK	245	18	7.2%
Total	4,290	751	17.5%

For population density considerations, ICF evaluated Eurostat data at the NUTS-3 province level, which is a highly granular approach encompassing hundreds of individual areas (see figure below).[14] For each country, the population density distribution was evaluated. Table 8 presents the access categories and the access percentages assigned to each category, which were developed by ICF based on experience in the U.S. (as no other basis was identified). Specifically, the access assumptions were based on a recently unpublished ICF study on shale gas resources and population density that assessed the Barnett Shale play in North Texas, located in and around the city of Fort Worth. A large number of shale wells had been drilled in the play around Fort Worth and thus, it was possible to evaluate the mapped relationship of wells and population density, albeit not accounting for land ownership rights, which may further restrict industry access in the EU.[15] The first two columns of

14 Eurostat webpage with population density statistics http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

15 In the United States, landowners control nearly all of the mineral ownership rights, whereas in Europe, such rights are typically owned by a government entity. Thus, while a landowner in the U.S. has a financial incentive to allow or encourage development, despite negative surface impacts and potential environmental risk, it is likely that industry access in Europe will be more restricted, even in areas with the same level of population density.

Table 8 presents the categories used in that study, while the third and fourth columns present the access percentages derived from the assessment. The highest density category used (i.e., more than 386 people per square kilometre) represents a moderately urbanised area. ICF's analysis of the U.S. indicates that in moderately urbanised areas, a very small percentage of the resource is accessible. As can be seen in Figure 1, a large portion of northwest Europe consists of areas with more than 500 people per square kilometre, but there are also widespread areas with densities of less than 135 people per square kilometre.

Figure 1. Eurostat NUTS-3 provinces and population density per square kilometre

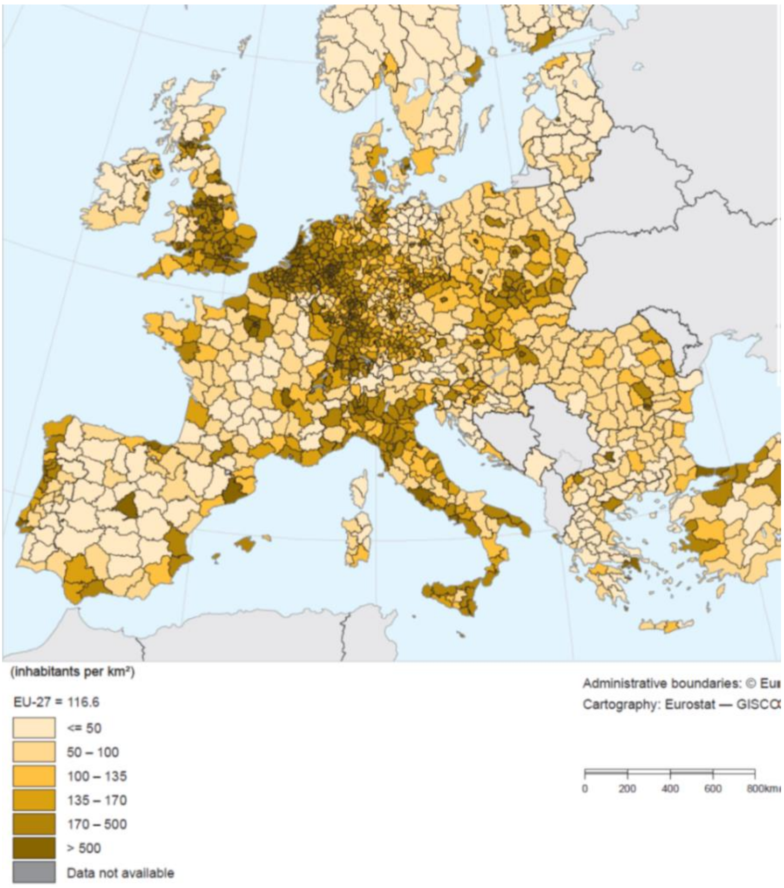


Table 8. Assumptions used for Population Density Access

People per Square Mile	People per Square Kilometer	Access %	Off Limits %
Less than 250	Less than 97	95%	5%
250 - 500	97 - 193	75%	25%
500 - 1,000	193 - 386	25%	75%
More than 1,000	More than 386	5%	95%

The following approach was used in this analysis to apply the results of the access analysis to the ultimately recoverable resource base:

- For the minimum and mean resource cases, the Natura areas are considered off limits and the population percentages shown above are applied.
- For the maximum resource case required for modelling purposes, there are assumed to be no access restrictions.

The mean accessible resource base was therefore determined using the following formula:

Accessible Resource =
*(1 – population access factor) * (1 – Natura access factor) * Mean Technical Recovery*

The final estimates for accessible resource base are shown in Table 9. The "mean" values were used in the base case as "best estimate"; while "max" values were used for the "high" shale gas resource base sensitivity parameter. These values are shown in yellow. As shown, the mean accessible resource base is estimated at 8,016 bcm, as compared to the technical recovery estimate of 12,351 bcm. This represents an aggregate reduction of approximately 35%.

Table 9. Estimated accessible URR

		Ultimately Recoverable Resource			Natura	Population	Accessible URR		
		Min	Mean	Max	Off limits	Off limits	Min	Mean	Max
Member State	Source	Bcm	Bcm	Bcm	Percent	Percent	Bcm	Bcm	Bcm
Austria	Thomson Reuters 2012	**159**	*200*	**241**	14.7%	14%	116	147	241
Bulgaria	Bloomberg 2012	**300**	*650*	**1,000**	33.9%	8%	183	395	1,000
Denmark	EIA 2013	*227*	**907**	*1,360*	8.9%	14%	178	710	1,360
Estonia	EIA 2011 play assessments/ICF allocations	3	**11**	*17*	17.8%	7%	2	9	17
France	EIA 2013	*970*	**3,881**	*5,822*	12.5%	17%	705	2,819	5,822
Germany	BGR 2012	**680**	**1,275**	**2,266**	15.4%	41%	339	636	2,266
Hungary	Veliciu and Popescu 2013	**399**	*700*	**1,000**	21.4%	14%	270	473	1,000
Ireland	Enegi Oil 2013	**42**	*76*	**109**	13.0%	6%	35	62	109
Latvia	EIA 2011 play assessments/ICF allocations	*4*	**17**	*25*	11.3%	5%	4	14	25
Lithuania	EIA 2013 for mean; EIA 2011 for maximum	0	**0**	**113**	12.1%	5%	0	0	113
Netherlands	EIA 2013	184	**737**	*1,105*	13.8%	74%	41	165	1,105
Poland	Polish Geological Institute 2012; EIA 2013 for max.	**346**	**558**	**4,193**	19.4%	16%	234	378	4,193
Romania	Veliciu and Popescu 2013; EIA 2013 for max.	*232*	**929**	**1,445**	17.9%	10%	172	687	1,445
Spain	ACIEP 2013 for mid; EIA 2013 for low	***227***	**1,977**	*2,966*	27.2%	15%	140	1,224	2,966
Sweden	EIA 2013	*71*	**283**	*425*	13.8%	7%	57	227	425
UK	UK DECC 2012; EIA 2013 for maximum	*38*	**150**	*737*	7.2%	49%	18	71	737
EU 27 Total		3,881	12,351	22,823			2,492	8,016	22,823

Notes:
Values in italics are ICF estimates to establish ranges. Published values are bolded.
Maximum access resource scenario assumes no access restrictions.
Minimum and maximum values are straight sums of each country's min/max values; they do not represent probability weighted values.

3.2 Shale gas production costs

To assess the impacts of shale gas development in the EU under the base case and alternative policy scenarios, the costs of shale gas production under these various scenarios were estimated and run through the POLES model to produce output on energy prices and energy mixes. To this end, separate supply curves were developed for the base case and environmental risk management policy scenarios—by play and by Member State. The overall approach that was used is as follows:

- Estimated shale gas drilling, completion, and operating costs per unit in the EU;

- Refined costs based on the drilling depths and gas and liquids[16] recovery per well distribution within each shale gas play;
- Generated play level "supply curves" representing the resource cost versus cumulative resource for each play by conducting a discounted cash flow analysis;
- Applied these play level supply curves to Member States, scaling the resource base to the estimated actual (mean) shale gas resource for each Member State;
- Refined supply curves by Member State to account for additional costs associated with environmental risk mitigation measures in the base case and across policy scenarios. The difference between the policy scenario curves and the base case represents the regulatory cost burden.

These steps are described further below.

3.2.1 Estimating shale gas drilling, completion, and operating costs

Due to the small number of shale gas wells that have been drilled in Europe and the fact that oil and gas companies active in Europe have not generally made drilling cost information available as is the case of the U.S., there is little public domain cost data available for horizontal shale drilling in Europe. Companies generally do not publish drilling cost data in the initial stages of exploration such as is the case with Europe shale. Also, costs are much higher for test or pilot programs due to the need to mobilise equipment to remote locations for only a few wells, the need to experiment with well configurations, and other factors (e.g., the need to drill individual wells as opposed to pads, and the potential for drilling and completion related problems). In contrast, a large amount of cost data is available for the U.S., where most plays are now in a development stage. Therefore, U.S. average production costs (adjusted for Europe, see below) were used as the basis for this analysis. Sources of information for U.S. costs include an unpublished one year proprietary study of North America shale gas by ICF, which included an industry cost survey of most of the U.S. shale operators, as well as the 2007 U.S. Joint Association Survey of Drilling Costs (API 2009) and a 2010 Department of Energy publication on U.S. operating and equipment costs (DOE 2010).

These costs were then scaled to the EU. For capital costs, a 50% cost premium was assumed over current U.S. well costs on a cost per meter basis, based on the following considerations:

- Shale wells in Poland have been reported to cost in the range of $10 to $15 million, compared to about half of that for a similar well in the United States (KPMG 2012).
- Over the long term, and assuming large scale drilling takes place in Europe, drilling and completion costs are expected to decline substantially; however, costs in Europe are not forecast by ICF to decline to U.S. levels because of a variety of factors—e.g., in the U.S., there is a larger oil and gas industry, good resource access, sparse population, flat terrain over large areas, and a large number of operators and service companies (i.e. economies of scale).

For annual operating and maintenance costs, U.S. costs were scaled to the EU assuming an approximately 25% cost premium. This reflects the fact that about half of well operating costs are producers' labour costs (assumed to be roughly equal to U.S.

[16] The study included estimations of both the gas and the liquids content of shale gas. Liquids can have a large positive impact on shale gas economics. Natural gas liquids include lease condensate, ethane, propane, butane and pentanes-plus.

costs) and the other half are purchased oil field goods and services[17] (assumed to cost 50% more than in the U.S., as described above).[18]

A summary of the major shale well cost components assumed for this study are presented in Table 10. The drilling cost per meter (which excludes stimulation) is assumed to be constant across all Member States for simplicity. The costs shown are those of the "business-as-usual" case. Additional environmental mitigation costs will add to both capital expenditures and operating costs, resulting in higher overall costs. These estimated drilling costs are the starting point for Member State costs; they are later customised based upon the required drilling depth of each play (as described in the subsequent sections). All horizontal laterals are assumed to be 1,200 meters with 10 frac stages.[19]

Table 10. Key shale well cost assumptions

Cost Component	Estimated Cost
Drilling costs (excludes stimulation)	€952/ metre
Stimulation cost per frac stage	€144,600/ stage
Drilling and stimulation capital costs for a well drilled to 2,420 meters (8,000 feet) vertical depth with 1,200 meter (4,000 foot) lateral and 10 stages	€4,908,000/ well
Other (non-environmental risk mitigation related) capital costs (equipment, geology and geophysics, and lease cost)	€230,769/ well
Basic annual operating and maintenance cost per well	€38,500/ well/ year
Other (non-environmental risk mitigation related) operating and maintenance costs (gathering and compression, gas processing)	€9.50/ thousand cubic metre

In addition to the above production costs, one-time and annual costs associated with the implementation of environmental risk mitigation measures are also applied, based on work conducted by AMEC (2014) in a parallel study commissioned by DG ENV on "Technical support for assessing the need for a risk management framework for unconventional gas extraction."

17 This is based on oil and gas well operating cost as reported by the U.S. Energy Information Administration of the U.S. DOE EIA survey of O&M costs at http://www.eia.gov/pub/oil_gas/natural_gas/data_publications/cost_indices_equipment_production/current/coststudy.html).

