OPTIEP-BCP

Optimalisering van de basiskennis over het energiepotentieel op het Belgisch Continentaal Plat (Contract AP/42)

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Dit onderzoeksrapport kwam tot stand in het kader van het programma '***Actie ter ondersteuning van de strategische prioriteiten van de federale overheid***' in opdracht van de POD Wetenschapsbeleid, ter ondersteuning van de FOD Economie, K.M.O., Middenstand en Energie.

Dit programma werd in het leven geroepen om snel en efficiënt te kunnen inspelen op de behoeften van de federale overheidsinstellingen inzake gerichte onderzoeksacties van bepaalde duur (6 maanden tot 1 jaar) en/of verkennend onderzoek met betrekking tot strategische gebieden. Het betreft een "horizontale" actie: ze staat open voor de financiering van onderzoeksprojecten binnen de verschillende beleidsthema's die in het kader van de regeringsbeslissingen naar voren worden geschoven.

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Executive Summary (EN)

Wind energy resource

The results presented in this report stem from the « *Optimal Offshore Wind Energy Developments in Belgium* » study carried out in 2004 for the Belgian Scientific Policy (SPD II). There has been, and still is, a lack of reliable wind measurement data at sea. The few meteo masts available on the « meetnet Vlaamse banken » on the Belgian continental plate are not adapted to evaluating wind potential. Given the lack of relevant data, this study of wind potential is based on the 2004 study.

In the Belgian part of the North Sea (BPNS), average wind speeds (long-term) at hub height (70m to 110m) vary between 8,4 et 9,8 m/s. Main wind direction is west-south-west winds. The figure below provides a visualization of the spatial distribution of wind speeds at 100m above the level of TAW[3].

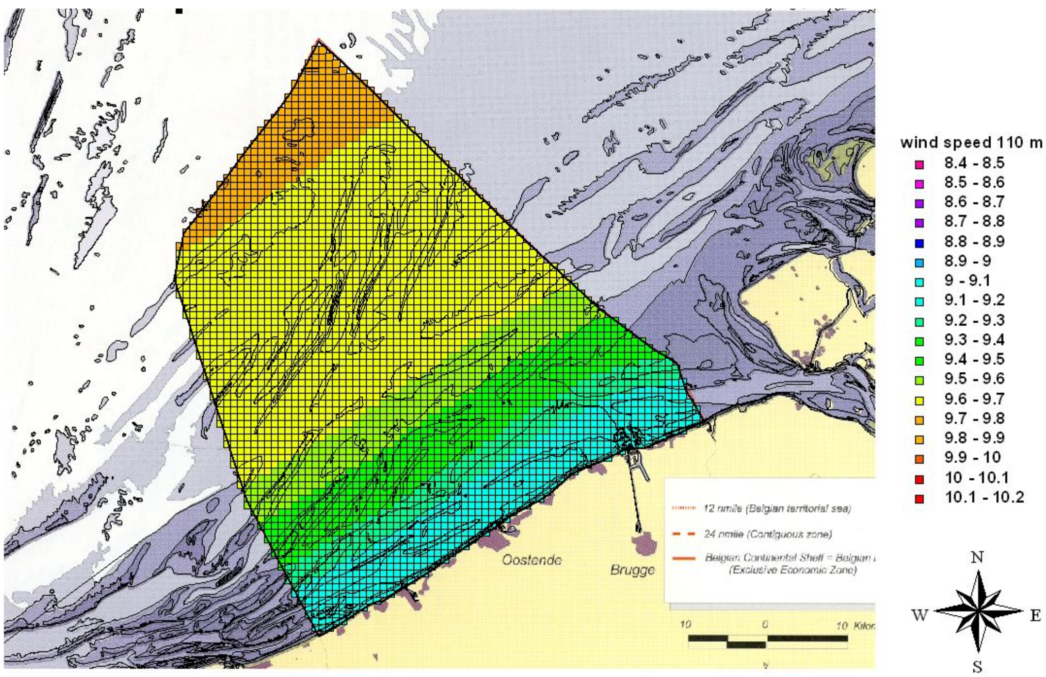

Figure 5 : GIS map of wind speeds in BPNS, based on POWER method described in *Optimal Offshore* study

