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2 ENERGY

2.1 DESCRIPTION

There is no off-shore oil or gas-exploitation within the Belgian part of the North Sea (BPNS). There are, however, three gas pipelines located on the floor of the BPNS.

In addition there is one on-shore wind-energy project that is currently running at the harbour of Zeebrugge. A proposed expansion of this wind-energy project was recently rejected. Since 2001 several proposals for the construction of off-shore wind-energy parks in Belgium have been submitted. An overview of these proposals can be found in Appendix 1. Currently N.V. C-Power has obtained all the necessary permits to start construction of a further wind farm on the Thorntonbank, which is approximately 27 km from the coast. The project Seanergy (TV Electrabel – Ondernemingen Jan De Nul) has also received the domain concession on the Vlakte van de Raan (in the Belgian territorial see) and the environmental permit, but the execution is currently suspended due to a legal case at the Council of State.

Emphasis is placed on wind-energy projects in the following paragraphs.

2.2 SUBUSES AND DESCRIPTION

Not applicable.

2.3 LEGISLATIVE FRAMEWORK

(updated by Cliquet A.)

2.3.1 Spatial delimitation

<u>Competent authority</u>

The competent authorities for wind-energy development are:

- Coastal zone: Flemish government (Zeebrugge)
- Belgian marine area (12-miles zone (territorial sea), 24-miles zone, EEZ = BPNS): Federal (wind-turbines at sea);
- Domain concession: Ministry of Economic Affairs, Directorate Energy
- Environmental permit: Ministry of Public Health, Food Safety and Environment
- Electricity cables: Ministry of Economic Affairs

Legislation

(Cliquet et al. 2004 ; Maes and Cliquet 2005)

Wind-energy is currently not jurisdictionally restricted to specific zones within the BPNS.

The following procedure needs to be followed prior to the construction and exploitation of wind farms within the BPNS. The following permits need to be obtained:

- a domain concession;
- an environmental permit for the construction and exploitation of the wind farm;
- a permit for the construction and exploitation of submarine electricity cables.

Procedure for granting a domain concession (Federal – Min. Of Economic Affairs):

- Royal Decree of 20 December 2000 on the conditions for granting a domain concession for the construction and exploitation of installations for energy production from water, streams or wind in the marine areas under Belgian jurisdiction, *BS* 30 December 2000.
- Procedure (10 months):
    - Submit application to CREG (Commission for the Regulation of Electricity and Gas)
    - Advice to the minister or Secretary of State of Energy by CREG mainly based on financial-economic motives and security
    - Decision by the minister of Energy (Ministerial decision)
        - ~ Come into effect after accreditation of environmental permit

Procedure for environmental permit (Federal: MUMM & Minister of Public Health, Food Safety and Environment and Minister of the North Sea):

- Law of 20 January 1999 on the protection of the marine environment in the marine areas under Belgian jurisdiction, *BS* 12 March 1999; as amended: an Environmental Impact Assessment (EIA) is needed for each activity that requires a permit or authorisation (art. 28).
- Royal decree of 7 September 2003 concerning the procedure of permit and authorization of certain activities in the marine areas under Belgian jurisdiction, *BS* 17 September 2003, err. BS 25 September 2003 .
- Royal decree of 9 September 2003 concerning the rules of the environmental impact assessment in application of the law of 20 January 1999 on the protection of the marine environment in the marine areas under Belgian jurisdiction, *BS* 17 September 2003.
- Procedure (6-12 months):
    - EIA (Environmental Impact Assessment) by MUMM based on EIS
    - Public consultation (during 45 days)
    - Submit EIS (Environmental Impact Study) by applicant
    - Advice of MUMM to the federal minister of Environment based on EIA and public consultation
    - Decision by minister Environment whether environmental permit should be granted

Procedures concerning electricity cables:

- Royal Decree of 12 March 2002 on provisions for the laying of electricity cables that enter the territorial sea or national territory or that are placed or used for the exploration of the continental shelf, the exploitation of mineral resources and other non-living resources thereof or for activities of artificial islands, installations or structures under Belgian jurisdiction, *BS* 9 May 2002.

- Royal Decree of 19 December 2002 concerning the technical reglementation for the management of and access to the public electricity net, *BS* 28 December 2002: Federal: administrator of electricity net ELIA.

- Flemish Decree of 18 May 1999 concerning the organisation of spatial planning, *BS* 8 June 1999, as amended: to get a planning permit for a land cable (Flemish Region: AROHM)

Other International legislation:

- Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market, *Official Journal L 283, 27 October 2001*: for Belgium 6% by 2010.

