Blue Growth

Scenarios and Drivers for Sustainable Growth from the Oceans, Seas and Coasts

Maritime Sub-Function Profile Report
Offshore oil and natural gas (3.1)

Call for tenders No. MARE/2010/01

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The research for this profile report was carried out in the period April – August 2011. This report has served as an input to the main study findings and these have been validated by an Expert meeting held on 9/10th November 2011 in Brussels. The current report serves as a background to the Final Report on Blue Growth.

Content

Summary

More than 80% of current European oil and natural gas production is offshore. The main activities can be found in the North Sea, but also in the Mediterranean, Adriatic and Black Seas. These fields are mature, with declining production and rising costs. In the near future, primary production of oil (on– and offshore together) in the EU is projected to decrease steadily, arriving at a 2030 production level of 30% of today's level. For natural gas, the decrease is less strong but still, 2030 production is projected to be less than half of today's production[1]. However, these domestic resources still represent an important contribution to European security of energy supply over the next years, especially given high global fossil fuel prices and uncertainties about security of supply. Total turnover of crude oil production of the EU in 2008 was 82,122 million euros.[2]

R&D is focusing on cost reductions, exploration techniques and applications such as EOR and EGR. Furthermore the development of ultra-deep and Arctic exploration and production is being researched, and the potential of shale gas is being investigated, as well as its environmental implications.

External drivers affecting the sub-function are the global demand for (fossil) fuels (particularly following economic growth in economies such as China, India), price of oil and gas, the availability of resources in Europe versus elsewhere, policy initiatives such as energy security and renewable energy ambitions, as well as physical influences.

As a mature sub-function, the industry responds to this by finding optimal production methods, reducing costs and spreading risk. EU players are active worldwide and do not just depend on the local opportunities within the EU. The likely future entails a gradual decline of production and employment in Europe and a shift to other regions.

[1]Baseline projection, see http://ec.europa.eu/dgs/energy_transport/figures/index_en.htm
[2]http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database

1 State of Play

1.1 Summary description of the nature of the sub-function

The functional profile includes all fossil fuels that are harvested offshore. Fossil fuels are those resources that can be extracted and processed in order to be used in various ways, especially in our energy supply. We have identified two main segments:

- Crude oil production;
- Natural gas production;

In addition, a potential new segment is that of methane hydrates.

Crude oil production

Crude oil – or petroleum – concerns naturally occurring, flammable liquids that are found in geological formations under the earth surface. They are created by conversion of micro-organisms like algae, under specific long-term geological conditions involving pressure, heat and permeability of the geological formations. The liquids consist of various hydrocarbon molecules, which after refining and separation, are transformed into a range of goods. These include gasoline, diesel, kerosene, fuel oil, asphalt, plastics and feedstocks for the pharmaceutical and chemical industry.

After exploration, the crude oil is produced by insertion of pipes in the oil field. Subsequently, the crude oil is transported to the main land for refining and selling. Onshore oil is cheaper than offshore oil at this point, because offshore oil production requires higher operational costs and specific materials that can withstand corrosion and erosion. There is extensive specialisation within the industry in these techniques, with entire companies devoted purely to developing the oil platforms that the extraction and processing companies use to produce the end-product.

Natural Gas production

Natural gas consists primarily of methane, and secondarily of ethane. The gas can be found in underground layers, possibly as a side-product of crude oil extraction. Like oil, natural gas occurs naturally in gas and oil reservoirs, created as a result of massive pressure over a long period of time on micro-organisms, under specific conditions of heat and permeability. However, it requires separate extraction and transportation. After extraction, before it can be used, it has to be processed to remove impurities that include water or sediment that is collected from the reservoir. Subsequently, the natural gas is used as fuel for transport, heating, cooking and to produce electricity, and is an important feedstock for fertilisers.

Unconventional fossil fuels

In addition, other sources of fossils fuels, known as unconventional fuels such as methane hydrates, could be exploited. Currently, their resources assessment, economics and environmental impact is not fully understood, imposing a barrier for developments of these resources. Methane hydrates are molecules of methane bonded to hydrogen atoms and trapped in ice-like particles.[3] The discovery of this source of methane is interesting, since it represents a vast source of natural gas, which can supplement the dwindling store of underground natural gas. Although the estimations of the total global amount of methane hydrates diverge, it is assumed to be of similar magnitude of all remaining coal, crude oil and conventional natural gas reserves together.[4,5]

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[3] K.A. Kvenvolden (2003). Methane hydrate – A major reservoir of carbon in the shallow geosphere?Chemical Geology **71** 41-51

[4] K.A Kvenvolden (1988) Methane hydrates and global climate. Global Biogeochemical Cycles 2 221-229

Current technologies are not yet advanced enough to produce this source economically, in comparison to crude oil production and natural gas extraction.[6]

In the USA, (on shore) shale gas has become an important source of natural gas. In Europe and elsewhere, interest is growing and a number of onshore as well as offshore resources have been found, the latter notably in the UK.[7] Whether or not this can lead to short term exploitation however remains too early to tell.

Environmental concerns associated to shale gas exploitation relate to water pollution caused by hydraulic fractioning methods using chemicals. Another concern is the uncontrolled release of methane. Investigations at several onshore US sites have been made, and results are controversial. In Europe a number of onshore drills have been made. In Poland, Germany, France and Sweden, exploration projects have taken place.[8] In the Netherlands test drills have been approved. So far two EU countries, France[9] and Bulgaria[10], have banned fractioning practices.

Some consider the development of shale gas opportunities as a potential disincentive to develop offshore renewable energy. In Poland spatial conflicts between shale gas and offshore wind platforms have already been encountered.[11] Others suggest shale gas could be a ‘bridging fuel’ helping to develop viable ways to step from carbon fuels to renewables although others criticise this.[12] [13]

1.2 Description of the current structures

The picture below demonstrates the location of major oil and natural gas production installations that were active in Europe in 2010. Activities are mainly found in the North Sea, the Adriatic Sea, the Mediterranean Sea and the Black Sea.