18 Thus, the weighted average O&M costs relative to U.S. cost are calculated as: 150% x 50% + 100% x (1-50%) = 125%.

19 This is an ICF assumption based on the review of well configuration data from investor presentations across all major U.S. shale gas firms, including Range Resources, Chesapeake Energy, EOG Resources, Devon, and others. In the U.S., lateral lengths have increased in many plays to greater than 1,500 meters, and the number of stimulation stages has also increased to 15 or more in many cases. Because very little information is available on well configurations in the initial European test wells, the assumptions of 1,200 meters and 10 stages were used as conservative estimates for European shale.

3.2.2 Refining costs based on EU shale gas play characteristics

To account for cost variations based on the distribution of resource quality and characteristics associated with each play within each Member State, ICF estimated the variability of key parameters of plays based on EIA (2011), which provides data and maps on 13 shale gas plays within the EU-27. In addition, data on five additional Romanian shale plays was obtained from Veliciu and Popescu (2013). This play level data, which is presented in Table 11, includes estimates of potentially productive areas, drilling depth, organic content, thermal maturity, thickness, porosity, and water saturation. ICF used this reported information to estimate average recovery per well for each play, which along with drilling depth, is one of the key factors in shale gas economics. Specifically, by assuming an average well spacing of 0.32 sq. km (80 acres), ICF estimated the total number of potentially productive wells in each play. This play data was used to develop play level cost of supply curves, described further below.

Table 11. Listing of plays used to develop supply curves

Basin Name	Country	Shale Formation	Prospective area (sq km)	Minimum gross thickness (m)	Maximum gross thickness (m)	Gross organic thickness (m)	Net organic thickness (m)	Minimum vertical depth (m)	Maximum vertical depth (m)	Average depth (m)	Reservoir pressure	Organic carbon %	Thermal maturity (Ro %)
Shale Gas Plays Reported in EIA (2011)													
Baltic Basin	Poland	Llandovery	22,917	100	248	174	96	2,485	4,970	3,727	Over.	4.0%	1.75%
Lublin Basin	Poland	Wenlock	30,207	100	338	126	69	1,988	4,076	3,032	Over.	1.5%	1.35%
Podlasie Basin	Poland	Llandovery	3,433	109	218	164	90	1,739	3,439	2,589	Over.	6.0%	1.25%
Baltic Basin	Estonia, Lat., Lith., Poland	Silurian	7,956	119	159	139	86	1,789	2,286	2,038	Over.	4.0%	1.20%
France Paris Basin	France	Permian-Carboniferous	46,482	50	2,187	116	35	2,584	3,976	3,280	Normal	4.0%	1.65%
France South-East Basin	France	Terres Niores	43,782	-	364	101	30	994	1,988	1,491	Normal	3.5%	1.25%
France South-East Basin	France	Liassic Shale	46,114	30	606	159	48	2,485	4,970	3,727	Normal	2.5%	1.45%
North Sea-German Basin	Germany	Posidonia Shale	6,865	8	106	45	30	994	4,970	2,982	Normal	5.7%	1.50%
North Sea-German Basin	Germany	Namurian Shale	10,282	75	2,102	123	37	2,485	4,970	3,727	Over.	3.5%	2.50%
North Sea-German Basin	Germany	Wealden Shale	4,689	8	98	34	23	994	2,982	1,988	Normal	4.5%	1.25%
Scandinavia Region	Norway, Swe., Est., Ger., Pol.	Alum Shale	99,018	-	139	99	50	-	-	994	Normal	10.0%	1.85%
U.K. Northern Petroleum System	United Kingdom	Bowland Shale	25,446	-	1,212	149	45	994	1,909	1,455	Normal	5.8%	1.40%
U.K. Southern Petroleum System	United Kingdom	Liassic Shale	415	303	497	126	38	3,485	4,697	4,091	Normal	2.4%	1.15%
Shale Gas Plays Reported in Veliciu and Popescu (2013)													
Moldavian Platform	Romania	Sil. - Ord.	8,225	9	59	30	15	394	2,333	1,364	Normal	1.3%	0.98%
Scithian Platform	Romania	Dev. - Sil. - Ord.	1,101	7	50	25	12	909	3,788	2,348	Normal	1.6%	2.09%
Moesia Lum Bailesti	Romania	Sil. - Mid. Dev.	795	103	686	343	172	3,061	4,364	3,712	Normal	1.2%	1.32%
Moesia Optasi	Romania	Sil. - Lower M. Dev.	8,497	223	1,489	745	372	2,000	2,485	2,242	Normal	1.2%	1.13%
Calarasi-S. Dobrogea	Romania	Sil. - Lower M. Dev.	11,956	111	738	369	184	909	3,788	2,348	Normal	1.1%	1.25%
Shale Gas Plays Reported in Kuhn and Umbach (2011)--shown for comparison purposes only													
Not specified	Poland Shale	Not specified	23,816				30-300	2,000	4,000	3,000	n/a	7.0%	1.0-4.0%
Not specified	Germany Shale	Not specified	7,500				20-500	0	2,500	n/a	n/a	2-12%	0.5-1.5%
Not specified	Vienna Shale	Not specified	900				1,500	4,500	8,000	6,250	n/a	1.5-2.0%	0.7-1.6%
Not specified	Sweden Shale	Not specified	2,010				30-100	100	3,500	n/a	n/a	2-25%	1.4-3.0%

It should be noted that the plays shown in Table 11 do not cover all EU countries assessed to have shale gas resources. For the non-covered countries (i.e., Austria, Bulgaria, Hungary, Ireland, and Spain), an estimation approach was developed in the last step of the supply curve development process, as described below.

The lower portion of Table 11 summarises EU play data compiled in a report prepared by the European Centre for Energy and Resource Security (Kuhn and Umbach 2011). This information is presented for comparison purposes with the EIA (2011) data.

3.2.3 Generating supply curves

Based on the estimated drilling depths and average recovery per well for each shale gas play, ICF created a set of play level "supply curves". A supply curve is a representation of the cumulative volume of gas that is recoverable at a given wellhead gas price. The basic analytic unit is an individual well –its shale gas and liquids production profile of *up to* 30 years,[20] and the costs that are incurred to complete the well and operate it over its lifetime. The gas production profile for all wells in the model is a hyperbolic decline curve with an initial 12-month decline of approximately 65% and a terminal decline of 6% per year. The decline parameters are based on ICF analysis of horizontal wells in the United States.

The supply curves are based on the "resource cost" concept using standard Discounted Cash Flow (DCF) methods. The resource cost is the wellhead price (including gathering and processing) that is necessary to develop and produce the shale gas and liquids and achieve the required rate of return on the investment. The table below presents the economic assumptions applied in the shale gas DCF analysis.

[20] Each well is assumed in this modelling to have a lifetime of 30 years unless its economic lifetime is lower, i.e., if production falls to the point that operating costs cannot be covered, the well will be assumed to shut down. In this analysis, the effective modelled lifetime of EU wells is on average of 26.6 years. ICF based the 30-year lifetime assumption on extensive analysis of U.S. and Canada historic shale well production data, which now includes years of production on many wells across a wide range of shale plays. Specifically, we have developed production profiles from actual data that indicate that well production from modern horizontal wells will extend for decades from individual wells in most areas. While most of the costs are incurred in the first year, revenues can flow for 30 years or more, due to the nature of the shale reservoir. The well will continue to produce until operating costs exceed revenues. The profitability of a given well is generally determined over the initial few years, due to high rates of initial decline, which can range from 50% to 80% after 12 months, declining thereafter to a long-term low decline rate. It should be noted however that literature sources vary as far as well lifespan is concerned (e.g., JRC IES 2013 refers to a 10-year average well lifespan).

Table 12. Economic assumptions used in DCF analysis

Economic Parameter	Assumption	Comments
Discount rate (real, after tax rate of return)	10%	Standard assumptions used by industry in the U.S. for exploration and production projects
Lease and plant fuel use (% of produced gas volumes)	4%	
Drilling success rate for shale plays	95%	Standard assumption used by ICF for U.S. shale gas, supported by drilling statistics across many U.S. plays; it represents a long term average, thus, early stages of a play may have a slightly lower rate.
Royalties (% of gross revenue)	20%	While each Member State has a unique tax regime, a more robust analysis of this aspect of economics was beyond the scope of the study
Income taxes (% of profit)	35%	
Inflation rate	2.5%	
Overhead/general & administrative costs	16%	

All costs are assessed downstream of the gathering system but do not include long distance transport to a market centre. Costs include gathering and compression and gas processing.

The following steps explain the development of the gas supply curves:

- Disaggregate the resource into "cells" to represent one step in the curve;
- Estimate capital and operating costs on an annual basis for each step;
- Estimate annual production volumes for oil, gas, and natural gas liquids from shale gas for each step;
- Develop algorithms to compute annual royalties, severance taxes, income taxes, as a function of revenues;
- Solve for hydrocarbon prices such that the net present value of net revenues minus costs is equal to zero; and
- Sort all steps from the least expensive to the most expensive and generate curve.

3.2.4 Scaling supply curves to estimated resource base by member state

Next, the play level costs of supply curves described above were customised to Member States to develop Member State level cost of supply curves. This was done using the play level DCF analysis to develop the shape of the supply curve for each country based on that country's estimated (mean) accessible shale gas resource (presented in Table 5).

For those Member States for which no play level data were available (i.e., Austria, Bulgaria, Hungary, Ireland, and Spain), an alternative estimation approach was required. For these countries, an average EU play level supply curve was developed and scaled to each country's mean shale gas resource.

Final costs are calculated in terms of Euros per billion joules, with the resulting base case supply curve for the EU-27 (average) shown below.

Figure 2. EU-27 Base case supply curve

3.2.5 Applying costs associated with environmental risk mitigation measures

Assumptions on level of uptake and costs of environmental risk mitigation measures under the base case and two alternative policy scenarios were made to feed into the supply cost curves. The costs associated with these measures, as well as the percentage uptake rates in the base case[21] and alternative policy scenarios, were developed in ICF (2014) and AMEC (2014).

3.3 POLES modelling

3.3.1 Objectives and scope of POLES modelling

The POLES model is used in this project to model EU shale gas production and gas prices under different policy scenarios (for this project and also the parallel DG CLIMA contract "Mitigation of climate impacts of possible future shale gas extraction in the EU").

Costs for gas producers to comply with the risk management policy options are translated by ICF into data sets of additional costs (in €/bcm) necessary to adopt a certain technology or to comply with a given policy. These additional cost "premia" are included in the production equations of POLES for the EU Member States.

The model is also used to simulate the effect of any policy barriers (moratoria or bans) on extracting shale gas in the base case scenario.

The POLES model simulates demand and supply dynamically and gas prices are an endogenous result of the annual demand/supply equilibrium. As a result, a study of shale gas production and production costs will result in different gas prices overall; in turn, this will change the competitiveness of gas as a fuel to energy consumers. Thus,

[21] Due to limited information regarding current practices for shale gas drilling in the EU, assumptions were also needed to define uptake rates in the base case.

forecasts of shale gas production levels associated with variants on technology costs or policies in producing countries will also be associated with corresponding forecasts of gas prices and gas demand levels by sectors in consuming countries.

Outputs from the POLES model for the base case and the different policy scenarios include:

- Annual production of shale gas (16 Member States assumed in the model to have shale gas resources)
  - Associated energy inputs for that production (16 Member States)
- Annual production of conventional gas, of conventional oil, of coal (27 Member States)
- Annual prices for fuels in international markets: oil (1 world market), gas and coal (European market)
- Annual demand of gas, oil, coal (27 Member States)
  - Demand of gas by sector (power generation, industry, residential, services, transport) (27 Member States)
- Annual CO_2 emissions from combustion (Fossil Fuels & Industry) (27 Member States)
- Annual exports of gas (shale + conventional) towards 14 regional markets globally (27 Member States)
- Annual imports of gas from the regional European market (27 Member States)
- Annual imports/exports of oil from/to a single global market (27 Member States).

3.3.2 Modelling approach, model details, data sources

A detailed description of the POLES model and how it works is provided in Annex 1.

3.3.3 Results of the base case

Gas continues to account for about 27% of the EU's gross energy consumption throughout 2030, as shown in the table below.