Other national legislation:

- Law of 22 April 1999 on the Belgian exclusive economic zone in the North Sea, *BS* 10 July 1999: expansion of the Belgian jurisdiction outside the territorial waters for among other things windenergy production + application on the needed cables.

- Law of 29 April 1999 concerning the regularisation of the electricity market, *BS* 11 mei 1999, as amended: concessions for wind farms in the Belgian marine waters max. for 30 years (art.6)

Future perspectives:

- The closing of certain areas in the framework of NATURA 2000.
- The Belgian Government has issued a zoning plan, which allows a total of 2000 MW of wind-energy to be generated offshore. This plan zones the Thorntonbank as an area in which wind-energy can be developed.

2.3.2 Type and intensity

Intensity per area-unit

There are no juridical restrictions on the number of wind-turbines per area or on the distance of the concession area from the coast.

To keep mutual influence of the wind-turbines to a minimum (array losses < 10%), the distance between two rows should preferably be 5 times the rotor diameter in the crosswind direction and 8 to 10 times the rotor diameter in the prevailing wind direction (Van Hulle et al. 2004).

Frequency per unit of time

Considering the current capacity of the HV-grid connection the wind farm production should not exceed 500 MW, otherwise reinforcements are needed (Van Hulle et al. 2004).

2.4 EXISTING SITUATION

2.4.1 Spatial delimitation

(Map I.2.2a)

At this moment no offshore wind farms are installed within the BPNS.

C-Power N.V. has obtained the necessary permits - a domain concession (MB 27/06/2003), the environmental permit (MB 14/04/2004) and cable permit (MB 13/02/2004) - to start construction and exploitation of a wind farm on the Thorntonbank, which is approximately 27 – 30 km from the coast. In April 2004 the necessary seafloor investigations were started.

C-Power has chosen a split location, which doesn't in any way overlap with the Navy's anti-mine and target practice areas and maintains a minimum distance of 500 metres from the cables and gas pipes and from the individualised sand concession. Taking this safety zone into account a total area of 26.4 (10.7 + 15.7) km² will be taken.

The layout configuration of the wind-turbine park comprises of 60 turbines (3.6 MW) with a rotor diameter of 100 metres. The 60 wind-turbines are developed to the East (6*6=36; area = 8.8 km²) and to the West (6*4=24; area = 5.0 km²) of the Interconnector gas pipeline and the Concerto South 1 telecommunication cable.

The submarine cable between the offshore transformer platform and the public 150kV grid (Sas Slijkens in Bredene) on land is responsible for transporting the power that has been generated. The offshore cable line consists of two 150 kV cables with an inter-distance of 100 m (2 m depth), with the exception of the shipping traffic zone where the cables are laid at a distance of 500 m (4 m depth) from each other.

The SEANERGY project has received a concession (MB 27/03/2002) and the permits (MB 25/06/2002 and 10/02/2003) for the construction and exploitation of a wind-turbine park and the electricity cables on the Vlakte van de Raan. The concession is approximately 12.5 km from the coast. Currently, legal cases still running at the Council of State resulted in the suspension of the execution of the project. The project exists of 50 2 MW turbines in 5 rows of 10 monopile turbines, taking up an area of 5.8 km² (excluding safety zones).

The construction will also include two measurement masts and a transformer platform. The electricity transport is ensured by one 150 kV submarine cable. The electricity cable will run from the tranformer platform to the port of Zeebrugge, crossing the shipping route Het Scheur.

Source

Ecolas NV., 2003. Milieueffectenrapport voor een offshore wind-turbine park op de Thorntonbank. In opdracht van C-Power N.V.

Web page C-power: www.c-power.be (16/09/2004)

Web sites MUMM: www.mumm.ac.be/NL/Management/Sea-based/windmills.php

Tractebel Development Engineering. 2001. Milieueffectenrapport voor het bekomen van een machtiging en een vergunning voor de bouw en de exploitatie van een windturbinepark.

Reliability margin

The prerequisite permits will ensure that the proposed location of the wind-turbines (coordinates) is not changed at a later date.

Future perspectives

In the context of the Flemish Electricity Decree (17/07/2000) regulating the opening of the electricity markets, power suppliers are obliged to supply at least 3% of electricity from renewable energy sources to their customers in 2004 (and in 2010 minimum 5%). This was estimated on a total of 560 GWh renewable energy (land and sea) per year.

Consequentially a number of applications for the construction and exploitation of offshore wind-energy parks in the Belgian part of the North Sea have been submitted since 2001. Only one project is still in the running: Sea-energy on the Vlakte van de Raan (50 wind-turbines – total capacity of 100 MW). Besides projects on the BPNS, an additional application was made for a wind-energy project in the intertidal zone (SPE). However, this proposal was recently rejected. An overview of all projects is given in Appendix 1.

