Draft advice base rates 2011 for electricity and green gas in the framework of the SDE scheme

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Paul van den Oosterkamp (ECN) and Mark Beekers (KEMA) have also contributed to this study. The authors would like to thank them for their input.

Abstract

On assignment of the Dutch Ministry of Economic Affairs, ECN and KEMA have researched the costs of renewable electricity production. This cost assessment for various categories is part of an advice on the base rate for the feed-in support scheme SDE. This report contains an advice on the costs of projects in the Netherlands targeted for realisation in 2011.

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Summary

The Dutch ministry of Economic Affairs asked ECN and KEMA to offer advice on the base rates for 2011. This report is a draft version of the advice, which was written for a round of consultations of the market parties on the projections made by ECN/KEMA. Table S.1 contains the overview of the base rates in this draft advice. The draft advice will be adjusted where necessary based on the reactions of the market parties. The final advice will be published together with the announcement of the SDE scheme for 2011.

Table S.1 *Base rates for renewable electricity and green gas 2011*

	Subsidy duration [year]	Calculated full load hours [hour]	**Electricity** **[€ct/kWh]**	**Green gas** *(crude biogas)* **[€ct/Nm^3]**	Base rate Final Advice 2010
Wind energy					
Onshore wind < 6 MW	15	2200	**9.6**	-	9.6
Onshore wind ≥6 MW	15	3000	**9.6**	-	-
Biomass digestion					
Landfill gas	12	6500	**8.3**	**37.1** *(9.0)*	8.3 / 37.1
WWTP	12	8000	**6.0**	**28.7** *(3.2)*	6.0 / 28.7
Manure co-digestion	12	8000	**17.0**	**71.3** *(53.9)*	18.3 / 83.1
VFG digestion	12	8000	**13.1**	**63.7** *(43.3)*	13.4 / 73.8
Other digestion	12	8000	**14.6**	**60.9** *(44.9)*	15.8 / 74.1
Thermal conversion of biomass					
Solid biomass <10 MW_e	12	8000	**21.1**	-	19.8
Solid biomass 10-50 MWe	12	8000	**12.0**	-	12.1
Liquid biomass <10 MW_e	12	8000	**17.3**	-	15.7
Liquid biomass 10-50 MWe	12	8000		-	12.3
Waste incineration plants					
Standard efficiency	15	8080	**5.2**	-	5.2
Increased efficiency	15	7800	**5.6**	-	5.6
High efficiency	15	7500	**6.2**	-	6.2
Hydropower					
Height of the fall < 5 metres	15	3800	**12.2**	-	12.3
Height of the fall ≥5 metres	15	4800	**7.1**	-	7.2
Free tidal wave energy	15	2250	**34.0**	-	-
Solar PV					
1-15 kW_p	15	850	**31.8**	-	47.4
15-100 kW_p	15	850	**26.8**	-	43.0

The base rates mentioned in this report are based on representative installations. In reality, costs may be lower or higher in some instances due to local conditions. Table S.1 includes the base rates for production of electricity, green gas and crude biogas. The base rate for crude biogas must be considered in the light of possible support for installations that are connected to a green gas hub.

1. Introduction

The Dutch Ministry of Economic Affairs requested ECN and KEMA to advise on the height of the base rates in the framework of the SDE scheme for 2011. As with comparable studies in previous years, ECN and KEMA, in consultation with the ministry, decided to present a draft advice to the market and subsequently publish a final advice based on this consultation.

This report, which is the draft advice, was written with the purpose of collecting responses from the market with regard to the projected techno-economic parameters. Based on the reactions received, the advice will be adjusted if deemed necessary by ECN and KEMA.

ECN and KEMA advise the ministry on the height of the base rates. The Minister of Economic Affairs decides on the opening of the SDE scheme in 2011, on the categories and on the base rates for the new SDE allowances in 2011.

Reading instructions
The starting points of the advice, such as assignment and calculation method, are listed in Chapter 2. Chapter 3 addresses the way in which the advice handles the supply of useful heat. Chapter 4 contains an overview of the emission requirements and how this advice deals with emission requirements.

The financial parameters are explained in Chapter 5. Chapter 6 elaborates on the prices of electricity, gas and biomass. Chapter 7 provides overviews of the techno-economic parameters of the renewable electricity options per category. Chapter 8 discusses the techno-economic parameters of the green gas options. Chapter 9 contains the conclusions and provides a translation to the base rate.

2. Approach

2.1 Assignment

The Dutch Ministry of Economic Affairs requested ECN/KEMA to establish the base rates for the SDE scheme for 2011. The advice on the base rate will address the production costs and any scheme-specific charges with regard to the electricity and gas contracts. The ministry defined the categories in advance. ECN/KEMA will calculate the production costs of renewable electricity and green gas for these categories. The categories for which advice was requested are listed in Table 2.1. The Minister of Economic Affairs will decide on the eventual opening of categories. Neither the presence nor the absence of a category in this advice request warrants any conclusions about the opening of a category.

Table 2.1 *Categories to be examined based on the research assignment*

	Electricity options	*Green gas option*
Thermal conversion of biomass	Solid biomass 0-10 MW_e	-
	Solid biomass 10-50 MW_e	-
	Liquid biomass 0-10 MW_e	-
	Liquid biomass 10-50 MW_e	-
Biomass digestion	Manure co-digestion	Manure co-digestion
	VFG digestion	VFG digestion
	Other digestion	Other digestion
	Landfill gas/WWTP	Landfill gas/WWTP
Waste incineration	Standard efficiency	-
	Increased efficiency	-
	High efficiency	-
Wind	Onshore wind < 6 MW	-
	Onshore wind ≥6 MW	-
Hydropower	Height of fall < 5 metres	-
	Height of fall ≥ 5 metres	-
	Free tidal current energy	
Solar	Solar PV 1-15 kW_p	-
	Solar PV 15-100 kW_p	-

2.2 Starting points

The starting points for the calculation were established in consultations between the ministry and ECN/KEMA. The effectiveness and efficiency of the SDE scheme were taken into account. This implies that the SDE payments, hence also the base rates, must be sufficiently high to enable the production of renewable electricity and green gas in the categories, but the base rates need not be sufficient for all planned projects. The rule of thumb is that the majority of the projects should be able to proceed with these base rates.

