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Documents

Construction of Environmental Pressure Information System (EPIS) for the Norwegian Offshore Oil and Gas Production

Contents

1. Background

The objective of the Environmental Pressure Information System (EPIS) of Eurostat is to provide a tool for the compilation of timely and harmonised data on environmental pressures arising from different activities. Accordingly, EPIS will contribute to the production of pressure indicators and indices, indicators of sustainable development (e.g. efficiency indicators), to the compilation of statistics on material flows and cumulative pressures as well as to the NAMEA system for environmental accounting (EPIS March 1998).

EPIS will be an integrated database, which makes use of existing and forthcoming statistical and administrative data (CORINAIR, PER, IEI), and will structure them in a coherent way, which will produce complementary pressure data through modelling and will provide a new information for decision making (EPIS March 1998).

The EPIS database relies on the material flow approach, where inputs of materials and energy to one process are in balance with the system accumulation and outputs of products and residuals arising from the same process in a given period (EPIS Oct. 1997). Such a database will for each priority process include input (energy, raw materials, air and water) and output (products, emissions and waste).

Table 1. Material balance of a process

Inputs				Outputs
Raw materials				Products
Operating substances				Residues
Energy	→	PROCESS	→	- air emissions
Water				- water discharges
Air				- waste

Source: EPIS, March 1998.

The final result of EPIS will provide data on direct and indirect pressures and flows of key resources in a consistent and harmonised way. A successful development of the EPIS database will also give an essential contribution to the development of statistics on the use of chemicals (EPIS Oct. 1997).

2. Project objectives

The aim of this part of the EPIS project is to establish an EPIS database for the Norwegian oil and gas industry. The data will be based on available statistics. The oil and gas industry is chosen as case as it is the major sector with respect to both income and environment in Norway. In 1997 oil and gas extraction accounted for 14 per cent of the GDP (gross domestic product), a doubling since 1988 (Statistics Norway 1998), and 22 per cent of the country's emissions of CO_2. Extraction of oil and gas offshore also gives emissions of NMVOC, CH_4, NO_x and CO to air; contaminated water, oil and chemicals to sea, and waste (e.g. cuttings, drilling fluid) which is brought to shore or reinjected.

In 1995, the emissions of CO_2 from oil and gas extraction offshore represented 20 per cent of the country's emissions of CO_2. Well testing, loading of oil on shore and emissions from ships transporting oil to shore are not included in this number. Emissions from the mentioned sources are not considered in the material flow analysis, since the balance is supposed to include the processes in the production of oil and gas offshore and not the whole life cycle. For the same reason are platforms, which is a huge waste problem, not included in the material balance. Emissions from loading of crude oil offshore will be included. This is the most important source of emission of NMVOC in Norway. In 1995 it constituted about 47 per cent of the total emissions of NMVOC in the country.

In this project, data for 1995 have been used. Most of the fields are combined oil and gas producing fields (about 70 percent in 1995 considering the net production). This percentage may alter from one year to another as new fields start up. When drilling a well, most commonly both oil and gas is explored, but some fields may just burn off the gas or use it to produce electricity rather than selling it as a product.

3. Nomenclature

With regard to the compilation of EPIS, standardised classifications and coding systems are used when they are available (see table 2). Unfortunately, there are some parts of the material flows which are not yet covered. The most import one refers to waste (EPIS March 1998).

Table 2. Classification and other codes used in the EPIS database

Subject	Classification or codification
Countries	EU*
Activities	NACE
Processes	PRODCOM, (NOSE-P, SNAP)
Production technologies	to be developed
Env. management technologies	to be developed
Raw materials, operating substances, products	PRODCOM, CPA, CN
Fuels	SIRENE, CORINAIR/NAPFUE
Waste water	Process and cooling water
Waste materials	Actual label, EWCSTAT Rev, EWC
Pollutants	CAS, aggregated pollutants

Source: EPIS, March 1998.

* EFTA countries also contribute to the EPIS database.

SNAP/NOSE-codes of interest in this project are given in table 3.

Table 3. Selected SNAP/NOSE-codes.

SNAP	NOSE-P
01 05 Coal mining, oil and gas extraction 01 05 04 Gas turbines 01 05 05 Stationary engines	101 Combustion processes 10104 Gas turbines 10105 Stationary engines
05 02 Extraction, 1st treatment and loading of liquid fossil fuels 05 02 02 Offshore activities	10602 Extraction, 1st treatment and loading of liquid fossil fuels 1060202 Offshore activities 1060203 Oil drilling: exhaust emission (Does not have a SNAP code)
05 03 Extraction, 1st treatment and loading of gaseous fossil fuels 05 03 03 Offshore activities	10603 Extraction, 1st treatment and loading of gaseous fuels 1060303 Offshore activities 1060303 Oil drilling: exhaust emissions (Does not have a SNAP code) 1060305 Natural gas cleaning (Does not have a SNAP code)
05 06 Gas distribution networks 05 06 01 Pipelines	10606 Gas distribution networks 1060601 Pipelines
09 02 Waste incineration 09 02 06 Flaring in gas and oil extraction	10901 Waste incineration 1090106 Flaring in gas and oil extraction

In the Norwegian national model for calculation of air emissions, the following codes are used:

Stationary combustion
101 Oil and gas extraction
- 1011 Natural gas
- 1012 Flaring
- 1013 Use of diesel

Process emissions
2011 Oil drilling: leakage
2012 Oil and gas extraction
- 20121 Venting etc.
- 20122 Loading of oil offshore
- 20123 Loading of oil on shore

Table 4 shows the correspondence between the SNAP codes and the codes used in the Norwegian national model.