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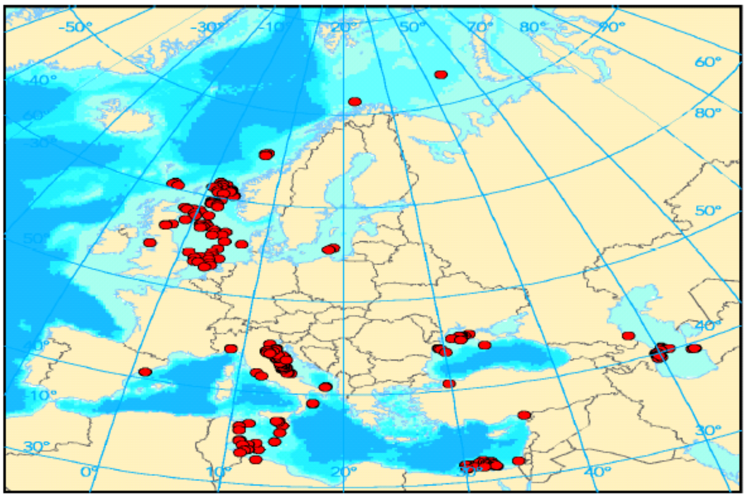
[5]Y.F. Makogon (1997) Hydrates of Hydrocarbon. Book published at PennWell Publishing, pp. 485
[6]Sloan, E.D. (2003). Fundamental principles and applications of natural gas hydrates, *Nature* 426, pp. 353-363
[7] Reuters, 17 April 2012, Exclusive: UK has vast shale gas reserves, geologists say, http://www.reuters.com/article/2012/04/17/us-britain-shale-reserves-idUSBRE83G0LE20120417, accessed 11 July 2012
[8] Philippe & Partners (2011), Final report on unconventional gas in Europe. Brussels, 8 November 2011, http://ec.europa.eu/energy/studies/doc/2012_unconventional_gas_in_europe.pdf.
[9] France24, 5 November 2011, French lawmakers ban controversial shale gas drilling, http://www.france24.com/en/20110511-france-votes-ban-shale-gas-drilling-fracking-ump-sarkozy, accessed 11 July 2012
[10] The Guardian, 14 February 2012, Bulgaria becomes second state to impose ban on shale-gas exploration, http://www.guardian.co.uk/world/2012/feb/14/bulgaria-bans-shale-gas-exploration, accessed 11 July 2012
[11] Wind Power monthly, 16 April 2012, Polish offshore plans suffer shale gas setback, http://www.windpowermonthly.com/news/1126980/Polish-offshore-plans-suffer-shale-gas-setback/, accessed 12 July 2012
[12] M. Ragheb, 2012, Natural gas as a bridging fuel toward renewables, https://netfiles.uiuc.edu/mragheb/www/NPRE%20498ES%20Energy%20Storage%20Systems/Natural%20Gas%20as%20a%20Bridge%20Fuel%20toward%20Renewables.pdf
[13] ZME Science, 2012, Shale gas isn’t a ‘clean bridge fuel’, study finds, http://www.zmescience.com/science/geology/shale-gas-21012012/, accessed 12 July 2012

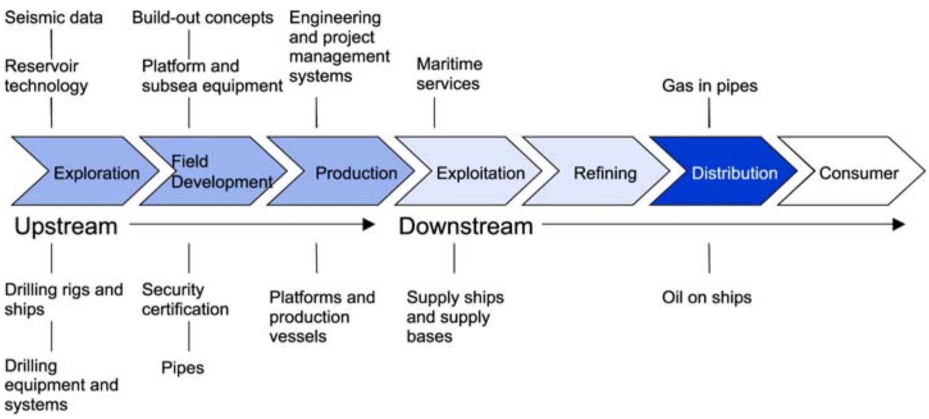
Figure 1.1 Offshore oil and gas production installations



Source: European Environment Agency, 2010

1.1.1 Value chain

The value chain for offshore oil and natural gas production consist of the following elements, which are largely the same for both:



The value chain can be explained in the following sections:

- Upstream:
  - o Exploration: where a range of methods are applied to find new oil and natural gas reserves;
  - o Production: bringing oil and natural gas to the surface, either naturally or artificially;
- Downstream:
  - o Refining: natural gas is treated and purified to send to the gas markets, and crude oil is converted into finished petroleum products. Refining of natural gas is often done at the platform, removing water, impurities and heavier hydrocarbons. In contrast, crude oil is often transported to a refinery first, because the refining process is complex, for producing a whole range of different products;
  - o Transportation: natural gas is transported to the main land by pipelines, and crude oil by pipelines or shuttle tankers;
  - o Sales and marketing: where the refined products are sold to the final consumers.

Most of the imports of fossil fuels into the EU are by sea. The vast bulk of oil and coal imports come by tanker and dry bulk carrier respectively. For natural gas, currently over 80% of imports are by pipeline, the rest is in the form of Liquefied Natural Gas (LNG), transported in tankers by sea and regasified in importing ports, or offshore, for transmission to Europe's natural gas networks.[14,15]

Despite its economic importance, the transportation of fossils fuels will not be covered in this section. Because refining and distribution are not offshore activities per se, we exclude these elements of the value chain from further analysis. We are aware that this is an arbitrary decision.

1.1.2 Economic performance

More than 80% of current European oil and natural gas production is offshore. As mentioned earlier, the main activities can be found in the North Sea, but also in the Mediterranean, Adriatic and Black Seas. These fields are mature, with declining production and rising costs. In the baseline scenario (Primes 2007), primary production of oil in the EU is projected to decrease steadily, arriving at a 2030 production level of 30% of today's level. For natural gas, the decrease is less strong but still, 2030 production is projected to be less than half of today's production.[16] According to the International Energy Agency (IEA) the production of crude oil and natural gas will decline the coming two decades with 4.2% and 0.9%, respectively. That means that in 2030, the European oil production will be 40% and 83% of today's production, respectively.[17]

However, these domestic resources still represent an important contribution to European security of energy supply over the next years, especially given high global fossil fuel prices and uncertainties about security of supply. Total turnover of crude oil production of the EU in 2008 was € 82,122 million.[18]

When looking in more detail at the Member States, the UK and Denmark cover more than 80% of the total production of crude oil in 2008. These countries predominantly produce oil offshore. Therefore, we arrive at an estimated offshore share of the total turnover to be between 80-90%. That means that the size of the offshore crude oil production sector ranges from € 66 to 74 billion.