Existing law and legislation must be taken into account in the calculation of the production costs, if they apply generically to the Netherlands. The advice is thus based on policy that will be in force in 2011 (based on decision making). The production costs are related to projects that are eligible for SDE in 2011 and can start as a construction project in 2011 or early 2012. As for the production costs of solar PV: the Ministry of Economic Affairs indicated that the production costs of the first half of 2012 serve as the basis.

The SDE scheme reimburses the difference between the production costs of renewable electricity and green gas on the one hand and the market price of renewable electricity or green gas on the other hand. The production costs are the additional costs needed to produce renewable electricity or green gas. These are the additional costs of the so-called reference installation compared to the alternative deployment of the renewable energy source. Especially in systems using biomass from waste flows or residual products, the definition of additional costs, i.e. the system boundary, can significantly influence the calculated biomass costs. Additional costs are calculated for using these flows or products for the production of renewable electricity or green gas. Biomass costs are calculated based on the prices that must be paid to deliver the biomass to the installation. In the case of biomass from waste or residual flows, calculations are made of the difference between the above-mentioned biomass prices and the price of biomass if it would not be used for the production of renewable electricity or green gas.

2.3 Calculation method

A reference installation was established for each category. The reference installation is based on a specific technique (or combination of techniques) and a reference fuel was also established for the bio-energy categories. ECN/KEMA considers the reference installation or fuel technique combination suitable for new projects in the category under investigation.

The techno-economic and financial parameters will be established per specific fuel-technique combination. Based on these parameters, the production costs and base rate will be established by means of the stylised cash flow model. This model can be viewed on the ECN website[1].

2.4 Process

This report, the draft advice, was published on 1 July 2010 to serve as input for the public market consultation. All parties that wish to respond to the projections of the techno-economic parameters and are able to substantiate their response with verifiable information (including contracts or quotations) are invited to send their response to the following e-mail address: sde@ecn.nl, or to the mail address below:

Energy research Centre of the Netherlands
Attn. Dr. S.M. Lensink
P.O. Box 1
NL-1755 ZG PETTEN
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All reactions will be treated with the utmost confidentiality. On 7 July there will be a closed information meeting, organised by ECN and KEMA. The invitations for this meeting will be sent through the branch organisations. During this meeting, information will be provided on the consultation process and on the main starting points for and the assumptions of ECN and KEMA with regard to the advice. The consultation is open to all parties, including parties that do not attend the information meeting.

All consultation reactions submitted before 4 August will be included in the final advice. ECN and KEMA will invite market parties for an explanatory meeting in August 2010. If deemed appropriate by ECN and KEMA, the market responses will result in adjustments in the advice. The final advice will be published at the same time as the official announcement of the opening of the SDE round for 2011.

[1] http://www.ecn.nl/units/ps/themes/renewable-energy/projects/sde/

3. Heat

3.1 Introduction

A bio-CHP plant can produce electricity and supply heat at the same time. Useful deployment of this heat requires expansion of the installation. This will result in an increase in investment costs. On top of that, the cost of business operations increases and there may be a decrease in revenue from electricity production.

In bio-CHP plants based on a gas engine the heat production will not affect the electrical efficiency, because the heat is derived from the exhaust gases and the coolers. In an installation based on a steam turbine there is a trade-off between heat and electricity. Part of the power supply is 'tapped' and deployed as heat. Loss of electricity production will lead to extra costs. This will be taken into account in establishing the base rate.

The nominal thermal efficiency depends on the type of installation and on the design. To make the various installations comparable in terms of useful heat deployment, a division is used based on heat demand in full load hours. The heat demand for space heating is not constant, for example; it depends on the outdoor temperature and on its deployment. The most intensive type of heat utilisation can be realised in non-stop industrial processes where up to 7000 full load hours per years is feasible. Non-stop heat supply does not often occur in practise, though. More common are heat supplies of 1000 full load hours, which is characteristic of space heating, or up to 2750 full load hours, which occurs in the supply to industry and greenhouses. Based on the number of full load hours and the nominal thermal efficiency, the annual average thermal efficiency is calculated.

3.2 Reference installation

A reference installation is established for each bio-energy category, and heat supply is not included at first. To establish the influence of heat supply on the techno-economic parameters of these reference installations, the increase in investment costs and O&M costs (*Operation and Maintenance*) is subsequently examined. The value of heat is established at the delivery point where the heat leaves the site of the installation. This value is lower than the value of the heat for the end user. This compensates for the transport losses and the costs arising from the infrastructure that links the heat producer to the heat user. In concrete terms, the costs of a heating grid are not included in the investment cost of the reference installation, for example. These costs are indirectly transferred by a decrease in the value of the heat for the supplier.

3.3 Useful heat production: general

In the SDE scheme of 2009 and 2010 the height of the base rate was linked to heat utilisation in some categories. As an installation is able to sell more useful heat, the base rate will increase accordingly. In 2009 and 2010 the graduated calculation of interest was shaped in such a way that the SDE payments per amount of avoided primary energy stays the same. However, the graduated calculation of interest for heat is not part of the research assignment. This draft advice does offer an estimate of the heat that can be usefully deployed in common situations. In most bio-energy categories this involves heat supply for space heating. The only exception is the category other digestion where heat can be supplied on an industrial scale. This makes the heat supply profitable. In this category, the base rate of an installation with useful heat production is similar to the base rate of an installation that generates only electricity.

Some techniques used in green gas installations enable heat supply. This heat supply is also not considered as common. Therefore, the reference installations in the green gas installations do not assume heat supply.

3.4 Useful heat production: waste incineration

Heat supply is very common in waste incineration plants. Waste incineration plants have a separate regulation to incentivise heat utilisation. The base rate in the category for waste incineration plants depends on the efficiency of the installation according to the graduated calculation of interest in the SDE scheme. A higher efficiency means a higher base rate. To incentivise heat utilisation, heat supply is included in the establishment of the efficiency. Heat counts for two-thirds in the establishment of the efficiency, as defined in the regulation guarantees of origin[2].