Table 4. SNAP codes and codes used in the Norwegian national model

SNAP	Norwegian model
	1 Stationary combustion
01 05 Coal mining, oil and gas extraction	101 Oil and gas extraction
01 05 04 Gas turbines	1011 Natural gas
01 05 05 Stationary engines	1013 Use of diesel
05 02 Extraction, 1st treatment and loading of liquid fossil fuels	2 Process
05 02 02 Offshore activities	2011 Oil drilling: leakage
	2012 Oil and gas extraction
	20121 Venting
	20122 Loading offshore
05 03 Extraction, 1 st treatment and loading of gaseous fossil fuels	
05 03 03 Offshore activities	2011 Oil drilling: leakage
	2012 Oil and gas extraction
	20121 Venting
	1 Stationary combustion
09 02 Waste incineration	101 Oil and gas extraction
09 02 06 Flaring in gas and oil extraction	1012 Flaring

In the material balance sheet (see appendix), the SNAP-codes 05 02 02 and 05 03 03 have been used for respectively production of oil and gas offshore. SNAP-codes 01 05 04 and 01 05 05 are used for both the processes. PRODCOM numbers used for the products are: 11.10.10.30 'Crude oil', 11.10.10.50 'Natural gas condensates' (NGL: Natural Gas Liquids) and 11.10.20.00 'Natural gas'.

Chemicals used in the oil and gas production are reported as the function of the chemicals (e.g. cleaning substances, lubricants, foam reducing substances) and not the name of the chemicals. This makes it impossible to relate the chemicals, both "raw material" and "release", to standard statistical terms, like PRODCOM.

4. Oil and gas production

The three main phases in the extraction of oil and gas are:

- exploration
- production
- transportation

The two main activities of the exploration phase are the seismic surveys and the exploration drilling (Bakkane 1994). Seismic surveys will not be included in the balance for the same reason as transportation of oil and gas to shore (see chapter 2).

The oil and gas production fields are located 80 to 270 km off the Norwegian coast (in 1994). The water depths for these fields range from 70 to 350 metres (in 1994). The production mainly takes place from steel and concrete platforms supported on the sea bottom. Floating production units and sub sea installed production facilities are also used (Bakkane 1994).

The main purpose of the drilling and production platforms is to support the facilities required to drill the production wells and separate the well fluid into oil and gas, and condition the two products to make them suitable for transportation from the offshore site to land based receiving terminals (Bakkane 1994).

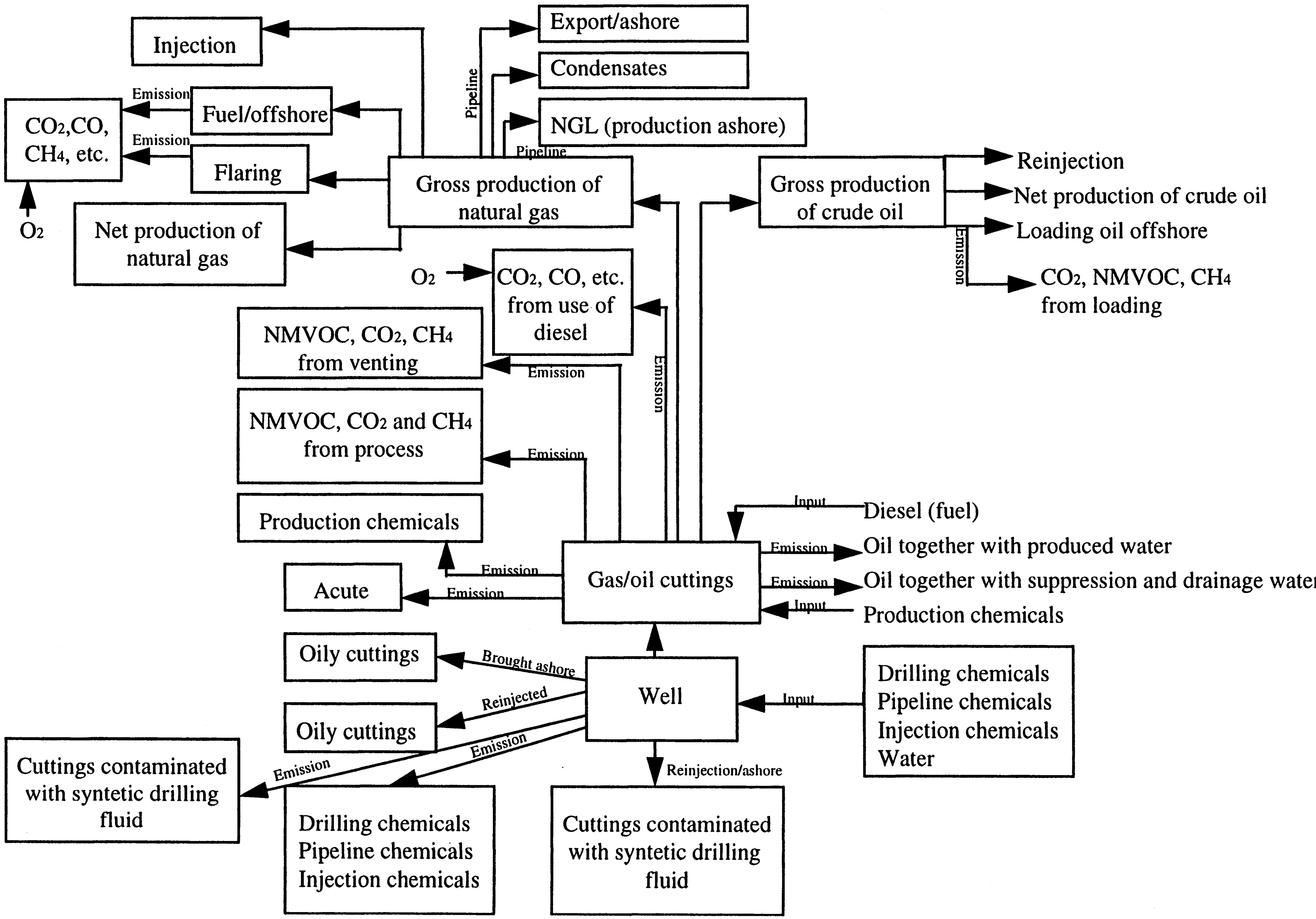
Depending on operating conditions oil and gas producing fields normally need facilities for:

- production well drilling
- oil and gas processing
- produced water handling
- oil storage
- oil and gas export
- power generation and utilities
- safety systems

Figure 1 shows the flows included in material flow analyses for Norwegian offshore oil and gas production.

Figure 1.

Material flow characteristics for production of oil and gas offshore



4.1. Process definition

The process of oil and gas extraction defined in this work, is the exploration and production of oil and gas offshore. Oil and gas are to be regarded as the main products. According to production statistics compiled by the Norwegian Petroleum Directorate, net production of crude oil and natural gas on the Norwegian continental shelf totalled 184 million Sm^3o.e., and NGL and condensate 8 million Sm^3o.e. in 1995. NGL is produced at terminals onshore, and the production process will therefore not be considered in the material flow analysis offshore. However the production data for NGL is included as NGL is included in the gross production for oil and gas. Production data of condensate shows that there is no such production reported at the fields only producing oil. Therefore, the amount condensate produced at combined oil and gas fields, is assumed to be attached mainly to the gas production. Flaring in connection with well testing will not be included as it takes place before the production of oil and gas starts.

4.2. Process description

Extraction of oil and gas includes several sub-processes which will be different for oil and gas. A simple overview is given below.

Drilling
Wells are classified as exploration or production wells. An exploration well is drilled to determine if interesting quantities of oil and gas are present in the formation. Drilling fluid is needed for drilling. The composition of the drilling fluid is adjusted to meet changing needs as the well penetrates the various formations. Drilling conditions determine the type of drilling fluid to be used. It is common to divide drilling fluids in two main groups, water based (water miscible) and oil based (water immiscible) fluids (Bakkane 1994).

Production
Production platforms handle the reception, treatment and export of well fluid. The well fluid on a combined field may consist of crude oil, natural gas, condensates, NGL, water, cuttings and chemicals. Crude oil is usually de-watered and gas is processed for platform use, re-injection or export, as required. Most of the oil fields on the Norwegian continental shelf also produce water. The amount of produced water normally increases as the oil reserves are depleted (Bakkane 1994).

Well stream processing
The main reasons for oil and gas processing are:
• to separate the oil, gas and water to obtain an oil product with sufficiently low vapour pressure to enable oil transportation by pipelines using export pumps or direct offshore loading to a crude tanker
• to remove water and higher hydrocarbons from the gas phase to avoid multiphase flow condition and hydrate formation
• to reduce water content for equipment corrosion protection
• to meet gas and oil sales specification.

Several stages of oil and gas separation may be required, depending on different factors such as composition of the well stream, oil to gas ratio and requirements dictated by the type of export system. As a result each well field will have its own tailor-made processing system. The processing system can be anything from a simple oil and gas separation to a complex multistage separation, dew point and compression system (Bakkane 1994).

Separating the produced water from the oil is accomplished through a phase separation. The gas is normally dehydrated by triethylene glycol in an absorption tower. The wet glycol is then regenerated in a heater before being recycled back to the absorption tower (Bakkane 1994).

After being separated from the oil/gas/water separators, the produced water is routed to a water cleaning system for removal of dispersed oil droplets before being discharged to sea. The treatment system removes most of the residual oil from the water. Some of the production chemicals added to the processing system, and many of the natural components dissolved in the produced water, will be discharged to sea together with the produced water (Bakkane 1994).

Transport
All gas produced on the Norwegian continental shelf is exported by pipelines. Oil is either exported by pipelines or loaded from the platform installations via a buoy into crude tankers on the field. Only emissions from the loading is included in this work.

Flaring and venting
Facilities for flaring of the gas to depressurise the oil and gas processing facilities are installed as a safety precaution on all production platforms. For safety reasons there will on most installations be a small continuous gas flaring stream.

Small amounts of hydrocarbon gases are vented directly to air from parts of the production processing line. The amount of gas venting is much lower on modern platforms than on the older ones (Bakkane 1994).