Applying a similar reasoning for natural gas production as used for the offshore oil production, the total turnover of natural gas production in the EU27 in 2008 was € 90,355 million. The UK and the Netherlands, producing equal amounts, together cover 75% of total turnover in the EU. In the Netherlands, 30% is produced offshore; for the UK this is around 80%, which means that of 75% of European gas production, 55% is produced offshore. Extending this reasoning to the other gas producing Member States while applying a larger range, means that between 45-65% of natural gas is produced offshore, yielding a turnover of € 41-59 billion.

The number of people employed in this sector – that is the European on- and offshore oil and natural gas production industry – was almost 60,000 in 2007.[19] This figure is derived from Eurostat, and some caution should be taken when making conclusions, since according to Eurostat employment fluctuated between 20,000 fte in 2004 and 80,000 in 2005, while production is steadily declining at 4% per year in the last decade. Again applying a very rough estimate, and a similar reasoning as for the turnover, we estimate the current employment in the European offshore oil and gas producing industry to be in the range of 25,000 to 50,000 fte.

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[14] Roughly 250 Billion Cubic Meters (BCM) were imported to the EU in 2005 by pipeline, whereas only 50 BCM were imported as LNG-shipments; see http://ec.europa.eu/comm/competition/sectors/energy/inquiry/index.html
[15] Sec(2007)12863
[16] Baseline projection, see http://ec.europa.eu/dgs/energy_transport/figures/index_en.htm
[17] World Energy Outlook, IEA, 2010
[18] http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database
[19] http://epp.eurostat.ec.europa.eu/portal/page/portal/employment_unemployment_lfs/introduction

The interviewees mentioned that the employment and value added is probably higher than the figures we have estimated above. Unfortunately, the stakeholders could not share information with us to confirm the arguments. In general, it firstly depends on how one limits the value chain, and what counts as direct, indirect and derived employment. Subsequently, it can be taken into account that per barrel of produced oil (equivalent) there are more people needed offshore than onshore. Similarly, materials are more expensive to cope with the harsher environment, and costs of operation and maintenance is higher offshore than onshore. However, there are no figures to quantify these effects, hence the large range.

The main actors in this sub-function can be distinguished according to which part of the value chain they are positioned in. For oil exploration, according to the position of market capital on the 20th May 2011, the largest players are Statoil ASA, TransOcean and Continental Resources. They generally rent equipment from large infrastructure organisations such as National Oilwell, Schlumberger and Cameron, while organisations such as Halliburton provide early-stage oil exploration consultancy.[20]

The largest production companies include Royal Dutch Shell, BP, Exxon Mobil, GDF Suez, Total, Gazprom and Chevron. All these players are active in most parts of the value chain, and have a large influence on the European market.

1.2.1 Environmental impacts

Activities associated with offshore production of oil and natural gas impose serious risks for the environment, as was demonstrated by the Deepwater Horizon oil spill of 2010 and more recently by the North Sea leakage in March 2012.[21][22] More specifically, the following impacts can be identified:[23]

- Seismic surveys, offshore drilling and driving piles into the seafloor impact fish and marine mammals, and disrupt the seafloor and benthic communities. However, it has been noted that offshore construction also enriches marine life, creating suitable substrate for benthic organisms, and thereby habitats for crustaceans, molluscs and fish that predate on them;
- Water pollution linked to the disposal of drilling fluid, oil spills and leakages, which contains hydrocarbon products and heavy metals that are toxic for marine life and seabirds; and,
- Air pollution, through the flaring of burn-off gases, which are gases that are economically not worth transporting and selling to the gas market, and through the operation of the platforms themselves.

Conversely, in Europe there are rather stringent Health, Safety and Environment (HSE) regulations. In order to comply, the European oil and gas industry has taken several severe measures that lower the chance of accidents such as oil spills and reduce environmental pressures. Such pressures include the installation of various kinds of safety mechanisms and restoration of the habitat after decommissioning of the platforms. These regulations make that the marine environmental footprint of the offshore oil and gas industry is considered to be average compared to other industries.

[20] OGJ 200/100, Oil & Gas Journal, September 15, 2008
[21] Jernelöv, A, 2011. The Threats from Oil Spills: Now, Then, and in the Future. *AMBIO: A Journal of the Human Environment* 39, pp. 353-366.
[22] BBC news, 28 March 2012, Flare still burning at North Sea gas leak Elgin platform, http://www.bbc.co.uk/news/uk-scotland-north-east-orkney-shetland-17522086
[23] Patin, S. (1999). Environmental impact of the offshore oil and gas industry, 425 pp.

1.3 Regulatory environment

The most important European regulations regarding (offshore) oil and gas exploration and production are listed below:

- The Hydrocarbons Licensing Directive Regulations 1995, No. 1434;
- Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions on the Practical Implementation of Health and Safety at Work Directives 92/91/EEC (mineral extraction through drilling) and 92/104/EEC (surface and underground mineral extraction);
- Directive 2004/35/EC of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage;
- Council Directive of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment;
- Council Regulation (EU, Euratom) No 617/20101 of 24 June 2010 concerning the notification to the Commission of investment projects in energy infrastructure within the European Union and repealing Regulation (EC) No 736/96;
- Regulation (EC) No 663/2009 of the European Parliament and of the Council of 13 July 2009 establishing a programme to aid economic recovery by granting Community financial assistance to projects in the field of energy;
- Council Regulation (EC) No 2964/95 of 20 December 1995 introducing registration for crude oil imports and deliveries in the Community;
- Council decision 68/416/EEC of 20 December 1968 on the conclusion and implementation of individual agreements between Governments relating to the obligation of Member States to maintain minimum stocks of crude oil and/or petroleum products, as amended by Council Directive 72/425/EEC;
- Council Directive 73/238/EC of 24 July 1973 on measures to mitigate the effects of difficulties in the supply of crude oil and petroleum production;
- Council Decision 77/706/EEC of 7 November 1977 on the setting of a Community target for a reduction in the consumption of primary sources of energy in the event of difficulties in the supply of crude oil and petroleum products;
- Council Directive 2009/119 of 14 September 2009 imposing an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products;
- Council Decision 1999/280/EC of 22 April 1999 regarding a Community procedure for information and consultation on crude oil supply costs and the consumer prices of petroleum products;
- Directive 2009/73 /EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC;
- Regulation (EC) No 715/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the natural gas transmission networks;
- Regulation (EU) No 994/2010 of 20 October 2011 concerning measures to safeguard security of gas supply.
- Directive 2008/92/EC of the European Parliament and of the Council of 22 October 2008 concerning a Community procedure to improve the transparency of gas and electricity prices charged to industrial end-users;
- Commission Decision 2003/796/EC of 11 November 2003 on establishing the European Regulators Group for Electricity and Gas.

In chapter 4, the European regulatory environment is discussed in further detail.