Neither the graduated calculation of interest for waste incineration plants nor the 'two-thirds regulation' is part of the research assignment. In the waste incineration category calculations were done for three reference installations with different efficiencies. The graduated calculation of interest of waste incineration plants can be established by means of these three calculations. This draft advice will address the techno-economic parameters of the three reference installations.

2 Regulation guarantees of origin for renewable electricity, article 3.

4. Emission requirements

4.1 Decision-making

On 1 April 2010 the Decree on Emission regulation of mid-sized combustion plants (BEMS) entered into force. This decree applies to the categories in which biomass is digested for electricity production and to the categories in which biomass is fired. The Decree on Waste Incineration applies to the waste incineration installations. Moreover, biomass installations larger than 20 MW_{th} are covered by the NO_x emission trade.

4.2 Starting point

The projections of the techno-economic parameters include the investment and maintenance sots that are needed to meet the emissions standards. The standards included in Table 4.1 often depend on the scale size of the installation. The values in Table 4.1 correspond to the scale sizes of the reference installations from Chapter 7.

Table 4.1 *Emission requirements*

Substance	*Unit*	**Starting points draft advice (BEMS unless stated otherwise)**
	Biomass digestion installations	
SO_2	[mg/Nm^3 dry flue gas, 3 vol.% O_2]	200
C_xH_y	[mg C/Nm^3 dry flue gas, 3 vol.% O_2]	-
NO_x	[mg/Nm^3 dry flue gas, 3 vol.% O_2]	340
	Biomass waste incineration installations – solid biomass	
SO_2	[mg/Nm^3 dry flue gas, 6 vol.% O_2]	200
PM_{10}	[mg/Nm^3 dry flue gas, 6 vol.% O_2]	5
NO_x[3]	[mg/Nm^3 dry flue gas, 6 vol.% O_2]	145
	Biomass waste incineration installations - liquid biomass	
SO_2	[mg/Nm^3 dry flue gas, 3 vol.% O_2]	200
PM_{10}	[mg/Nm^3 dry flue gas, 3 vol.% O_2]	50
NO_x	[mg/Nm^3 dry flue gas, 3 vol.% O_2]	450
	Waste incineration installations[4]	
SO_2	[mg/Nm^3 dry flue gas, 11 vol.% O_2]	50 (BVA)
PM_{10}	[mg/Nm^3 dry flue gas, 11 vol.% O_2]	5 (BVA)
C_xH_y	[mg C/Nm^3 dry flue gas, 11 vol.% O_2]	10 (BVA)
NO_x	[mg/Nm^3 dry flue gas, 11 vol.% O_2]	70 (BVA)

[3] Installations larger than 20 MW_{th} are covered by emission trade.
[4] Table 4.1. Shows boundary values for waste incineration plants of 97% of the half-hourly averages, except for NO_x with the boundary value of 100% of the monthly averages.

5. Financing renewable energy projects

5.1 Starting points

The capital costs are included in the assessment of the production costs. The starting point is project financing. The capital consists partly of loan capital and partly of equity capital. The ratio between them depends primarily on the risk profile of the project. The interest rate for loan capital is assumed to be 6%. The return on equity capital is calculated with 15%.

The European Commission has approved the SDE scheme, allowing for a reasonable remuneration of capital. A remuneration of capital (WACC before taxes) of 7.8% is considered reasonable. This remuneration of 7.8% corresponds for example to a situation in which 80% of the capital is provided as debt equity at 6% and 20% as private equity at 15%. In the abovementioned reasonable remuneration for capital other debt-equity ratios and returns are also conceivable.

Market parties have indicated that anyone taking out a loan for investing in a renewable energy plant may be faced with extra demands or provisions. One can think of a commission, a '*debt service reserve account*', a *maintenance reserve account*', a decommissioning reserve account and a loan with a duration that is shorter than the subsidy duration. These demands and provisions are considered as remunerations of capital that exceed the criterion set by the European Commission. Hence, they cannot be included in the calculations for establishing the base rate.

Small solar PV systems are assumed to be financed by private individuals. Private individuals finance solar PV systems in the mortgage on their house. The benefits of mortgage interest deduction are deducted from the capital cost.

5.2 Additional support

Additional financial support will be deducted from the base rate, to the extent that the financial support applies generically to the category in question and to the reference installation. In addition to the SDE payments there are two generic policy instruments for additional support for renewable electricity. EIA and green financing. Any benefits resulting from the MIA (environmental investment deduction)/VAMIL(depreciation of environmental investments) are not included in the projections of the base rate.

The energy investment deduction (EIA) is a fiscal scheme enabling entrepreneurs to deduct up to 44% of the investment cost from the taxable income of the enterprise. This way one can save on corporation tax. In addition to the limits to the EIA benefits per KW_e there are also demand with regard to the efficiency of the installation. Biomass installations that supply only heat must meet a heat efficiency of 80% and CHP plants must have an energetic efficiency of 60%, with heat accounting for two-thirds. In general this energetic efficiency will not be met because heat supply has practical limitations. As a result there is not enough heat supply and reference plants do not meet the EIA efficiency demand. In the calculations for the base rate it has therefore been assumed that biomass installations are not eligible for EIA. The EIA benefit has been taken into account for the categories onshore wind, solar PV and hydropower.

A second supplementary scheme is the option of green financing; obtaining a loan at a favourable interest rate. The Dutch Green Funds Scheme 2010 provides the criteria that must be met by renewable energy projects in order to obtain a green declaration. A green declaration is usually valid for 10 years and results in tax benefits for private investors in green projects. In the case of hydropower and solar PV, the green declaration is valid for 15 years. Green projects are thus able to contract loans at favourable interest rates. This report uses an effective interest rebate of 1% for projects that are eligible for a green declaration. Complications in finance may arise when the subsidy duration in SDE is 12 or 15 years and the green certificate is only valid for a period of 10 years. The calculations assume an interest rate of 5% during the first 10 years and 6% in subsequent years. In the financial starting points this translates into an interest rate of 5.1%. The green declaration is included in the calculation when it is provided generically for this category. This is the case for onshore wind, solar PV and hydropower. In the case of bioenergy projects, the project must be innovative, which does not imply a generic advantage in principle.