Power supply systems
Gas turbines are used for power generation on production platforms, while diesel engines are used on mobile installations. Diesel driven emergency power systems are installed on all manned installations. Diesel fuel must be supplied from land while fuel gas supplies are taken directly from the gas produced at the platform (Bakkane 1994).

4.3. Emissions

In a report by the Norwegian Oil Industry Association (OLF 1994), the emissions from the petroleum industry are categorised in the following types:

- emissions from combustion (e.g. CO_2, NO_x)
- direct loss of natural gas (e.g. venting, loading of crude oil offshore)
- emissions from processes (e.g. produced water, chemicals, hydrocarbon gases)
- emissions from drilling
- other emissions (e.g. acute emissions)
- discharges needing special treatment (e.g. oil, solvents, tar, discharges containing Hg or Cd, discarded platforms. The latter is not included here as it is produced ashore.)

The five first mentioned types normally generate emissions to air or the sea. Special wastes are brought ashore.

Oil is emitted to sea from drilling, production and spill/accident. Chemicals are among other things emitted from drilling, production, water injection and testing/start up of pipelines (Norwegian Pollution Control Authority 1996a).

Discharges from drilling include in addition to drilling fluid also discharges from other well operations. Emissions from production include produced water, suppressing water and drainage water. Produced water follows the well stream at production and is separated from the oil at the platform. Produced water contains chemicals and organic and inorganic substances from the formation (OLF 1994). Suppressing water is emitted from platforms which have store cells for oil when oil fill the cells. Drainage water is water from flushing of deck, tanks etc. in addition to rainwater. This water is reported together with suppressing water (Norwegian Pollution Control Authority 1996a). In a material flow balance it is dubious whether suppressing and drainage water should be considered, as it is not involved in the process. According to Øko-Institut (1996), process water covers all water flows involved in the process or coming into direct contact with the materials. The latter occurs as some oil is following the emissions of suppression and drainage water. See section 5.3 for further discussion.

The rock cuttings from a well contain traces of the drilling fluids and chemicals. In the case of water based fluids, the cuttings are commonly discharged untreated to the sea. The use of water based fluids will not be considered in the material balance as no data are available. Oil contaminated cuttings are not permitted to be discharged untreated to the sea, and are re-injected or transported to shore for treatment and disposal (Bakkane 1994).

Acute discharges of oil and chemicals from the offshore activity may arise from accidents in connection with drilling, production or break in pipelines. Spill may also arise by loading.

5. Material flow characteristics

A problem in making a material balance for the production of oil and gas separately, is that most fields, as mentioned in chapter 2, are producing both oil and gas. We only have data for fuel, chemicals etc. used for both oil and gas production. The problem is to decide how much of the mentioned materials at a combined field have been used for gas production and oil production respectively. Splitting the data for combined fields is a difficult matter as factors like age of field, type of reservoir etc. play a central role.

When splitting the data for combined fields, data from a field producing gas only may be used as a reference. At the gas field, the relation between fuel used and net gas, NGL and condensate produced is about 0.013 kSm^3 o.e./kSm^{3}o.e.. It is assumed that this relation between fuel used and gas produced is the same for the combined fields. When using this factor about 14 per cent of the fuel used at the combined fields seems to be attached to the gas production, and thus 86 per cent to oil production. This seems to be the most convenient method, as the relation fuel used/oil produced for fields only producing oil, is quite different between the different oil fields. This is probably due to old fields needing more fuel to produce oil at the same level as new ones.

The same method is used to split other data for the combined fields (see section 5.1 for operating substances). It must be remembered that there is considerable uncertainty attached to the split data.

5.1. Input

Raw and auxiliary materials

Gross production of oil and gas is defined as raw material use while net production of the products is used as measure of the output (production) in the material flow. This is because an extraction process is not a "classic" input-output process. Data for gross and net production of oil and gas are available. Gross production is measured at the field, while net production is the saleable oil. The difference is very important for gas production, as a considerable part is being used as fuel (for turbines, compressors etc.), injected, flared and vented. In 1995 the gross production of gas was 47 mill. Sm^{3}o.e., and the gross production of oil 158 mill. Sm^{3}o.e.. The net production was 28 mill. Sm^3 o.e. gas and 156 mill. Sm^3 o.e. oil. For some of the fields, NGL and condensate are included in the gross production data for natural gas, while it is included in data for gross oil production in other fields. In addition to some NGL and condensate, the gross production of gas includes:

- gas used as fuel: 2640 kSm^3 o.e. (split; 439 for gas production and 2202 for oil production)
- flaring of gas: 409 kSm^3 o.e. (split; 53 for gas production and 356 for oil production)
- gas used for injection: 15112 kSm^3 o.e. (split 2547 for gas production and 12565 for oil production)

The amount of gas used in the production of oil, about 15000 kSm^3 o.e., will be subtracted from the gross production of natural gas, since its corresponding amount of emission will not be accounted for in the balance for gas production.
Some water is also included in the gross production data.

Materials and operating substances
The use of drilling chemicals in 1995 was about 277 ktonnes (including several different chemicals, like foam reducing chemicals and disperse substances) (Norwegian Pollution Control Authority 1996a). In general it is very difficult to split the use of chemicals in quantities used for oil production and for gas production.