Currently, there are turbines for offshore applications at 6MW power, rotor diameter of 125m and hub height of 90 to 100m. It is expected that 8 to 10MW machines will be available on the market within 3 years. However, as shown in this study, the impact of this market development for the BPNS is relatively limited.

In addition, as characteristic of the offshore sector, the current trend is moving towards the development of new concepts adapted to offshore conditions. Big efforts are being made, on the

[3] TAW : At present, "TAW" (Tweede Algemene Waterpassing) is used as vertical reference level for all tide monitoring along the Belgian coastline. In 1947, the National Geographical Institute determined the TAW reference height as vertical reference level for the whole area of Belgium. The 0 value for TAW corresponds to the mean water level at low tide in Ostend.

one hand, to reduce operational costs and improve machine reliability and longevity of components, and on the other hand, to develop preventive maintenance strategies. Much work has also been done on developing innovative concepts for hub replacement at sea (swing-off concept), for automatic oil cleaning, modular power transmission systems, etc… New techniques for foundations, component transportation and general logistics are also being improved.

It has been concluded in neighboring countries that park density has a very big influence on energy yield, as exemplified in table below. In a dense configuration, yield can decrease by up to 86%. In addition, experience has demonstrated that current calculation models underestimate real losses (Table 1).

Table 1 : Losses as a function of distance between turbines (calculations carried out with WindPro software for a square park layout)

Turbine type [distance gap]	RePower 5MW [6D]	RePower 5MW [8D]	RePower 5MW [10D]
Rotor diameter (m)	125	125	125
Hub height (m)	100	100	100
Number of turbines	80	80	80
Installed power (MW)	400	400	400
Distance between turbines (m)	750	1000	1250
Surface (km²)	45	80	125
Overall power density (MW/km²)	8.9	5.0	3.2
Park yield (%)	86.6	90.9	93.4
Production (GWh/an)	1390.7	1461.3	1503.4
Capacity factor (%)	39.7	41.7	42.9

A literature review of the largest offshore wind parks in operation in Europe, shows that overall power density is in the range of 5 to 7 MW/km².

Whereas in the past, smaller distances between turbines were preferred, the trend today is clearly for larger distances. This is due mainly to the higher yields achievable and therefore better profitability. This trend has the added advantage of reducing fatigue. Indeed, wake effects not only cause production losses but also heighten the strains and forces applied to turbine components. A few turbine manufacturers have previously concluded that too small distances between turbines can no longer be accepted due to the incompatibly with allowed loads on a turbine.

With a minimum distance of 7 times the rotor diameter between turbines, the installed power density can reach 7 to 8 MW/km². For a very large park, with a surface area of several hundred square kilometres, we recommend a slightly lower number of MW/km², in the range of 5 to 6 MW/km². A recent ECN publication comes to the same conclusions.

In this study, a 6 to 8MW/km² bracket is used to determine wind potential. Theoretically, available surface area is 2101 km, after exclusion of the 3 miles zone and all constraints tied to other activities (Table 2).

However, certain restrictions remain (secondary navigation routes, aquaculture, natural reserves, exploration zones…) which strongly reduce the availability of the BPNS. This also holds for the composition of marine soil, which will be known only after drilling.

Table 2 : Typical figures on wind power potential installed in the BPNS

	Zone [km²]	Power density [MW/km²]	Potential installed power [GW]
Maximum physical potential	2101	6 - 8	12,6 - 16,8
Potential in zones dedicated to wind energy	270	6 - 8	1,62 - 2,16

Taking into account wind characteristics and distribution in the BPNS, the wind energy potential is in the range of 39 to 63 TWh per year, for a bracket of 6 to 8 MW/km² for new parks (with increase in hub hight and advanced technology) in development.