5.3 Financing parameters

The preparatory costs are not included in the assumptions for the investment costs. In accordance with the research assignment, these costs are covered in the calculation by the return on equity, which is usually 15%.

Calculations were based on a corporation tax of 2.5% and an annual indexation of the O&M cost of 2%, including fuel and substrate costs. The subsidy amounts are usually paid in advance for 80% and settlement takes place in the next year. The used calculation model (De Noord and van Sambeek, 2003) does not take into account the shifts in working capital within one year. See Table 5.1 for the used financial economic calculation parameters.

Table 5.1 *Financial parameters*

	Share of equity	Interest	Return on equity	Capital cost (WACC)	Duration of loan	Economic lifetime	Green financing	EIA maximum (EIA in reference installation)
	[%]	[%]	[%]	[%]	[yr]	[yr]		[€/kW$_e$]
Wind energy								
Onshore wind < 6 MW	20	5.1	15	6.0	15	15	Yes	600
Onshore wind ≥6 MW	20	5.1	15	6.0	15	15	Yes	600
Biomass digestion (electricity)								
Landfill gas, WWTP	20	6	15	6.6	12	12	-	-
Manure co-digestion	20	6	15	6.6	12	12	-	-
VFG digestion	20	6	15	6.6	12	12	-	-
Other digestion	20	6	15	6.6	12	12	-	-
Biomass digestion (green gas)								
Landfill gas	20	6	15	6.6	12	12	-	total
WWTP	20	6	15	6.6	12	12	-	total
Manure co-digestion	20	6	15	6.6	12	12	-	upgrading
VFG digestion	20	6	15	6.6	12	12	-	upgrading
Other digestion	20	6	15	6.6	12	12	-	upgrading
Thermal conversion of biomass								
Solid biomass <10 MW$_e$	20	6	15	6.6	12	12	-	-
Solid biomass 10-50 MW$_e$	20	6	15	6.6	12	12	-	-
Liquid biomass <10 MW$_e$	20	6	15	6.6	12	12	-	-
Liquid biomass 10-50 MW$_e$	20	6	15	6.6	12	12	-	-
Waste incineration plants								
Standard efficiency	33	6	12	7.0	15	15	-	-
Increased efficiency	33	6	12	7.0	15	15	-	-
High efficiency	33	6	12	7.0	15	15	-	-.
Hydropower								
Hydropower, height of fall <5 meters	20	5	15	6.0	30	30	Yes	turbine
Hydropower, height of fall ≥5 meters	20	5	15	6.0	30	30	Yes	turbine
Free tidal current energy	20	5	15	6.0	15	15	Yes	turbine
Solar PV								
1-15 kW$_p$	0	2.6	2.6	2.6	15	15	Yes	n.a.
15-100 kW$_p$	15	5	15	5.5	15	15	Yes	3000

6. Development of fuel prices

6.1 Gas and electricity

The base rate is not directly influenced by the prices of fossil fuels such as coal, gas and oil. After all, the base rate is a measure for the production cost of renewable energy options. The SDE payments, i.e. the subsidy amount, is established every year by applying a correction based on the electricity or gas price. There are two exceptions:

Electricity
Green gas installations use electricity. The supply tariff is assumed to be 14 €ct/kWh. This amount is based on the long-term electricity price of 6.6 €ct/kWh (Lensink and Van Tilburg, 2008) plus the Energy Tax (1.0 €ct/kWh at a use of 10 million kWh per year), supply and transport costs.

Gas
Natural gas is used as an indication for the yields in heat supply of bio-energy installations. Natural gas has a long term price of 22 €ct/Nm^3 as a starting point (Lensink en Van Tilburg, 2008). It is assumed that commercial small users up to 170,000 m^3 annually pay about 45 €ct/^{m3}, including 14 €ct/Nm^3 energy tax.

6.2 Solid biomass

Wood waste
The market for B-quality wood is part of an international market that is continually under pressure, mainly due to demand from Germany and a new installation in Belgium. The first loads of B-quality wood are imported from England, which balances the market supply and demand. The average price for B-quality wood is expected to be around 25 € per tonne at a net heating value of 14 GJ/tonne. B-quality wood is the reference fuel for incineration plants of 10-50 MW_e. The market initiatives are (for the largest part) based on the deployment of B-quality wood.

Cut wood and wood waste
There are no international price-making forces with regard to cut wood and wood waste; it is a regionally oriented market. It is the reference fuel for incineration plants smaller than 10 $MW_{e.}$ The average price for 2011 is expected to be around 34 € per tonne at a net heating value of 7 GJ/tonne.

Pellets
Due to the expiring MEP subsidies (subsidies on environmental quality of electricity production) there is some uncertainty about the future demand for pellets. The current spot price of wood pellets is low at 118 €/tonne (CIF Rotterdam). Until recently the price was around 130 € per tonne. Expectations at the ENDEX market (European Energy Derivates Exchange) are that the price will return to this level by the end of 2010. Therefore, the average price for 2011 is expected to be around 130 € per tonne at a net heating value of 17 GJ/tonne.

6.3 Liquid biomass

The price of vegetable oils shows an upward trend with an increase of approximately 15% compared to 2009. The price movements of these oils can be considered leading for the price movements of the reference fuel 'animal fat'. The average price for 2011 is expected to be around 520 € per tonne at a net heating value of 39 GJ/tonne.

Used vegetable oils as a reference fuel for large-scale thermal conversion of liquid biomass of 10-50 MW_e are not included. In consultation with the Dutch Ministry of Economic Affairs it was decided to not advise on a base rate for the category of incineration of liquid biomass of 10-50 MW_e (see also Section 7.6).