Table 13. EU's Gross Inland Consumption in the base case

	2000	2005	2010	2015	2020	2025	2030
Gross Inland Consumption (Mtoe)	1686	1774	1710	1671	1649	1609	1572
Oil	623	631	562	514	500	469	429
Gas	391	441	442	435	468	460	418
Coal	320	314	275	283	199	126	97
Nuclear	250	264	242	226	229	244	266
Biomass & waste	66	87	134	137	159	186	213
Other renewables	37	38	56	76	94	124	149

As shown, renewables (biomass, waste and other renewables) make up for the decline in coal, while gas is more competitive so demand remains relatively flat. Due to increasingly stringent carbon policies aiming at significant GHG reduction in the long-term, gas eventually becomes less competitive to the benefit of renewables.

EU shale gas production begins as early as 2015 but does not become significant before 2020. This development is accompanied by a gradual decline of conventional gas production, brought about by depletion of available resources. For conventional EU gas production, POLES is based on the reported historical production from the latest release of 2011 data from the IEA, which is also in line with the historical data reported in JRC (2012). The raw data used in developing these values are consistent with official values from IEA and Eurostat.[22]

Table 14. Primary Production in the EU in the base case

	2000	2005	2010	2015	2020	2025	2030
Primary Production (Mtoe)	956	921	913	924	905	883	894
Oil	166	128	97	97	90	78	54
Gas, *of which*	215	197	165	153	153	128	114
Conventional	215	197	164	151	135	103	74
Shale gas	0	0	0	1	17	25	39
Coal	223	209	220	235	180	122	96
Nuclear	250	264	242	226	229	244	266
Hydro, geothermal	33	29	34	30	31	33	33
Biomass & waste	65	86	134	137	158	186	213
Wind, solar	2	7	21	46	62	78	92

Table 15 details the contributions to the EU's overall gross consumption from domestic conventional and unconventional gas production, as well as gas imports, with the information presented graphically in subsequent figures.

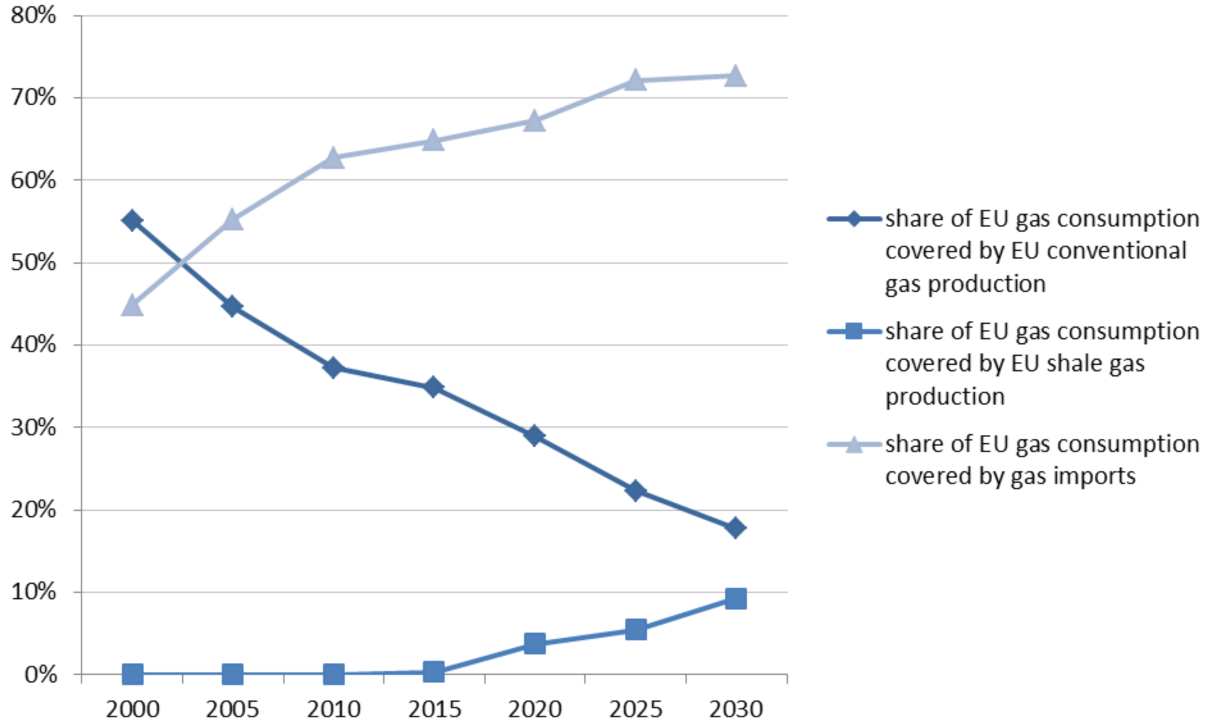
Table 15. Contributions to the EU's total gas consumption in the base case

	2000	2005	2010	2015	2020	2025	2030
Total EU natural gas production, of which	55%	45%	37%	35%	33%	28%	27%
Conventional[a]	55%	45%	37%	35%	29%	22%	18%
Shale gas	0%	0%	0%	0%	4%	5%	9%
Imports	65%	69%	71%	70%	69%	73%	73%

[a] The decreasing trend of EU conventional gas production reported by POLES differs from the increasing trend shown to 2020 in the JRC (2012) report (on Figure 6-24). The results shown in the JRC report include Norway, as net imports to Europe are discussed, while the results presented here include only the EU-27 countries (i.e., they exclude Norway).

[22] Minor discrepancies may exist between values from POLES reported in 'Mtoe' and the official values from IEA and Eurostat since data are entered into the model as 'bcm' and endogenous conversion factors are calculated to equate gas supply (bcm) with gas demand (Mtoe).

Figure 3. Share of EU gas consumption covered by different sources in the base case



When put in perspective with EU gross inland energy consumption, EU shale gas production could cover about 2.5% of EU energy needs in 2030 (39 Mtoe of EU shale gas production as compared to 1,572 Mtoe of gross inland energy consumption).

POLES projects the volume of LNG imports to the EU to increase over 2010-2020 then stabilise. Given the continued importance of Russia and other pipeline routes, the modelling simulates the weight of LNG in imports to the EU as gradually stabilising around 50% in the long term (from 57% in 2010).

In the modelling results, shale gas development in the EU follows a similar evolution compared to what has been observed in the USA in terms of the speed at which production increases, with a delay of about 20 years. It is assumed to take the EU about 15 years to reach 30 bcm/year of production (in 2030), which is about 15% of the USA's current production.

These volumes related to gas are forecasted in an energy context, where the EU implements efforts to reduce its greenhouse gas emissions, which impacts overall demand—particularly demand for gas. The base case reaches a 40% reduction of GHG emissions in 2030 compared to 1990 levels (achieved in POLES through a wide number of measures across all sectors of the economy, notably the power sector (e.g., CCS, fuel switching, renewables, nuclear, enhanced efficiency) and final demand (e.g., electrification, efficient buildings, other efficiency improvements), as shown below.

Table 16. GHG emission reductions in the base case

	1990	2000	2005	2010	2015	2020	2025	2030
Total CO2 Emissions	4282	4065	4179	3810	3691	3396	2978	2628
Total GHG Emissions	4816	4479	4571	4168	3994	3625	3138	2765
% Reduction compared to 1990								
Total CO2		-5%	-2%	-11%	-14%	-21%	-30%	-39%
Non-CO2 GHGs		-22%	-27%	-33%	-43%	-57%	-70%	-74%
Total GHG		-7%	-5%	-13%	-17%	-25%	-35%	-43%

Table 17. Energy price forecasts in the base case based on POLES modelling

	2000	2005	2010	2015	2020	2025	2030
International Oil Market Price ($05/bbl)	32	55	71	83	89	113	132
European Gas Market Price ($05/MMBtu)	4.1	6.9	5.1	7.0	6.9	8.1	8.6
European Coal Market Price ($05/t coal)	42	75	102	135	138	142	146

1.1.1 Exploring the base case: with and without shale gas

To explore the workings of the POLES model and its outputs, a variant on the base case was run. Specifically, a "without shale gas" scenario was run assuming moratoria or bans are adopted across all EU Member States on the exploitation of shale gas throughout 2030 (not elsewhere). The macroeconomic and policy context is otherwise assumed to be the same as in the base case.

The results show a diminishing of overall gas production in the EU; indeed, conventional gas production fatally decreases over time in both scenarios, and in this scenario, it is not even partially offset by the rise of shale gas production.

Table 18. Total Primary Production in Base Case with vs. without shale gas

2030	Base Case	Base Case (No Shale in EU)
Total Primary Production (Mtoe)	**894**	**855**
Gas, *of which*	114	76
Conventional, total	*76*	*76*
Non-conventional (shale gas)	*38*	*0*

This decrease results in imports of gas increasing by essentially the same amount, with gas prices and primary gas consumption in the EU being sensibly similar. Indeed, we do not foresee these changes in EU production having a significant effect on international markets: prices are set at an international level at supply/demand equilibrium and, to a large extent, the EU is a price-taker of international developments (for both scenarios).[23]

Table 19. European gas market price in base case with vs. without shale gas

European Gas Market Price ($05/MMBtu)	2000	2005	2010	2015	2020	2025	2030
Base Case	4.1	6.9	5.1	7.0	6.9	8.1	8.6
Base Case (No Shale in EU)	4.1	6.9	5.1	7.0	6.9	8.1	8.6

The absence of shale gas in the EU is, as regards volumes, easily covered by production of gas elsewhere, notably Russia and Central Asia without an effect on international, and thus domestic, prices. As a consequence, the absence of shale gas in the EU does not trigger any changes as regards the relative share of the different fuels in the EU energy mix in the modelling results.

3.3.4 Energy system impacts of the policy scenarios: results of POLES modelling

Gas Production

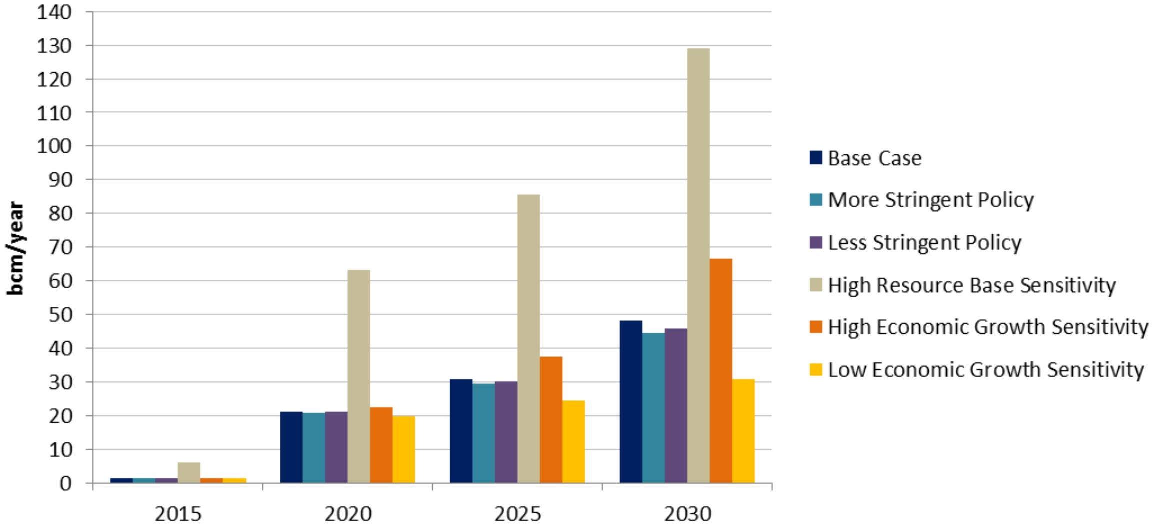
Shale gas production starts with over 1 bcm produced as early as 2015. Production then ramps up gradually to reach anywhere between about 30 bcm (low economic growth) and about 130 bcm (high resources) in 2030, with development trends pointing to higher volumes expected after 2030 for all scenarios.

Table 20. EU Shale gas production (bcm/year)

Modelling Scenario	2015	2020	2025	2030
0 – Base Case	1.60	21.25	30.86	48.18
1 – More Stringent Policy	1.60	20.88	29.63	44.42
2 – Less Stringent Policy	1.60	21.05	30.12	45.82
3 – High Resource Base Sensitivity (with More Stringent Policy)	6.24	63.16	85.76	129.06
4 – High Economic Growth Sensitivity (with More Stringent Policy)	1.60	22.55	37.37	66.62
5 – Low Economic Growth Sensitivity (with More Stringent Policy)	1.60	19.80	24.41	30.76

[23] More precisely, POLES includes the representation of three large regional markets for price setting (European/African, North/South American, and Asian/Pacific), as well as 37 gas exporting countries/regions and 14 importing regions across the world. Thus, the EU, part of the European/African market, has a consistently higher price for gas compared to the USA, which are part of the North/South American market. Prices evolve with the effects on global trade of production of reserves and the exploitation of new resources, as well as with an indexation to the oil price (decreasing effect over time) and a convergence of the three regional prices (reflecting increasing market fluidity and the importance of LNG).