2.4.2 Type and intensity

(Maps I.2.2b-c)

Intensity per area-unit

At present a total of 23 wind-turbines (yearly production of 17.500 MWh) are exploited by Interelectra in the harbour of Zeebrugge (eastern longitudinal embankment). They provide electricity to 5000 families. Strictly taken they don't make part of spatial planning at sea as they are built on the breakwater itself (part of harbour).

The approved wind farm of C-power on the Thorntonbank will have a maximum installed capacity of 216 MW, which corresponds to an estimated annual electricity production of approximately 0.7 TWh (www.c-power.be). The Seanergy wind park has a planned maximum installed capacity of 100 MW.

Total energy consumption in Belgium is approximately 80 TWh per year (Annual report of BFE - 2001). At present only 2% of this total is generated from renewable sources. This means that Belgium must generate a further 4% of "green electricity" or about 3.2 TWh by 2010.

The intensity per area unit (maximum installed capacity per km² of concession zone) of the C-power poject corresponds to 15.7 MW / km², whereas that of the Seanergy project corresponds to 17.2 MW / km². Estimates of electricity production differ between different projects, not only because the installed turbines differ in technical specifications and mutual distance, but also because estimates depend on assumptions of windintensity and operational hours.

Intensity (expressed in MW / km²) depends on the size of the windturbines. In general a distance between windturbines should be minimally 5 rotor diameters because turbulence behind the rotor decreases the efficiency of downwind-turbines. Larger distances between turbines increase efficiency, but result in lower intensity (expressed as turbines /km² or installed capacity /km²).

Source:

Ecolas NV, 2003. Milieueffectenrapport voor een offshore wind-turbinepark op de Thorntonbank. In opdracht van C-Power N.V.

Web site C-power: www.c-power.be (09/01/2005)

Reliability margin:

High.

Future perspectives:

Several other projects have been submitted without positive results (see Appendix 1).

With regard to the future of the Seanergy project, the future and effective execution will depend on the outcome of the legal cases.

The wind-energy potential in terms of installed capacity is proportional to the available sea surface area and to the assumed wind power density. The available area amounts to 2101 km², after excluding the 3 miles zone and all hard exclusion zones (Van Hulle et al. 2004). In Van Hulle et al. (2004) it has been demonstrated that for purposes of potential estimation, the power density for the relevant future can be reasonably assumed to be constant and equal to 10 MW per km².

Turning the total available BPNS area into a giant wind farm would result in 21 GW of installed wind power capacity, sufficient to produce an amount of energy needed to cover a major part of the annual electricity consumption of the country. Optimisation of the site is strongly determined by the project investment cost, which is mainly driven by water depth and distance to the shore (Van Hulle et al., 2004)

The installed wind power capacity is further limited by configuration of the electrical grid. The present Belgian HV grid configurations do not allow more than 0.5 GW wind power to be taken from offshore. Expansion of wind power beyond this capacity would involve additional measures in the electrical power network (Van Hulle et al. 2004).

Frequency per unit time

Not applicable for windenergy production.

2.5 INTERACTIONS

Source:

- Ecolas NV., 2003. Milieueffectenrapport voor een offshore wind-turbine park op de Thorntonbank. In opdracht van C-Power N.V.
- Van Hulle, F., Le Bot, S., Cabooter, Y., Soens, J., Van Lancker, V., Deleu, S., Henriet, J.P., Palmers, G., Dewilde, L., Driesen, J., Van Roy, P. and R. Belmans, 2004. Optimal Offshore Wind Energy Developments in Belgium. Part I. Sustainable production and consumption patterns. Report SPSD II. 153 p.

2.5.1 Suitability for user

Biological suitability

Not applicable

Geological/physical suitability

- E.g. sinking in bottom, cable laying, compactness of bottom
- Changes in bottom structure and composition: at each wind-turbine's location the sandy bottom will be replaced by a hard underground footing (the pedestal of the wind-turbine). Because of changes in the currents (see further) the sediment surrounding the wind-turbine can undergo certain changes. For example, the supply of silt can change in places where the velocity of tidal currents is broken by the base of the wind-turbines.
- In principle there are no zones excluded with regards to soil properties for the installation of mono-pole foundations for wind-turbines. However, in particularly narrow areas the soil structure could possibly include some hazards, including: the Tertiary stone layers, the most heterogeneous Quaternary deposits (scour hollows) and zones with important deformations (Van Hulle et al. 2004). The most geotechnical suitable soils are clay and clayey sands, which show homogeneous natural and geotechnical properties without stony inclusions (Van Hulle et al. 2004).
- The wind resources at sea are very favourable because of the much higher values of wind speed than on land. On the BPNS, the average wind speed varies in a range from 8.4 to 10.1 m/s at heights of between 70 m and 150 m above sea level. In the first 20 km from the coast, the average wind speed increases quite fast with distance, however, from 20 km distance onwards the increase is very modest. In addition, the increase of wind speed with height is very moderate from 70 m onwards. In this respect, it is recommended to try to exploit the resource not too far from offshore and to be modest with tower heights, in view of optimal generation costs (Van Hulle et al. 2004).