6.4 Digestion

Vegetable, fruit and garden waste
The fuel price is assumed to be nil for the digestion of VFG, similar to the incineration of waste in waste incineration plants. This decision is based on the fact that generating energy for this type of installation must be considered as 'extra'. The base rate is calculated by establishing the additional price compared to composting. The difference between aerobic digestion (in composting) and anaerobic digestion (in biogas use) does not affect the mass of the residual product.

Biomass for large-scale mono-digestion
Large-scale mono-digestion of residual flows is based on residual products from the food and feeds industry or from biofuel production. The reference fuel is assumed to consist of residual products from the biofuel production, where the price level is determined by the markets for feed. The prices for moist feed have decreased with 20% since late 2009. The cost of removing digestate, which is about 70% of the input mass, remains at the same level as last year's advice, i.e. 10 €/tonne. The reference price for feedstocks for a mono-digestion plant for 2011 is expected to be 23 €/tonne.

Feedstocks for manure co-digestion - manure
The price of slurry shows regional differences, varying from 0 to -5 € per tonne in areas with manure shortage up to a maximum of -15 to -20 € per tonne in manure surplus areas. The reference price (excluding transport costs) is assumed to be -10 € per tonne. The removal of digestate is calculated as the price of animal manure including transport costs. On average, the removal of digestate requires an additional 15 € per tonne.

Feedstocks for manure co-digestion - co-substrate
Since the end of 2009 the price of maize decreased with 10%. As the higher price of maize in recent years resulted in increased deployment of other agricultural residual products to lower the average co-substrate price, a new equilibrium in the input mix will be sought. The average reference price for co-substrates in 2011 is expected to be 22 € per tonne.

See Tale 6.1 for an overview of the used prices for reference fuels.

Table 6.1 *Price projections biomass*

	Energy content	Price range	**Reference price Draft advice 2011**		Reference price[5] Final advice 2011	
	[GJ/tonne]	[€/tonne]	**[€/GJ]**	**[€/tonne]**	[€/GJ]	[€/tonne]
Liquid biomass						
Animal fat	39.0	500-550	**13.3**	**520**	11.5	450
Solid biomass						
Cut wood and wood waste	7	30-40	**4.9**	**34**	4.6	32
Wood waste	14	20-30	**1.8**	**25**	1.8	25
Wood pellets	17	125-135	**7.6**	**130**	6.8	125
Digestion						
Mono-digestion input	5.0	-	**4.6**	**23**	4.0	27
Supply of animal manure	*1.0*	*-20 to 0*	***-10***	***-10***	*-10.0*	*-10*
Removal of animal manure	*1.0*	*-30 to -5*	***-15***	***-15***	*-15.0*	*-15*
Co-substrate	*4.8*	*5 to 50*	***4.6***	***22***	*4.8*	*23*
Co-digestion input	2.9	14-32	**6.6**	**18**	6.6	19

[5] The prices used in this report are bases on the entire product; not on the dry-matter content alone. This always refers to the gate tariff, i.e. supply to the installation.

7. Electricity options

7.1 Landfill gas/waste water treatment plants

Description of reference installation

New installations near landfills will not be developed. The reference installation for the landfill category replaces an existing installation. These are replacement investments in decreasing biogas production. The waste water treatment plants seem to show a trend towards up-scaling in the renewal of installations.

Additional comments

It is mainly due to the decreasing biogas production near landfills that the production costs near landfills are higher than near waste water treatment plants. The base rate for waste water treatment plants is aimed at feeding electricity into the grid. Using biogas for one's own purposes is not reimbursed by the SDE scheme and has therefore not been considered in the projection of the base rate. See Table 7.1 for an overview of the techno-economic parameters.

Table 7.1 *Technical economical parameters for landfill gas/WWTP*

		Draft advice 2011		Final advice 2010	
		Landfill gas	*WWTP*	Landfill gas	WWTP
Installation size	[MW]	0.3	0.3	0.3	0.3
Investment cost	[€/kW_e]	2385	2185	2385	2185
Full load hours	[hour/year]	6500	8000	6500	8000
Fixed O&M costs	[€/kW_e]	240	220	240	220
Variable O&M costs	[€/kWh]	-	-	-	-
Energy content biomass	[GJ/tonne]	-	-	-	-
Feedstock costs	[€/tonne]	0	0	0	0
Electrical efficiency	[%]	35.0	35.0	35.0	35.0
Thermal efficiency	[%]	4.6	4.6	4.6	4.6
Avoided fuel costs	[€/m^3]	0.45	0.45	0.45	0.45

7.2 Manure co-digestion

Description of reference installation

Manure co-digestion plants seem to be growing in size, with new initiatives ranging from 1 to 2.5 MW_e. The reference plant scale is assumed to be 2 MW_e. Not all components of manure co-digestion decrease in cost in case of a larger scale. A generic scale effect has been calculated to map the cost benefits of scaling-up.

Additional comments

The feedstock costs of manure co-digestion are volatile due to the dependence on both manure prices and co-substrate costs. It is impossible to close long-term contracts to cover all these price risks. See Table 7.2 for an overview of the techno-economic parameters.

Table 7.2 *Techno-economic parameters manure co-digestion*

		Draft advice 2011	Final advice 2010
Installation size	[MW]	2.0	0.8
Investment cost	[€/kW_e]	2740	3000
Full load hours	[hour/year]	8000	8000
Fixed O&M costs	[€/kW_e]	220	240
Variable O&M costs	[€/kWh]	-	-
Energy content biomass	[GJ/tonne]	2.9	2.9
Feedstock costs	[€/tonne]	18	19
Electrical efficiency	[%]	26	26
Thermal efficiency	[%]	3	3
Avoided fuel costs	[€/m^3]	0.19	0.19

7.3 VFG digestion

Description of reference installation

Tenders put out by decentralised authorities to VFG processors often include sustainability criteria with a preference for VGF digestion from the viewpoint of sustainability. However, as this is not a legal obligation, composting of the waste remains the reference technique. The reference plant scale is assumed to be 2 MW_e. A generic scale effect has been calculated to map the cost benefits of scaling-up.