Figure 4. Shale gas production in EU-27



Economic growth and resources assumptions have a very important impact on production levels.

The "high resources" sensitivity holds 185% more shale gas in the EU compared to all other scenarios. Compared to Scenario 1 with which it shares a stringent policy context, production in 2030 is 191% higher with these high resources estimates.

Scenarios 0, 1 and 2 differ on risk management policy options, and thus on shale gas production costs. The effects are scaled accordingly:

- With about 8% difference in production costs, shale gas production in 2030 in the base case is 8% higher than in the More Stringent policy scenario (or Scenario 1).
- With about 4% difference in production costs, shale gas production in 2030 in the base case is 5% higher than in the Less Stringent policy scenario (or Scenario 2).

However, the impacts on production levels are significantly smaller compared to the impacts of economic growth and resources assumptions.

Indeed, given that a more stringent risk management policy (Scenario 1) adds relatively little additional shale gas production costs, it has comparatively marginal impacts on shale gas production levels compared to a "no additional policy" (i.e.. base case).

Prices

The international gas price is defined at global supply and demand equilibrium after trade between producers and importers is made. The gas price for the European market, net of taxes, is drawn from the gas price at Zeebrugge at the start of the POLES simulation.

In all scenarios, including with high domestic shale gas production, the exposition of the EU to international markets is such that the differences in domestic shale gas production have little effect on global supply and thus on international gas prices. As a result, prices between scenarios are largely similar, and we observe essentially a trade-off between domestic shale gas production and imports in all scenarios defined by internal EU factors (i.e. risk management policies and domestic shale gas resources).

As expected, the highest and lowest prices are attained in the high and low economic growth scenarios (modelled with the more stringent policy scenario), as global demand drives prices. Indeed, economic growth has an impact on fossil fuel prices, which increase (or decrease, respectively) correspondingly. This is because:

- If world economic activity is significantly higher, it will result in higher energy demand;
- Oil prices will rise as OPEC lacks sufficient spare capacity to ramp up production; this will also cause world LNG prices to be higher due to high development costs; and
- High oil prices would tend to depress EU economies somewhat relative to the base case. However, EU takes advantage of world growth to export more goods, resulting in EU economies growing more overall relative to the base case.

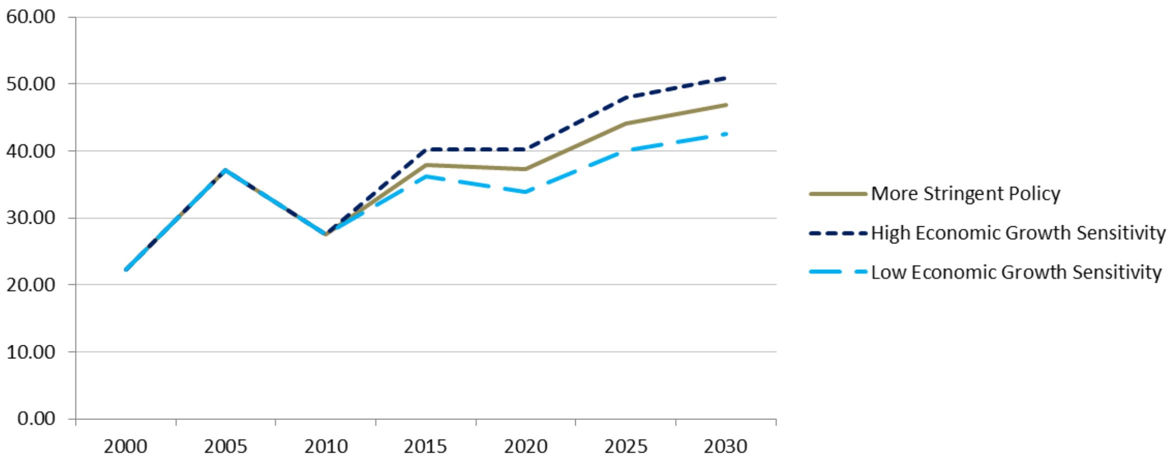
The “high economic growth” scenario (modelled with the more stringent policy) leads to an increased incentive for EU shale gas development, driven by high profitability of shale gas because of high prices.

The scenarios that are defined by exclusively European considerations (risk management policies or domestic shale gas resources) result in very similar gas prices. Indeed, more (or less) domestic shale gas production is balanced by less (or more) imports at a marginal effect on prices. The change in European shale gas production between the base case and high resources scenarios (approximately 81 bcm/year in 2030) represents only 4% of the total volumes of the market in which the regional price is set in the modelling (EU-CIS-Africa-Middle East; see footnote 23). This large price market is considered valid for modelling given the strong infrastructure links between the smaller gas import markets. The additional shale gas production within the EU does indeed reduce the average import cost to the European market, but this has only a negligible effect due to the relatively small European share (14%) in the total import volumes to the greater price setting market.

Table 21. European gas market price (USD2005/boe)

Modelling Scenario	2000	2005	2010	2015	2020	2025	2030
0 – Base case	22.31	37.13	27.61	37.89	37.27	44.05	46.82
1 – More Stringent Policy	22.31	37.13	27.61	37.89	37.27	44.04	46.81
2 – Less Stringent Policy	22.31	37.13	27.61	37.89	37.27	44.04	46.81
3 – High Resource Base Sensitivity (with More Stringent Policy)	22.31	37.13	27.61	37.89	37.26	44.12	46.80
4 – High Economic Growth Sensitivity (with More Stringent Policy)	22.31	37.13	27.61	40.17	40.25	48.00	50.85
5 – Low Economic Growth Sensitivity (with More Stringent Policy)	22.31	37.13	27.61	36.27	33.86	40.09	42.60

Figure 5. International gas price for the European market (USD2005/boe)



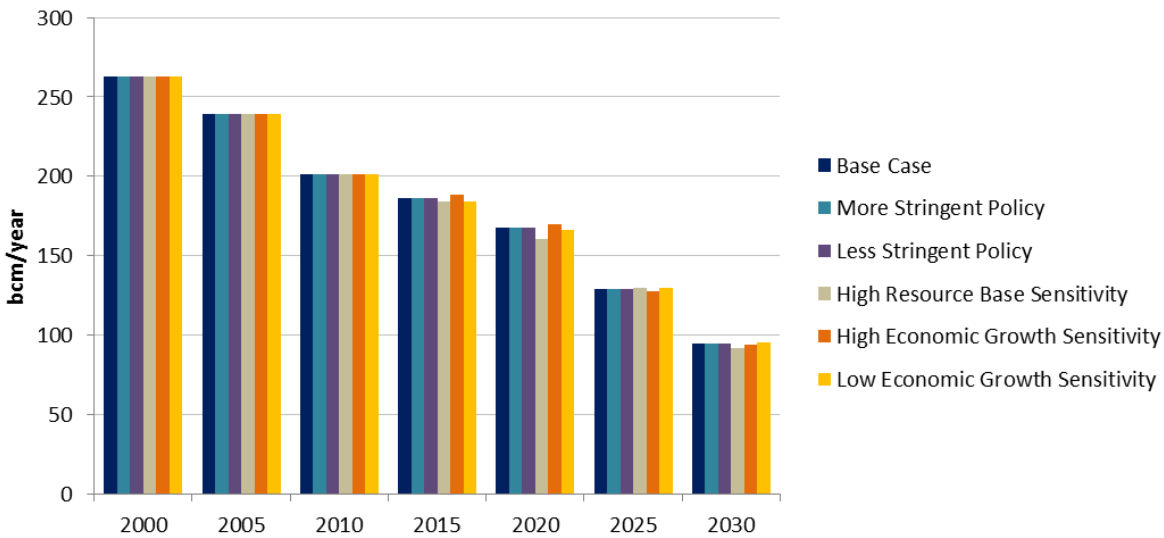
Note that since the European Gas Market price changes very little between Scenarios 0, 1, 2 and 3 (i.e., the base case, the two policy stringency scenarios, and the high resource base scenario), only the price for Scenario 1 (i.e., the more stringent policy scenario) has been shown in the above figure.

Primary gas supply in the EU-27

Gas demand, which is largely driven by economic growth and energy prices, is supplied by domestic shale gas, domestic conventional gas, and imports.

Conventional gas production is largely not impacted between scenarios assumptions, due to uniformly geologically depleting resources in the EU and to similar gas prices between scenarios.

Figure 6. Conventional gas production in EU-27



Gas Imports

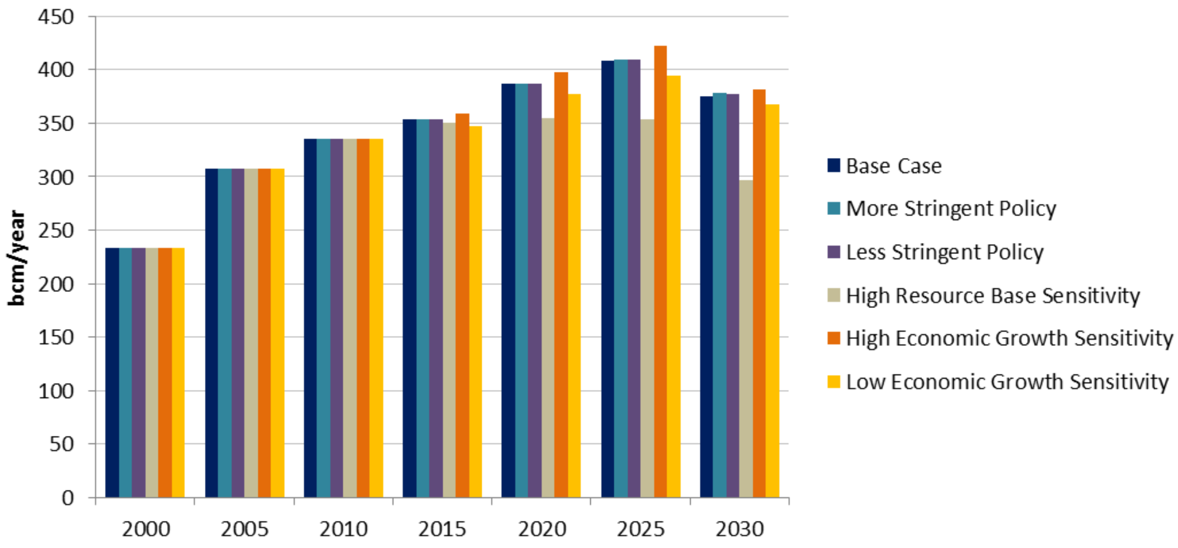
The rest of the supply is covered by imports.

Table 22. Gas imports (bcm/year)

Modelling Scenario	2000	2005	2010	2015	2020	2025	2030
0 – Base case	233	307	335	353	387	409	375
1 – More Stringent Policy	233	307	335	353	387	410	379
2 – Less Stringent Policy	233	307	335	353	387	409	377
3 – High Resource Base Sensitivity (with More Stringent Policy)	233	307	335	350	354	353	297
4 – High Economic Growth Sensitivity (with More Stringent Policy)	233	307	335	359	397	422	381
5 – Low Economic Growth Sensitivity (with More Stringent Policy)	233	307	335	347	377	394	367

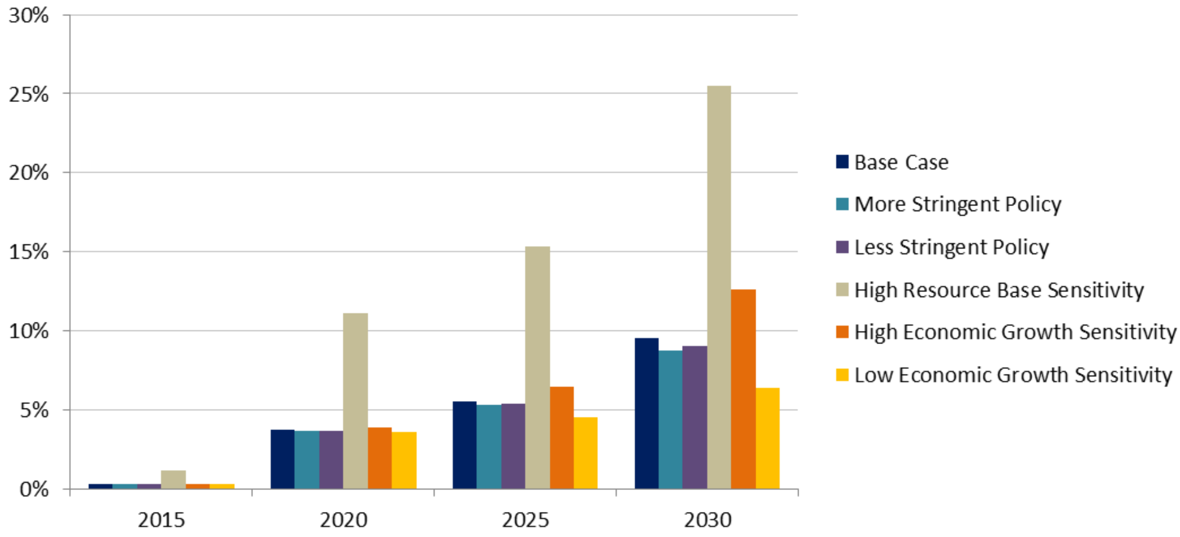
All scenarios reach a maximum of imports around 2025, except the "high resources" scenario, in which the EU produces sufficient gas to sensibly decrease its import needs back to the levels of the 2000s by 2030, with domestic shale gas production more than compensating for the depletion of domestic conventional gas supplies.

