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On the valuation of wind energy resources

The economy behind wind energy production

Preliminary results
This report presents the concept and methdologies to compile statistics for the economy behind wind energy production. This report focuses on concepts and methodologies. The presented figures in this report are preliminary results of the study. The figures in this report are compiled in the year 2010. New insights and new data have led to slightly different figures for the economy behind wind energy production.

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Remark: The views expressed in this report are those of the authors and do not necessarily reflect the opinion of Statistics Netherlands. The authors would like to thank Sjoerd Schenau, Reinoud Segers, and Dirk van de Bergen for their useful comments and suggestions.

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1. Introduction

More and more, the subject of renewable energy receives public attention. The debate on renewable energy is fostered by the fact that fossil fuels are becoming scarce and that their combustion produces CO_2 which contributes to climate change (IPCC, 2007). Renewable energy is a substitute for non-renewable energy. Renewable energy can be produced in many different ways, i.e. wind energy, hydropower energy, solar energy, geothermal energy and so on. These energy transformation technologies are considered more environmentally friendly than conventional, fossil sources based transformation technologies. For example, they go along with fewer emissions to air than their fossil counterparts which are based on the combustion of fossil fuels. Secondly, these alternative technologies consume no or less fossil energy and thereby preserve existing national and international fossil energy reserves.

The problems related to scarcity of fossil fuels are expected to become more severe over time, especially for countries which are highly dependent on non-renewable energy resources. In reaction to this, governments are trying to develop and implement policies to reduce air emissions and to reduce fossil energy depletion. A lot of countries are in the process of transforming their energy policy to a more sustainable one.

In the System of National Accounts, fossil energy resources are recorded as non produced assets in the national balance sheet. In order to comply with the general definition of an economic asset, natural assets must not only be owned, but must also be capable of bringing economic benefits to their owners, given the technology, scientific knowledge, economic infrastructure, available resources and set of relative prices prevailing on the dates to which the balance sheet relates or expected to do so in the near future (SNA 2008, §10168). These requirements are generally met for fossil energy resources like coal, natural gas and oil. As a logical consequence, an increasing number of countries publish statistics on the public and private ownership of fossil natural energy deposits.

So far renewable natural energy resources are, however, not generally recorded as assets on the national balance sheet. This is because the ownership criteria are not fulfilled (nobody "owns" renewable energy resources like wind or solar radiation[1]). This seems to be a serious omission since their share in total energy production is increasing. Fostering the exploitation of renewable energy resources is undoubtedly an important part of sustainable development policy strategies around the world. Balance sheets that are restricted to non-renewable energy resources only could lead to a serious underestimation of a country's available energy resources.

The purpose of this study is to gather all kind of economic information related to wind energy production. Data for production, intermediate consumption, value added, investments, capital services and finally the resource rent are presented in this study. Another purpose is to compile monetary balances for renewable energy resources. The focus of this study is only on wind energy production because this is by far the most important technology (after the biomass technology) producing renewable energy in the Netherlands. Internationally, water energy production is also a very important technology for producing renewable energy but in the Netherlands this technology plays only a relative small role.

[1] Biomass is not taken into account because biomass is already incorporated in the value of timber. Supply of biomass is an eco-system service of forests. Forests are already classified as an separate asset category in both the SEEA and the SNA.

This report is set up as follows. In section two we discuss the conceptual background, definitions and boundaries. In section three the general methodology for valuation of renewable energy resources is presented. In section four we present methodologies for typical data production for variables such as production, intermediate consumption, value added and other relevant variables. In section five monetary and physical balances for wind energy resources are introduced. In section six all data gathered in this study is summarized. In section seven an application of the information gathered in this study is presented. In the end, we conclude and formulate some recommendations for future studies.

2. Conceptual background, definitions and boundaries

Renewable energy sources are generally not recorded as assets on the national balance sheet. This seems to be a serious omission since their share in total energy production is increasing and fostering the exploitation of renewable energy sources is undoubtedly an important part of sustainable energy policy strategies around the world. Balance sheets that are restricted to non-renewable energy sources could lead to a serious underestimation of a country's available energy sources. This conceptual background reflects both the London Group's conclusions reached at its 15th meeting in Wiesbaden, based on the discussion paper "On the valuation of renewable energy resources" (Van Rossum, M. and Schenau, S.J. (2009)) and the conclusions reached at its 14th meeting in Canberra, based on the issue paper "Renewable energy resources in the SEEA" (Van Rossum, M. de Haan, M. and Schenau, S.J. (2009)).

More generally, the London Group considers the accounting for renewable energy sources as highly policy relevant (Obst, C (2010)) and considers that the energy flows and economic transactions related to renewable energy production and use are covered in an insufficient detail in the current statistical system and that this detail should be expanded in future statistical system. It is noted however that to date, the accounting experiences in this area seem quite limited.

Definitions and boundaries; renewable energy and the value of land
Discussion within the London Group concluded that the value of renewable energy sources was incorporated into the price of the land on which mechanisms to capture the energy are based. For example, the land in a particularly windy area would be priced more highly than similar land in a non-windy area if investment is made to construct windmills to capture the energy from the wind source. Thus, as such, energy production opportunities based on natural resources like wind, solar radiation and geothermal energy are expected to be reflected in the price of land (water is exception here). As a result there is no need to create an additional asset within the SEEA (System of Environmental and Economic accounting) called a "renewable energy source" as this will lead to double counting. Ideally, it would be good to decompose the value of the land into a value for the renewable energy source and the value of the physical land itself. However, isolating the resource rent that accrues to the investment in energy capture as distinct from other resource rent is very complicated. Specifically there may be various forms of government intervention and information asymmetry which hide the true value of the income that should be attributable to the renewable energy source as distinct from the land itself.

Subsidies for renewable energy
Through the work on this topic it has become clear that there are a range of policies and schemes in place to support the development of renewable energy sources and at the same time reduce the reliance on non-renewable energy sources. In this process a range of positive

and negative externalities are likely to arise. Within the system of national accounts (SNA) there is no explicit accounting for these externalities and indeed accounting for these externalities is a complex task. Nonetheless there are some techniques that may be applied to advance the understanding of this issue. For the SEEA, having the ambition to monitor and measure other phenomena than the SNA, it is advocated to at least monitor subsidies on products as well as "implicit" subsidies (such as tax reductions related to investments) related to renewable energy production. Explicit and implicit subsidies are important for financing renewable energy projects. By taking into account renewable energy subsidies in determining the resource rent one starts to take into account relevant externalities in relation to renewable energy production. One could argue that the price of 'grey' electricity is too low. The government does not tax the external effects associated with the production of 'grey' electricity completely (exception is the emission-rights trading system, however the emissions rights are initially allocated for free). The government therefore implicitly subsidies 'grey' electricity production. In other words the basic price for grey electricity is too low. The social preferred price for 'grey' electricity is higher than the basic market price. The government decided not to tax the producers of 'grey' electricity, in order to create a level playing field, instead they decided to subsidize renewable energy production. Because there exists no real data on the difference between the market price and the social price, subsidies per unit production are used here as a proxy for quantifying the external effects related to grey electricity production. This issue will be further elaborated in section 4.7. Nonetheless, given the measurement difficulties and need for further research, these approaches for valuation are included in this study as part of a presentation on the valuation of ecosystem services. Further, alternative approaches taking into account implicit subsidies could be presented as analytical items will be presented too. This work may also be accompanied by a discussion on the potential policy applications (such as scenario modelling).

The stock of renewable energy sources

There is a strong link between produced assets, such as windmills, and the renewable energy asset since the energy potential and, hence, income source must be captured in some way. This link can be interpreted as a reflection of the proper market reaction of the producers. Producers react to better market conditions by investing more in relevant produced assets. In other words, they are investing more in order to pick up more of the resource rents created by favourable market conditions. This is a specific characteristic of the renewable energy asset. It emerges when benefits are present and it disappears when benefits vanish. Further, this (implicit) resource rent is expected to be incorporated in the increasing price of land.

The discussion of this issue has focused on accounting for the income earned from the capture energy from renewable energy sources. Given the nature of these sources however, it may be reasonable to seek answers to how large the *potential* renewable energy source might be and hence determine required levels of investment in capture technology, etc. While important, these matters were beyond the scope of this study. Only those renewable energy sources that are an input in the energy transformation process are taken into account in the valuation process. In other words, the total potential of renewable energy resources is not subject of measurement is this study.

3. Methodology for valuation of renewable energy resources

This section discusses the actual calculation of resource rents and asset values for renewable energy assets. The methods correspond with those recommended for other natural resources in

SEEA (UN et al., 2003). According to the SNA any balance sheet item should be valued on the basis of representative market values. Such valuation relies on market prices for these items being available. Unfortunately, this valuation method is not broadly applicable to environmental resources as market price information is often not available. SNA's next-best option to market price valuation is by calculating the net present value[2] of current and future income streams derived from the asset in question. Like any other natural resource, renewable energy resources provide capital services to its owner and their remuneration should be an element in the gross operating surplus[3] of the energy producer. This income element addressing the value of the renewable energy capital service is called the resource rent.

BOX for resource rent calculation

Production value[4]	300		
Intermediate consumption[5]	-100		
Value added [6]	200		
of which			
	Compensation of employees	0	
	Balance taxes and subsidies(production related)	0	
	Gross operating surplus	200	
	of which		
		Consumption of fixed capital[7]	50
		Return to capital[8]	50
		Resource rent[9]	100

Figure 1-Box for resource rent calculation

[2] *Net present value* - Net present value is defined as the total present value of a time series of cash flows. Present value is the value on a given date of a future payment or series of future payments, discounted to reflect the time value of money.

[3] *Operating surplus / mixed income* - Gross operating surplus by industry is the balance that remains after deducting from the value added (basic prices) the compensation of employees and the balance of other taxes and subsidies on production. The operating surplus of family enterprises is called mixed income, because it also contains compensation for work by the owners and their family members.

[4] *Production (basic prices)* - Production covers the value of all goods produced for sale, including unsold goods, and all receipts for services rendered. Output furthermore covers the market equivalent of goods and services produced for own use, such as own account capital formation, services of owner-occupied dwellings and agricultural products produced by farmers for own consumption. The output of such goods is estimated by valuing the quantities produced against the price that the producer would have received if these goods had been sold.