Additional comments

The multitude of initiatives seems to have an oppressive effect on the gate fee of VFG and the SDE payments (i.e. 17 €/tonne) are partly used to compensate for the lower price of VGF waste. Despite the fact that the price was set at nil in the SDE calculations, as composting is the reference technique, there seems to be interaction between the SDE payments and the gate fees for VGF waste. See Table 7.3 for an overview of the techno-economic parameters.

Table 7.3 *Techno-economic parameters VGF digestion*

		Draft advice 2011	Final advice 2010
Installation size	[MW]	2.0	1.5
Investment cost	[€/kW_e]	4165	4285
Full load hours	[hour/year]	8000	8000
Fixed O&M costs	[€/kW_e]	435	445
Variable O&M costs	[€/kWh]	-	-
Energy content biomass	[GJ/tonne]	2.5	2.5
Feedstock costs	[€/tonne]	0	0
Electrical efficiency	[%]	26.0	26.0
Thermal efficiency	[%]	3.0	3.0
Avoided fuel costs	[€/m^3]	0.19	0.19

7.4 Digestion of other biomass

Description of reference installation

In this category (large-scale) mono-digestion is considered to be the reference technique. Feedstocks for mono-digestion usually consist of residual flows that are released in the food and biofuels sectors. In this digestion option, an existing factory is expanded with an energy company. This is done in an integrated manner. The feedstock mainly comes from the factory and the produced energy is mostly supplied back to the same factory as electricity, green gas, heat or a combination of these. A typical range of the installations is 2 to 7 MW_e with a reference capacity of 3 MW_e. The feedstock prices are primarily determined by the feed market where almost all feedstocks have an alternative use. The feedstock price is projected to be 23 €/tonne.

Additional comments

Depending on the energy demand of the factory, it could use its own green gas, electricity and heat production. It is assumed here that the electricity is entirely fed back into the grid. The useful deployed heat is considered to be avoided use of natural gas with a generation efficiency of 90%. The cost of removing the digestate is transferred to the feedstock cost. The feedstock cost is assumed to be 23 €/tonne. The energy content of the substrate is 5 GJ/tone. See Table 7.4 for an overview of the techno-economic parameters.

Table 7.4 *Techno-economic parameters other digestion*

		Draft advice 2011	Final advice 2010
Installation size	[MW]	3.0	3.0
Investment cost	[€/kW_e]	3200	3200
Full load hours	[hour/year]	8000	8000
Fixed O&M costs	[€/kW_e]	210	210
Variable O&M costs	[€/kWh]	-	-
Energy content biomass	[GJ/tonne]	5	5
Feedstock costs	[€/tonne]	23	27
Electrical efficiency	[%]	26.0	26.0
Thermal efficiency	[%]	8.2	8.2
Avoided fuel costs	[€/m^3]	0.22	0.22

7.5 Thermal conversion of solid biomass

Description of reference installation

Many initiatives up to 10 MW_e are developed on a local scale, for example by decentralised authorities. Installations up to 10 MW_e must meet BEMS requirements (Decree on emission regulation mid-sized combustion plants), resulting in additional measures having to be taken to reduce the emission of nitrogen, for example by means of a DeNOx installation. The additional investment of a DeNOx installation is projected at 45 /kW_e for small installations. Using a reduction substance such as urea translates into higher O&M costs, which are projected at 0.006 €/kWh.

The initiatives in the category 1-50 MW_e seem to be growing. To reflect this increase, the installation size of medium-sized wood incineration has increased from 20 MW_e to 25 MW_e and the specific investment cost and O&M costs have been adjusted to the scale size.

Additional comments

Installations larger than 10 MW_e have wood waste (B-quality wood) as reference. The amount of B-quality wood released in the Netherlands is almost entirely utilised. There is a large demand for wood waste from Germany, while at the same time wood waste is being imported from England. See Table 7.5 for an overview of the techno-economic parameters.

Table 7.5 *Techno-economic parameters of thermal conversion of solid biomass*

		Draft advice 2011		Final advice 2010	
		Incineration 0-10 MW_e	Incineration 10-50 MW_e	Incineration 0-10 MW_e	Incineration 10-50 MW_e
Installation size	[MW]	2.0	25	2.0	20
Investment cost	[€/kW_e]	4445	3600	4400	3635
Full load hours	[hour/year]	8000	8000	8000	8000
Fixed O&M costs	[€/kW_e]	340	250	340	255
Variable O&M costs	[€/kWh]	0.006	-	-	-
Energy content biomass	[GJ/tonne]	7	14	7	14
Fuel costs	[€/tonne]	34	25	32	25
Electrical efficiency	[%]	23.0	28.6	23.0	28.6
Thermal efficiency	[%]	4.1	5.5	4.1	5.5
Avoided fuel costs	[€/m^3]	0.158	0.127	0.158	0.127

7.6 Thermal conversion of liquid biomass

Description of reference installation

Small-scale installations based on liquid biomass larger than 2.5 MW_{th} must meet the BEMS requirements. The reference installation stays just below this limit at 2.4 MW_{th}, resulting in no additional cost projections for BEMS.

Apparently there is not a suitable fuel technique combination available to develop initiatives in the category thermal conversion of liquid biomass 10-50 MW_e. In consultation with the Dutch Ministry of Economic Affairs it was decided to not advise on a base rate for the category of incineration of liquid biomass of 10-50 MW_e.

Additional comments

There is no longer a market for large diesel engines running on imported vegetable oils. An emerging development involves the firing of pyrolisis oil from wood, which could be put in this category. See Table 7.6 for an overview of the techno-economic parameters.