Conclusions and recommendations

The development of offshore wind energy has slowed down in comparison to initial scenarios, mainly because of technical difficulties and unfavorable economic conditions. Belgium is experiencing the same slow-down caused partly by economic conditions, but also by the requirements on authorization procedures in place and the technical difficulty of installing parks in relatively distant and deep waters. The technical complexity for the foundations and the preparation of the electric cabling layout are some examples of these difficulties. However, experience acquired in the UK, Denmark and the Netherlands shows that offshore wind turbine technology is maturing. On the other hand, the economic climate is also progressively improving.

Five concessions have been granted to different project developers for Belgium: C-Power (300MW), Eldepasco (216 MW), Belwind (330 MW), Rentel (288 MW) and Norther (420 MW). In general, it is planned to use turbines in the 5MW product range. The development of larger turbines does not affect the exploitable potential of the defined zone. These developments can however help reduce investment costs on offshore wind in the long run.

Wind parks planned on the Belgian continental plate have a very high power density. This is a consequence of the required optimization of available space use, one of the criteria for the granting of a concession (Figure 6).

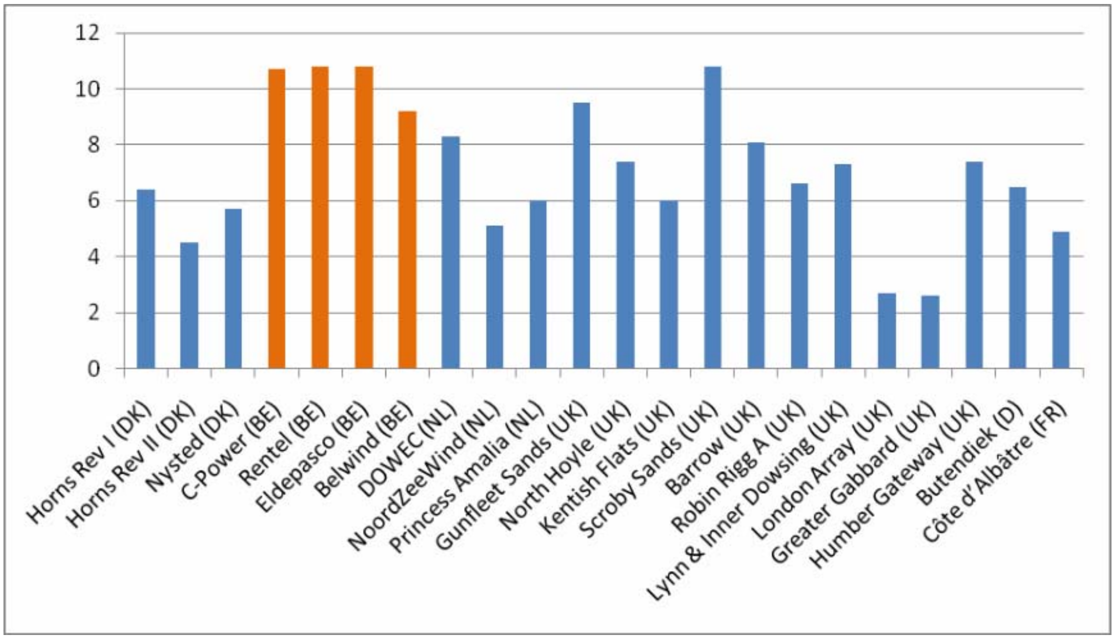

Figure 6: Global powerdensity (MW/km²) for the biggest EU offshore windmill parks.

It is however not recommended to use density as a determining factor since it can lead to lower park efficiency and hence lower park profitability. In addition, structural loads on turbines are higher given smaller inter-turbine distances. Nevertheless, there still is much uncertainty related to the definition of optimal distance between turbines, especially for large wind parks (>100 machines), due to limited experience on the subject.