[5] *Intermediate consumption (purchasers' prices)* - includes all goods and services used up in the production process in the accounting period, regardless the date of purchase. This includes for example fuel, raw materials, semi manufactured goods, communication services, cleansing services and audits by accountants. Intermediate consumption is valued at purchasers' prices, excluding deductible VAT

[6] *Value added* – The income created during the production process. Value added at basic prices by industry is equal to the difference between output (basic prices) and intermediate consumption (purchasers' prices).

[7] *Consumption of fixed capital* - Consumption of fixed capital represents the depreciation of the stock of produced fixed assets, as a result of normal technical and economical ageing and insurable accidental damage. Losses due to catastrophes and unforeseen ageing are seen as a capital loss.

[8] *Return to capital* - compensation for invested capital. It is calculated by multiplying the opportunity costs (discount rate) by the fixed capital stock.

[9] *Resource rent* –income that accrues to the owner of a natural resource through it use in production. It is derived residually by deducting from output all the costs of production

The first step in determining the resource rent is to determine production, intermediate consumption and subsequently the gross operating surplus of renewable electricity producers which is equal to value added minus compensation of employees[10] minus taxes plus subsidies on production. In a subsequent step the consumption of fixed capital is subtracted together with a return to capital[11] on fixed assets.

The valuation of renewable resources is equal to the resource rent in year *t* divided by the discount rate in year *t*. The value of renewable energy resources very much depend on the used discount rate. We used a nominal discount rate of 6 percent. This rate is used for cost benefit analyses of renewable energy projects in the Netherlands (ECN (2008)). In discounting the resource rent we apply the real discount rate instead of the nominal discount rate. This means that we divide the resource rent by 4 percent instead of 6 percent (inflation is on average equal to 2 percent).

4. Methodology for data production

4.1 Production

In this section the methodological framework to construct monetary production statistics for renewable energy is explained. Hereafter the different steps that need to be taken are explained.

Step 1: Identification of gross physical renewable energy production (in Joules).
Information on net renewable energy production is available on the website of CBS (Statline). Information on production is available at product and technology level.

Step 2*:* Calculate monetary value of production for renewable energy products by making use of price information.

In formulae,
$W_{in}^{j}=P_i * Q_{in}^{j}$*correction factor
Where:

W_{in}^{j} :	monetary value of renewable product i by technology j
P_i:	basic price of renewable product i
Q_{in}^{j}:	physical production of product i by technology j

It has been decided that production is valued at basic prices and not at market prices. This decision is convenient since basic prices do not include taxes, subsidies, and transport- and trade margins. Excluding government support (subsidies, transfers) from prices makes it possible to analyse how large the renewable energy sector is without government interference. P_i is defined as the basic price of renewable product *i*.

Calculation of P_i is done by dividing the monetary production level product *i* by NACE class 40123 (electricity production) at basic prices (source National accounts) by physical

[10] In this study we assume that all labour involved in renewable energy production is hired externally and is therefore part of intermediate consumption. Therefore value added only comprises the capital services. This decision is taken because of data availability.

[11] Opportunity costs of capital. Not necessary equal to rent paid.

production level of product *i* by NACE class 40123 (source Energy accounts) NACE class 40123 is a sub sector of the energy sector (NACE 40), specialised in energy transformation.

The employed method is based upon the assumption that the development of the basic price for all renewable electricity production is equal to the development of the average electricity price. Electricity from sources which are able to anticipate on demand acquires a higher price than electricity from sources which are supply tied. Wind energy installations are supply-side driven and are unable to anticipate on changes in demand in the short run. For example, the price for electricity from wind mills is probably lower than the standard price as they are "less reliable" to supply energy at every moment in time. More research has been done in order to compute relevant prices for wind energy (based upon information of Windunie and ECN). Price information has been adjusted for the fact that wind energy production is supply-side driven. The difference between prices for normal energy and wind energy is approximately 5 percent in between 2007 and 2009 (see figure 2). This difference has been taken into account in determining the price of wind energy over time (see figure 3)[12]. Production is valued here in basic prices. Subsidies are not included in the value of production.

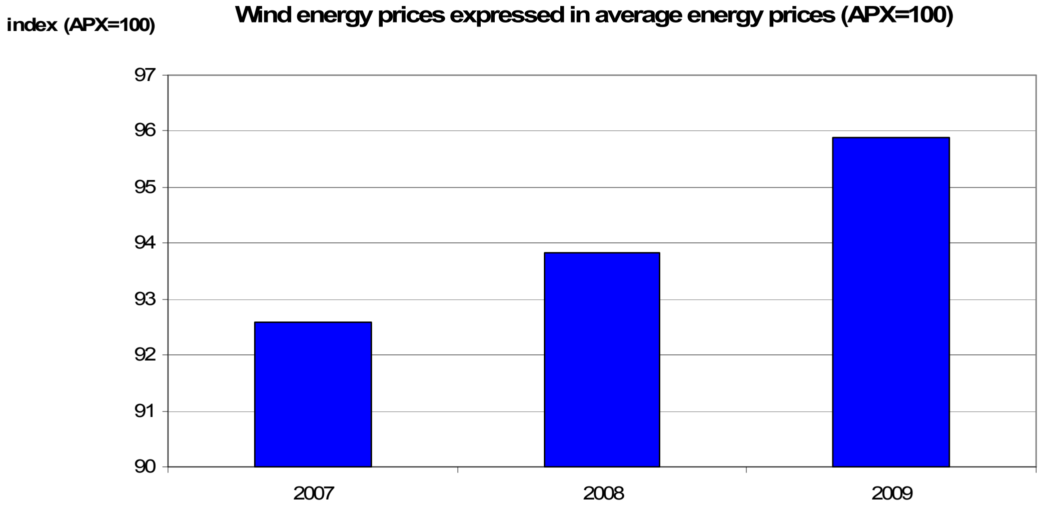

Figure 2- Wind energy prices expressed in average energy prices (APX=100)

[12] Many producers of wind energy have long-term contracts with distributors of energy. This means that they receive a fixed price per unit GWh in a certain period of time. These contracts are not monitored by statistical institutes. A lot of producers do not receive APX prices for their electricity. The rationale for using prices which are corrected for the fact that wind energy systems are supply side driven is the following. The difference in APX prices received by wind energy producers and other producers can be used in negotiations between producer and distributor. This advantage of the distributor is reflected in setting fixed prices in long term contracts.

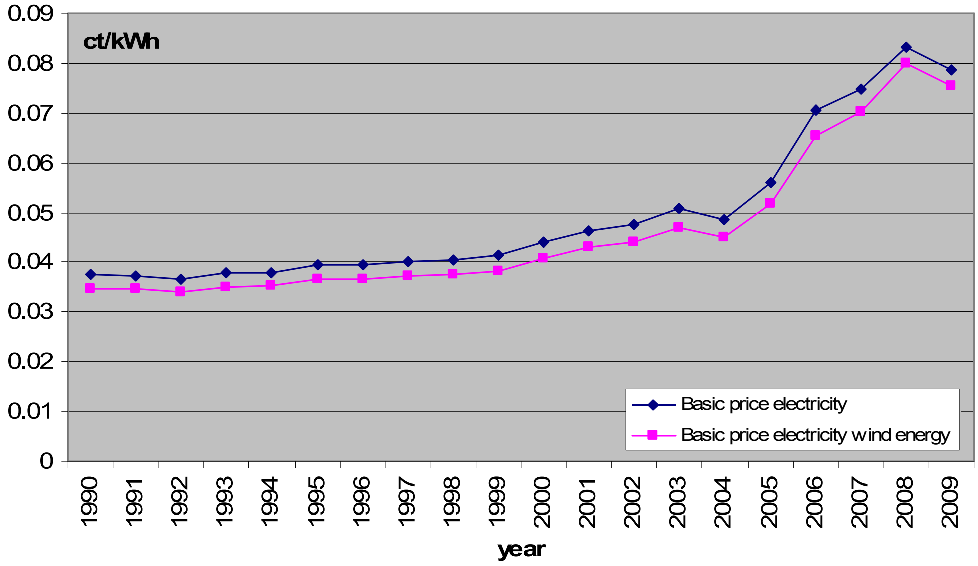

Figure 3-Timeseries for energy prices, electricity

The monetary value of production is calculated by multiplying the price information with the physical production information (see figure 4). In 2009, the production value for wind energy was almost equal to 350 million euro.

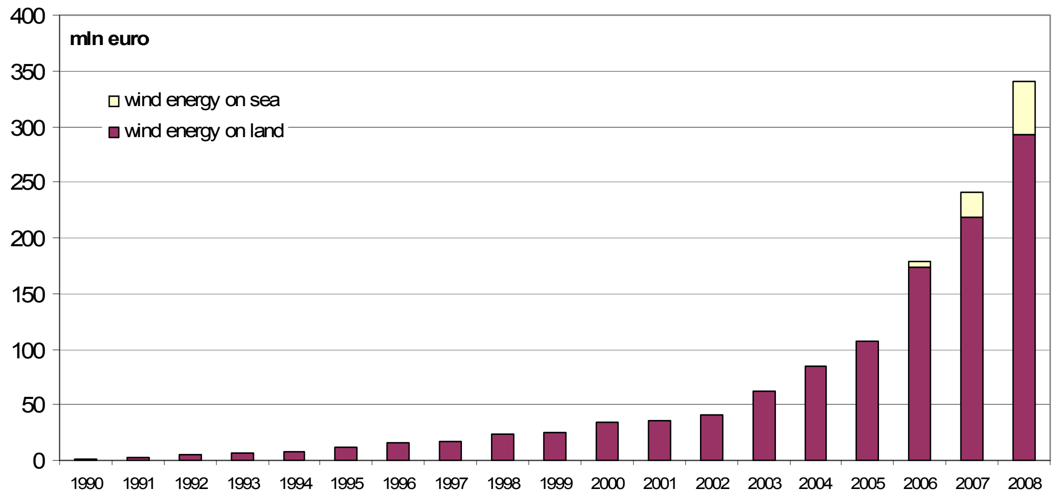

Figure 4-Production value for wind energy production, time series

4.2 Intermediate consumption

Intermediate consumption of wind energy producers is defined as the sum of maintenance costs, costs for imbalance[13] and network services. The maintenance costs and other material costs are directly derived using information of ECN studies (ECN, 2002, 2003, 2004, 2007,

[13] Power imbalance is created by differences in predefined programs and actual consumption or production. TenneT corrects this imbalance and calculates the costs to the person who caused the imbalance.