Table 7.6 *Techno-economic parameters of thermal conversion of liquid biomass*

		Draft advice 2011		Final advice 2010	
		Incineration 0-10 MW_e	Incineration 10-50 MW_e	Incineration 0-10 MW_e	Incineration 10-50 MW_e
Installation size	[MW]	1.0		1	20
Investment cost	[€/kW_e]	1600		1600	1350
Full load hours	[hour/year]	8000		8000	8000
Fixed O&M costs	[€/kW_e]	175		175	155
Variable O&M costs	[€/kWh]	-		-	-
Energy content biomass	[GJ/tonne]	39		39	39
Fuel costs	[€/tonne]	520		450	375
Electrical efficiency	[%]	42.0		42.0	47.3
Thermal efficiency	[%]	4.6		4.6	2.7
Avoided fuel costs	[€/m^3]	0.158		0.158	0.127

7.7 Waste incineration plants

Description of reference installation

Only the so-called energy company of the waste incineration plant is considered; not the waste-processing plant. The energy company encompasses all costs that are required to enable energy deployment at waste incineration plants.

Additional comments

The 'BREF Waste Incineration' sets requirements with regard to the efficiency of new built installations. A minimum efficiency in combination with heat transfer must be realised. Heat transfer increases the installation's efficiency and the investment costs increase accordingly, as illustrated in the next table. See Table 7.7 for an overview of the techno-economic parameters.

Table 7.7 *Techno-economic parameters of waste incineration plants*

		Draft advice 2011			Final advice 2010		
		Standard efficiency	Increased efficiency	High efficiency	Standard efficiency	Increased efficiency	High efficiency
Installation size	[MW]	19.8	25.4	29.2	19.8	25.4	29.2
Investment cost	[€/kW$_e$]	2450	2550	2750	2450	2550	2750
Full load hours	[hour/year]	8080	7800	7500	8080	7800	7500
Fixed O&M costs	[€/kW$_e$]	-	-	-	-	-	-
Variable O&M costs	[€/kWh]	0.012	0.013	0.014	0.012	0.013	0.014
Energy content biomass	[GJ/tonne]	10	10	10	10	10	10
Fuel costs	[€/tonne]	0	0	0	0	0	0
Electrical efficiency	[%]	23.0	28.5	31.5	23.0	28.5	31.5
Thermal efficiency	[%]	-	-	-	-	-	-
Avoided fuel costs	[€/m^3]	-	-	-	-	-	-

7.8 Wind energy

Description of reference installation
For 2011 two categories of wind projects were examined, i.e. onshore wind with turbines up to 6 MW and onshore wind turbines of 6 MW or more.

Onshore wind < 6 MW
In the categories 'onshore wind < 6 MW' the same starting points were used as in previous years. An important criterion is the full load hour limit of 2200 hours. The reference installation is an imaginary park of about 15 MW. Several of the most commonly used turbine types in the Netherlands were assumed. The additional costs include the electrical infrastructure of the park, the connection to the grid and civil engineering (preparation of construction and access roads). On top of the turbine price, additional costs of 25% were calculated to arrive at the investment amount. The turbine prices range from 950 to 1500 €/kW. For each turbine type the production was established under three different wind regimes as well as the productions costs. By means of interpolation, the arithmetic average production cost at 2200 hours was established, regardless of the type of turbine. These production costs correspond to the investment cost of 1350 €/kW. The turbine cost and the total investment cost are assumed to have remained the same as in the last year. The variable costs are made up of guarantee and maintenance contracts and are estimated at 1.1 ct/kWh, assuming 1.0 ct/kWh at the start of the project and an increase during the lifetime. The annual fixed costs were projected to amount to 25.8 €/kW.

Onshore wind ≥ 6MW
An SDE base rate was established for the category 'onshore wind ≥ 6MW' in 2009. The assumptions that are at the basis of this tariff are also the basis of the current investment amounts and exploitation expenses. Wind turbines of this size are not yet common, though. The first experiences with wind turbines of this size are currently being gained in Germany. The investment cost and therefore also the generation cost is higher than in the category onshore wind < 6 MW. For the turbines an investment amount is projected at 1700 €/kW. Due to the larger number of full load hours, the maintenance cost is lower than in the category of smaller wind turbines, amounting to approximately 0.0095 €/kWh.

Additional comments
The economic recession and the more limited financing options have ended the large tightness in the market for wind turbines. The market is assumed to recover in 2011. The prices appear to remain at a stable level. See Table 7.8 for an overview of the techno-economic parameters.

Table 7.8 *Techno-economic parameters wind energy*

		Draft advice 2011		Final advice 2010
		Onshore wind < 6 MW	Onshore wind ≥6 MW	Onshore wind ≥6 MW
Installation size	[MW]	15	60	15
Turbine cost	*[€/kW$_e$]*	*1040*	*1700*	*1040*
Other costs	*[€/kW$_e$]*	*310*	*250*	*310*
Investment cost	[€/kW$_e$]	1350	1950	1350
Full load hours	[hour/year]	2200	3000	2200
Fixed O&M costs	[€/kW$_e$]	25.8	25.8	25.8
Variable O&M costs	[€/kWh]	0.011	0.0095	0.011

7.9 Hydropower

Description of reference installation

In 2010 the scheme was set-up for two categories, i.e. hydropower with a height of fall of less than five metres and hydropower with a height of fall of five metres or more. Hydropower projects based on free tidal energy do not use a height of fall but the kinetic energy of free flowing water. No separate category was established for these hydropower projects in 2010. The technique has been included in the current advice, because in May 2010 the Dutch Minister of Economic Affairs promised the Dutch Lower House that a new study would be conducted on the cost price and potential of free tidal energy. Her successor will inform the Lower House about the results around 1 November 2010.

Dammed hydropower

The fall of the rivers in the Dutch Delta is limited. Existing constructions in rivers are suitable for creating drops that can be utilised in hydropower plants. In practise these usually range from 3 to 6 meters and up to 11 meters in exceptional cases. Two reference installations were established for small-scale hydropower (drop < 5 m and drop of ≥ 5 m). The potential projects in the category hydropower have a wide distribution in investment costs and corresponding base rate. Therefore the base rate in this advice is based on specific projects, the realisation potential and the costs playing leading roles in selection. The new inventory of hydropower initiatives for this advice did not lead to any adjustments in the reference plants.