Hydrological suitability

- Effects of currents, waves and sand movements on the construction has to be checked by use of models (e.g. WAVE, Delft 3D).
- Hydrological constraints are so far not being investigated in detail, but presumably there is no problem for the BPNS (m.m. 3E). It is, however, clear that going beyond 30 m water depth does not make sense in terms of adding to the potential (Van Hulle et al. 2004).

2.5.2 Impact on other users

Spatial conflict

Tourism:

- Positive: options for new diving sites with specific fauna and flora, new attraction for pleasure craft
- Negative: danger zone for diving because of currents; disturbance of natural view (less than when placed on land), possible sound nuisance during construction and exploitation phase depending on distance from the coast; Exclusion because of safety reasons

Shipping:

- Positive: none
- Negative:
  - nuisance of shipping traffic during repair/ construction wind-turbines
  - collision danger (additional chance estimated for C-Power windfarm: 1 accident per 200 year, with a leak of 50-75 ton oil)
  - interaction with electricity cables
  - loss of area
  - "shadow effect" on radar system because of turning blades, false echoes
- Exclusion because of safety reasons

Fisheries:

- Positive: new fishing areas for oyster or mussel culture (potential for aquaculture)
- Negative:
  - Conflict fishermen: In gullies sandbank: beam trawl fishery; on top of sandbanks: shrimp fishery
  - Loss of fishing grounds of several square meters; following aspects should be taken into consideration:
    - ~ Within 20-mile zone of the Belgian coast, no real poor areas can be found (areas without value for the fishermen (as fishing ground (direct) or spawning ground (indirect).
    - ~ Coastal fishery has handed in a lot of fishing ground during the last decades (to the harbour of Zeebrugge, the shipping routes to the harbour of Oostende, Zeebrugge and the Western Scheldt, etc.)
  - Disturbance of fishery during construction

Sand extraction:

- Negative: loss of exploitation area and exclusion for safety reasons

Military use:

- Negative: possible interference with radar transmission (low level air-defense radar) (Van Hulle et al. 2004) and exclusion for safety reasons

2.5.3 Impact on environment

Biological

- Positive:
  - Offshore wind-turbine foundation can to a limited extent act as artificial reefs for rocky shore fauna and flora, thus increasing the amount of food available for fish (Van Hulle et al. 2004). Examples are sponges, polyps, sea anemones, nude slugs, mussels, barnacles, crabs and lobsters, algae;
  - fishery free, biological rich zones; possible new spawning grounds or "child chambers" for fishes;
  - during construction negative effects (noise, vibrations), but these will be only temporarily;
  - saving of primary energy: Due to the proposed windenergy goal (land and sea) of 560 GWh per year against 2004 (omzendbrief 17/07/2000) 120000 ton coal, 3700 ton oil equivalent and 60 million m³ natural gas/methane was estimated as being saved.

- Negative:
  - Disturbance of benthic-communities of soft sediments during construction phase (cable phase: afterwards recovery correct sediment)
  - Loss of area for fishes and invertebrates according to the size of the erosion protection layer (e.g. Thorntonbank: 0.1 km²)
  - Disturbance of spawning ground of certain fish species
  - Possible danger for collision of birds (tracking route) or deterrence of birds: impact depends a.o. on the protection status of birds. Little is known about the real impacts of operating offshore wind farms on birds. The most extensive study available showing factual results is a three year study of the impact of Tuno Knob on Eider Duck populations by the Danish National Environmental Research Institute. This study concluded with the statement that offshore wind-turbines have no significant effect on water birds (Van Hulle et al. 2004). On the other hand a recent study of Everaert et al. (2002) on the impact of wind-turbines on birds in Flanders (Belgium) stated that in accordance with other European studies wind-turbines do have an effect on birds (casualty, change in behaviour). They conclude that important bird areas and migration routes should be avoided when locating offshore wind farms. The impact is, however, species and site specific and local studies are essential to estimate the potential impact on birds. In the study a safety distance of 150- 300 m from the turbines would be sufficient for most waterbirds.
  - Changes in the current-regime can lead to changes in community structure in and around the location area. The SW-NE orientated rest current along the Belgian coast is responsible for the transport of sediments, nutrients and fish larvae. A change in this current can have an effect on the transport of larvae as on the supply of nutrients, which can have huge consequences for the fish stocks. The changes in the current regime can also disturb the morphology of the spawning grounds and "child chambers" of several fish species. The rest current is also of importance for the adult fish. Migration for food or for reproduction forms an essential part in the dynamics of fish populations. A disturbance of this process can have severe consequences on the fish stocks. Many migration routes along the Belgian and Dutch coast follow the SW-NE pattern, so together with the rest-current. This is the case for the cod, twhting and plaice and several pelagic fish species (like haring, sprat, mackerel). The location of permanent structures in these migration routes could lead to some serious problems.
  - Noise and vibrations can disturb fishes and sea-mammals: interference with their orientation mechanisms. Available knowledge about the effect of underwater noise and vibration on marine life suggests that the underwater noise generated by offshore wind farms will be in the same range of frequencies as existing sources such as vessels, wind and waves (Van Hulle et al. 2004). In order to prolong machine life, vibration should be "designed-out" as far as possible (Van Hulle et al. 2004).
  - Possible effect of electrical and magnetic radiation of cables on organisms