2008, and 2009). These studies report data for these typical costs. The costs for network services are computed making use of information on constant cost per kW (using information of ECN studies) and information on produced kWh. These mentioned costs are unequal for wind energy production on sea and for energy production on land. Intermediate costs for wind energy on sea are slightly larger (see figure 5). In this study we assume that all labour involved in renewable energy production is hired externally and is therefore part of intermediate consumption. This decision is taken because of data availability.

Wind on land		*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
Intermediate costs (excluding network services)	ct/kWh	1.9	1.9	1.9	1.9	1.9	1.6	1.7
Network services	ct/kWh	2.7	2.2	2.3	1.8	1.3	1.1	1.1
Intermediate costs (total)	ct/kWh	4.6	4.1	4.2	3.7	3.2	2.7	2.8
Wind on sea		*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
Intermediate costs (excluding network services)	ct/kWh				2.9	2.9	2.9	2.9
Network services	ct/kWh				5.4	0.9	0.9	0.9
Intermediate costs (total)	ct/kWh				8.3	3.8	3.8	3.8

Figure 5-Intermediate consumption per kWh for wind energy production

These intermediate costs per kWh can be multiplied by actual production levels (in kWh). This leads to total intermediate consumption in mln. euro (figure 6).

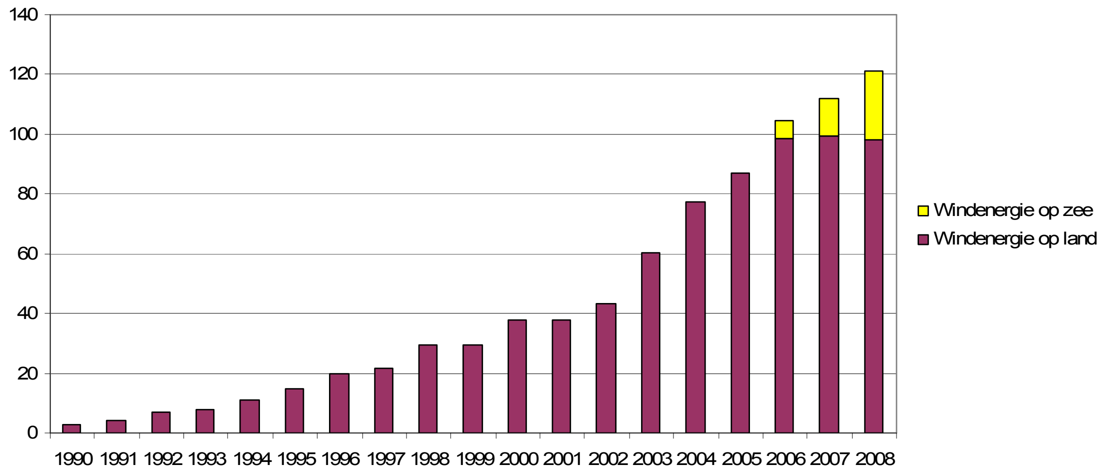

Figure 6-Intermediate consumption in mln. euro for wind energy production, time series

4.3 Value added

Value added is defined as production in basic prices minus intermediate consumption in purchaser prices. Value added for wind energy production is presented in figure 7. Value added is since 2003 positive even without government support.

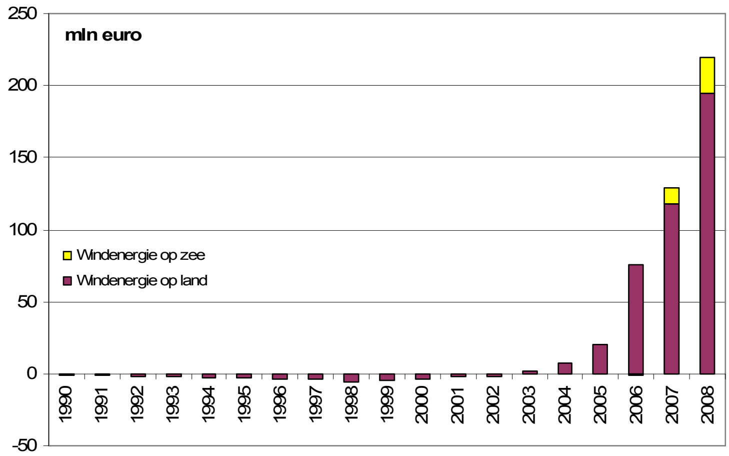

Figure 7-Value added for wind energy production, time series

4.4 Investments in physical capital

Investment in physical capital is calculated by multiplying the capacity of newly installed windmills (in MW) in year t with the corresponding price per MWof a windmill in year t. Information on newly installed windmills in year t is already available at the Energy statistics (see statlinelink). Information on prices per windmill is available using information of ECN studies (ECN, 2002, 2003, 2004, 2007, 2008, and 2009). These investments take into account the expenditures on turbines, foundations, electric infrastructure, mains connection and civil engineering (construction preparation and unlocking roads). Investments necessary for overhead activities (such as buildings) are not taken into account. For investments on land as well as on sea different investment numbers have been used in the model. This information is combined and leads to investments of millions of euros per year (see figure 8).

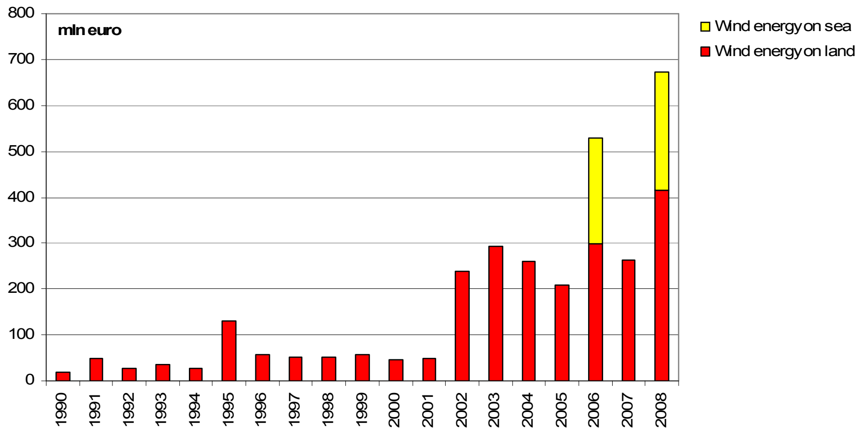

Figure 8-Investments in physical capital for wind energy, time series

Construction time for windmill parks is often longer than one year. Therefore we have decided *to smooth* the investment numbers over time. The approach we have used in smoothing is the following:

Investment in million euros in $_t$=
*((Number of newly installed windmills in year $_t$)*0.5)*
*+ (Number of newly installed windmills in year $_{t+1}$*0.5))*
**price windmill MW in $_t$*

The results are depicted in figure 9.

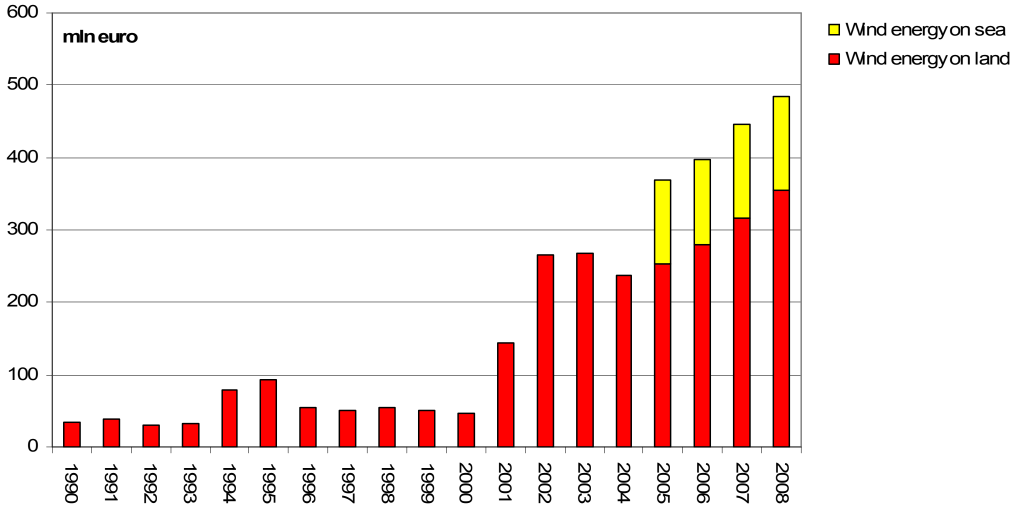

Figure 9-Investment in physical capital for wind energy, smoothed, time series

4.5 Capital stock of physical capital

Using PIM (Perpetual Inventory Method) and the investment data already constructed we are able to calculate the fixed capital stock for windmills. In compiling the capital stock for wind mills the assumption is made that the depreciation time is equal to 15 year. For the purpose of discounting we make use of the price-index of machinery equipment[14] (see shaded row in figure 10, cumulative). In figure 10 the remaining value of the investments done in year *t* are depicted for every year in the economic life cycle of the windmill.