1.4 Strengths and weaknesses

Strength of the offshore oil and natural gas sector in a global perspective

- Sector size (~b€ 80 in Europe). The offshore oil and natural gas sector provides thousands of jobs directly, and supports millions of indirect and derived jobs indirectly.[24] In addition, the sector provides tax revenues and adds value to the EU GDP;
- Contribution to the European security of energy supply, reducing dependence of (unstable) countries outside of the EU;
- Investment power, both for developments inside as well as outside Europe;
- Mature technology with key (offshore) experience and developed techniques. A mature technology also drives prices down. This causes low fuel prices and lowers prices of goods from the EU manufacturing industry;
- Main elements of the value chain are within single companies. This benefits the efficiency of the supply chain and streamlines the different intermediary products between the elements, ultimately reducing costs and prices;
- Export potential (5 of top-6 oil producing companies are EU based). The market for offshore oil and gas production is growing outside of Europe;
- Norway (as part of the European Economic Area) is a key player in offshore oil reserves. As such, the EU and Norway together are the fourth largest producer of oil and gas in the world.

Weaknesses of this sub-function in a global perspective

- Finite natural resource. This problem is widely discussed, and the alternative (renewables) could slowly be favoured over the years. Moreover, energy efficiency measures could affect demand negatively in the long run;
- Increasing competition and decreasing supply for specialised personnel, skills and materials due to other, growing marine sectors (such as offshore wind) and unpopular study choice;
- Capital intensive, making the large upfront investments risky in an unpredictable political and policy environment;
- Size slowly declining in Europe (1-5%/year);
- Bad public image, partly caused by events such as the Exxon Valdez and Deepwater Horizon oil spills;
- Higher capital and operational expenditures than onshore production.

[24] OGP (2010) Oil & gas for Europe - it's about time and innovation

2 Research and Technology

2.1 Research topics

The offshore oil and natural gas sector is a mature sector. Still, there is ongoing research to improve technologies and extent the longevity of the whole sector, knowing that the oil and gas resources are finite. Moreover, the European market is dominated by a few large players so the companies have enough investment power to finance for research and development. Furthermore, since most of the global large players are European, Europe is well-positioned to lead the research globally and reap the benefits from technological breakthroughs.

Cost reductions

Interviewees have clearly indicated that most research is conducted in the field of cost reductions. The installations are capital intensive and operational costs are high. Cost reductions enable companies to develop more and smaller new fields, and operate longer on existing platforms.[25] A few examples of recent cost reductions include:

- New, cheaper materials;
- Onshore control units, monitoring several offshore, unmanned platforms;
- Mobile platforms, enabling companies the ability to reuse platforms for other fields;
- Unit operations, so that platforms can be constructed and deconstructed from basic building blocks.

Exploration techniques

There is ongoing research in enhanced exploration techniques for oil and gas and other raw material reserves.[26] Geophysicists, biologists and petroleum geologists are constantly developing better exploration techniques. Examples of the latest improvements include:

- 3-D and 4-D seismic imaging. In this 4-D imaging technique, time is added as a dimension, so that geophysicists know how the subsurface layers change over time;
- Enhanced microfossil biostratigraphy, that provides better information regarding reservoir characteristics;
- Measurement While Drilling (MWD), improving drilling accuracy and efficiency;
- Dynamic position devices, enabling engineers to adjust drilling paths while drilling.

Enhanced oil and gas recovery and carbon capture and storage

Depending on the geological formation deposit in which the oil and/or gas are stored in, the oil and gas can only be extracted partly from the field. Normally this part ranges somewhere between 20 and 60%.[27] Recently, techniques known as Enhanced Oil Recovery (EOR) and Enhanced Gas Recovery (EGR) have been developed. With these techniques, more oil and/or gas can be extracted from the fields, thereby providing a higher return on the investments when developing a field and producing oil or gas. EGR can be linked with Carbon Capture and Storage (CCS), where the captured CO_2 is stored in a gas field, enabling an increase in gas production.[28] Moreover, CCS provides the whole oil and natural gas industry the ability to make the whole sector more sustainable. In fact, CCS fits perfectly in the cradle-to-cradle (C2C) concept by providing a sink to

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[25] NPC Global Oil & Gas (2007). Oil and Gas Technology development. Topic #26

[26] http://www.naturalgas.org/naturalgas/extraction_offshore.asp

[27] R.W. Bently (2002). Global oil & gas depletion: an overview. Energy Policy 30 189-205

[28] E. Tzimas, A. Georgakaki, C. Garcia Cortes and S.D. Peteves. Enhanced Oil Recovery using Carbon Dioxide in the European Energy System. DG JRC Institute for Energy. December 2005

the CO_2. Around 30% of the CO_2 emitted by the European power sector can be captured and stored by 2030, rising to 60% by 2050.[29] Offshore oil and gas fields – whether depleted or in operation – are ideally suited for CCS, since there are no risks for local communities or Not In My Back Yard (NIMBY) issues.

Methane hydrates

Until date the exploration of offshore methane hydrates exploration and production has only been performed under laboratory conditions. Onshore the technique has been tested in 2008 by Japanese and Canadian scientists. Technically the process seems most feasible in permafrost regions and a production test is now being prepared in Alaska. An offshore test is scheduled for 2012-2014 in Japan[30]. It is however unlikely to arrive at large scale production levels within the next decade.

Natural Gas Fuel Cells

Natural gas fuel cells are a promising technology. Fuel cells generate electricity based on electrochemical reactions. This is opposed to common combustion. The fuel cells can be mounted on the offshore platforms, and generate electricity that can be immediately transmitted to the consumer.[31] In general, natural gas fuel cells have the advantage that they:

- Produce cleaner electricity;
- Omit transportation of natural gas to gas fired power plants, and shortening the supply chain of electricity;
- Produce less CO2 per unit of generated electricity;
- Are more efficient energy converters.

Ultra-deep and Arctic

Finally, with today's technology, rising oil prices and declining availability of new oil and natural gas reserves, there is an increased interest in exploration and production from unconventional locations. These include exploring the ultra-deep (>2000m) and the Arctic regions. The Arctic provides opportunities with warming of the poles due to global warming. However, due to the harsh environment in which to operate – such as extremely high pressures, corrosion and frozen surfaces for parts of the year – more research is needed to cope with these conditions.

2.2 Research & Technology mining patterns

The number of patents in the Oil & Natural Gas sector has doubled over the past decade, rising from 156 per year in 2001 to 340 in 2010[32].

This number is lower than that of sub-function that are in their development stage, but higher than the levels seen in other mature sub-functions. The increase over time is similar to what is seen in other sub-functions.

The number of scientific publications has about tripled, which is again similar to the trend for other sub-functions.

The graph below presents the number of inventions and publications in Oil & Natural Gas, over the last decade.