Additional research is urgently needed in order to analyze wind park yield and structural impact of wake on turbines. More data and measurements are needed as basis for more relevant decisions in the future.

To achieve set objectives for renewable energy and offshore wind, the zone attributed to offshore wind developments needs to be extended. It is also recommended that allocation of concessions be based on other criteria, for example guarantees on results based on real wind speed measurements.

Independent and more frequent wind measurements, specifically adapted to wind energy needs are essential. These measurements will facilitate project financing and will provide better general visibility on park performance. Several countries have already organized these types of measurement campaigns in their parts of the North Sea for several years.

Finally, detailed follow-up of energy production would provide better information on wake effects and associated energy losses.

Wave energy resource

Wave and tidal energy are two marine renewable energy sources which are under full development. In order to apply these energy sources on the Belgian Part of the North Sea (BPNS), an overview of the existing technologies has been presented. Three Wave Energy Convertors (WECs) and 3 Tidal Energy Convertors (TECs) were discussed because of their suitability to the conditions on the BPNS.

The wave energy ressource on the BPNS was determined with an Optimal Interpolation technique. This methodology allows to combine the high accuracy but low geographical resolution of the buoy data with the high geographical resolution of a numerical wave propagation model. By doing so, a fairly accurate and a high spatial coverage was obtained. The wave resource is shown in Figure 7. According to this analysis, the Domain Concession Zone for offshore windenergy, has a wave resource of 4.5 – 5.8 kW/m. This is a rather moderate wave resource compared to locations which are exposed to the high swell waves of the Atlantic Ocean. The energy production (and hence the revenues) originating from wave energy are directly linked with the average wave resource. However, it is the extreme wave resource that determines the structure (and hence the costs) of a WEC. The low extreme waves and the moderate wave resource make the BPNS very appropriate as a test site for WECs.