Capital stock	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Capital stock
	1.29	1.26	1.22	1.19	1.16	1.14	1.10	1.08	1.06	1.06	1.05	1.03	1.02	1.00	1.00	1.00	1.00	1.00	1.00	
1990	43																			**43**
1991	41	48																		**88**
1992	38	44	38																	**120**
1993	35	41	36	38																**149**
1994	32	38	33	35	92															**230**
1995	29	35	30	33	86	107														**320**
1996	26	32	28	30	79	100	60													**356**
1997	23	29	25	28	73	93	56	55												**382**
1998	20	25	23	25	67	86	52	51	57											**408**
1999	17	22	20	23	61	78	48	48	54	54										**426**
2000	14	19	18	20	55	71	44	44	50	51	49									**436**
2001	12	16	15	18	49	64	40	40	46	47	46	149								**541**
2002	9	13	13	15	43	57	36	37	42	44	42	139	271							**760**
2003	6	10	10	13	37	50	32	33	38	40	39	129	253	269						**958**
2004	3	6	8	10	31	43	28	29	34	36	36	119	235	251	238					**1107**
2005	0	3	5	8	24	36	24	26	31	33	33	109	217	233	222	370				**1372**
2006		0	3	5	18	29	20	22	27	29	29	99	199	215	206	346	397			**1643**
2007			0	3	12	21	16	18	23	25	26	89	181	197	190	321	371	446		**1940**
2008				0	6	14	12	15	19	22	23	79	163	179	174	296	344	416	484	**2247**

Figure 10- Remaining value of investments done in year t for windmills

These remaining values can be summed (sum of the columns) and this leads to the capital stock of windmill in million of euros (see figure 11).

[14]For the purpose of deflating, in this study we do not use the price change of windmills because there is no data available for the complete time series (1995-2008).

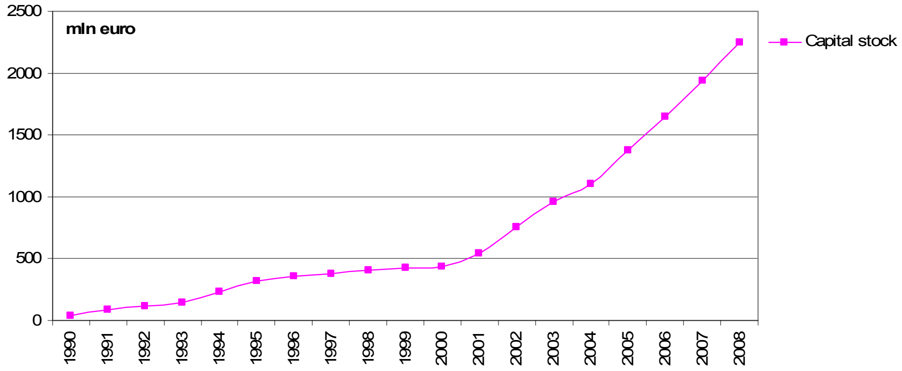

Figure 11-Capital stock for windmills in million euros

4.6 Capital services

Like consumption of fixed capital, the return to capital is part of value added. The sum of consumption of fixed capital (depreciation) and return to capital is known as the capital services rendered by the asset (SNA 2008, 6.445). Consumption of fixed capital constitutes a negative change in the value of the fixed assets used in production. Consumption of fixed capital must be measured with reference to a given set of prices, that is, the average prices of the type of asset of constant quality over the period. It may then be defined as the decline, between the beginning and the end of the accounting period, in the value of the fixed assets owned by an enterprise, as a result of their physical deterioration and normal rates of obsolescence and accidental damage.

The capital services consist of the return to capital and depreciation (see figure 12). Return to capital and depreciation are both derived by making use of the capital stock number in a particular year. Return to capital is equal to 6 percent[15] of invested capital, i.e. the capital stock.

Depreciation in year $_t$*=Value of capital*$_t$*-Value of capital*$_{t-1}$*-Investment*$_t$
Return to capital in year $_t$ *=6% x capital stock in year* $_t$

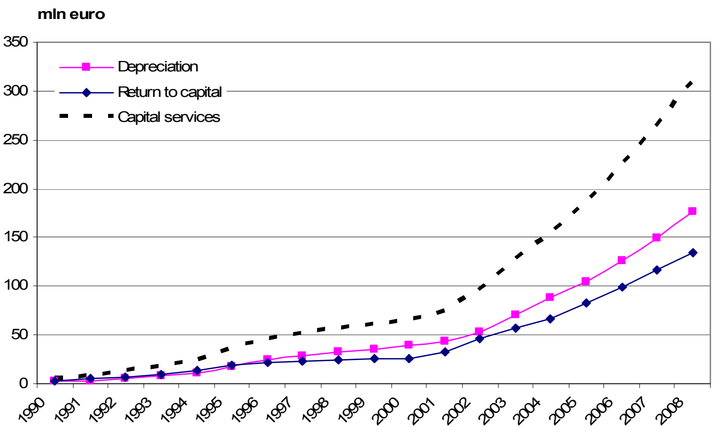

Figure 12- return to capital and depreciation for wind energy projects, time series

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[15] WACC, Weighted Average Cost of Capital, ECN (2008) implements a WACC of 4.9-7.1 percent. For this study we use the average, which is exactly 6 percent (nominal).

4.7 Market based resource rent

Market based resource rent is equal to value added minus the cost of capital (i.e. capital services). This market based resource rent is negative for all years under consideration (see figure 13). This means that the value of wind (which is an *of which* item of the value of land), using the narrow economic approach[16], is equal to zero.

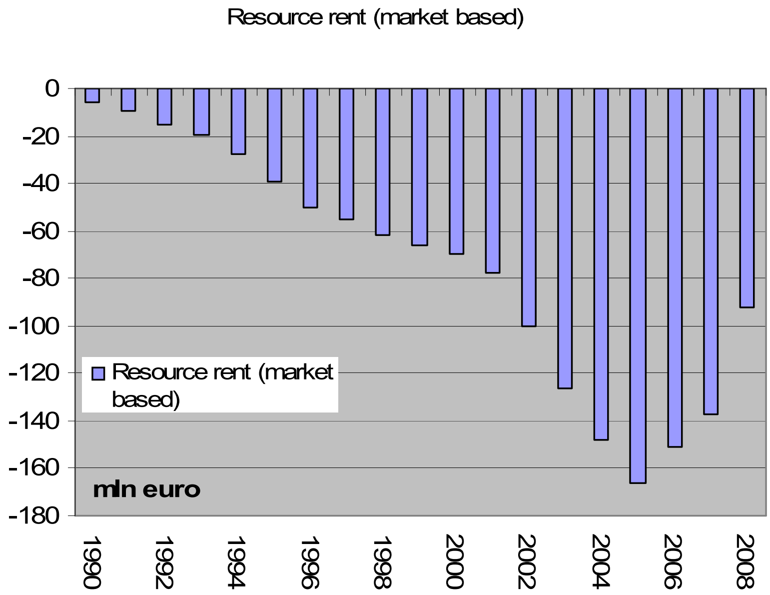


Figure 13-Market based resource rent, time series

From a narrow economic point of view one could conclude that the producers of wind energy are irrational. They produce products which are not profitable but indeed generate losses. The value of less negative spill-overs for the environment and less dependency of foreign fossil energy reserves are not taken into account in this narrow market based approach. For example, wind energy production goes along fewer emissions than conventional production techniques. These avoided emissions have nowadays an explicit price in the economy due to implementation of the European Union Emissions Trading System (EU ETS). To avoid double counting, the value of wind due to less emissions to air is presented as an *of which* item in the total value of wind (see figure 18). This is done because one can assume that the price of emissions (external costs) is already reflected into the basic price of electricity.

[16] Only taking into account market based transactions and valuation. Not taking into account the reduction of externalities.

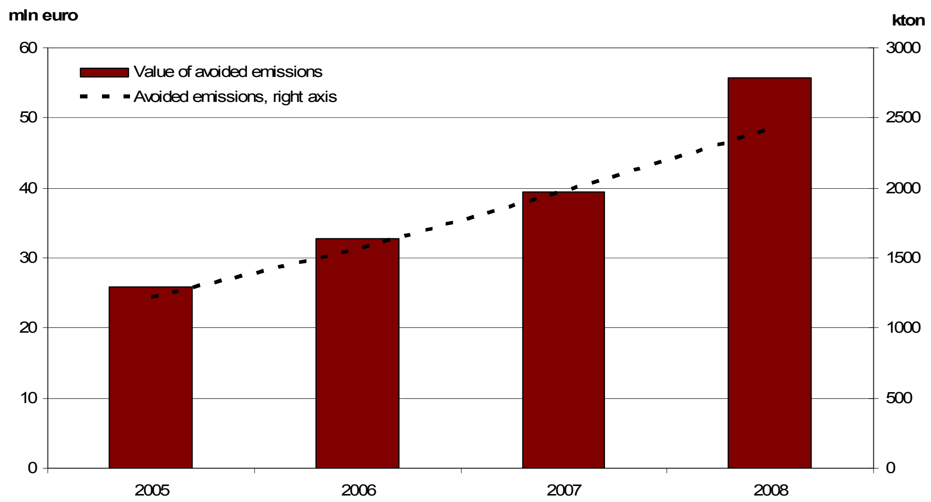


Figure 14- Avoided emissions, kton and mln euro.

The value of the avoided emissions is in 2008 equal to approximately 55 million euro (see figure 14)[17]. This value can be attributed to the energy resource 'wind' because wind is the essential input in generating this electricity in a sustainable manner. These 'social' benefits are not recognized by the market in first instance. The government indeed does recognize these external benefits. The recognition of the government has been followed by the implementation of several different subsidy schemes. Other mentioned benefits of wind energy production are less dependency of foreign energy reserves, employment and stimulation of innovation potentials.

For every externality, positive or negative, holds that the SNA approach for valuation is too narrow. Fixed capital producing grey electricity is valued equally as fixed capital producing green electricity (assuming the same costs, etcetera). SNA simply does not recognize the value of clean air because clean air is no asset in the SNA. The SEEA should value the means to produce more environmental friendly goods and services since the boundaries of the SEEA are broader than that of the SNA. Indeed, in theory, the SEEA should value a capital input that is capable of producing the same goods and services in a more environmental friendly way.

Many aspects of the environment are interrelated with externalities which are a by-product of economic production. Exactly these externalities are not valued by private market parties, but these are valued by the society as a whole. Ideally, these externalities are compensated by government policies, like taxes and subsidies. It might be possible to divert from the SNA approach regarding resource rent calculation. The SEEA wants to value the means to produce less externality, like air emissions, because it also intends to value the asset atmosphere.