Figure 7. Gas imports to EU-27



In all cases except the "high resources" sensitivity (modelled with the more stringent policy scenario), the contribution of shale gas gradually reaches around 10% of EU gas consumption 15 years after start of production.

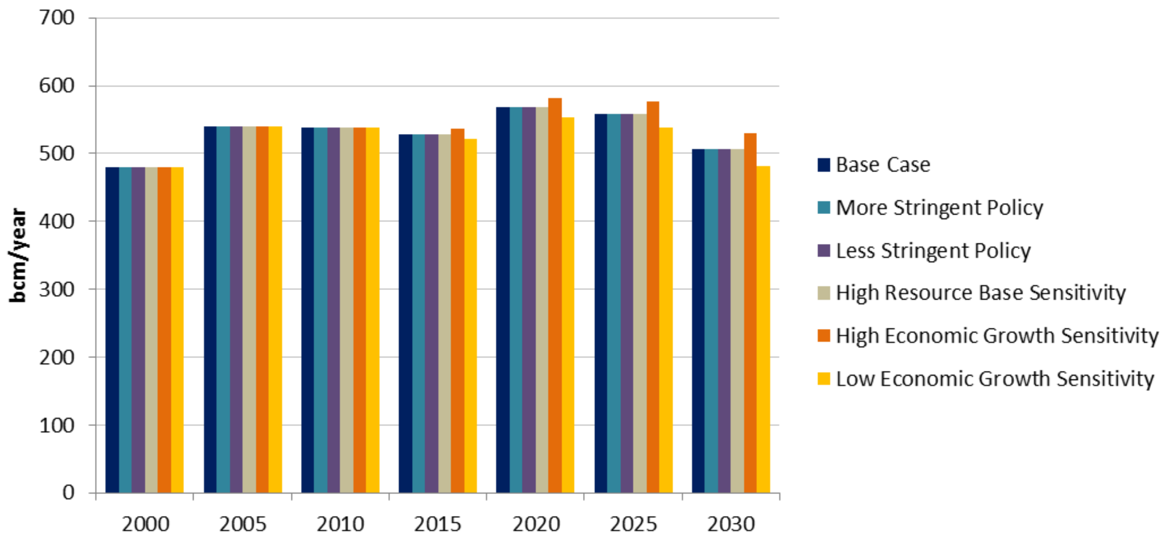
Figure 8. Contribution of domestic shale gas supply in EU-27 gas consumption



Energy consumption in EU27

Gas demand is largely driven by economic growth and energy prices; with gas prices being significantly similar between scenarios, the only differentiating factor between scenarios is economic growth.

Figure 9. Primary gas consumption (bcm)



Gas grows in importance in the EU's energy mix in all scenarios in the medium term, from about 26% today to about 29% between 2020 and 2025, before starting to decrease, progressively displaced by renewables as technologies mature.

Table 23. Percent of gas in eu-27 primary energy consumption, 2030

0 – Base Case	26.56%
1 – More Stringent Policy	26.56%
2 – Less Stringent Policy	26.56%
3 – High Resource Base Sensitivity (with More Stringent Policy)	26.57%
4 – High Economic Growth Sensitivity (with More Stringent Policy)	26.60%
5 – Low Economic Growth Sensitivity (with More Stringent Policy)	26.48%

Summary of energy impacts based on POLES modelling

Based on the POLES modelling work, the energy system impacts of the shale gas resource and policy scenarios explored in this analysis can be summarised as follows:

- Production of shale gas starts with over 1 bcm in 2015 and ramps up gradually to between about 30 bcm (low economic growth) and about 130 bcm (high resources) in 2030, with development trends pointing to higher volumes expected after 2030 for all scenarios.
- Production levels differ relatively little between risk management policy options (-8% with the most stringent option explored in this analysis compared to the base case).
- Conventional gas production is largely not impacted between scenarios assumptions, due to uniformly geologically depleting resources in the EU and to similar gas prices between scenarios.
- In all scenarios, including the more stringent policy scenario with high domestic shale gas production (Scenario 3), the exposition of the EU to international markets is such that the differences in domestic shale gas production have little effect on global supply and thus on international gas prices. As a result, prices between scenarios are largely similar, and we observe essentially a trade-off between domestic shale gas production and imports in all scenarios defined by internal EU factors (i.e. risk management policies and domestic shale gas resources).
- In all cases, the contribution of shale gas to domestic gas consumption gradually reaches around 10% in 2030, i.e. 15 years after start of production (except in the "high resources" sensitivity, where it reaches 25%).
- With gas prices being significantly similar between scenarios, the only differentiating factor between scenarios for total gas demand and total CO_2 emissions in the EU is economic growth.

4 Macroeconomic Impacts

4.1 Objectives and scope

This chapter provides an assessment of the competitiveness and employment impacts of the shale gas risk management policy options in comparison to the base case.

The analysis is carried out at a sectoral level, recognising that there could be distributional effects as well as macro-level impacts.

4.2 Modelling approach, model details, data sources

Impacts on competitiveness and employment are based on the results of the market impact analysis from the POLES model. The E3ME macroeconomic model converts key outputs from the POLES model—i.e., energy consumption (by fuel and sector), source of energy (domestic or imported), energy prices (by fuel) and investment by the energy sector—into impacts on:

- GDP
- Employment by sector
- Unemployment
- Other macroeconomic indicators: Household incomes (by income group), Consumption, Investment, Government expenditure, Inflation
- Sectoral indicators (output, exports, imports and prices)

The model is based on Eurostat data, with a historical database covering the period 1970-2010 (1995-2010 for CEE countries). Energy balances are obtained from the IEA. As macroeconomic models require a complete data set, gaps in the data have been estimated using customised software algorithms. To ensure that the analysis is carried out on a consistent basis, E3ME was calibrated to the same baseline forecast as the POLES model. The labour market baseline forecast in E3ME has been calibrated to be consistent with the most recent version of the EU projections published by CEDEFOP.

Results are presented in the sections below.

4.3 Results

4.3.1 Sectoral competitiveness

As shown in the table below, in Scenarios 1 and 2, sector output in Mining and Quarrying (which includes Oil and Gas extraction) decreases by less than 0.1% in comparison to the base case. The knock-on effects to other sectors are therefore negligible. The impact is very slightly greater in Policy Scenario 1 than 2.

Table 24. EU-27 output in 2030 (% difference from base case)

Sector	0- Base Case	1- More Stringent Policy	2- Less Stringent Policy	3-High Resources Sensitivity (with More Stringent Policy)
Agriculture, forestry and fishing	0.0	0.0	0.0	0.2
Mining and quarrying	0.0	-0.7	-0.5	27.3
Food, drink & tobacco	0.0	0.0	0.0	0.2
Textiles & leather	0.0	0.0	0.0	0.3
Wood & paper	0.0	0.0	0.0	0.4
Coke & refinery petroleum	0.0	0.0	0.0	-0.2
Chemicals	0.0	0.0	0.0	0.2
Pharmaceuticals	0.0	0.0	0.0	0.0
Rubber & plastic, Non-metallic minerals	0.0	0.0	0.0	0.5
Basic metals & metal products	0.0	0.0	0.0	1.1
Computer, optical & elec products	0.0	0.0	0.0	0.2
Electrical equipment	0.0	0.0	0.0	0.3
Machinery & equipment n.e.c.	0.0	0.0	0.0	0.7
Motor vehicles, transport equipment	0.0	0.0	0.0	0.1
Manufacturing nes	0.0	0.0	0.0	0.2
Electricity, gas, steam and air con	0.0	0.1	0.0	-0.5
Water and waste management	0.0	0.0	0.0	0.2
Construction	0.0	0.0	0.0	0.5
Wholesale and retails	0.0	0.0	0.0	0.2
Transport and storage	0.0	0.0	0.0	0.3
Accommodation and food services	0.0	0.0	0.0	0.1
Publishing activities	0.0	0.0	0.0	0.1
Telecommunications	0.0	0.0	0.0	0.2
Computer programming, consultancy	0.0	0.0	0.0	0.2
Financial services	0.0	0.0	0.0	0.2
Real estate activities	0.0	0.0	0.0	0.2
Imputed rents	0.0	0.0	0.0	0.0
Legal, accounting, consultancy	0.0	0.0	0.0	0.4
R&D	0.0	0.0	0.0	0.3
Advertising and other professionals	0.0	0.0	0.0	0.4
Administrative and support services	0.0	0.0	0.0	0.5
Public admin and defence	0.0	0.0	0.0	0.0
Education	0.0	0.0	0.0	0.0
Human health	0.0	0.0	0.0	0.0
Residential care	0.0	0.0	0.0	0.0
Art, entertainment and recreation	0.0	0.0	0.0	0.2
Other service activities	0.0	0.0	0.0	0.1
Households as employers	0.0	0.0	0.0	0.0

In Scenario 3, sector output increases by around 27% for Mining and Quarrying between Scenario 3 and the base case. This is a direct result of the net increase in shale gas production; the employment increase is smaller than the output increase. The sectors that are most affected are those that both provide inputs to the Mining sector:

- Basic metals and metal products (1.1%)
- Rubber & plastics, and Non-metallic minerals (0.5%)
- Machinery and equipment n.e.c (0.7%)
- Construction (0.5%)

With the exception of the Mining and Quarrying sector, trade is largely unaffected by the impact of the extra shale gas extraction represented by Scenario 3. Imports of other products increase slightly, driven by demand for inputs to the mining sector and because incomes are slightly higher, driving slightly higher consumption (some of which is spent on imported products and services). However, this slight increase in products import is not enough to offset the shale gas impact, which reduces imports. Overall, imports decrease by around 1.2% in Scenario 3 compared to the base case, while the impact on exports is negligible. In Scenarios 1 and 2, the trade balance is worsened compared to the base case, but only by less than 0.01% expressed as a share of GDP (€1.8 and-€1.1bn, respectively) as gas imports displace the shale gas that could have been extracted without the policies in place.

4.3.2 Household incomes

There is zero impact on income under Scenarios 1 and 2. The relative impact on income under Scenario 3 is small (0.1%), arising as a result of the employment creation.

4.3.3 GDP

The policy options represented by Scenario 1 and Scenario 2 have a negligible economic impact compared to the base case. At all levels (macro and sectoral), the results for these scenarios are negligible because the policies have almost no impact on energy production, energy prices or energy demand (and therefore, no impact on the economy is observed).

Table 25. EU27 GDP in 2030 (% difference from base case)[24]

Base Case	1- More Stringent Policy	2- Less Stringent Policy	3-High Resources Sensitivity (with More Stringent Policy)
0	-0.02	-0.01	0.34

The negative GDP impact arising in Scenarios 1 and 2 is the direct result of the marginally worsening trade balance.

The positive EU-27 GDP impact between Scenario 3 and the base case arises from displacement of gas imports with domestic shale gas production: the implication is that more economic value is retained in Europe, rather than spent on imports, which has knock-on indirect and induced effects on other sectors.