The amounts drilling fluid used will be dependent on number of wells drilled. A common rule is that a gas field most likely have to drill less wells than an oil field. But this rule is very uncertain, as use of drilling chemicals also is dependent on other factors, like formation conditions and the type of the reservoir. There may be some uncertainty attached to the data for emission and use of drilling chemicals, because it is very difficult to measure appendage of drilling fluid on cuttings and similar things. The method mentioned earlier is used for splitting the use of drilling fluids at combined fields. At a field producing gas only the relation between drilling fluid used and net production of gas, condensate and NGL is 0.59 tonne/kSm^3 o.e.. If this relation is used for the fields producing both oil and gas, the amount of drilling fluid used for gas production is about 7 per cent of the total fluids used at the combined fields. It is important to remember that this percentage is very uncertain, but is used in lack of something better.

For the use of production chemicals, the relation production chemicals/net production of gas, condensate and NGL, is about 0.08 tonne/kSm^3. When this relation is used, about 21 per cent of the total use of production chemicals is used for gas processing. In lack of data, this percentage is used instead of percentage of production chemicals used for gas production in a combined field. Most likely this is of the same quality as the percentages for use of fuel and drilling chemicals. It is assumed that the same percentage also applies for injection chemicals. In 1995, the use of production chemicals was 14021 tonnes and the use of injection chemicals 8994 tonnes (Norwegian Pollution Control Authority 1996a).

The percentage of pipeline chemicals used for gas production is estimated in the same way as the production chemicals, using the only gas field as a reference. It gives an estimate of 6 per cent of the total pipeline chemicals being attached to gas production. In 1995 the amount of pipeline chemicals used was 5144 tonnes (Norwegian Pollution Control Authority 1996a).

The use of operating substances in relation to one tonne of oil and gas produced, is respectively 2.1 kg/t oil and 1.0 kg/t gas.

Energy
The amounts of natural gas and diesel used as fuel in the sector extraction of crude oil and natural gas in 1995 were (The Norwegian Petroleum Directorate):
2640 kSm^3 o.e. natural gas
117 ktonnes diesel (stationary combustion)
409 kSm^3 o.e. flaring natural gas

Only natural gas and diesel used for stationary combustion is included in the material flow, since transport to shore is not considered. There is a need for splitting the fuel used for oil and gas production respectively. The percentages mentioned above, where about 86 per cent of the fuel seems to be going to oil production while about 14 per cent is used for gas production, is used.

It is important to remember that the use of natural gas as fuel is already accounted for in the gross production of natural gas as raw material.

Calculated energy use in relation to one tonne of oil and gas produced:
diesel for stationary engines: 33 MJ/tP oil produced
diesel for stationary engines: 31 MJ/tP gas
natural gas, fuel and flaring: 703 MJ/tP oil
natural gas, fuel and flaring: 761 MJ/tP gas

Air

Combustion and flaring of natural gas consume oxygen from the air to produce CO_2. Emission of CO_2 from combustion and flaring of diesel and natural gas is 7507 ktonnes in 1995, giving a consumption of oxygen at about 5460 ktonnes. It gives 35 kg O/t oil produced and 33 kg O/t gas produced.

Water

Water used for injection offshore was 226 Mm^3 in 1995. When using the same percentage as mentioned above for fuel, for combined fields, 191 Mm^3 injection water is used for oil production and 35 Mm^3 for gas production. The amount of input of suppression and drainage water is the same as the output, 87 Mm^3.

5.2. Process

SNAP-codes for the production of oil and gas offshore:
05 02 02 Extraction, 1st treatment and loading of liquid fossil fuels, offshore activities.
05 03 03 Extraction, 1st treatment and loading of gaseous fossil fuels, offshore activities.

Prodcom number: 11.10.10.30 Crude oil
11.10.10.50 Natural gas condensates
11.10.20.00 Natural gas

Net production in 1995 (The Norwegian Petroleum Directorate):
Main products: Crude oil: 156 mill. Sm^3 o.e.
Natural gas: 28 mill. Sm^3 o.e.
By-products: Condensate: 3378 kSm^3 o.e.
NGL: 5060 kSm^3 o.e.

NGL is produced at terminals on shore, and the production process is therefore not considered in the material flow analysis offshore. However, the production data for NGL is indirectly included as NGL is included in the gross production data for oil and gas. Production data of condensate shows that there is no such production at the fields only producing oil. Therefore, the amount condensate produced at oil and gas fields, is assumed to be attached mainly to the gas production.

5.3. Output

Main products

Net production in 1995: Crude oil 133 mill. tonnes
Natural gas 24 mill. tonnes

For some of the fields the gross production of oil is less than the net production. This is because condensate and oil from different fields often are mixed before sale. The same situation is also appearing for gross and net production of gas, which may be due to gas borrowed earlier from one field is allocated back. Another possible reason for the gross production being less than the net production may be errors in the reporting.

By-products
In 1995 the production of condensate was 110 kg/t natural gas produced, and the production of NGL was 118 kg/t gas and 8 kg/t oil produced.

There exists no data for gross production of NGL and condensate, as it is included in either gross production of oil or gas, dependent on the field, as mentioned in chapter 5.1.

Waste water
Waste water origins from the separation of oil-gas water fluid from the well.

The discharges of oily water (from production, displacement, drainage and sinks) gave a total oil discharge of 1400 tonnes in 1995. 1100 tonnes of this followed 46 million m^3 produced water, and the rest (about 280 tonnes) followed 87 million m^3 suppressing and drainage water (Norwegian Pollution Control Authority 1996a). Table 5 shows the emission of water. The data for both gas and oil producing fields have been split using the same percentage as for fuel.