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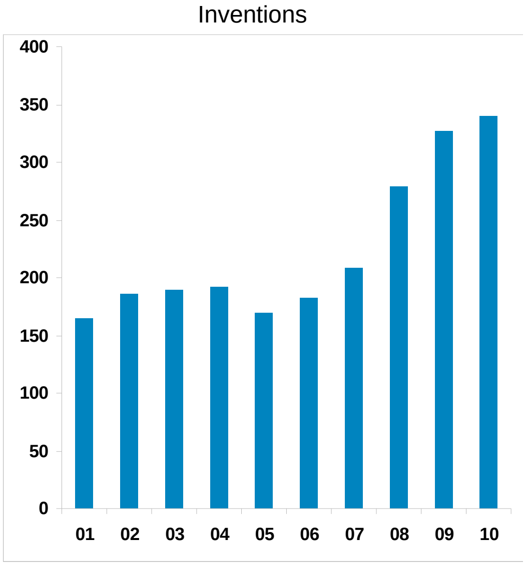
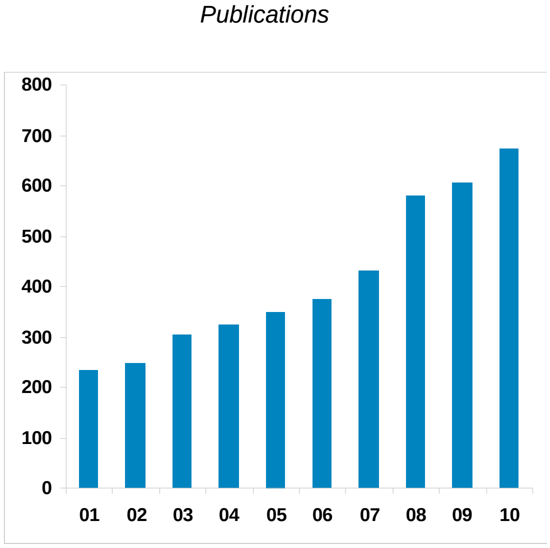
[29]http://ec.europa.eu/energy/coal/sustainable_coal/ccs_en.htm
[30]Maribus (2011), World Ocean Review.
[31]B.C.H. Steele (1999). Fuel-cell technology: Running on natural gas. Nature 400 619-621
[32] ThomsonReuters analysis conducted specifically for this study

Table 2.1 Total number of global inventions and publications related to Oil & Natural Gas (2001 – 2010)





Source: Thomson Reuters

The table below compares EU-27 countries in terms of patents filed on their grounds, with competing countries (2001–2010). Priority country means the place where the invention was invented and filed.[33]

Table 2.1 Top – 10 Countries with highest score in inventions related to Oil & Natural Gas

Priority countries	Total inventions (2001 - 2011)	% of global
US	1415	29%
EU-27	1068	22%
China	371	8%
Japan	213	4%
South Korea	53	1%
Global	4820	

Source: Thomson Reuters

Figures above indicate that in terms of Oil & Natural Gas, the US is leading in terms of inventions, with 29 % of global inventions in this subfunction. The EU-27 countries are following with a bit more than one fifth of global inventions taking place within the 27 Member States.

Table 2.2 Country score in scientific citations related to Oil & Natural Gas

Priority countries	Total citations (2001 - 2011)	% of global
EU-27	14068	43%
US	5441	17%
Japan	1801	5%
China	1388	4%
South Korea	487	1%
Global	32873	

Source: Thomson Reuters

[33] Priority country is used in the absence of an inventor country within the patent statistics. The particular field is not present across a good amount of authorities

Table 2.3 country score in publications related to Oil & Natural Gas

Priority countries	Total published papers (2001 - 2011	% of global
EU-27	1747	30%
US	1352	23%
China	358	6%
Japan	287	5%
South Korea	91	2%
Global	5790	

Source: Thomson Reuters

Table 2.5. Top 20 global patent assignees - organizations or individual owners of the patent's invention - are presented in the table below in Oil & Natural Gas:

Top assignees	Total number of patents filed (2001- 2011)
ABB GROUP	115
CHINA NAT OFFSHORE OIL CORP	76
HALLIBURTON CO	59
SHELL OIL CO	55
TECHNIP	47
EXXON	42
SCHLUMBERGER TECHNOLOGY CORP	42
BAKER HUGHES INC	38
INST FRANCAIS DU PETROLE	32
CHEVRON CORPORATION	29
FMC CORP	29
COFLEXIP	28
PETROBRAS PETROLEO BRASIL SA	28
WEATHERFORD	20
MITSUBISHI GROUP OF COMPANIES	19
SAIPEM	19
DEEP INDUSTRIES LTD	18
DEN NORSKE STATS OLJESEL	17
INFINEUM INT LTD	15
STATOIL ASA	14

Source: Thomson Reuters

About half of the assignees of the patents reside in Europe (EU-27 countries and Norway), which is exceptionally high compared to other sub-functions assessed. This indicates EU companies are leading in this sub-function.

3 Future developments

3.1 External drivers affecting the performance of the cluster

In this section, key potential external drivers that might affect the growth (or reduction) of the offshore oil and gas sector are described.

Demand

The global demand for (fossil) fuels – or energy in general – is increasing over the next decade (primarily due to demand growth in China, India and the Middle East), despite a forecasted decrease of oil demand in Europe[34]. This contributes to an increased pressure on the oil & gas market leading to upward price pressure and the feasibility of raising production capacity.

Price

Fuel prices have been rising over the past decade, which can partly be attributed to the increased demand growth but which also relates to the increased scarcity, easy accessible fields becoming depleted and other fields more complex to exploit (think of the oil sands in Canada which are being explored but where costs are substantially higher than in the North sea fields).

Whether the remaining oil reserves are economically exploitable is thus primarily dependant on the oil price. A slow increase in the oil price is forecasted[34], mainly because the world supply just slightly lags behind the increasing demand. With increasing prices, nowadays suboptimal reserves and unconventional oil resources such as tar sands become economically exploitable.

Available resources elsewhere

Major oil & gas discoveries in other parts of world (but also occasionally in Europe, such as in Norway earlier this summer), affect the activities of the sub-function. Globally they will have impact on the proven reserves and thereby indirectly on the oil price. Regionally they can reshape the opportunities of the industry and create potential for market players having knowledge of the area concerned.