Geological/physical

- Positive: effects mostly temporarily
- Negative:
  - Temporarily disturbance of bottom structure during construction, cable laying and dismantlement
  - Disturbance of bottom because of the installation of an erosion protection layer. Diameter depending on the diameter of wind-turbine (F.ex. wind-turbine with 4-5 m Ø: stone dump of 48 m Ø or e.g. Thorntonbank: 1800 m² around the wind-turbine; total 0.1 km²))
  - Effect of sediment transport on bottom: research needed

- Bottom pollution: indirect

Hydrological

- Positive: breaking of power of currents/ waves
- Negative:
  - Temporary increase of turbidity during construction, cable laying and dismantlement
  - Obstruction hydrodynamics restricted
  - Accidental leaks also limited

2.5.4 Impact on socio-economy

The socio-economic impact is mainly based on the most recent study for the BPNS:

Van Hulle, F., Le Bot, S., Cabooter, Y., Soens, J., Van Lancker, V., Deleu, S., Henriet, J.P., Palmers, G., Dewilde, L., Driesen, J., Van Roy, P. and R. Belmans, 2004. Optimal Offshore Wind Energy Developments in Belgium. Part I. Sustainable production and consumption patterns. Report SPSD II. 153 p.

Some additional socio-economic data from other literature is given in Appendix 3.

Economic

Offshore wind-energy potential in the Belgian part of the North Sea (BPNS):

The wind-energy potential in terms of installed capacity is proportional to the available surface area and to the assumed wind power density. The available area amounts to 2101 km², after excluding the 3 miles zone and all hard exclusion zones (sand and gravel, shipping routes, military use, dredging zones, industrial waste and dumping zones, cables and pipelines) (Van Hulle et al. 2004).

The power density for near future and far future can be reasonably assumed to be constant and equal to 10 MW per km² (Van Hulle et al. 2004). Turning the total available BPNS area into a giant wind farm would result in 21 GW of installed wind power capacity, sufficient to produce an amount of energy needed to cover a major part of the annual electricity consumption of the country.

Optimisation of the site is strongly determined by the project investment cost, which is mainly driven by water depth and distance to the shore. Economically, it makes a lot of sense to limit the water depth to 20 m and the distance to the coast to 40 km, as the relative contribution from far and deep sites (expensive sites) is not very substantial. (Van Hulle et al. 2004).

The installed wind power capacity is further limited by the limitations posed by the electrical grid. The present Belgian HV grid configurations do not allow more than 0.5 GW wind power to be taken from offshore. Expansion of wind power beyond this capacity would involve additional measures in the electrical power network (Van Hulle et al. 2004).

The main numbers are summarised in Table I.2.2a and I.2.2b

Table I.2.2a: Main figures about the potential in terms of installed wind power capacity (GW) (Van Hulle et al. 2004)

	GW installed wind power	Restrictions
Maximum physical potential	21	Exclusion zones
Economic potential	2.1 - 4.2	15% to 30 % of all areas with max. water depth of 20 m, max. distance to shore of 40 km

2004 status of grid integration absorption capacity	0.5	Based on static load flow calculations, available grid connection points in Zeebrugge and Slijkens

Table I.2.2b: Potential energy annual energy generation (Van Hulle et al. 2004)

	TWh/year	Restrictions
Maximum physical potential	66 - 79	Exclusion zones
Economic potential	6.3 – 12.6	15% to 30 % of all areas with max. water depth of 20 m, max. distance to shore of 40 km

Offshore wind-energy costs:

In the study of Van Hulle et al. (2004) the following estimations were given, taking into consideration a number of assumptions and limitations.