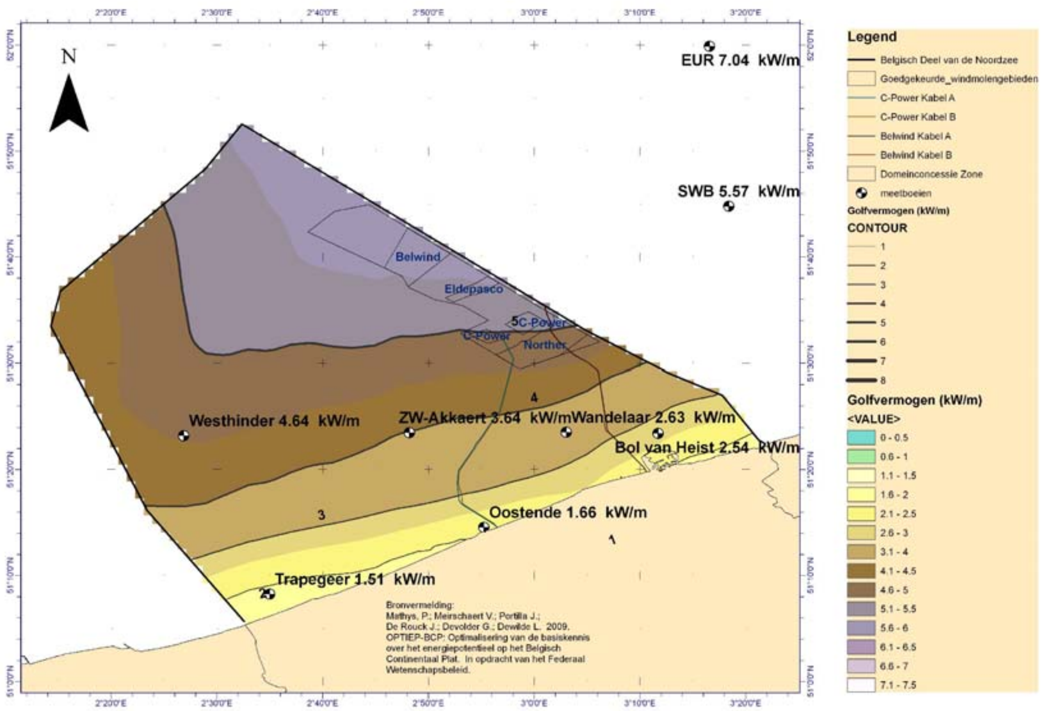

Figure 7: Wave resource on the Belgian Part of the North Sea, obtained by an Optimal Interpolation Technique. The results nearshore are less reliable.

Tidal energy resource

The tidal energy resource on the BPNS was calculated based on the results of a numerical hydrodynamical model of the MUMM (Management Unit of the North Sea Mathematical Models). The results from a full spring-neap tide cycle were used to calculate the tidal energy resource (Figure 8). Four zones with a higher resource were detected: zone West, 2 zones in the proximity of the Domain Concession Zone for offshore wind energy, the harbor of Zeebrugge and the navigation channel to the harbor of Antwerp. The results in the proximity of the Domain Concession Zone need to be interpreted with care, since nor the bathymetry nor the geometry of the North Sea can provide a clear explanation of the higher resource.

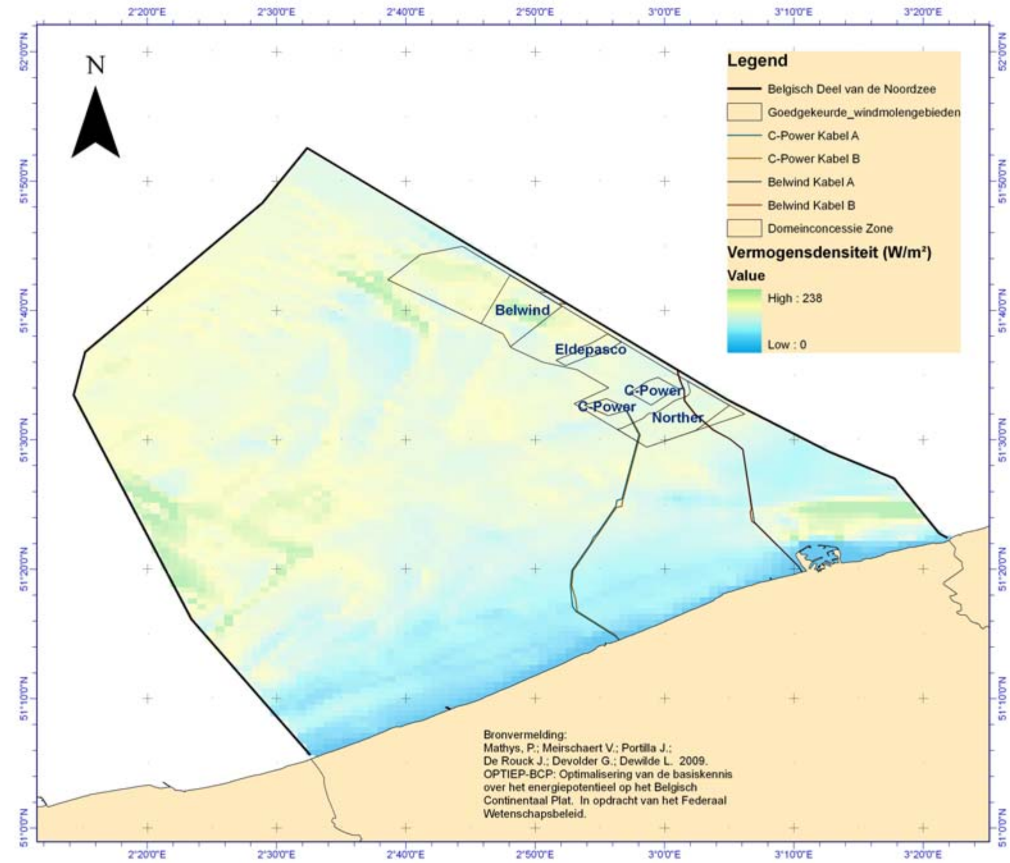

Figure 8: Tidal energy resource on the Belgian Part of the North Sea, based on a numerical hydrodynamical model.