The growing relevance of shale gas might, if rising as some expect it to be, change the energy sourcing structure, lowering the dependency of natural gas suppliers like Russia or the Middle East, according to some.[35] Furthermore since it concerns different techniques than traditional gas mining. Others however believe European shale gas exploitation will not easily become as big as America for geological reasons (deposits are deeper underground), limited drilling capacity, and regulatory differences.[36]

Energy security

Energy security is one of the spearheads of the EU energy strategy. The Commission proposed a five-point EU Energy Security and Solidarity Action Plan[37], including infrastructure needs and the

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[34] World Energy Outlook, IEA, 2010

[35] Shale Gas Information Platform, 4 July 2012, London University Workshop on Shale Gas and Renewable Energy, http://www.shale-gas-information-platform.org/areas/news/detail/article/london-university-workshop-on-shale-gas-and-renewable-energy.html, accessed 11 July 2012

[36] The Economist, 26 November 2011, Fracking here, fracking there. Europe will have trouble replicating America's shale-gas bonanza. http://www.economist.com/node/21540256, accessed 11 July 2012

[37] EU Energy Security and Solidarity Action Plan: 2nd Strategic Energy Review. European Commission MEMO/08/703, 2008

diversification of energy supplies, and the keeping of Oil and gas stocks and crisis response mechanisms.

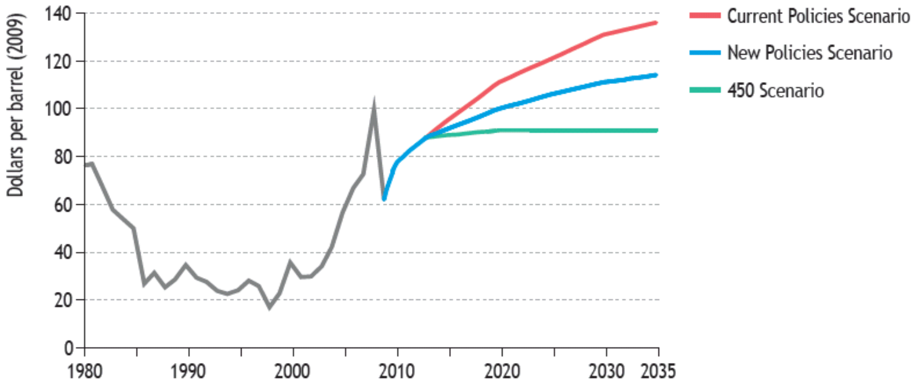
Increased focus on renewable energy

National, EU and global (climate) policies put large focus on renewables. Also the general public is promoted to shift to 'green' energy (f.i. home electricity consumption). While the impact on total oil & gas demand may remain limited for the near future, it does affect interest of e.g. investors.

Political landscape.

The oil price is strongly influenced by political stability. Turmoil such as taking place over the past months in Northern Africa and the Middle East has major impact on oil prices, even if the countries concerned only account for a few percentages of global production. The impacts however are mainly visible on the short term, while they become less pronounced on the longer term.

Figure 3.1 Average IEA crude oil import price by scenario (annual data)



Source: IEA (2011), World Energy Outlook 2010

Physical influences

Apart from socio-economic and financial drivers, there are also physical influences that affect the oil & gas sub-function. Although the offshore sector has always had a rather harsh environment to operate in, climate change effects could potentially worsen it even further. Indeed, offshore operating companies have been found to take climate change into account in their business decisions and invest to cope with issues like alternating sea currents, increased wind speeds and storm events and changing air and sea temperatures.[38] However, this driver is likely to play a minor role compared to the other drivers.

3.2 Barriers and conditions for further development

The oil, gas and methane hydrates sub-function faces several barriers and framework conditions under which it currently has to operate:

- Geographic constraints: oil & gas fields are only present in certain sea basins, where, particularly in the North Sea, Northern Atlantic and Arctic, conditions are harsh, acting as a barrier. Furthermore natural resources in the EU are getting depleted, especially the larger, more economical fields.

[38]Ecorys, 2011. Investment needs for future adaptation measures in EU nuclear power plants and other electricity generation technologies due to effects of climate change.

- Public acceptance: as do other sub-functions, oil & gas tends to face public resistance, which can obstruct activities if not accompanied by stakeholder consultation and mitigation measures. Large companies are especially 'suspect' and are at a disadvantage vis-à-vis local populations.
- Maritime legislation as developed by international organisations (IMO) often targets generic shipping groups and is filled in from a maritime transport perspective, while specific services such as offshore supply, dredging and other specialised shipping segments may face requirements reducing their operating efficiency.
- Environmental protection regulations may limit the possibilities to explore certain areas (Habitat areas), removing some resources from being a business opportunity.
- Other economic activities (fishing, sand or other minerals deployment, off shore wind, leisure

3.3 Response capacity of stakeholders

The oil & gas industry is a mature sub-function with healthy competition in various parts of the value chain. Because of its large size, it has enormous investment power, especially when compared to less mature sub-functions such as renewables. Environmental and safety matters are well embedded in company cultures and structures. Technological levels are high allowing to effectively respond to events. Furthermore the industry is active worldwide and EU companies have foothold in other oil & gas production regions. This makes it easy for them to export their knowledge and technology and compensate for reduced activity in the EU.

The high oil price allows the industry to respond in several ways:

- The efficiency of production can be raised. As mentioned in Ch.1, nowadays only some 50-60% of a field is exploited. More expensive technologies such as EOR/EGR as well as the combination with CCS may contribute to increase field outputs.
- Smaller oil fields become commercially viable to exploit. The development of movable/reusable platforms is one type of response the industry already is undertaking to pick up this opportunity.
- Several techniques that have been developed are only viable above a certain price threshold. As the industry is risk averse a stable high price will lower the commercial risk of applying these.
- Exploring deeper waters: higher prices cover the higher costs of deepsea oil & gas exploration and production. However from the interviews it is concluded that oil companies are hesitating to take the step into deeper waters. As long as other fields in known areas can still be further exploited the deep water fields may remain in the exploration stage, also because of the technological and environmental risks at hand. Increasing proven reserves (such as in Brazil) together with a constant high oil price may however change this attitude.

Policy ambitions such as energy security allow the industry to respond with regard to energy security. The plans to construct a Southern gas corridor, to transport gas directly from the Caspian Sea into the EU, is an example of infrastructure providing an opportunity for the EU oil & gas supply industry. Empty fields may provide storage for desired stocks.

The expected increased demand for Arctic services has already entailed the development of offshore support vessels capable of operating in more severe environments with regard to temperature, wave height, and ice coverage. EU shipyards are doing intensive research trying to maintain their market position.

3.4 Most likely medium-term developments

The future production of crude oil and natural gas in the EU27 will decrease in the coming two decades with 4.2% and 0.9% per year, respectively (IEA, 2011) However, the world production of crude oil and natural gas will increase annually by 1.0% and 1.5% respectively in the coming 20 years (IEA, 2011). That means that the competitive global position for European oil and gas production will decline. Although statistics on the share of offshore production compared to total European production are not readily available, it can be assumed that no major changes in the share of offshore production will occur in the coming decade.