The investment cost estimates range from 1500-2400 Euro/kW with 2005 technology and from 900-1600 Euro/kW with 2015 technology. The ranges are depending on water depth, distance to coast, wind-turbine hub height (70 m and 110 m), and assumptions on technology status. On every sandbank, the investment cost decreases because of cheaper foundations. For instance, on the Thorntonbank, 28 km from the coast, with an average water depth of 16 m, the investment cost is ± 1800 €/kW (2005 level technology). For a given hub height and technology level, the lower values correspond to near shore locations, the higher values to sites at the far end of the BPNS (Table I.2.2c). These values compare well with numbers found in literature.

Table I.2.2c: Range of specific total investment costs (Van Hulle et al. 2004)

Time frame	Hub height (m)	Lowest value (€/ kW)	Highest value (€/kW)
2005	70	1500	2200
	110	1600	2400
2015	70	900	1500
	110	1000	1600

The estimated generation costs range from 65-90 Euro/MWh with 2005 technology and 36-54 Euro/MWh with 2015 technology. Again, the ranges are depending on water depth, distance to coast, wind-turbine hub height (70 m and 110 m), and assumptions on technology status (Table I.2.2d). Increasing hub height is not really yielding better economics.

Table I.2.2d: Summary of generation costs of offshore wind-energy on the BPNS (Van Hulle et al. 2004)

Time frame	Hub height (m)	Lowest value (€/ MWh)	Highest value (€/MWh)
2005	70	65	88
	110	66	90
2015	70	36	53
	110	36	54

In Van Hulle et al. (2004) an example is given of the breakdown of the generation cost for 10MW/km² at a site 30 km in the sea, 70 m hub height, 2005 technology and at a distance of 40 km to the onshore grid connection point (Table I.2.2e). The annual energy production for the particular grid point is 31.6

GWh/yr (for 10 MW). The local water depth is 16 m, the foundation is a monopole and the total installation cost is 1815 €/kW. The calculated generation cost is 7.3 cents per kWh.

Table I.2.2e: Breakdown of generation cost for 10 MW/km², hub height 70 m, improved technology (Van Hulle et al. 2004)

Item	Percentage (%)
Investment costs	63
Operation and maintenance	28
Overhaul	5
Decommissioning	4

The production cost for the same site with 2015 technology decreases to 4.2 € cents/kWh, but the relative contribution of the major cost items are the same as for 2005 technology. The cost breakdown is also identical assuming a 110 m hub height.

Nearshore/farshore wind-energy development:

The importance of distance as a determining factor for costs is also stated by C-power who has made a comparison between the costs for a nearshore and a farshore wind farm (http://www.c-power.be). A farshore wind farm costs approximately 30 % more per installed MW than a nearshore farm.

Table I.2.2f: Comparison costs nearshore versus farshore wind-energy development

	Nearshore (Wenduinebank)	Farshore (Thorntonbank)
Number wind farms	2 * 50 MW	2 * 50 MW
Distance to shore	6 km	27 km
Distance to grid connection (length of cables)	9 km	38 km, crossing 2 main shipping routes
Distance for mobilisation of units (pontoons, etc) 3 knots/h	5 h mobilisation	5 h mobilisation + 5 h demobilisation (20% less working days)
Mean water depth	7 m	15 m
Cost per installed MW	X	X + 30 %

Economical profit in comparison with classical production:

The decrease of external costs (costs due to fuel supply, consumption of resources, human health, corrosion of monuments, greenhouse effect,...) due to avoiding classical production, based on fossil fuel, of 560 GWh electricity, can be estimated to be 38.9 mio Euro yearly. The application of wind-energy avoids 6.94 eurocent/kWh external costs in comparison with the fossil electricity park (anno 1997) (omzendbrief 17/07/2000).

The external costs of wind energy are about 1/10th of these of a STEG (steam and gas), and about 1/40th of a coal plant with smoke gas purification (Omzendbrief 17/07/2000).

Social

Visual impact:

Visual impact can be estimated by means of mapping the zone of the visual influence (ZVI), which shows how many wind turbines are visible from any location and how dominant they appear. Based on previous experiences, it is assumed that it will not be realistic to implement wind farms within the 3 nautical mile zone (corresponding to 5.5 km from the coast) (Van Hulle et al. 2004). Further away the effects have to be judged case by case.