At the macro level, *after* redistribution of taxes and subsidies, the market values green products more than grey products. Society as a whole was before redistribution of taxes and subsidies already capable to value green products more than grey products. Consequently, society as a whole also values the means to produce these green products more than the means to produce grey products. The fact that the government has here a distribution of income

[17] Price of emission right is based upon data of ECX (so called EUA Futures Contract (EU Allowances)), average year price based upon day prices.

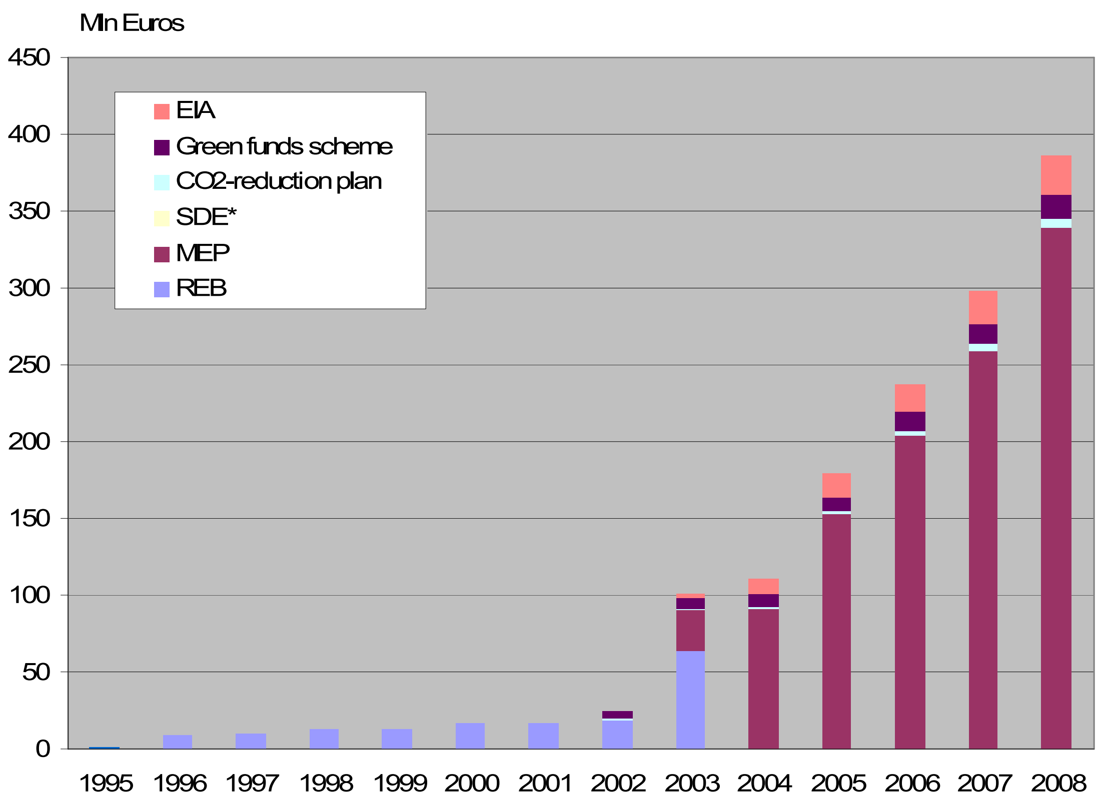
function does mean that society as a whole has a certain preference for a particular production method. Indeed, the government is the only party in place to restore the inefficient market equilibrium. If we value clean air, than we have to value the means to produce this clean air. The existences of subsidies for renewable energy production is evidence for the fact that society as a whole has a certain preference for a certain production method. This should be reflected in valuation of the necessary capital input.

For the SEEA, which wants to monitor and measure other phenomena than the SNA, it is advocated to monitor subsidies on products as well as other implicit subsidies (tax reductions related to investments) related to renewable energy production. This is because subsidies are an important financing item for renewable energy projects. If one sticks to the valuation rules of the SNA, then the reduction in externalities, which is expressed in the valuation of means to produce goods and services, are underestimated. If one diverts from SNA rules, and indeed takes into account subsidies, then the reduction in externalities will be expressed in the valuation of the means to produce goods and services and this valuation is closer to the social preferences regarding energy production (van Rossum et al, 2009).

These subsidies related to wind energy production will be discussed in detail in the next section.

4.8 Subsidies

Here only subsidies related to wind-energy are considered. Figure 15 gives an overview of the most relevant subsidies since 1995. Hereafter the treatment of each of these relevant subsidies is discussed.



* SDE in 2008 amounts only to 0.7 mln euro.

Figure 15- Amount of issued subsidies related to wind energy.

Subsidies on production

REB and MEP
In 1996 a levy on the use of electricity and natural gas (REB: Regulating Energy Tax) was introduced. The goal of the REB was to improve the efficiency of energy use. However, foreign producers could, due to EU legislation, also benefit from the REB. In order to avoid this, the REB was replaced by the MEP (milieukwaliteit electriciteitproductie) in 2003. The MEP regulation provides compensation for the unprofitable part of the investment for a period of 10 years. The subsidy takes the form of a fixed premium paid on top of the price of wholesale electricity. The premium was paid to installations established after 1 January 1996. The MEP was terminated in 2006 and replaced by the SDE (stimulering duurzame energieproductie) in 2008.

SDE
The SDE scheme aims to boost further development by offering operators long-term security for the revenues from new wind turbines. A system has therefore been set up to subsidise the 'financial gap' of such projects, i.e. the difference between the cost price and the revenue from an onshore wind project. The SDE subsidy for wind projects is above and beyond the net-price revenue for new wind projects, bringing the income to a level where it becomes commercially viable. The netprice revenue is the amount the operator receives from the sale of electricity produced, per MWh, minus the so-called costs of imbalance. The SDE subsidy for wind concerns the sustainable electricity supplied to the national grid and covers a period of 15 years. As electricity prices vary from year to year, so the amount of subsidy will also vary.
The following figures are important when determining the annual subsidy amount: (1) The base rate is the income per MWh that can make a project viable. (2) The correction amount is the net-price revenue of sustainable produced electricity per MWh. The correction amount is estimated at the beginning of each year, but is actually determined at the end of the year. Ministry of Economic Affair determines the corrective amount on basis of calculations of (ECN). The amount of SDE subsidy received in a particular year is calculated as the difference between the base rate and the correction amount. In 2008 the SDE was still very small.

Environmental transfers

The EIA (Energie InvesteringsAftrek) is the most important environmental transfer that stimulates the generation of renewable energy. Also considered are CO_2-reductieplan and the Green Funds Scheme “groen beleggen”.

EIA (energie investeringsaftrek)

The EIA, which took effect on the first of January 1997, was set up to stimulate businesses to invest in energy saving techniques and renewable energy. The EIA is a fiscal settlement of the ministry of finance and economic affairs. Agentschap NL and the tax authorities implement the EIA. Before 2005, a business could deduct 55 percent of their profit with EIA. After 2005 only 44 percent could be deducted. The financial profit amounts to, depending on the tax rate, about 14 percent of the investment expenditures before 2005 and 11 percent after 2005. These percentages are multiplied with the attributed EIA investments to determine the financial profit in a year.

In the above computation method a few assumptions are made. Firstly, the attributed subsidies are allocated to the year in which the investor plans to take the investment (e.g. windmill) into production. In this way the subsidies are allocated to the same year the investment expenditure is recorded. Unfortunately, the year an investment is definitely taken into production might deviate from the year it was originally stated by the investor. Secondly, as EIA is a subsidy on an investment, it is argued to estimate the subsidised capital expenses. Therefore, in estimating the EIA, the subsidies are divided over the life span of the investment (15 year for a windmill). The subsidies are discounted to the relevant year. An advantage of this method is that the yearly allocated subsidies are smoothened over time. As a result, the allocation of subsidies to the year the investment is taken into production becomes less important.

Groen beleggen (Green Funds Scheme)

Groen beleggen (Green funds scheme) is a tax incentive scheme launched in 1995 by the Dutch government to encourage green initiatives. The Green Funds Scheme is a tax incentive scheme enabling individual investors to put money into green projects that benefit the environment. Individuals who invest in a green fund or save money with financial institutions practicing ‘green banking’ receive a lower rate than the market interest rate, however this is compensated by a tax incentive. In return, the banks charge green projects a lower interest rate. The bank finances green projects and asks for a return that works out at about 1% under the going rate. Therefore, the subsidy for wind energy is estimated by taking 1% of the total asset of windmills in the Netherlands.

CO_2 reductieplan (CO_2 reduction scheme)

A project that deals with energy savings, use of renewable energy sources and a direct reduction of emissions can apply for a subsidy of the CO_2 reduction scheme. The CO_2 reduction scheme is assessable for industry, government, institutions and non-profit organisations. Between 1997 and 2002, the CO_2 reduction scheme released five tenders. Similar to the EIA, the subsidies of the CO_2 reduction scheme are divided over the life span of the investment.

4.9 Resource rent (social preferences, subsidies included))

After investigating all different subsidies related to wind energy production we add these subsidies to the already market based resource rent. In this way the resource rent in which social preferences are incorporated is computed. This new concept of resource rent is depicted in figure 16. Social preferred resource rent is not always negative, it is instead positive in the years after 2004. This is because of the huge amount of subsidies given to renewable energy producers.