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24 Note that E3ME results are usually presented to 1dp. They are shown to 2dp in this section so actual numbers can be seen but placing emphasis on specific results to 2dp implies a false level of precision.

The GDP impact is more pronounced for Member States that have a large difference between shale gas production in the base case and in Scenario 3 (the high resource base sensitivity) relative to the overall size of a Member States economy.

4.3.4 Employment

The policy options represented by Scenario 1 and Scenario 2 have a negligible impact on employment compared to the base case, as shown below.

Table 26. EU-27 Employment in 2030 (% difference from the base case)

0- Base Case	1- More Stringent Policy	2- Less Stringent Policy	3-High Resources Sensitivity (with More Stringent Policy)
0	0	0	0.15

The employment impact is relatively small for Scenario 3, less-than-half of the relative impact on GDP. Therefore, the 0.34% GDP impact generates a 0.15% employment impact, which translates to around 350,000 jobs (measured in full-time equivalence) across Europe by 2030.

The impact is modest because the sectors most affected (the gas extraction sector) have a low-intensity of labour, and are far more capital intensive than the economy as a whole.

4.3.5 Other macroeconomic indicators

In Scenario 3, the trade balance is improved as a result of the displacement of gas imports with EU-27 shale gas extraction compared to the base case. However, this impact is ever so slightly offset by the impact of increased consumer expenditure (some of which is met by imports) and the demand for inputs to the gas extraction sector (again, some of which is met by imports). Overall, imports are reduced by around 1.2% in Scenario 3 by 2030 (see Table 20). The trade balance is further improved because sector competitiveness is improved as a result of lower (gas) prices (see Sector results), but this impact is modest.

Scenario 1 and 2 have almost no discernible impact on Europe's trade balance, since the impact on shale gas production is quite small. Scenario 1 leads to an increase in imports of nearly 0.1% by 2030 compared to base case, all of which arises from gas imports displacing shale gas extraction as a result of the more stringent policy regime.

As noted the impact on employment is small, and so the impact on real incomes is small. Household income increases by 0.1% across the EU-27 under Scenario 3.

4.4 Uncertainties and sensitivities

Uncertainty associated with the shale gas resource base is explored in Scenario 3, which presents the results of a high resource base modelled with a more stringent policy.

In addition, there are several key types of uncertainty in the economic modelling. These include inaccuracies in the data, parameter estimates, baseline forecast and model/scenario assumptions. In addition, uncertainty in the results from E3ME will also reflect to some extent the uncertainty of the POLES results that are used as model inputs.

For a single econometric equation, it is possible to produce a formal statistical estimate of uncertainty of results but there is no equivalent test for a set of modelling results. The assessment of uncertainty is therefore more qualitative in nature.

The conclusions from the modelling are drawn from results that may be considered as robust, given the results from the POLES model. The changes in model inputs are quite small in nature and this is reflected in the model results. The sectors that benefit the most in the scenario are those that supply the gas extraction sector; although there may be some uncertainty in the magnitude of the effects, it is unlikely that this would not be the case. Again, however, the scale of impacts would be quite small.

In summary, it is important to think about uncertainty when considering the detailed quantitative impacts. The direction of results and the qualitative conclusions can be considered robust, given the model inputs used.

4.5 Summary

Table 27 provides a summary of key economic indicators of the risk management options in 2030, EU27, as percentage difference from the base case. The table illustrates the policy options represented by Scenario 1 and Scenario 2 have a negligible economic impact compared to the base case. At all levels the results for these scenarios are negligible because the policies modelled have almost no impact on energy production, energy prices or energy demand according to the POLES modelling (and therefore, no impact on the economy is observed).

Table 27. EU-27 Summary of impacts of economic and social impacts of risk management policy options in 2030 (% difference from base case)

	0- Base Case	1- More Stringent Policy	2- Less Stringent Policy	3-High Resources Sensitivity (with More Stringent Policy)
GDP	0	-0.02	-0.01	0.34
Employment	0	0	0	0.15
Extra-EU Export	0	0	0	0.02
Extra-EU Import	0	0.07	0.04	-1.22
Household Consumption	0	0	0	0.12
Investment	0	-0.01	-0.01	0.44
Unemployment	0	0.02	0.02	-0.53

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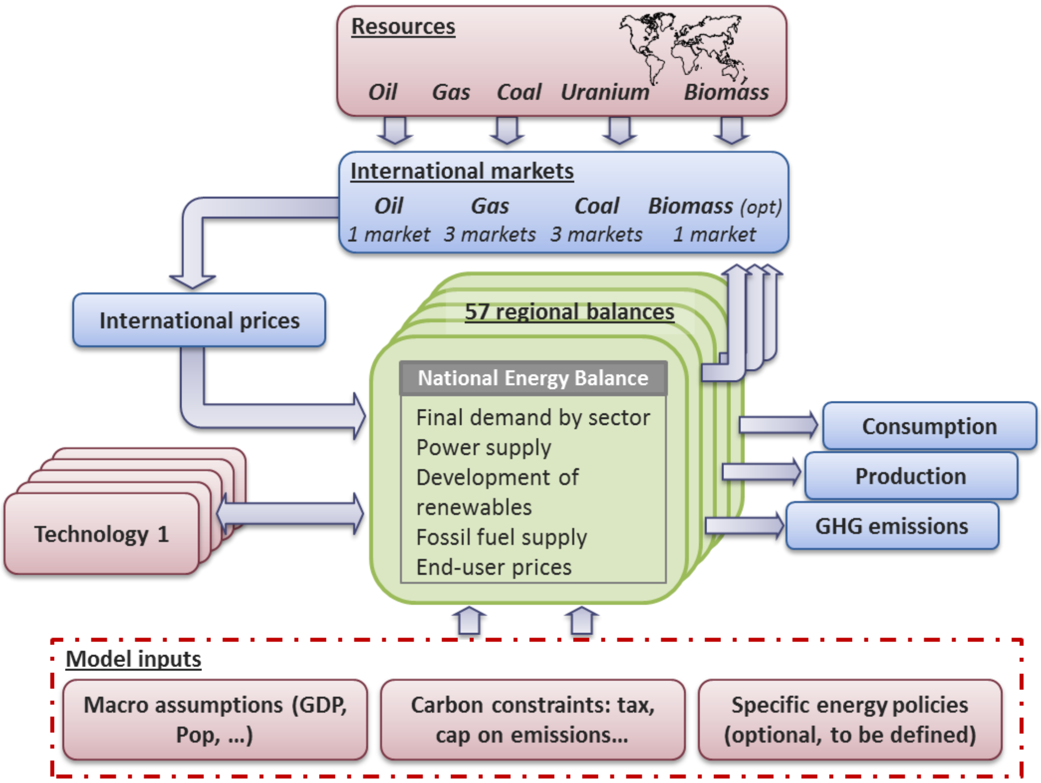
Annex 1– Overview of the POLES model

A1.1 Overview of the POLES model

Enerdata offers the world recognized POLES model to provide quantitative, scenario-based, empirical and objective analyses. As the POLES model is used by many members of the energy sector (private companies, governments, European Commission), it is very well adapted to forecast the effects of different energy-related engagements (GHG emissions limitations, promotion of renewables and energy efficiency, energy security issues…). In addition, with its global coverage and the endogenous calculation of demand, supply and prices of numerous energies including oil, gas, and coal, the POLES model is very relevant to capture all of the impacts of energy policies and climate change measures and to ensure that all the forecasts are coherent within the global environment.

POLES is a world energy-economy simulation model of the energy sector, with complete modelling from upstream production through to final user demand. The POLES model uses a dynamic partial equilibrium framework, specifically designed for the energy sector but also including other GHG emitting activities (e.g., the six GHGs of the "Kyoto basket"). The simulation process uses dynamic year-by-year recursive modelling, with endogenous international energy prices and lagged adjustments of supply and demand by world region, which allows for describing full development pathways to 2050.

Figure A1.1 Overview of POLES Model



The use of the POLES model combines a high degree of detail for key components of the energy system and a strong economic consistency, as all changes in these key components are influenced by relative price changes at the sectoral level.

The model provides technological change through dynamic cumulative processes such as the incorporation of Two Factor Learning Curves, which combine the impacts of "learning by doing" and "learning by searching" on technologies' development. As price-induced diffusion mechanisms (such as feed-in tariffs) can also be included in the simulations, the model allows for consideration of key drivers to future development of new energy technologies.

One key aspect of the analysis of energy technology development with the POLES model is indeed that it relies on a framework of permanent inter-technology competition, with dynamically changing attributes for each technology. In parallel, the expected cost and performance data for each key technology are gathered and examined in the TECHPOL database that is developed at the EDDEN laboratory of the Grenoble Université Pierre-Mendès-France for any modelling and policy-making purpose.

Key features of the model include:

- Long-term (2030, and possibility to go beyond) simulation of world energy scenarios/projections and international energy markets.
- World energy supply scenarios by main producing country/region with consideration of reserve development and resource constraints (80 producing countries/regions).
- Outlook for energy prices at international, national and sectoral level.
- Disaggregation into 25 energy demand sectors, with over 40 technologies (power generation, buildings, transport).
- Detailed national/regional energy balances, integrating final energy demand, new and renewable energy technologies diffusion, electricity, hydrogen and Carbon Capture and Sequestration systems, fossil fuel supply, and uranium (57 consuming countries/regions).
- Full power generation system (and feedback effect on other energies).
- Impacts of energy prices and tax policies on regional energy systems. National greenhouse gas emissions and abatement strategies.
- Costs of national and international GHG abatement scenarios with different regional targets/endowments and flexibility systems.
- CO_2 emission Marginal Abatement Cost curves and emission trading system analyses by region and/or sector, under different market configurations and trading rules
- Technology diffusion under conditions of sectoral demand and inter-technology competition based on relative costs and merit orders.
- Endogenous developments in energy technology, with impacts of public and private investment in R&D and cumulative experience with "learning by doing". Induced technological change of climate policies.
- Data are derived from scenarios simulated on the POLES model, using up-to-date data up to 2011, and GDP and population forecasts from CEPII and UNPD.
- Figures on energy and GHG emissions encompass the energy sector (fossil fuel combustion and industrial processes), but not LULUCF or waste.

GHG policies in POLES can take several forms, such as:

- Carbon price (ETS) / carbon value;
- Feed-in-tariffs or subsidies;
- Changing the competition for new electricity generating capacities to reflect a preference for low-emitting technologies/fuels (as in a renewable portfolio standard or specific political choices); and

- More optimistic assumptions on technological learning rates to reduce production costs for low-emitting technologies;
- Increase in final energy efficiency measures though technological innovation, price-induced mechanisms (e.g. pricing of end-user emissions), etc.

Additional information regarding the assumptions and workings of the POLES model can be found at http://ipts.jrc.ec.europa.eu/activities/energy-and-transport/documents/POLESdescription.pdf.

A1.2 Recent model updates

During 2012, a major update in data and modelling of the oil and gas production in POLES took place to better reflect the current and foreseen state of conventional and unconventional resources. Types of data sources include official government and industry assessments and forecasts.

Data and modelling were evaluated for relevance and comprehensiveness regarding unconventional liquid and gaseous resources, production costs, and energy inputs, covering liquid fuels:

- **Oil:** conventional (conventional petroleum, tight oil[25]), non-conventional (shale oil, Bitumen (oil sands), extra heavy oil, oil shale (kerogen)) and environmentally sensitive (Deepwater (>500 m depth), Artic (as defined by the USGS))
- **Gas:** conventional (conventional gas, tight gas[26]), non-conventional (shale gas)[27] and environmentally sensitive (e.g., deepwater[28] and arctic)

A1.1.2 GHG emissions

A1.1.2.1 CO_2 emissions

CO_2 emissions are calculated according to the fossil fuel consumption at the level of:

- Transformation sectors (electricity and hydrogen generation and other energy sector)
- Final demand of energy
- International bunkers

The emissions level is obtained by applying a carbon content factor to consumption according to the fuel and the sector, to which we remove, if necessary, certain amounts due to carbon sequestration or non-energy uses or carbon uptake in steel-making.

Biomass combustion is considered to be carbon-neutral; biomass associated with carbon capture and storage (CCS) technologies is considered to result in negative emissions.

A1.1.3 Non-CO_2 GHG emissions

The other greenhouse gases emissions that are simulated in POLES are the 5 GHGs identified in the Kyoto protocol on top of energy-CO_2. They are methane (CH_4), nitrous

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25 Tight oil is considered a conventional resource in the POLES model as it has been produced for many years and does not require the same extent of fracturing or horizontal drilling as shale oil.