For a further and more accurate resource of both wave and tidal energy, the reader is referred to the results of the BOREAS (Belgian Ocean Energy Assesment) project, also funded by the Belgian Science Policy.

Stakeholderanalysis

Interviews with stakeholders from the Belgian offshore wind sectors allowed to identify the strengths and weaknesses of the current policy as well as the threats and opportunities of the future development of the policy. The following issues are based on the opinion of the consulted stakeholders, and do not necessarily reflect the opinion of the authors.

A better fine tuning amongst the different permit procedures has been identified as an important measure to speed up the offshore wind development. However, it is not the intention to change the existing permits into one single permit, since that would make it probably to difficult. Furthermore, the sector asks:

- A permit procedure that offers legal certainty for the common exploitation of the offshore wind cable by different project developers.
- A higher transparency regarding the criteria and approval of the domain concession zones.

- A quick decision regaring the adaptation and if necessary, extention of the domain concession zone in order to solve the objections made by navigation for the most Southernly and Northernly zones.
- A possible prolongation of the duration of the domain concession zone (current: 20 + 10 years, but in the future could last up to 50 years)

The interviews also identified economic opportunities. The adaptation of the Belgian harbours to become logistic offshore wind energy hubs was a clear example. This hub could not only serve the Belgian offshore market, but also the UK offshore wind market. Both the logistics as well as pre-assembly provide chances for the harbor. The financing of the grid reinforcements, both on- as offshore, should be a key priority for the policy.

Different proposals for new consultative structures were formulated. One of them could focus on the on- and offshore cabling, with both national and international participation of stakeholders. The conditions and technical criteria of a 'plug-socket at sea' would also fit in the scope of this structure. A second consultative structure would be similar to BNSWEP, but then for project developers who did not yet received a Domainconcession. A third consultative structure would be a forum for emergency planning, in case of severe accidents. The latter kan be integrated in already existing structures such as BNSWEP or the Coast Guard (KWGC).

The stakeholders provided some valuable input for possible scenarios to support policy. These scenarios were investigated in the economical analysis of the policy.

Analysis of the economical and legal instruments to support offshore wind energy

Finally, both a quantative and qualitative analysis of the offshore windenergy policy were conducted. Based on a literature study, the advantages and disadvantages of certain policy instruments were discussed in the qualitative analysis.

The TGC-certificates are technology specific, both on the Federal and Community level. This specifity is important as it takes into account the maturity of the technology. The maturity is a function of the production costprice. Since wave and tidal energy are less mature then offshore wind, it is recommended to increase the guaranteed tariffs for the TGC-cerficates from wave and tidal energy. This increase should be at least up to the level of offshore wind.

After the qualitative study, a quantative (economical) analysis was conducted. The project rentability of a generic 300 MW offshore windmill park was assessed by means of the calculation of the Net Present Value under different scenarios and variations. An extensive literature study was used to determine the input parameters for this financial analysis. The Belgian framework was compared with the framework of neighbouring countries. Furthermore an extra scenario was studied whereby the domain concession was prolongated up to a period of 50 years.