Table 5. Emission of produced, suppression and drainage water. 1995

Type	Emission of water, m^3	Amount oil emitted, tonnes
Produced water	46122278	1121
Suppression and drainage water	87285946	281

Source: Norwegian Pollution Control Authority, 1996a.

As mentioned in section 4.3, suppressing and drainage water should maybe not be considered in a material flow balance, as it is not involved in the process. Since it is coming in direct contact with the main product, it is nevertheless included.

Injection water, which is injected to the wells, mix together with formation water and return to the platform as produced water (OLF 1994). A water balance is presented in table 6. As seen in the table, the amount of input water is much higher than the output water, which is due to water being left in the wells. How much water that is actual left is not known, and it differs from one well to another, but it is not unlikely that up to 80 per cent may be left.

Table 6. Water balance

Input	**Mm^3**
Injection water	226
Suppression and drainage water	87
Output	
Produced water	46
Water left in wells	NA
Suppression and drainage water	87

Waste
Drilling
Drilling chemicals are discharged to the sea with used drilling fluid. When drilling cuttings and used drilling fluids are returned to shore for treatment and disposal they are reported as classified waste (Bakkane 1994).

No discharges of oil based drill cuttings have been reported for 1995, as the oil contaminated cuttings were transported to shore or reinjected. Therefore there were no discharge of oil as appendage on drilled cuttings. From 42 wells a total of 13533 tonnes of oily cuttings were reinjected into the formations. A total of 14387 tonnes of oil based cuttings were brought ashore (Norwegian Pollution Control Authority, 1996a). Table 7 shows the disposal of cuttings. To split the emission data from both gas and oil producing fields, the same percentage as used to split the drilling fluid in the input section is used, about 7 per cent attached to gas production.

Table 7. Disposal of contaminated cuttings. 1995. Tonnes

Oil contaminated cuttings reinjected		**Oil contaminated cuttings to shore**	
Oil on cuttings	Cuttings	Drilling fluid on cuttings	Cuttings
2977	13533	2542	14387

Source: Norwegian Pollution Control Authority, 1996a.

Drilling fluids not classified as water or oil based drilling fluids, so-called synthetic drilling fluids, are being used as an alternative to oil based fluids. The total discharge of synthetic drilling fluids as appendage on cuttings, was 5546 tonnes in 1995 (Norwegian Pollution Control Authority 1996a). The discharge is included in the total emissions of drilling chemicals in table 9. Table 8 shows emission of cuttings and appendage of synthetic drilling fluid.

Table 8. Emissions of synthetic drilling fluids. 1995. Tonnes

Synthetic fluid on cuttings	Cuttings	Cuttings reinjected/brought to shore
5546	37504	225*

Source: Norwegian Pollution Control Authority, 1996a.
*Cutting containing ether

There is no data available for the use and emission of water based drilling fluids.

Chemicals
The discharges of chemicals were 152000 tonnes in 1995. Drilling chemicals constitute the major part with 148000 tonnes, i.e. an average of about 1000 tonnes per well as in the previous years (Norwegian Pollution Control Authority 1996b). Table 9 gives the consumption and emissions of different types of chemicals. The emissions from combined fields have been split using the same percentages as used for chemicals in the input section above.

Table 9. Consumption and emission of chemicals. 1995. Tonnes

Type	**Consumption**	**Emission**
Drilling chemicals	277292	148104
Production chemicals	14021	2763
Injection chemicals	8994	725
Pipeline chemicals	5144	714

Source: Norwegian Pollution Control Authority, 1996a.

Air emissions
Table 10 shows the emissions to air from production of oil and gas from the Norwegian national emission model. The data are split in the material balance (see the appendix).

Table 10. Air emissions from oil and gas production. 1995. Tonnes

	CO_2	CO	SO_2	NO_x	NMVOC	CH_4	N_2O	Particulates	Pb
Stationary combustion									
- Natural gas	6178620	4489		16556	607	2403	50		
- Flaring	956295	613		4904	24	98	8		
- Use of diesel	372218	488	164	6444	424	97	2	101	0.014
Process									
- Leakage	364				30	100			
- Venting	34451				3565	8670			
- Loading oil offshore	559346				172781	14965			

Source: Statistics Norway and Norwegian Pollution Control Authority

6. Summary and conclusions

Table 11 and 12 give an overview of emission and consumption pr. tonne produced oil and gas. The table also shows a column were all the factors have the same unit.

As seen in the tables, there are considerable differences between the input and output values for both the processes. For the two processes the input values are considerably higher than the output values. Especially are the differences between input and output of water high, due to a lot of water being left in the wells. If it is assumed that 50 or 80 per cent of the water injected is left in wells, the differences between the input and output for the two processes are considerably reduced, as seen in table 11 and 12. A material balance including estimated coefficients for water left in wells, will probably give the most proper balance, since water is an important matter in the balance.

If the water flows are not included at all in the material balance, the differences in table 11 and 12 are about the same as in the case assuming 80 per cent of the water being left in wells/formations. The water flows cannot be excluded from the material balance as water is included in the oil and gas stream.