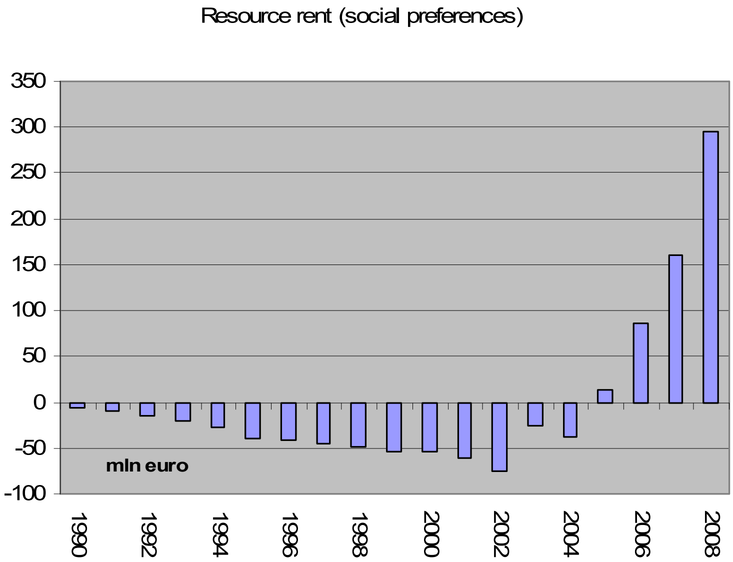


Figure 16- resource rent in which social preferences are incorporated

Resource rent (social preferences) calculations are very much dependent on subsidy levels. Subsidy levels can be adjusted for volatility over time and can be assumed constant over time per unit production (base level is 2008). This way estimating resource rent has also a disadvantage. The value for cleaner air or for being less dependent upon foreign energy is not constant over time. The perception of these problems differs over time and by assuming a constant subsidy per unit production, this change in perception is not reflected in the value of the resource rent (social preferences) anymore. Valuation of assets is always the result of a perception of benefits at a particular moment in time. Therefore we advocate using the volatile subsidies (real subsidies) in stead of the constant subsidies (fictitious) in calculating the resource rent and subsequently the valuation of wind.

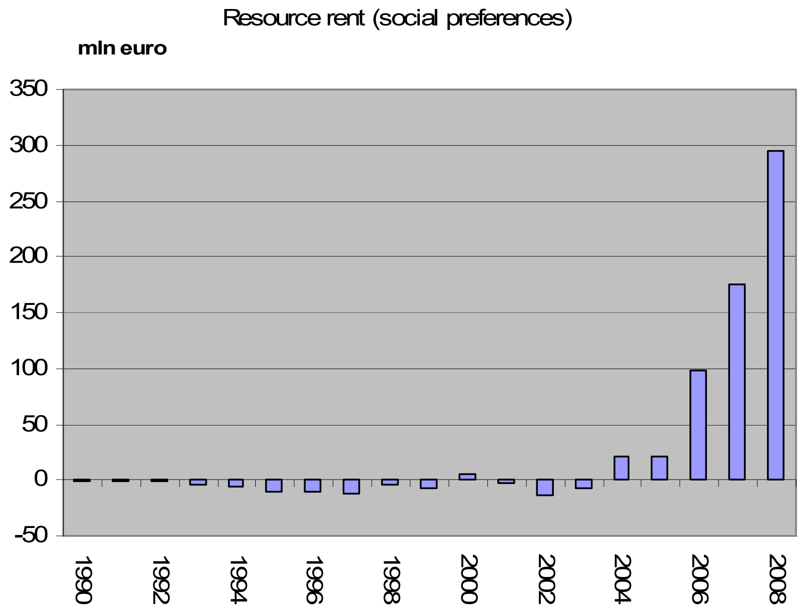


Figure 17- resource rent in which social preferences are incorporated, 2008 subsidies are leading for complete time series

4.10 Value for wind energy resources

The valuation of renewable resources is equal to:

Resource rent in year t/discount rate in year t.

The value of wind energy can be decomposed into a value for avoided emissions and into a value for other positive and negative externalities related to wind energy production. Once the market based resource rent is positive, you can decompose the value of the renewable energy resources in three parts, also including the narrow economic valuation of wind. The value related to avoided emissions is smaller than the value related to other positive and negative externalities. The market based approach for valuation leads to a zero sum valuation for wind energy resources. Taking into account the different subsidies, reflecting social preferences for production techniques, leads to a valuation of more than 7 billion euro in 2008 (see figure 18). More than one billion of this seven billion can be explained by the avoided emissions related to wind energy production[18]. The remainder is explained by other positive and negative externalities.

Some studies argue that the subsidies for renewable energy production were too high in order to be socially efficient (ESB (2007); CE (2007)). This indicates that subsidies were too high in order to compensate for the extra costs of renewable energy production. One could state that due to these high subsidies the value of wind is overestimated. These subsidies were, according to mentioned studies, too high because of government failure. Overestimation and consequently re-evaluation is not uncommon for assets in general. The 'internet bubble' and the credit crisis are examples where in the first place assets were overestimated (for example stock certificates of internet companies and banks). Due to market failure and/or government failure (too little regulation) the values of these financial assets were too high in first instance. After some time, the markets re-evaluated these financial assets because they had better or more information than before. Valuation is dependent upon available information at a particular moment in time and based upon a particular institutional framework. Once subsidies for wind energy production decrease over time, due to new measures based upon better information of the government, the asset 'wind' will be re-evaluated too. Taking into account this parallel with other assets, 'wind'is not really a special asset but in fact it has the same characteristics like other assets. Maybe one could really speak of a 'wind bubble' here.

[18] It is assumed that the European Union Emissions Trading System (EU ETS) sets reasonable prices for emissions taking into account the level of initiated emission rights.

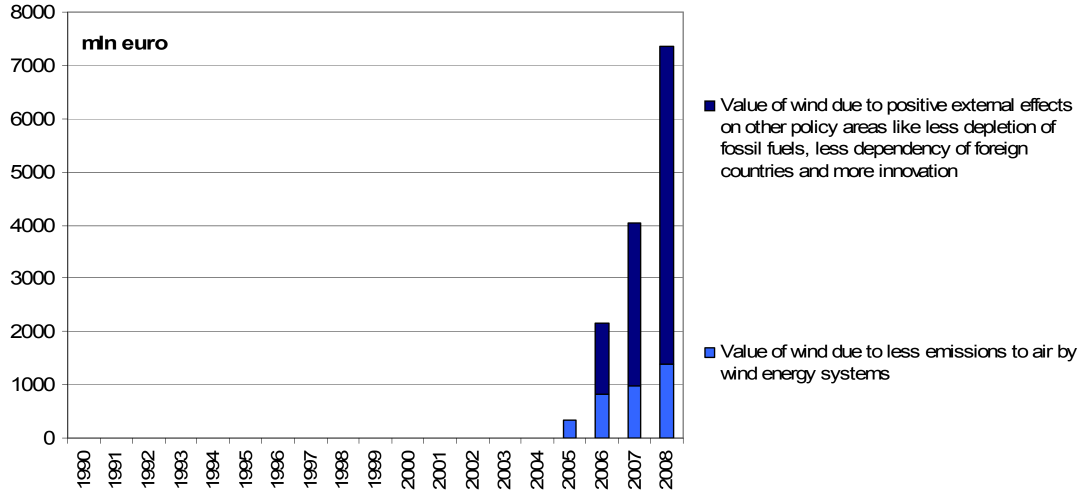


Figure 18-Decomposition of value of wind (social preferences)

5. Compilation of monetary and physical balances for renewable energy resources

Monetary balances

The value of renewable energy resources is monitored by presenting the results as a balance. This makes it possible to compare the balance for renewable resources with the balance for non-renewable resources. The value of the energy resource changes yearly due to different effects. These effects need to be distinguished and quantified. The effects that play a key role are examined hereafter. First the market based approach for valuation is presented (19A). Resource rent is negative from a narrow economic point of view. This means that the value of wind equals zero. The price effect in 2008 has an upward effect (prices rises) on the valuation of wind while the capacity effect has a negative impact (more capacity but still generating losses) on the valuation of wind. In the end, resource rent is still negative, and therefore the value of wind equals zero. Secondly the more broad approach for valuating wind, taking into account subsidies, is presented in a balance, represented in figure 19B. Here resource rents are positive and this leads to positive monetary values for wind on the balance.

Monetary balance for Wind, market based approach	2006	2007	2008
Stock value 1/1	zero	zero	zero
Price changes	690	331	841
Capacity changes	-919	-702	-445
Stock value 31/12	zero	zero	zero

Figure 19A- Monetary balance for wind, market based approach

Monetary balance for Wind (subsidies included), social preferences	2006	2007	2008
Stock value 1/1	322	2166	4031
Price changes	690	331	841
Capacity changes	-919	-702	-445
Subsidies changes	1453	1519	2212
Other effects	620	718	723
Stock value 31/12	2166	4031	7362

Figure 19B- Monetary balance for wind (subsidies included), social preferences

Price change

Price changes in electricity lead to higher production values and in the end to more resource rent. More resource rent leads to a higher valuation of wind resources. The effect of price changes is computed as follows:

$((P_t-P_{t-1})*Q_{t-1})/0.04$

Capacity

More capacity leads to a higher value for wind resources if the resource rent per unit production is positive. Resource rent per unit production is in the Netherlands negative (see figure12. Production of energy is a good proxy for the capacity in the Netherlands. Although production (and capacity) has grown sharply over time, the capacity effect is still negative for the value of wind resources. Once resource rent per unit production (market based approach, subsidies excluded) is positive, an increase in the level of production will lead to a positive capacity effect for the value of wind resources. The effect of capacity is computed as follows:
$((Q_t-Q_{t-1})*(RRMB_t/Q_t))/0.04$

Subsidies

A rise in subsidies is a proxy for the recognition of external benefits by the government. This is incorporated in the value of wind energy resources. The effect of subsidies is computed as follows:
$(SUBS_t-SUBS_{t-1})/0.04$

Other effects

A balance item is introduced to close the remaining gap between Stock value 1/1 and Stock value 31/12. The effect of ‘Other effects’ is computed as follows:
Stock value 31/12-Stock value 1/1- price change effect-capacity effect-subsidy effect

Physical balances

Physical balance for Wind	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
	PJ													
Stock value 1/1	16	31	36	39	42	45	47	48	72	101	121	134	172	187
Depreciation	-1	-2	-3	-3	-4	-4	-4	-5	-7	-9	-11	-13	-15	-17
Investment	16	7	6	6	7	6	6	29	30	30	24	50	31	60
Stock value 31/12	31	36	39	42	45	47	48	72	101	121	134	172	187	230