The 3 different scenarios (optimistic, basic, pessimistic), allowed to vary 4 input parameters: electricity price, investment cost, operation and maintenance cost and the capacity factor. In the scenarios, all 4 parameters were changed at once, but a sensitivity analysis by changing the individual parameters, learned that the capacity factor has the highest effect of the NPV (€ 29,5 million in base scenario, 137.5 million with an optimistic capacity factor, -78.5 million for a pessimistic scenario. It can be concluded that the technical developments (R&D) for offshore wind turbines remains an important issue, independent of the economical and legal support policy. In the Belgian context, 5 extra variations were considered in comparison to the base scenario:

1) decrease of the interest rate;
2) degressive depreciation instead of a linear;
3) introduction of the balancing cost;
4) a federal-regional harmonized Tradable Green Certificate (TGC) market and
5) a subsidy of € 25 million.

The variation with the highest effect on the rentability is a harmonized TGC market (NPV in base scenario 29,5 million goes up to 62,7 million with harmonized market, (

Table 3). This is due to the fact that the TGC achieved 216 MW can benefit from the market price of 108€/MWh, instead of the guaranteed and fixed price of 90€/MWh. However, an important assumption in this scenario is that harmonizing itself, has no influence on the price settting of the certificates. Wheter this assumption holds, should be investigated in depth by a full economical analysis on the price and liquidity of these markets. This was beyond the scope of this project.

If one compares Belgium with other European contries, the following conclusions can be drawn. Only Germany and Italy have a good score. Italy has a similar TGC system as Belgium, hence the NPV values are quite comparable throughout the different scenarios and variations. Germany has installed a very innovative support policy in 2009, based on a feed-in tariff and a guaranteed period which can be prolongated in function of the distance to the shore and the waterdepth. The negative result of Denmark is surprising. However the real investment cost in Denmark will probably lower. On top of that, almost no non-technical barriers exist.

Table 3: The different NPV for a generic windmillpark with an installed capacity of 300MW, according to the different scenarios and variatons.

VARIATIONS	Optimist. scenario		Base scenario		Pessim. scenario	
Country	NPV	Var.	NPV	Var.	NPV	Var.
Belgium						
Reference	k€ 358,621	1.00	k€ 29,535	1.00	k€ -268,275	1.00
Low interest rate	k€ 364,268	1.02	k€ 33,387	1.13	k€ -265,669	0.99
Degressive depreciation	k€ 371,468	1.04	k€ 44,338	1.50	k€ -251,517	0.94
Balancing cost	k€ 319,114	0.89	k€ -5,033	-0.17	k€ -297,905	1.11
Harmonized TGC-market	k€ 396,547	1.11	k€ 62,721	2.12	k€ -239,830	0.89
Subsidy of 25 mio	k€ 383,621	1.07	k€ 54,535	1.85	k€ -243,275	0.91
Denmark	k€ -231,463	-0.65	k€ -419,007	-14.19	k€ -580,671	2.16
France	k€ 60,816	0.17	k€ -145,761	-4.94	k€ -344,617	1.28
Germany	k€ 274,886	0.77	k€ 40,920	1.39	k€ -184,994	0.69
Italy	k€ 353,182	0.98	k€ 24,777	0.84	k€ -272,353	1.02
Portugal	k€ -108,798	-0.30	k€ -321,341	-10.88	k€ -520,354	1.94
Spain	k€ -7,744	-0.02	k€ -299,500	-10.14	k€ -556,971	2.08

The project rentability of a Belgian domain concession up to 50 years (whereby new turbines are placed in year 26, but the existing foundations are kept) has been investigated, under the assumption of a changed TGC system. Furthermore, a shift in policy support towards the internalization of the external costs for the conventional electricity production and different technical input parameters were assumed. Eight different scenarios were considered (combinations of a TGC of 0 or 10 €/MWh and a carbon tax of 0, 10, 25 or 40€/ton $CO_{2,equivalent}$). An important conclusion is that the NPV decreases in this new base scenario (no TGC support, no carbon tax) compared to the domain concession of 25 years from 29.5 million to 28.8 million (Table 4). In other words: if the current policy remains a project investor will not start up a second exploitation term of the domain concession, since the NPV is lower than in the base scenario.