26 Tight gas is considered a conventional resource in the POLES model as it has been produced for many years and does not require the same extent of fracturing or horizontal drilling as shale gas.

27 Coal bed methane is also considered to be a non-conventional gas; however, its inclusion in POLES is scheduled to occur in conjunction with upgrades to the coal sector currently underway.

28 POLES includes deepwater gas resources in European countries for United Kingdom and Norway and in the Mediterranean for Israel and Egypt, where fields have been significantly studied and reliable data are available; resources are not yet included for Cyprus and the Black Sea.

oxide (N_2O), perfluorocarbons (PFC), hydrofluorocarbons (HFC), and sulphur hexafluoride (SF_6) gases. GWP figures used are from IPCC's Fourth Assessment Report (2007).

Table A1.2 Sectoral disaggregation for non-CO_2 emissions balances, per country

Sector	GHG
Energy sector	
▪ Gas production	CH_4
▪ Coal production	CH_4
▪ Oil production	CH_4
▪ Power T&D	SF_6
Industry	N_2O
	HFCs
	PFCs
	SF_6
Buildings	CH_4
	N_2O
Road Transport	N_2O
Waste	CH_4
	N_2O

Unlike CO_2 emissions, which can be tracked with a great detail in POLES and related to the direct combustion of fuels, non-CO_2 emissions are related to a policy-dependent emissions intensity index and one activity indicator: energy production or energy consumption. This activity is represented through an endogenous variable of the POLES model. The generic equation for non-CO_2 emissions is:

Emissions = Emission Intensity Index parameter x Activity parameter x Trend

Where:

Emission Intensity Index parameter: a full equation that depends on gas- and sector-specific parameterization (maximum reduction potential, scaling factor), and on the carbon value that is included in the climate policy;

Activity parameter: depends on an Activity Indicator and a gas- and sector-specific elasticity;

Trend: Autonomous technological trend, i.e. assumption that technological developments will in most cases contribute automatically to reduce the emissions, even in the absence of any specific abatement policy.

Parameters were established in a sector-specific study conducted for POLES,[29] using data from US Environmental Protection Agency, IEA, RIVM, and other sources and non-linear regressions. Typical scenarios with POLES do not modify these parameters, but the parameterization allows the simulation of a dynamic reduction potential and a dynamic level of emissions.

The table below classifies the POLES series of non-CO_2 GHG emissions, coming from a wide variety of activities related to fossil fuel production, transportation and use, industrial production, etc., and mapping them to categories in UNFCCC accounting tables.

[29] Greenhouse Gas Emission Control Strategies (GECS). 2002. DG Research 5th Framework Programme, Research Project EVK2-CT-1999-00010. Available at http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_RCN=4767127.

Table A1.3 Emission categories for non-CO_2 gases and corresponding activities

Data Series	POLES Activity Indicator	UNFCCC Code	UNFCCC Category
CH_4 from gas production	Conventional + non-conventional gas production (with the possibility of distinguishing the two)	1B2B1	Total Energy > Fugitive Emissions From Fuels > Oil And Natural Gas > Natural Gas > Exploration
		1B2B2	Total Energy > Fugitive Emissions From Fuels > Oil And Natural Gas > Natural Gas > Production Processing
CH_4 from gas transport	Final demand for gas	1B2B3	Total Energy > Fugitive Emissions From Fuels > Oil And Natural Gas > Natural Gas > Transmission
		1B2B4	Total Energy > Fugitive Emissions From Fuels > Oil And Natural Gas > Natural Gas > Distribution
		1B2B5	Total Energy > Fugitive Emissions From Fuels > Oil And Natural Gas > Natural Gas > Other leakage
CH_4 from oil production	Conventional + non-conventional oil production	1B2A1	Total Energy > Fugitive Emissions From Fuels > Oil And Natural Gas > Oil > Exploration
		1B2A2	Total Energy > Fugitive Emissions From Fuels > Oil And Natural Gas > Oil > Production
		1B2A3	Total Energy > Fugitive Emissions From Fuels > Oil And Natural Gas > Oil > Transport
CH_4 from surface coal mining	Surface coal mining production	1B1A2	Total Energy > Fugitive Emissions From Fuels > Solid Fuels > Coal Mining And Handling > Surface Mines
CH_4 from underground coal mining	Underground coal mining production	1B1A1	Total Energy > Fugitive Emissions From Fuels > Solid Fuels > Coal Mining And Handling > Underground Mines
CH_4 from residential, agriculture, services	Final consumption of gas and biomass in buildings	1A4	Total Energy > Fuel Combustion Activities > Other Sectors
N_2O from transport	Final consumption of oil in transport	1A3	Total Energy > Fuel Combustion Activities > Transport
N_2O from industrial waste powerplants	Value added of industry	6	Waste
N_2O from residential, agriculture, services	Final consumption of oil and biomass in buildings	1A4	Total Energy > Fuel Combustion Activities > Other Sectors
SF_6 from electricity transmission	Power demand	2E + 2F	
CH_4 from landfills	Urban population	6	Waste
N_2O from industry	Value added of chemistry	1A2	Total Energy > Fuel Combustion Activities > Manufacturing Industries And Construction
		2	Industrial Processes
		3	Solvents And Other Products Use
HFCs from industry	Value added of other industry	2	Industrial Processes
PFC from other industries (inc. semi-conductors)	Value added of other industry	2 - 2C	Industrial Processes (exc. Metal Production)
PFC from aluminium	Value added of other industry	2C	Industrial Processes > Metal Production

Data Series	POLES Activity Indicator	UNFCCC Code	UNFCCC Category
SF_6 from industry	Value added of industry	2 - 2E - 2F	Industrial Processes

A1.2 Base case

Our "base case" is the scenario we started from for the calibration of the reference scenario for this project. It differs from a "Business As Usual" scenario, as it includes climate-related policies that change investment decisions (as described below) compared to the historical behaviour of most energy sector actors. It includes policies resulting in emissions reductions by 2030 of around 40% compared to 1990.

This base case forms the scenario on which policy scenarios and sensitivities in relation to shale gas are assessed.

A1.2.1 Storyline

Once the global recession is over, Business as Usual behaviour is restored rather quickly, and economic growth begins recovering from 2013 onwards. Sustained growth of China and other emerging countries is a powerful driver of energy demand. On the climate side, only current or already planned policies are maintained, including a 20% GHG emissions reduction in the European Union by 2020 (GHG emissions related to combustion and industrial processes). No additional policies are assumed on the international level, resulting in a GHG emissions profile that continues to increase across the world and in emerging economies in particular. The future fuel mix is dominated by fossil fuels.

For the EU after 2020, a stylised scenario is assumed that sees a carbon price signal across all sectors ensuring that the EU reduces its GHG emissions (related to fossil fuel production and combustion and industrial processes) in 2030 by 40% compared to 1990 levels, see below for sectoral coverage). International fossil fuel prices increase significantly as world economic growth puts stress on demand.

A1.2.1.1 Default Policies in the Base Case

Key default policies in the base case include:

- A carbon value within Europe sufficient to reach a 20% reduction in GHG emissions by 2020 (represents the evolution of the EU ETS as well as support for low-carbon technologies and policies);
- No carbon value is included outside of Europe;
- Extension and intensification of the carbon value throughout 2030 sufficiently so as to reach a 40% reduction of GHG emissions at the EU level compared to 1990,[30] as previously noted;
- Policies already publicly declared, including those on nuclear (e.g., nuclear phase-out schedule of Germany) and renewables (e.g., feed-in-tariffs, subsidies, and support for biofuels in road transport), with a timeframe dependent on countries' announced policies, but generally not extending beyond 2025 since few tangible policies are declared that far in advance.

A1.2.1.2 Policies and Assumptions Pertaining to Shale Gas in the EU

The following policies and assumptions specifically pertaining to shale gas in the EU are included in the POLES model base case:

[30] This broadly aligns with the trajectory required to meet the EU's 2050 GHG emission reduction target per the EC's Low Carbon Economy Roadmap Communication and the Energy Roadmap 2050 Communication.

- Shale gas resources drawn from IEA, BGR, and most up-to-date national reports reviewed by ICF (see Section 3.1); according to this review, shale gas is assumed to be present in 16 EU Member States.[31] Estimated Ultimate Recoverable Resources (URR) are constant through time and consider access based on Natura 2000 and population density (see Section 3.1.2 for more detail); resources progressively enter reserves and can then be produced.
- At the time of conducting the modelling analysis for this report, moratoria or bans on exploration and production are enacted in France, Bulgaria, the Netherlands, Luxembourg, the Cantabria Region of Northern Spain and the North Rhine Westphalia part of Germany.[32] In the modelling exercise, these moratoria are assumed to continue until 2015 (for France, it is likely to be 2017, but, in all cases, in the absence of firm information, the same assumption was made); beyond that date, no constraints in shale gas exploitation in these countries are assumed.
- There are no legal barriers imposed to shale gas exploitation elsewhere in the world throughout the modelling period.
- Technological costs are fixed at 2011 levels, but production costs rise over time with cumulative depletion of the resource, due to increasing extraction energy requirements (production cost curve as a function of the share of resource that has been produced); simultaneously, this effect is counter-balanced by technological learning effects that tend to decrease costs, and the production costs are a result of these two effects combined. Production cost curves have been assigned to EU shale gas based on the US production cost curve: on past experience and expert estimates on where it is headed in the future. Clean-up costs and other environmental costs are not included in these production cost curves.
- Shale gas, once produced, is indistinguishable from natural gas from other sources (domestically produced or imported) and contributes to a single commodity that is gas. Policies that make renewables or other fuels comparatively more competitive than gas will result in a reduction of the demand for gas, be it conventional or not.

A1.2.2 Energy prices

Table A1.4 Energy price forecasts in the base case based on POLES modelling

	2000	2005	2010	2015	2020	2025	2030
International Oil Market Price ($05/bbl)	32.1	54.5	71.3	82.5	89.0	112.8	132.4
European Gas Market Price ($05/MMBtu)	4.1	6.9	5.1	7.0	6.9	8.2	8.7
European Coal Market Price ($05/t coal)	39	69	95	125	127	131	135

A1.2.3 Macro-economic assumptions

Population data and growth rates are included from the UN Population Division medium fertility scenario from 2011.[33] GDP data and growth rates are included from:

- World Bank (values for 2000-2011);[34]
- IMF (values for 2012-2017);[35] and

31 Austria, Bulgaria, Denmark, Estonia, France, Germany, Hungary, Ireland, Latvia, Lithuania, Netherlands, Poland, Romania, Spain, Sweden, and United Kingdom.

32 Shale gas resources in the North Rhine Westphalia are estimated by ICF to represent about 10-15% of Germany's total; to be conservative, 15% is assumed in this analysis.

33 Available at http://esa.un.org/unpd/wpp/Excel-Data/population.htm.

34 Available at http://data.worldbank.org/indicator/NY.GDP.MKTP.CD.

35 Available at http://www.imf.org/external/ns/cs.aspx?id=28.

- CEPII (values for 2018-2030).[36]

Assumptions on population and GDP growth rates are provided in the tables below.

Table A1.5 Population growth rates (%)

Member State	2000	2005	2010	2015	2020	2025	2030
Austria	0.12	0.72	0.23	0.12	0.12	0.10	0.04
Belgium	0.25	0.55	0.77	0.24	0.24	0.22	0.20
Bulgaria	-1.80	-0.53	-0.55	-0.67	-0.73	-0.81	-0.85
Cyprus	1.43	1.13	0.07	1.01	0.82	0.67	0.53
Czech Republic	-0.09	0.19	0.36	0.21	0.17	0.07	-0.05
Denmark	0.34	0.27	0.38	0.32	0.31	0.27	0.19
Estonia	-0.45	-0.22	-0.05	-0.08	-0.14	-0.25	-0.33
Finland	0.21	0.34	0.46	0.29	0.26	0.18	0.08
France	3.65	0.75	0.52	0.49	0.43	0.39	0.36
Germany	0.15	-0.06	-0.24	-0.19	-0.12	-0.18	-0.23
Greece	0.32	0.38	0.32	0.19	0.10	0.04	0.03
Hungary	-0.26	-0.20	-0.14	-0.15	-0.16	-0.18	-0.22
Ireland	1.34	2.20	0.50	1.06	0.91	0.76	0.67
Italy	0.05	0.74	0.48	0.11	-0.03	-0.07	-0.09
Latvia	-0.75	-0.53	-0.53	-0.36	-0.40	-0.45	-0.47
Lithuania	-0.89	-0.62	-0.56	-0.40	-0.37	-0.38	-0.43
Luxembourg	1.35	1.54	1.62	1.22	1.16	1.03	0.88
Malta	0.52	0.64	-0.08	0.28	0.18	0.08	-0.04
Netherlands	0.76	0.23	0.49	0.26	0.21	0.17	0.11
Poland	-0.53	-0.04	0.09	0.03	-0.02	-0.12	-0.27
Portugal	0.51	0.45	0.10	-0.03	-0.21	-0.31	-0.33
Romania	-0.07	-0.23	-0.18	-0.23	-0.27	-0.32	-0.38
Slovak Republic	-0.12	0.08	0.27	0.16	0.12	0.02	-0.13
Slovenia	0.18	0.17	0.64	0.19	0.08	-0.03	-0.11
Spain	0.84	1.65	0.38	0.51	0.42	0.28	0.18
Sweden	0.13	0.36	0.87	0.54	0.56	0.47	0.34
United Kingdom	0.36	0.60	0.68	0.60	0.56	0.53	0.45

[36] Available at http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=11.