Figure 20-Physical balance for wind in PJ

As already mentioned in the introduction of this paper, renewable natural energy resources are not generally recorded as assets on the national balance sheet. This seems to be a serious omission since their share in total energy production is increasing. Fostering the exploitation of renewable energy resources is undoubtedly an important part of sustainable development policy strategies around the world. A lot of investments have been done in recent years in the Netherlands to solve the problem of energy dependency and depletion of non-renewable energy reserves. The stock of oil and gas reserves in Netherlands declines over time (see figure 21). On the other hand, the usable part of the stock of wind energy in the Netherlands is growing over time due to the large investments in windmills and the improved energy efficiency of these windmills. In figure 22 one can depict the development of the stock of wind in PJ. This stock is calculated as follows (5 steps):

1. Determine initial MW taken into production in every single year from 1990 until the year 2008
2. Determine stock of capital in MW using the perpetual inventory method for the whole time series (depreciation time is 15 year).
3. Multiply the capital stock in MW by the average production in GWh per MW in order to determine total production capacity in one year (in GWh).
4. Multiply this number by 15 (depreciation period) in order to determine production capacity over the life span of 1 windmill (in GWh)
5. Multiply this by 0.036 (conversion factor GWh to PJ) in order to calculate stock of wind in PJ

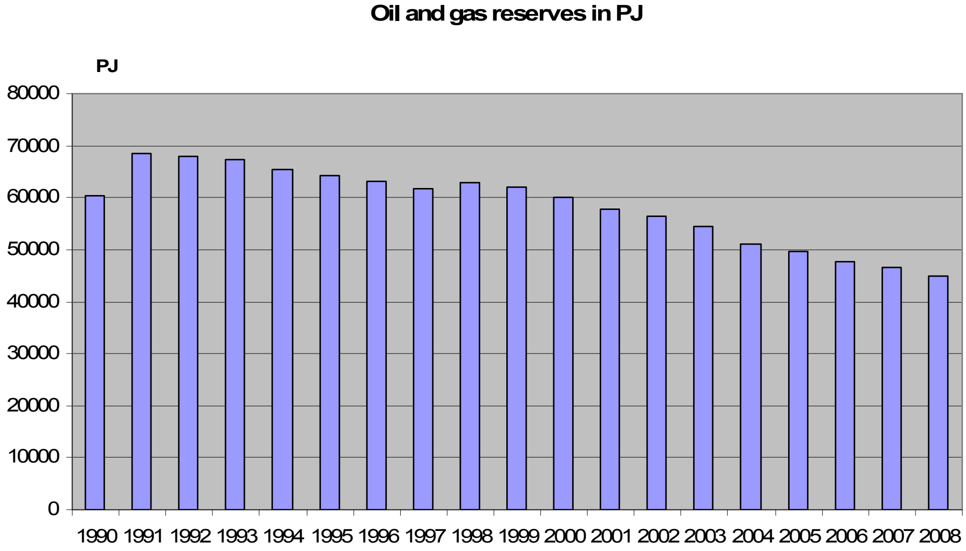


Figure 21- Oil and gas reserves in the Netherlands, in PJ

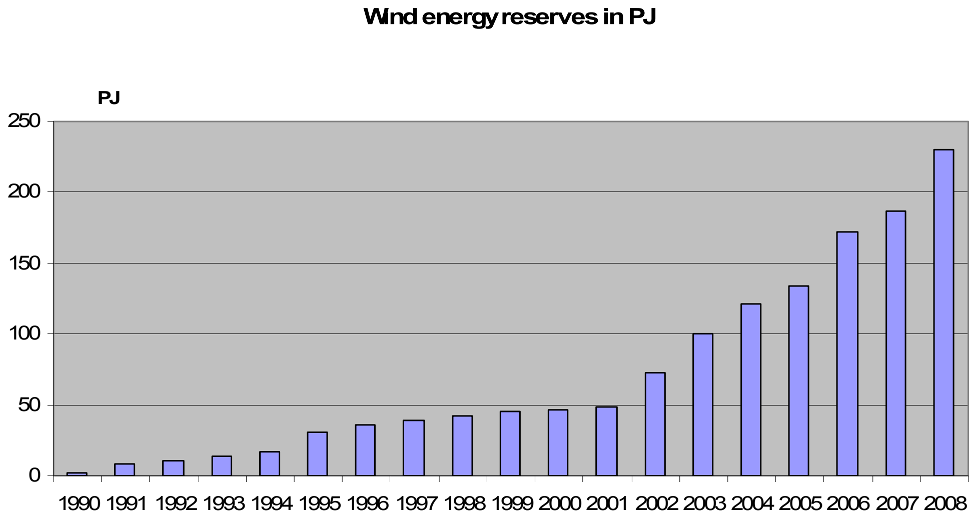


Figure 22- Wind energy reserves, in PJ

The percentage shrinkage of oil- and gas reserves is smaller than the growth in the wind reserves in PJ. In absolute levels, however, the increase in wind stock cannot compensate for the decrease in the stock of oil and gas reserves. Total energy reserves in PJ decreased over time (see figure 23, in terms of primary energy units, before conversion). Taking into account the fact that transformation of gas into electricity is accompanied by energy losses; the picture is slightly brighter but is still far away from compensation.

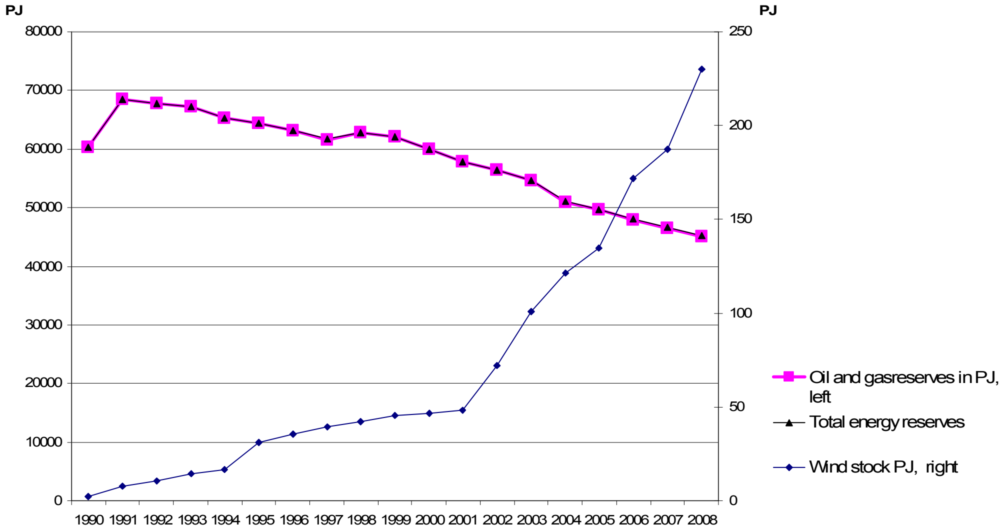


Figure 23-Total energy reserves, oil, gas and wind, in PJ

6. Summarization of the data

Figure 24 presents an overview of all gathered data in this study.

Economic information related to wind energy production

		1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008
Monetary information												
Production	*mln*	2	12	34	35	42	62	84	107	178	241	340
Intermediate consumption	*mln*	3	15	38	38	43	60	77	87	104	112	121
Value added	*mln*	-1	-3	-4	-2	-2	2	7	20	74	129	219
Net operating surplus	*mln*	-4	-20	-44	-45	-54	-69	-82	-84	-52	-21	43
Investments	*mln*	34	94	47	144	266	268	237	370	397	446	484
Capital stock	*mln*	43	320	436	541	760	958	1107	1372	1643	1940	2247
Capital services	*mln*	6	36	66	75	98	128	155	187	225	266	312
Consumption of fixed capital	*mln*	3	17	40	43	53	71	89	105	126	150	177
Return to capital	*mln*	3	19	26	32	46	57	66	82	99	116	135
Resource rent (market based)	*mln*	-6	-39	-70	-78	-100	-127	-148	-167	-151	-137	-92
Subsidies	*mln*	0	0	17	17	25	101	110	179	237	298	387
Resource rent (social preferences, subsidies included)	*mln*	-6	-39	-53	-61	-75	-26	-38	13	87	161	294
Value of wind (market based)	*mln*	0	0	0	0	0	0	0	0	0	0	0
Value of wind (social preferences)	*mln*	0	0	0	0	0	0	0	322	2166	4031	7362
Physical information												
Production	*GWh*	56	317	829	825	946	1318	1867	2067	2733	3438	4260
Investments	*PJ*	2	16	6	6	29	35	30	24	50	31	60
Depreciation	*PJ*	0	-1	-4	-4	-5	-7	-9	-11	-13	-15	-17
Energy resource stock	*PJ*	2	31	47	48	72	101	121	134	172	187	230

Figure 24- Economic information related to wind energy production

The overview table (figure 24) represents the evolvement of wind energy production over time from an economic and physical perspective. A yearly update of this overview table makes it possible to analyse and monitor the economy behind wind energy production in a consistent manner. The table contains both monetary as well as physical data. The monetary data is split into three parts. In the first part a few elements of the production accounts are discussed. In part two different elements of the capital accounts are discussed and lastly, in part three analytical calculations of resource rent, subsidies and the value of wind have been depicted. This table also contains information from a physical point of view. Production in GWh is shown for the whole time series. Also investments in and depreciation of physical stocks of energy resources (here wind) are included in order to have a complete integrated framework of monetary and physical statistics on wind energy production.

7. Applications of the gathered data

As already discussed, the stock of energy reserves in the Netherlands declines sharply over time. The decline in oil- gas reserves is not compensated by the increase in wind energy reserves. This has serious consequences for the sustainability of energy supply and also for sustainability of the GDP level. Oil and gas production is an important player in the economy of the Netherlands (CBS, 2008). Once oil and gas reserves have been depleted, there will be no production of oil and gas anymore. As a consequence, value added of this industry will disappear. This will have serious consequences for the level of gross domestic product of the Netherlands. For the sake of sustainability, both serving security of energy supply and the level of GDP, there needs to be a transition from fossil energy reserves to non-fossil energy reserves.

So far, investment in windmills is not sufficient to set of the decline in oil and gas reserves in physical terms. The question of how much needs to be invested in new windmills on a yearly basis to offset the decline in oil-and gas reserves is an interesting one. From a financial point of view it is also interesting if and how these investments can be financed. These two questions are addressed hereafter. First we want to know how much needs to be invested in windmills to setoff the change in oil and gas reserves. This can be calculated very easily:

(1) Depletion of oil an gas reserves in PJ_t/Wind stock in PJ_t*Capital stock in $MW_t/3$ = Number of windmills needed to offset depletion of in oil and gas reserves[19].