However, future technological development – such as exploitation of new territories, Enhanced Oil Recovery and Enhanced Gas Recovery, and production of unconventional fossil fuels – as well as the development of prices could potentially counteract this decline, or even provide options for future growth. Research on extracting methane hydrates will continue but not lead to massive production within the next decade yet.

Overall, the offshore oil and gas industry should not be too much affected by the renewable energy policy. Firstly, because a relative increase in the share of renewables in the EU energy mix does not mean a necessary decrease of fossil fuels, since energy consumption is still rising. Moreover, there is a trend to replace coal fired electricity plants with natural gas plants. And, secondly, oil and to a lesser extent natural gas are world commodities. So, as long as the rest of the world keeps increasing their oil and gas demand[34], the EU oil and gas industry should be able to maintain their production levels.

The further development of (offshore) shale gas exploitation may change the energy mix more than current scenarios foresee. Since the research on offshore shale gas exploitation has only started off recently and a number of technical challenges are faced adding to those relevant onshore, we do not expect a major role for this type of gas within the time horizon of this study.

3.5 Impacts/consequences of these developments

For the coming decade, the main economic consequences of the declining oil & gas production in Europe will be a gradual reduction in employment figures at the upstream part of the value chain. In terms of value added European players may still remain stable as they are expected to grow in terms of turnover outside Europe. Furthermore in the Arctic sea basin growth of employment and added value is expected.
Environmental impacts will change mainly because of the shift in locations of activity (away from European sea basins). It is however uncertain how the increased exploration of smaller fields will affect the environment.

Table 3.1: Impact matrix of the medium-term and longer-term developments

Function	Indicators	General	Bal-tic	North Sea	Medi-terr.	Black Sea	Atlan-tic	Arc-tic	Outer most
1. Economic impacts	Added value created in Europe	-	n/a	-	-	-	-	++	
2. Employment impacts	Employment in Europe	-	n/a	-	-	-	-	+	
3. Environmental	Emissions Water pollution	+	+	0	0	0	+	--	

Function	Indicators	General	Bal-tic	North Sea	Medi-terr.	Black Sea	Atlan-tic	Arc-tic	Outer most
impacts	Seafloor disruption								
4. Other impacts	Export of technology / revenues outside Europe	+							

Use the following symbols:

++ = Strong positive impact expected

+ = Considerable positive impact expected

0 = Negligible impact expected

- = Considerable negative impact expected

-- = Strong negative impact expected

3.6 Indicative review of possible synergies and tensions with other maritime functions and clusters (dependencies)

The oil and gas industry could possibly link with wind energy, through multi-use platforms[39] and other offshore constructions, increased energy security, energy demand and supply patterns. This also creates synergies with the offshore support industry, including port services and shipbuilding.

Another link can be found with CCS, though usage of empty fields and potential for EOR and EGR.

The expected growth of deepsea exploration and production may also benefit from the oil & gas sub-function, through the transfer of staff and technology. Already today some players active in the offshore oil & gas support services are exploring their opportunities in deepsea minerals mining (see marine minerals sub-function).

The increased production outside Europe will benefit the maritime transport sub-function through the growth of oil & gas shipments to Europe and the required investments especially in LNG terminals in EU ports as well as equipment manufacturers supplying the LNG carrier building industry.

Finally, due to potential spatial competition and marine spatial planning, oil and gas is directly linked with all other sub-functions. One main complexity (tension) here is the confidentiality character of information on oil sources, which creates difficulties when planning for e.g. offshore wind. The growth of other maritime functions further increases this tension (shipping, increased safety requirements, marine aquaculture, etc.).

39 http://cordis.europa.eu/fp7/energy/home_en.html

4 Role of policy

4.1 Policy and political relevance

The natural resources oil and natural gas play a crucial role in modern society world wide. Today, Europe is strongly dependant on oil and natural gas production, which meets a large share of the energy demand in Europe and sustains the European way of living. The European Oil and gas production – offshore and on land – has strong socio-economic effects,[40] including:

- Satisfaction of ~50% of the oil and gas demand in Europe, fuelling the European economy;
- Investments of €500 billion, contributed €440 billion tax directly from the industry since 1971;[41]
- Supports millions of indirect and derived jobs in Europe;[41]
- Supports the European manufacturing and service industry.

The European demand for oil and natural gas will remain stable for the coming two decades at least.[42,43] That means that there is a large political relevance to maintain the sector in Europe, and secure a stable supply of oil and natural gas. In order to accomplish just that, the EU has formulated an “EU Energy Security and Solidarity Action Plan”.[44]

A political agenda is formulated in this action plan to achieve supply security. Amongst others, there are objectives to strategically invest in energy infrastructures such as offshore gas pipelines. In addition, the EU revises its strategic oil and gas reserves legislation. The new legislation aims to cohere with the International Energy Agency (IEA) regime, and increases the transparency and reliability of existing European oil and gas reserves. Finally, due to the declining European oil and natural gas resources, high oil prices and a stable demand, unconventional reserves should contribute to a secure supply of oil and natural gas as well.

As with most large, mature sectors, the offshore oil and gas sector is strongly regulated. This is opposed to small, immature sectors – such as ocean energy – where the focus is on promotion and support. The regulation in mainly divided in two main policy fields: market regulation and HSE standards. Market regulation aims at common access rules to the natural gas transmission networks,[45] transparency of taxes, excise duties and oil and natural gas prices,[46] fair competitive (internal) market conditions and import and export regulations.[47]

HSE standards aim at reducing the impact on the environment, workers and local community. Environmental Impact Assessments reduce the ecological footprint, prevent disasters and include effective and efficient clean-up methods in case of an accident. Moreover the EU has set a whole range of health and safety regulations in order to safeguard the employees in the offshore oil and

[40] http://www.oilandgasuk.co.uk/
[41] OGP (2010) Oil & gas for Europe - it's about time and innovation
[42] ec.europa.eu/energy/.../strategic_energy_review_wd_future_position2.pdf
[43] World Energy Outlook 2010. International Energy Association, 2011
[44] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0781:FIN:EN:PDF
[45] Regulation (EC) No 715/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the natural gas transmission networks
[46] Directive 2008/92/EC of the European Parliament and of the Council of 22 October 2008 concerning a Community procedure to improve the transparency of gas and electricity prices charged to industrial end-users
[47] Directive 2009/73 /EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC

natural gas industry as well as local communities. These regulations are often imbedded within national legislation, creating inconsistencies and gaps among the Member States.[48]

Finally, natural gas contributes to the transition to a low-carbon economy. Natural gas is widely available, easy transportable and has relative clean burning properties. Therefore, producing, transporting and consuming natural gas produces the lowest amount of green house gases of all fossil fuels. Consequently, the EU Climate and Energy Package and the EU Emission Trading Scheme provide incentives for replacing of coal and oil with natural gas,[49] providing opportunities for (increased) offshore natural gas production.