Table A1.6 GDP growth rates (%)

Member State	2000	2005	2010	2015	2020	2025	2030
Austria	2.16	2.40	2.31	2.15	1.52	1.16	1.02
Belgium	4.19	1.73	2.27	1.57	1.40	1.05	1.05
Bulgaria	11.15	6.36	0.20	3.50	3.76	2.92	2.69
Cyprus	5.10	3.91	1.04	2.50	2.88	2.76	2.68
Czech Republic	3.65	6.32	2.35	3.62	3.23	2.92	2.87
Denmark	3.35	2.45	1.75	1.90	1.49	1.12	1.06
Estonia	7.36	9.43	3.10	3.79	4.51	4.92	4.76
Finland	4.51	2.92	3.64	1.98	1.64	1.28	1.22
France	3.73	1.83	1.48	1.90	1.77	1.54	1.52
Germany	2.15	0.68	3.69	1.29	0.90	0.45	0.39
Greece	3.17	2.28	-3.52	3.15	2.86	2.82	2.71
Hungary	5.74	3.96	1.26	2.26	2.63	2.97	2.74
Ireland	10.16	6.02	-0.40	2.84	2.53	2.14	2.05
Italy	3.67	0.66	1.30	1.00	0.75	0.29	0.29
Latvia	7.01	10.60	-0.34	3.53	4.47	4.92	4.86
Lithuania	4.02	7.80	1.33	3.72	4.46	4.92	4.77
Luxembourg	10.04	5.43	2.68	2.89	2.73	2.18	1.87
Malta	5.50	4.01	3.15	2.22	2.53	2.77	2.77
Netherlands	4.30	2.05	1.69	1.83	1.59	1.22	1.10
Poland	4.35	3.62	3.94	3.90	3.47	3.04	2.85
Portugal	7.49	0.76	1.39	1.90	1.58	1.67	1.68
Romania	2.20	4.17	0.95	3.98	3.75	3.44	3.16
Slovak Republic	1.39	6.66	4.24	3.90	3.65	3.56	3.21
Slovenia	4.64	4.01	1.38	1.90	2.03	1.96	1.84
Spain	5.09	3.61	-0.14	1.65	2.03	2.18	2.14
Sweden	5.01	3.16	5.63	3.00	2.06	1.67	1.56
United Kingdom	5.28	2.17	1.35	2.61	2.43	1.95	1.79

Annex 2– Overview of E3ME model

This section describes the macroeconomic E3ME model and summarises how it will be applied in the study. The model will be the principle tool used to assess the macroeconomic costs and benefits, including employment impacts. Further information about E3ME, including the full manual, is available at www.e3me.com.

A2.1 Introduction to E3ME

While in our view it is clearly necessary to apply a modelling approach to the tasks, E3ME is particularly well suited because:

- It covers each of the European Member States at national level
- It has a detailed sectoral specification
- It has been applied extensively at European level before, for a variety of clients
- Its econometric specification provides a strong empirical grounding
- It has a detailed treatment of labour market effects
- It incorporates physical flows of energy in its structure

A general model description is provided below and further information, including the full model manual, is available online at www.e3me.com.

A2.1.1 Economic pedigree and recent applications

E3ME is a computer-based model of Europe's economies, linked to their energy systems and the environment. The model was originally developed through the European Commission's research framework programmes in the 1990s and is now widely used in collaboration with a range of European institutions for policy assessment, for forecasting and for research purposes.

Examples of recent studies that have made use of the E3ME model include:

- Input to the Impact Assessment of the proposed Energy Efficiency Directive[37] (DG Energy)
- Input to Impact Assessment of the proposed revised Energy Taxation Directive[38] (DG TAXUD)
- Sustainability and Green Jobs[39] (DG Employment)
- The EU's current projections of labour skills supply and demand[40] (CEDEFOP)
- Assessment of green fiscal stimulus packages in Europe[41] (DG Environment)

In addition, the E3MG model, which is identical in structure to E3ME, but covers the whole world (although not the EU Member States at national level) contributed to the European Commission's communication on moving beyond the 20% GHG reduction target.

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37 http://ec.europa.eu/energy/efficiency/eed/eed_en.htm

38 http://ec.europa.eu/taxation_customs/taxation/excise_duties/energy_products/legislation/index_en.htm

39 http://ec.europa.eu/social/BlobServlet?docId=7436&langId=en

40 http://www.cedefop.europa.eu/EN/publications/15540.aspx

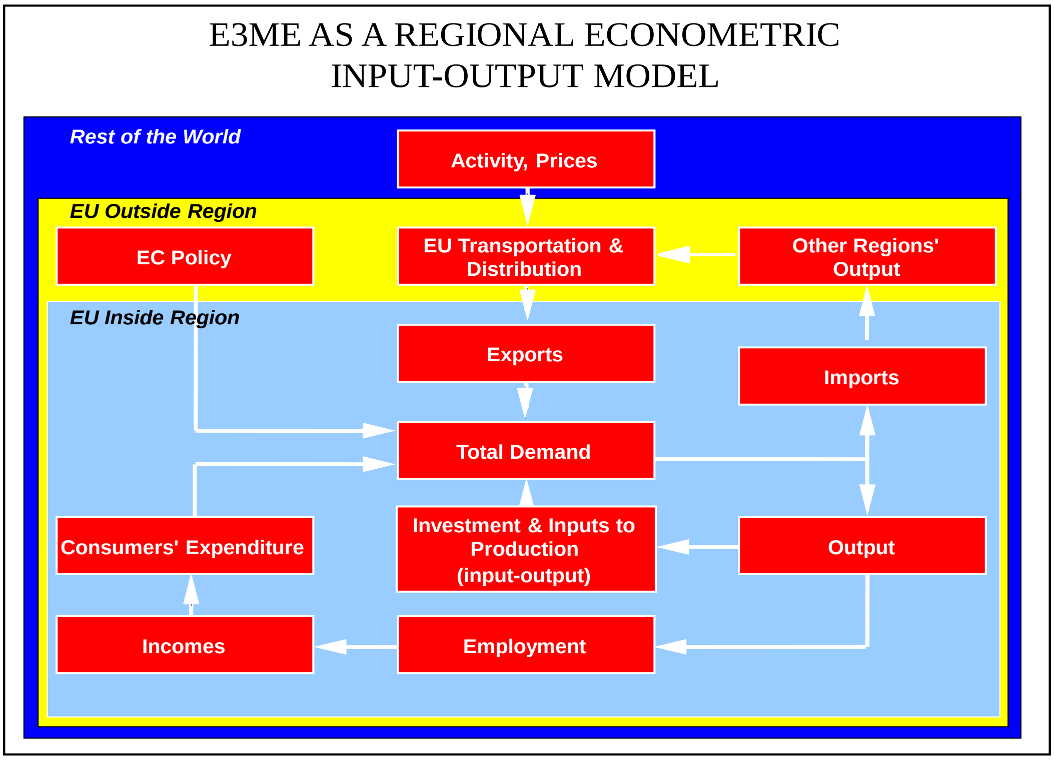
41 http://ec.europa.eu/environment/enveco/memberstate_policy/pdf/green_recovery_plans.pdf

A2.1.2 Economic structure

The economic structure of E3ME is based on the system of national accounts, as defined by ESA95 (European Commission, 1996). Figure A2.1provides a summarised graphical representation of the main economic flows for a single European country. Short-term multiplier effects occur through the various interdependencies and feedback loops that are present in the model structure.

The labour market is also covered in detail, with estimated sets of equations for labour demand, supply, wages and working hours. In total, there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

Figure A2.1 E3ME Economic Structure

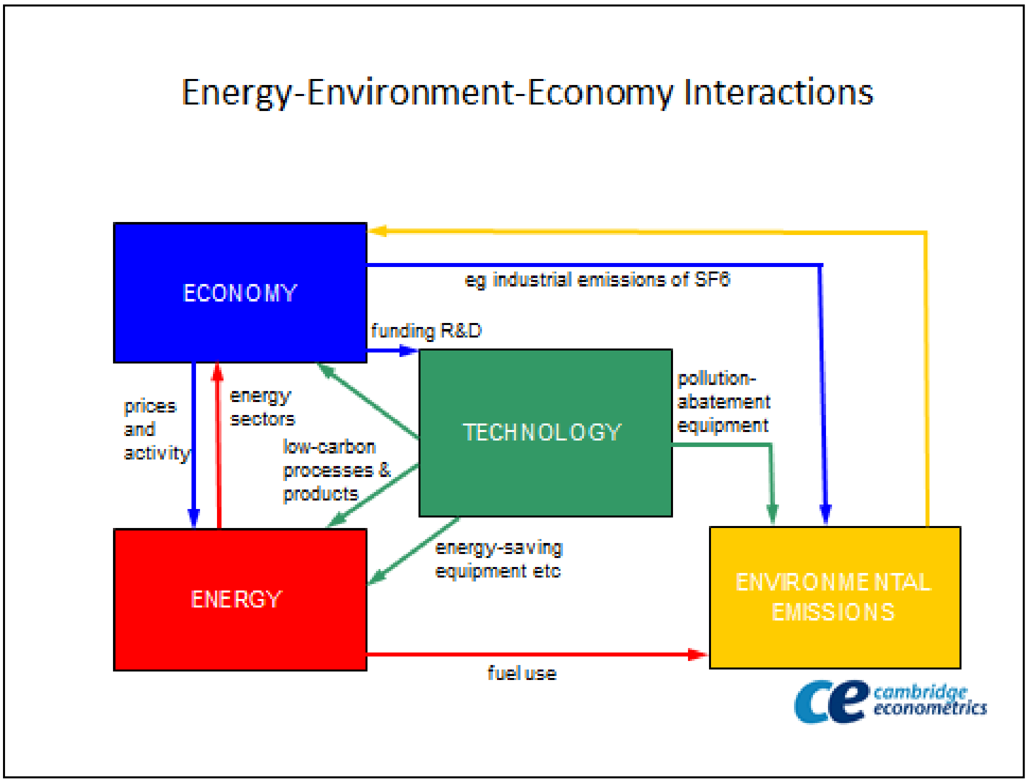


A2.1.3 Energy and Environment linkages

Figure A2.2 shows the main modules in E3ME. The economy and energy demand are closely linked; economic activity creates the demand for energy, but energy consumption also affects the economy through output in the energy production and distribution sectors (e.g. electricity sector, oil and gas sector). Most environmental emissions are caused by fuel combustion (modelled as a fixed coefficient) but there are also direct economy-emission linkages through process emissions.

Technology, which is endogenous in E3ME, can affect many of these relationships. For example, the use of energy-efficient vehicles allows an increase in economic production without an increase in energy consumption and emissions. Some particular technologies like CCS or renewables allow energy consumption to increase without increasing emissions.

Figure A2.2 E3ME Modules



A2.1.4 The main dimensions of the model

The main dimensions of the model are:

- 33 countries (the EU27 Member States, Norway and Switzerland and four candidate countries)
- 69 economic sectors, defined at the NACE (rev2) 2-digit level, linked by input-output relationships
- 43 categories of household expenditure
- 13 types of household, including income quintiles and socio-economic groups such as the unemployed, inactive and retired, plus an urban/rural split
- 19 different users of 12 different fuel types
- The 6 Kyoto GHGs; other emissions where available