Acoustic noise:

The impact of acoustic noise differs according to the consulted literature:

In the C-power study (Ecolas NV 2003) it was stated that continuous acoustical noise levels under water of 90 – 100 dB (re 1µPa) in the frequency area of 100 Hz to some kHz in shallow coastal waters are not abnormal. Natural sounds are responsible here for the highest contribution. It can be assumed that the noise effect of a wind turbine under water will, in the worst case, be limited to the area between the wind turbines and will not produce noise outside the 500 m safety zone around the windmill park. Theoretical (modelling) calculations show that the above water noise (Lsp) of the wind turbines, in a moderate loaded situation, could be heard up to 10-15 km when 3.6 MW turbines are operated or up to 20-21 km when 5 MW turbines are used. In these calculations the background noise of waves or other surface noises are not taken into account.

In Van Hulle et al. (2004) the level of acoustic noise emission of modern wind turbines is found so low, that from a short distance (less than one km) it is lower than the background noise of the sea and thus not audible any more. This factor does not play any role in excluding areas of the BPNS from wind farming.

Health:

The avoided harmful emissions from the combustion of fossil fuels in power plants for the production of 560 GWh have been estimated at (omzendbrief 17/07/2000):

- 0.42 mio ton CO_2/year (the total difference between the normal evolution without extra measures been taken and the Kyoto-target is estimated at 26 mio ton CO_2) (per kWh approximately 0.7 kg CO_2);
- 1380 ton SO_2/year
- 1050 ton NOx/year
- 122 ton dust/year

Employment:

The approved C-power project is good for the following employment (http://www.c-power.be):

Table I.2.2g: Employment in wind-energy projects

Part	Man years
Project development	43
Fabrication on land	682
Transport/ Construction at sea	460
Exploitation/ maintenance	473
Break-down	255
Total	1913

As Belgium is one of the pioneers in farshore wind energy, the gained experience in the C-power project can create export possibilities for Belgium.

Source

- Van Hulle, F., Le Bot, S., Cabooter, Y., Soens, J., Van Lancker, V., Deleu, S., Henriet, J.P., Palmers, G., Dewilde, L., Driesen, J., Van Roy, P. and R. Belmans, 2004. Optimal Offshore Wind

Energy Developments in Belgium. Part I. Sustainable production and consumption patterns. Report SPSD II. 153 p.

- Web page C-power (http://www.c-power.be)

2.6 REFERENCES

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- Fina-Eolia II documents (February 2003)
- C-Power I documents (May 2002)
- Electrabel - Jan de Nul I documents (April–October 2002)

Web page C-power
http://www.c-power.be/

Web page EWEA
http://www.ewea.org

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http://www.zeebruggeport.be

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Appendix 1: Overview of off-shore wind-energy projects in Belgium (source: http://www.mumm.ac.be/)

Current projects

Project developers	**Location**	**Number wind turbines**	**Total capacity (MW)**	**Total area (without surrounding safety area (km²)**	**Water depth (m)**	**Shortest distance to coast (km)**	**Status of the project concerning domain concessions**	**Status of the project concerning environmental permit**
C-Power II	Thorntonbank	60	216-300	13.7-18.1	6-25	27	Concession granted 27.06.03 for the divided layout by the State Secretary of Energy	Environmental permit requested 17.06.2003. Environmental permit procedure stopped on 01.08.2003. New environmental permit request on 10.10.2003. Advice MUMM to Minister 02.03.2004. Environmental permit granted by Minister competent for the Marine Environment on 14.04.2004.
Electrabel-Jan De Nul I (Sea-energy)	Vlakte van de Raan	50	100	5.8	5-10	12.5	Concession granted by the State Secretary of Energy 27.03.02, BS 11 May 2002	Environmental permit granted by the Minister of Environment 25.06.02. Annulation procedure running by Council of State; permit suspended since 25.03.2003. New request for environmental permit on 01.10.2003; declared inadmissable by Minister on 17.10.2003.

Earlier projects

Project developers	Location	Number wind turbines	Total capacity (MW)	Total area (without surrounding safety area (km²)	Water depth (m)	Shortest distance to coast (km)	Status of the project concerning domain concessions	Status of the project concerning environmental permit
SPE	Harbour Zeebrugge	14	28	/	/	7 mills at sea, 7 on harbour wall	/	Environmental permit requested 12.11.2003. Public Consultation January 2004. Environmental permit denied by the Minister competent for the Marine environment on 14.06.2004.
SPE-Shell	Thorntonbank	110	275-300	20	6-25	27	Unfavourable advice of CREG 17.04.03, concession denied end of June 2003 by the State Secretary of Energy	/
Fina-Eolia II	North of Vlakte van de Raan	36	108-129	8.7	6-20	16.5	Favourable advice of CREG 17.04.03, concession denied end of June 2003 by the State Secretary of Energy	Environmental permit requested 06.02.03, procedure stopped 27.06.03
C-power I	Wenduineban k	50	115	12.5	5-10	5.1	Concession granted by the State Secretary of Energy 26.02.02	Environmental permit denied by the Minister of Environment 05.08.02. procedure under consideration by the Council of State; negative advice
Fina-Eolia I	Vlakte van de Raan	33-40	100	7.3	5-10	8	Concession denied by the State Secretary of Energy 05.07.02	/
Electrabel-Jan De Nul II	Vlakte van de Raan	50*2 en 80*2.5	300	18	5-10	11	Concession denied by the State Secretary of Energy 05.07.02	/