The considerable differences between the input and the output values make the estimated coefficients quite uncertain. It is important to remember that there is considerable uncertainty attached to the split data from the combined fields. A lot of factors may influence the splitting, which ideally should be carried out for each field. That would be a very difficult and time consuming job.

Table 11. Material flow characteristics for production of oil offshore.

Input		**Unit**	**Value**	**Value, kg/tP**
Raw materials	*Gross production of crude oil*	*kg/tP*	*1010*	*1010*
Operating substances (total)		*kg/tP*	*2.12*	*2.12*
- Drilling chemicals		kg/tP	1.94	1.94
- Production chemicals		kg/tP	0.08	0.08
- Injection chemicals		kg/tP	0.05	0.05
- Pipeline chemicals		kg/tP	0.04	0.04
Energy carriers (total)		*MJ/tP*	*736*	*17.1*
- Natural gas used as fuel		MJ/tP	605	14.1
- Natural gas flaring		MJ/tP	98	2.3
- Diesel		MJ/tP	33	0.8
Gas injected		*MJ/tP*	*3454*	*80.2*
Water		*m^3/tP*	*2.0*	*2033*
Air				*35.1*
Output				
Product		*tP*	*1*	*1000*
By-product	NGL (produced ashore)	*kg/tP*	*8*	*8*
Waste water		*m^3/tP*	*0.86*	*858*
Water left in wells				*736*[1)]
Waste (total)		*kg/tP*	*1.51*	*1.49*
- Chemicals	incl. acute emissions	kg/tP	1.06	1.06
- Waste brought ashore		kg/tP	0.12	0.10
- Waste reinjected		kg/tP	0.09	0.09
- Oil and cutting	incl. acute emissions	kg/tP	0.23	0.23
Air emissions		*kg/tP*	*54.4*	*54.4*
- Gas turbines		kg/tP	39.9	39.9
- Flaring		kg/tP	6.2	6.2
- Diesel engines		kg/tP	2.4	2.4
- Oil processing		kg/tP	5.9	5.9
Difference (input-output)		kg/tP		1256
		kg/tP		520[1)]
		kg/tP		78[2)]

[1)] Data not available, an estimate is made by assuming 50 per cent of injected water being left in wells.
[2)] Data not available, an estimate is made by assuming 80 per cent of injected water being left in wells.

Table 12. Material flow characteristics for production of natural gas offshore.

Input		Unit	Value	Value, kg/tP
Raw materials	*Gross production of natural gas*[1)]	*kg/tP*	*1167*	*1167*
Operating substances (total)		*kg/tP*	*0.99*	*0.99*
- Drilling chemicals		kg/tP	0.78	0.78
- Production chemicals		kg/tP	0.12	0.12
- Injection chemicals		kg/tP	0.08	0.08
- Pipeline chemicals		kg/tP	0.01	0.01
Energy carriers		*kg/tP*	*792*	*18*
- Natural gas used as fuel	included in raw material	MJ/tP	679	15.8
- Natural gas flaring	included in raw material	MJ/tP	82	1.9
- Diesel		MJ/tP	31	0.72
Water		m^3/tP	*1.8*	*1820*
Air				33.3
Output				
Product		*tP*	*1*	*1000*
By-product (total)		*kg/tP*	*228*	*228*
- Condensate		kg/tP	110	110
- NGL	produced ashore	kg/tP	118	118
Waste water		*m^3/tP*	*0.81*	*813*
Water left in wells				*644*[2)]
Waste (total)		*kg/tP*	*0.64*	*0.63*
- Chemicals	incl. acute emissions	kg/tP	0.46	0.46
- Waste brought ashore		kg/tP	0.05	0.04
- Waste reinjected		kg/tP	0.04	0.04
- Oil and cutting	incl. acute emissions	kg/tP	0.10	0.10
Air emissions (total)		*kg/tP*	*46.2*	*46.2*
- Gas turbines		kg/tP	37.8	37.8
- Flaring		kg/tP	5.9	5.9
- Diesel engines		kg/tP	2.3	2.3
- Gas processing		kg/tP	0.24	0.24
Difference (input-output)		kg/tP		935
		kg/tP		291[2)]
		kg/tP		-96[3)]

[1)] Gas used for oil production is subtracted from the gross production. Gas injected is included in the gross production.
[2)] Data not available, an estimate is made by assuming 50 per cent of injected water being left in wells.
[3)] Data not available, an estimate is made by assuming 80 per cent of injected water being left in wells.

Making a material flow analysis for the production of oil and gas offshore is not an easy task. The conditions differ from one field to another, there is a lot of flows through the system and some of the product may be used during the production, like natural gas. Awareness of this is important to avoid double counting. Detailed knowledge of production and special conditions of the particular fields is needed.

The production on the Norwegian continental shelf is featured by the increasing effort to increase the exploration from oil fields where the production is decreasing. This involves more need for injection of water and gas, very energy consuming efforts, and at the same time the amount of production will decrease. The energy need per produced oil unit is therefore expected to increase, a trend already registered at some of the old fields. The production of water increases, giving higher amounts of emissions to handle (OLF 1997).

It is important to remember that the coefficients given in table 11 and 12 are general coefficients for the fields, as special factors such as age, type of reservoir etc. for each particular field is not considered. It would be a very time consuming job to make a material flow balance for each field. However, the coefficients estimated in this work are probably good general coefficients for the production of oil and gas offshore. The coefficients apply specially to Norwegian conditions. The production characteristics differ between fields in Norway concerning age, number of wells etc., and the coefficients may differ even more from one country to another.