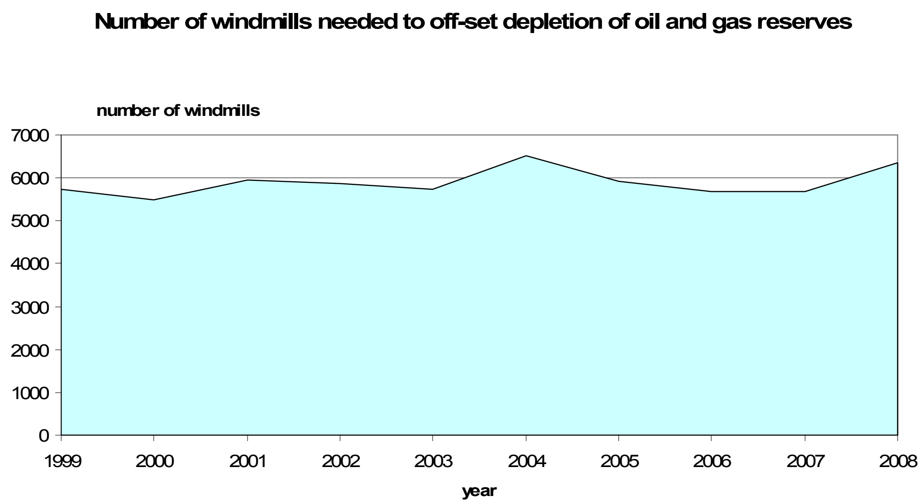


Figure 25-Number of windmills needed to off-set depletion in oil and gasreserves

The number of windmills needed to set off the change in oil and gas reserves is depicted in figure 25. On average (1999-2008), every year nearly 6000 new windmills should have been built to compensate for the oil and gas depletion. In comparison, on average, only 200 new

[19] Assumption: One windmill has 3 MW power (http://www.windenergie.nl/140/faqs/alle-vragen/_faq/4). One windmill produces every year on average 8GWh.

wind mills were build every year in this period of time[20]. These figures only represent the number of windmills needed in order to have a stable energy stock in physical terms (PJ) over time. In the economy, all kind of transformation processes take place after extraction which lead to energy losses. So far this aspect has not been taken into account in this analysis.

Now the second question comes into place, how are going to finance these windmills and to what extent is this possible? The idea is to finance the transaction with money generated by the oil and gas industry. The question is if this is financially feasible. In other words, how many windmills can be bought by the money earned in the oil and gas industry?

(2) Value added oil and gas industry/ (investment costs per MW*3) =
Number of windmills that can be bought of value added oil and gas industry

Looking at figure 26 it turns out that it was not possible to finance the windmills with value added generated by the oil and gas industry. Only a part of the total windmills needed in order to off-set depletion could be financed (approximately 80 percent in 2008). This part is growing due to increasing energy prices. From a sustainability point of view this extra investment would not only ensure a more stable energy stock level over time but also the capability to exports energy products (i.e. electricity) to other countries over time. This will help in stabilising the GDP contribution of energy suppliers in The Netherlands.

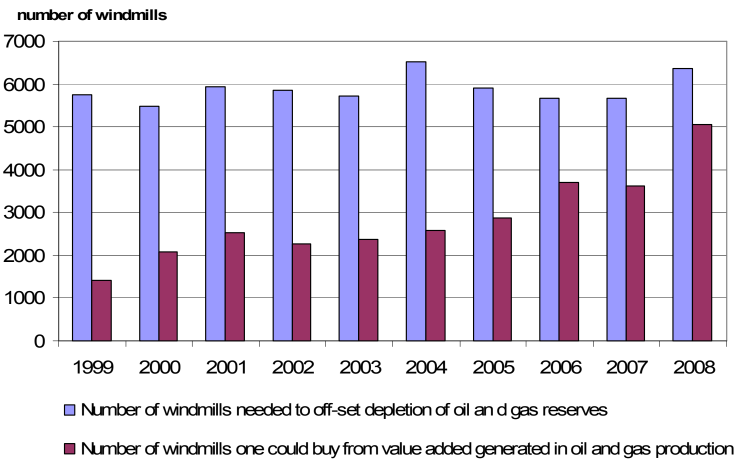


Figure 26-Number of windmills needed to off-set depletion of oil and gas reserves and the possibilities to finance these windmills.

Of course there are some serious caveats in these calculations. Firstly, the newly installed windmills need to be maintained during their production life (even although maintenance costs are small in the total cost picture). Also, once transition has been completed, depreciated windmills need to be replaced by new windmills and this will incur extra investments. This cannot be financed anymore with money earned in the oil and gas industry. Renewable energy producers have to finance these investments by means of their own production cash flows. Secondly, value added of the oil and gas industry is at this moment in time not sufficient to finance the windmills needed to off-set depletion of oil and gas reserves. Due to the likelihood of more scarcity of fossil energy in the future prices of gas and oil will rise probably too. This will make it easier to finance the windmills needed to off-set depletion of oil and gas reserves during the transition period. Another argument for interpreting these figures very carefully is

[20] Power taken (MW) into production divided by 3 (Statline) .

that 1 PJ of electricity is worth more than one PJ of natural gas or oil. Electricity is a high quality energy carrier while natural gas is a low-quality energy carrier. Once the transition has been completed (or even before) it is expected that the new energy sector (a fictitious wind energy sector) creates more gross value added than the oil and gas industry. This extra value added can be used to finance the maintenance costs and can be used to invest in new windmills which are needed to replace the depreciated ones. All these complications need to be further investigated before conclusions can be stated.

Imagine all oil and gas reserves will be replaced by installing windmills. How many windmills will be needed and how many windmills should be installed per squared kilometre in the Netherlands[21] This information is a good indicator how much space should be reserved for installing windmills in order to replace the oil and gas reserves. These figures give an indication of to what extent the needed windmills influence the scarcity of land (see figure 27).

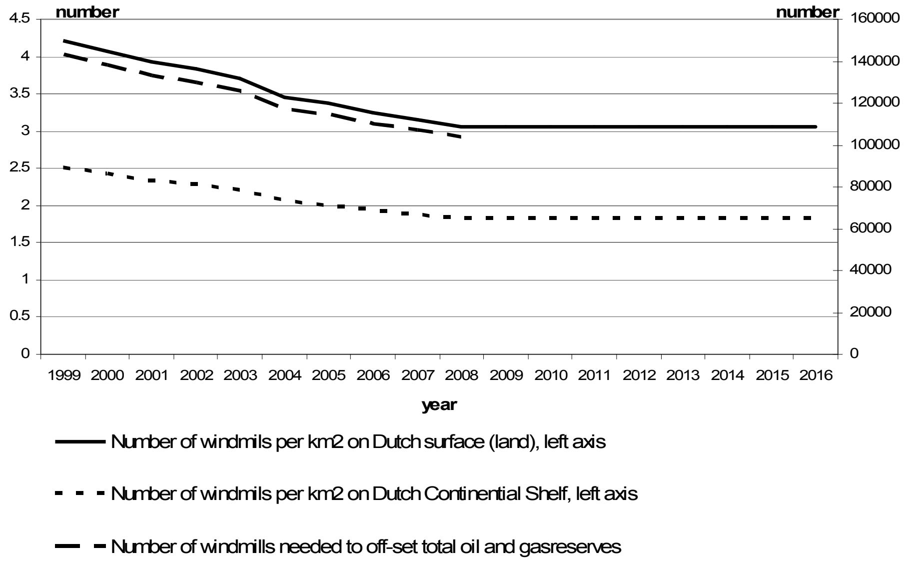


Figure 27- Number of windmills needed to sett-off oil and gas reserves and the scarcity of space

8. Conclusions and recommendations

The market based resource rent for wind energy production is negative. This means that the market based value of wind for the Dutch economy is equal to zero. From a narrow economic point of view this indicates that economic agents are producing goods and services which generate losses instead of profits. Still these agents do produce wind energy. This is fostered by the existences of all kind of subsidy schemes for renewable energy production.

These subsidy schemes do exist because the government tries to internalise the negative external effects related to conventional energy production. Adding subsidies to the resource rent calculation leads to a positive resource rent for the years 2005-2006-2007-2008. This

[21] Surface area (land) of the Netherlands is equal to 33883 km^2 (source: wikipedia) Surface area of the Dutch Continental Shelf is equal to 57000 km2 (source:www.compendiumvoordeleefomgeving.nl/).

alternative resource rent (socially preferred resource rent) reflects the benefits related to renewable energy production for both the renewable energy producer and the society as a whole. In the future, it could be the case that the market based resource rent will be positive. Scarcity of fossil fuels and more strict emission rights systems will push electricity prices up and thereby in the end also the resource rent.

This study shows that it is possible to gather all relevant data to construct the different monetary indicators (production, intermediate consumption, value added, depreciation and others) relevant to describe the economy behind renewable energy production. Although some assumptions were needed to set reasonable levels for certain variables, the developments are really based upon strong indicators reflecting developments in reality.

Monetary stock values for wind energy resources have been compiled and the changes over time have been decomposed into different causes (price changes, changes in capacity, changes in subsidies). Also on the physical side some experimental calculations have been carried out. Numbers for stock of wind in PJ units have been calculated. This number can be compared with the stock number in PJ for physical non-fossil reserves.

All presented indicators provide a comprehensive overview and insight into the economy behind renewable energy production. Most indicators can be calculated very easily and the workload is quite small. We recommended producing these statistics on a two yearly basis in order to monitor the economy behind renewable energy production. Once other renewable energy resources are more prominent in the Dutch economy, like for example solar radiation or geothermal energy, these energy resources could be monitored using the same methodology.

Of course there are many ways to improve the statistics presented in this study. Still it is believed that macro-economic developments are well-monitored using the developed methods presented in this study. One should not focus too much on the levels of particular variables but more on the developments in evaluating the statistics in this study.

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