Appendix 2: Technical details of importance for impact study (Ecolas, 2003)

Unit	**Characteristics**	**Diameter**	**Depth**
Monopile	350-500 ton	5 m	20-40 m
Tripod (only at bigger depths)		1.5 m	
Corrosion protection	Spatzone: Epoxy of polyurethaan under water: protective coating by paint thickness wall: over dimensioning		
Erosion protection: not relevant for tripod	Natural stone (2 layers of 1m): Layer 1: gravel (1.5 to 4 cm diameter) Layer 2: stone dump (10-50 cm diam, with 4 m round pole extra heavy stones (60-300 kg))	48 m	
Cables	Inert polyester via cable laying ship or jettrencher 3-fase energy cable of 36 kV (farm) 2 x 3-fase energy cables of 150 kV (farm to land: 40 km) when crossing shipping lane or PEC cable		2 m depth 1 m 2 m > 4m

Appendix 3: Overview ecological and socio-economic data.

	C-Power	Circular letter[1]	ODE-ARNE[2]	EWEA[3]	Mineco[4]	Greenpeace[5]
Windpark	**Based on power of 216 MW (713 GWh)**	**Based on power of 214 MW (560 GWh)**	**Based on capacity of 214 MW (677 GWh)**	**EU; Based on capacity of 214 MW (677 GWh)**	**Based on capacity of 214 MW (256 GWh) ALSO (30.97 MW and 37 GWh)**	
Ecological						
Saving primary energy		120000 ton coal 3700 ton oil-equivalent 60 million m³ gas/meth.				
Dependency fossil fuels		Reduced				
Social						
Health/ Environment Avoidance of …/year		0.42 mio ton CO2	0,47 mio ton CO2	6.3 mio ton CO2 (2003) 28 mio ton CO2 (2005)		
		1380 ton SO2		21000 ton SO2 (2003) 94000 ton SO2 (2005)		
		1050 ton NOx		17500 ton NOx (2003) 78000 ton NOx (2005)		
		122 ton dust				
		Other HNS		No more recyclable		
Decrease external cost due to avoiding classical production (fossil fuel)		38.9 mio Euro (6.94 euro/kWh)				
Economical						

1 Circular letter 17/07/2000 VL. Gemeenschap: Afwegingskader en randvoorwaarden voor de inplanting van Windturbines.
2 ODE-ARNE brochure 1998: Windenergie Winstgevend.
3 European Wind Energy Association (EWEA)
4 België: Mineco
5 Greenpeace-DEWI study: Offshore wind in the North Sea. Technical possibilities and ecological consideration

	C-Power	**Circular letter**[1]	**ODE-ARNE**[2]	**EWEA**[3]	**Mineco**[4]	**Greenpeace**[5]
Production	713 GWh (51.7 kWh/m²/y)	560 GWh	677 GWh		256 GWh (37 GWh)	
Maximum potential						Offshore Belgium: 24 TWh/year
Families provided		227027	274459		15000	
Investment cost:		311.35 mio Euro (1455 €/kW)	223 mio Euro (1042 €/kW) without net	209 mio Euro (980 €/ KW)	353 mio Euro (1650 – 2200 €/Kw) (0.03 to 0.08 €/KWh)	(963.9 €/kW)
Cost wind-turbine			744 €/kW	700 €/KW (how larger, reduction in cost)	Depends on wind speed and on institutional factors	Depends on distance to shore and water depth
Cost installation, foundation, ground cost			223-298 €/kW	105-280 €/kw 15-40% turbine cost	Depends on size; 30% more than on shore	
Cost "net connection"			??	??	25% more than on shore	
Varia cost (insurance)					12395 €/year for 600 kW turbine 25000 €/year for 1.5 MW	
Operational cost				25 €/kW/yr (200 Kw turb) 15 €/Kw/yr (500 Kw turb)		4.5 €/kWh
Maintenance cost			1-2% of investment cost 4.45 mio Euro		2% of investment (first 10Y) 12% from 11 year	
Return		42.1 mio Euro/year	52.02 mio Euro/year (0.077 Kw/h)			
Job creation		1280		15-19 people/MW		
Direct		550				
Indirect		550				Double as direct
Consultancy		180				