4.2 Domains for EU policy

From the interviews with the industry it became clear that there is no need for large new policy initiatives. This is not surprising, because the focus for EU policy is on regulation. Still, some interviewees have indicated a few domains in which EU policy should be created or changed.

Regulation

According to industry interviewees, market regulation should not be too restrictive for the European offshore oil and natural gas. In their view, it should aim at competitive conditions and fiscal regimes that promote investments in offshore field development and production and transportation capacity in Europe. This prevents that activities will move out of the EU, so that tax revenues will be collected and value will be added to the European economy. Moreover, many jobs then will remain within the EU borders.

HSE standards are very important, as verified by all stakeholders. However, industry interviewees mentioned that policy makers must be aware of irrational reactions by the public on global events. Examples include the Deepwater Horizon oil spill in the Gulf of Mexico in April 2010 and the Fukushima Daiichi nuclear disaster in March 2011. After such events, industry impression is that policy makers have the tendency to overreact, and set the standards too high. From a learning curve perspective however both policy makers and regulators do use these incidents and in hindsight the industry seems to agree that targeted attention following events has helped to raise the HSE levels across the value chain.

Marine spatial planning and administration

There is competition for space in marine waters. Marine Spatial Planning (MSP) should take this problem into consideration, and provide for an integrated approach as mentioned in the 'Roadmap on maritime spatial planning'.[50]Transparent aims and plans for recoverable resources and proven reserves will provide investor confidence, and should be part of the European MSP framework. Furthermore, clear guidelines on new exploration areas and how this fits in the whole spatial planning of marine waters is currently lacking.

In addition, there are different application and permitting procedures per Member State. Complex administrative procedures – such as obtaining environmental, construction, spatial planning, financial and infrastructure permits – can form a barrier to investments in the offshore oil and gas industry. The EU could provide for guidelines based on best practices from some Member States. Best practises can be in the form of one-stop shopping procedures, streamlining applications procedures or pre-permitted areas with designations for offshore oil and natural gas developments.

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[48]http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0560:FIN:FR:PDF
[49]http://ec.europa.eu/clima/policies/package/index_en.htm
[50]http://ec.europa.eu/maritimeaffairs/press/press_rel251108_en.html

Predictability and consistency

The timeliness of investment decisions is affected by the policy decisions by national governments and the European Commission, especially long term policies. Predictability and consistency of energy, climate and maritime policy is thus essential for offshore oil and natural gas producing companies.

The current EU energy policy focuses on 2020. The technical depreciation period of offshore platforms is in the order of 30-40 years, in any case longer than ten years. Therefore, investors want to know how the EU future energy mix is likely to develop, and how demand is likely to be affected in the long run. Linked to this is the future EU climate policy. The third phase of the EU emission trading scheme will commence in 2013, but it is not yet entirely clear which sectors will fall under the scheme and how the carbon prices are likely to develop. A similar reasoning holds true for uncertainties in future EU maritime, internal market and international policies, which affect spatial planning, price volatility and international competition, respectively.

If long term policies affecting the offshore oil and natural gas industry can be formulated in a consistent and permanent fashion, investment risks are lowered considerably.

Level playing field and removal of contradicting policies

The interviewees mentioned that there is a need for a level playing field for policies for all member states, or at least for North-West Europe. Moreover, there is a wish for a common policy approach for all energy sources.

In addition, contradicting policies should be removed or adapted. In such cases, an integrated European policy is needed between several DGs within the EC.

Annex 1: Stakeholders interviewed

Interviewee	Organisation	City/country	Specific theme	Interviewer	Face to face, or telephone
Bram van Mannekes	NOGEPA	The Hague, Netherlands	Offshore oil and gas exploration and production	Sil Boeve	F2F
Aart Tacoma	NOGEPA	The Hague, Netherlands	Offshore oil and gas exploration and production and environmental affairs	Sil Boeve	F2F
Jorg Mutschler	VDMA	Hamburg, Germany	Offshore construction	Sil Boeve	Tel.
Annabel Holroyd	OGP	Brussels, Belgium	Upstream part of the oil and gas sector in Europe	Sil Boeve & Johan Gille	Tel.
Leo Hendriquez	Ministry of Economic Affairs	The Hague, Netherlands	Regulator, enforcement	Eric van Drunen	Tel.

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Annex 3: Table of cross-links and synergies

Indicate in the table below which interlinkages are of key importance to the future development of this sub-function:

Function affected	Sub-function Affected	General	Explanation
1. Maritime transport and shipbuilding	1.1 Deepsea shipping	+	Shift to oil production outside Europe will increase crudes shipments to the EU
	1.2 Shortsea shipping (incl. RoRo)	0	
	1.3 Passenger ferry services	0	
	1.4 Inland waterway transport.	0	
2. Food, nutrition, health and eco-system services	2.1 Catching fish for human consumption 2.2 Catching fish for animal feeding 2.3 Growing aquatic products 2.4 High value use of marine resources (health, cosmetics, well-being, etc.) 2.5 Agriculture on saline soils		
3. Energy and raw materials	3.1 Oil, gas and methane hydrates 3.2 Offshore wind energy 3.3 Marine renewables (wave, tidal, OTEC, thermal, biofuels, etc.) 3.4 Carbon capture and storage 3.5 Aggregates mining (sand, gravel, etc.) 3.6 Mineral raw materials 3.7 Securing fresh water supply (desalination)		
4. Leisure, working and living	4.1 Coastline tourism 4.2 Yachting and marinas 4.3 Cruise including port cities 4.4 Working 4.5 Living		
5. Coastal protection	5.1 Protection against flooding and erosion 5.2 Preventing salt water intrusion and water quality protection 5.3 Protection of habitats		
6. Maritime monitoring and surveillance	6.1 Traceability and security of goods supply chains 6.2 Prevent and protect against illegal movement of people and goods 6.3 Environmental monitoring		

Explanation:

++ = Strong positive impact on other subfunctions/sea basins expected

+ = Considerable positive impact on other subfunctions expected

0 = Negligible impact on other subfunctions/sea basins expected

- = Considerable negative impact on other subfunctions expected

-- = Strong negative impact on other subfunctions expected

S = Synergy (developments as portrayed above leads to positive developments of other subfunctions and vice versa)

T = Tensions (developments as portrayed above leads to negative developments of / constraints for other subfunctions and vice versa)

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