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Appendix

Material characteristics of production of oil and gas offshore.

Year		INPUT															
		Energy carriers					*Materials and operating substances*					*Raw material*		*Air*	*Water*		Sum input
		Natural gas	Natural gas	Natural gas	Diesel	Sum	Drilling chemicals	Production chemicals	Injection chemicals	Pipeline chemicals	Sum	crude oil/natural gas					kg/tP
		MJ fuel	MJ flaring	MJ injected	MJ	MJ/tP	tonnes used	tonnes used	tonnes used	tonnes used	kg/tP	$1000Sm^3$ o.e.	kg/tP	kg O/tP	m^3 injection	m^3 suppression and drainage	
1995	Gas turbines, oil production	8,1E+10				605								29			**43**
1995	Gas turbines, gas production	*1,6E+10*				679								27			**27**
1995	Stationary engines, oil production				4,3E+09	33								1,7			**2,5**
1995	Stationary engines, gas production				7,3E+08	31								1,6			**2,4**
1995	Crude oil			4,6E+11		3454	258842	11148	7151	4826	2,1	158235	1010		2,0E+08	7,5E+07	**3126**
1995	Natural gas			*9,3E+10*		3943	18450	2873	1843	318	1,0	32465	1167		3,0E+07	1,3E+07	**2988**
1995	Natural gas condensates																
1995	NGL																
1995	Flaring, oil production		1,3E+10			98								4,5			**6,7**
1995	Flaring, gas production		*1,9E+09*			82								4,2			**4,2**

Numbers in italics are included in raw material (gross production of natural gas).

PROCESS					OUTPUT										
Designation	SNAP		PRODCOM number		*Main-product*	*Byproduct*	*Byproduct*	***Waste water***			***Waste***				
				mill tonnes /year	tP	kg/tP (oil)	kg/tP (gas)	Process water	Suppression and drainage water	Water left in well/formation	Production waste, tonnes				
						NGL	Condensate and NGL	m^3 (produced water) emission	m^3 emission		drilling chemicals emitted	oily cuttings reinjected	oil on cutting reinjected	drill cutting (oil based) brought ashore	drill fluid (oil based) on cuttings brought ashore
Gas turbines, oil production	01 05 04														
Gas turbines, gas production	01 05 04														
Stationary engines, oil production	01 05 05														
Stationary engines, gas production	01 05 05														
Oil, offshore activites	05 02 02	Crude oil	11.10.10.30	133	1,3E+08			3,9E+07	7,5E+07	NA	138204	9849	2778	11051	2372
Natural gas, offshore activites	05 03 03	Natural gas	11.10.20.00	23,6	2,36E+07			6,6E+06	1,3E+07	NA	9901	707	199	794	170
Natural gas condensates		Natural gas condensates	11.10.10.50				110								
NGL		Natural gas condensates	11.10.10.50			8	118								
Flaring, oil production	09 02 06														
Flaring, gas production	09 02 06														

Year		Waste									
		Production waste, tonnes					Hazardous waste of production waste		Acute emissions		Sum
		cutting (from drilling with syntetic fluid) emission	cutting (from drilling with syntetic fluid) ashore/reinjected	production chemicals emitted	injection chemicals emitted	pipeline chemicals emitted	oil (together with prod. water) emission	oil (together with suppression and drainage water) emission	chemicals acute emission	oil acute emission	kg/tP
1995	Gas turbines, oil production										
1995	Gas turbines, gas production										
1995	Stationary engines, oil production										
1995	Stationary engines, gas production										
1995	Crude oil	29817	210	2197	577	567	959	240	81	117	1,5
1995	Natural gas	2141	15	566	149	146	161	40	6		0,6
1995	Natural gas condensates										
1995	NGL										
1995	Flaring, oil production										
1995	Flaring, gas production										

Year		Air emissions										Difference
		SO_2	CO_2	NO_x	CO	CH_4	N_2O	Dust	NMVOC	Sum	Sum output	Input-output
		kg/tP	kg/tP	kg/tP	kg/tP	kg/tP	kg/tP	kg/tP	kg/tP	kg/tP	kg/tP	
1995	Gas turbines, oil production		39,7	0,1	0,03	0,015	0,0003		0,00	39,9	**39,9**	3,1
1995	Gas turbines, gas production		37,7	0,1	0,03	0,015	0,0003		0,00	37,8	**37,8**	-10,4
1995	Stationary engines, oil production	0,001	2,4	0,04	0,00	0,0006	0,0000	0,0006	0,00	2,4	**2,4**	0,1
1995	Stationary engines, gas production	0,001	2,3	0,04	0,00	0,0006	0,0000	0,0000	0,00	2,3	**2,3**	0,1
1995	Crude oil		4,4			0,17			1,32	5,9	**1873***	1252
1995	Natural gas		0,2			0,009			0,02	0,2	**2042***	947
1995	Natural gas condensates											
1995	NGL											
1995	Flaring, oil production		6,1	0,03	0,004	0,001	0,0001		0,00	6,2	**6,2**	0,6
1995	Flaring, gas production		5,8	0,03	0,004	0,001	0,0000		0,00	5,9	**5,9**	-1,6

*Include NGL and condensate.

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