Free tidal current energy

This advice looks exclusively at the *inshore* free tidal current energy; this involves projects that are realised in or near constructions such as seawalls or semi-permeable dams that use the existing tidal movement. The reference installation is based on the number of projects that are eligible for short term realisation according to the sector. These are pilot projects that are commercially exploitable with adequate production subsidy according to the sector. The technology of free tidal current turbines is at the start of commercialisation. As a result the investment and O&M costs are relatively higher. See Table 7.9 for an overview of the techno-economic parameters.

Table 7.9 *Techno-economic parameters hydropower*

		Draft advice 2011			Final advice 2010		
		Hydropower, height of fall <5 meters	Hydropower, height of fall ≥5 meters	Free tidal current energy	Hydropower, height of fall <5 meters	Hydropower, height of fall ≥5 meters	Free tidal current energy
Installation size	[MW]	4.0	2.8	1.0	4.0	2.8	n.a.
Investment cost	[€/kW$_e$]	3890	2440	5830	3890	2440	n.a.
Full load hours	[hour/year]	3800	4800	2250	3800	4800	n.a.
Fixed O&M costs	[€/kW$_e$]	66.5	84.0	112.5	66.5	84.0	n.a.
Variable O&M costs	[€/kWh]	0	0	0	0	0	n.a.

7.10 Solar PV

Description of reference installation

A distinction is made in base rate for two categories: solar PV small (1-15 kW_p) and solar PV large (15-100 kW_p). The reference installations have a capacity of respectively 3.5kW_p and 100 kW_p. In the category solar PV small, the additional costs of electrical adaptations in a dwelling and installation of a gross production meter for the subsidy on the generated solar power for own use are included in the investment cost. These additional costs amount to 170 €/kW_p and 25 €/kW_p including VAT. Solar power systems are low maintenance. In both categories the O&M costs include the costs of maintenance and small repairs. Currently, the standard guarantee on the converter can be extended from 5 years to the entire subsidy duration. These costs have been included in the O&M costs of the category large, but not in the category small. Replacement of the converter at the end of its lifetime (after about ten years) is considered as a separate investment decision that will have a positive result in the category small, even without SDE payments.

Additional comments

In 2009 7.2 GW_p of solar panels was installed worldwide, 3.8 GW_p in Germany (EPIA, 2010). The current worldwide installed capacity amounts to almost 23 GW_p. Germany is expected to be the most important market in 2010, too. The additional regression of the German feed-in tariffs for solar PV of 1 July will have a large influence on the development of demand in 2010. Due to this decrease of tariffs, demand peaks in the second quarter of 2010. It is expected that, due to the decreasing German feed-in tariff, the panel prices will decrease in the second half of 2010 by approximately 15%; this is the result of decreased production costs. Partly due to the influence of German peak demand, a strong worldwide market growth is anticipated up to 10 to 15 GW_p in 2010; in 2011 the market will continue to grow. Based on historical price developments the panel prices can be expected to decrease 20 to 25% in the period 2010-2011.

The Dutch Ministry of Economic Affairs asked ECN/KEMA to assume the most economical systems in the market and to incorporate the price development of 2011 in their advice on the base rate. In 2010 the realised prices of the most economical turnkey systems in the Netherlands amount to 2350 to 2600 €/kW_p excluding VAT for a system of about 100 kW_p. These costs are built up as follows: 1625 €/kW_p panel costs and 850 €/kW_p *balance of system* (BoS) and installation. In the short term the decreasing panel prices are expected to result in lower investment costs. Taking into account the above-mentioned anticipated decrease in the period 2010-2011, the investment costs for early 2012 are projected at 2060 €/kW_p excluding VAT (1260 €/kWp panel costs and 800 €/kWp BoS and installation). These costs are slightly higher for smaller systems at 2310 €/kW_p excluding VAT. See Table 7.10 for an overview of the techno-economic parameters.

Table 7.10 *Techno-economic parameters of solar PV*

		Draft advice 2011		Final advice 2010	
		1-15 kW_p	15-100 kW_p	1-15 kW_p	15-100 kW_p
Installation size	[MW]	0.0035	0.1	0.0035	0.1
Investment cost	[€/kW_e]	2945	2060	4570	3375
Full load hours	[hour/year]	850	850	850	850
Fixed O&M costs	[€/kW_e]	-	-	-	-
Variable O&M costs	[€/kWh]	0.031	0.024	0.031	0.027

8. Green gas options

8.1 Introduction

Biomass options in which biomass is first converted into methane gas (and other gases) also have the option of upgrading this gas blend to natural gas quality and subsequently feeding it into the natural gas grid. Van Tilburg et al (2008a) provide detailed descriptions of the systems for green gas production, including the various steps in the process. In addition to the green gas categories of landfill gas, WWTP, manure co-digestion, VGF digestion and other digestion, this draft advice will also examine the costs of digesters in relation to the green gas hub. The calculated base rate for crude biogas must be considered in the light of possible support for installations that are linked to the green gas hub.

Reference technology for gas purification

In previous advices (Van Tilburg et al, 2008a; Lensink et al, 2009) selected membrane separation as the reference technique for landfill gas and gas scrubbing in the categories WWTP, manure co-digestion, VFG digestion and other digestion. An alternative cost-effective new technology could be cryogenic separation (see also: Jansen et al, 2009; Colsen b.v, 2009; Veth, 2008). There are several initiatives based on cryogenic separation. These have not yet been realised, however, which means that there is no practical experience yet. Therefore the reference technologies have been maintained.

Other digestion

Given the signals from the market, the category other digestion has (large-scale) mono-digestion as reference technique. Mono-digestion relates to the biomass residual flows that are released by the food and feeds industry or the biofuels industry. The latter includes the industry for the production of bio-ethanol and biodiesel.

The digestate that is released in mono-digestion cannot be straightforwardly used in agriculture. This is only standard practise in co-digestion where a minimum of 50% of the input is animal manure. Some initiatives cater for follow-up treatment of digestate, such as separation of a thick fraction (with most of the phosphate) and a thinner one (with the largest part of the nitrate). The thin fraction can be discharged after purification; the thick fraction can be removed at a lower transport cost. The removal of this flow will have to be charged according to expectations.

As mono-digesters can be integrated into an existing installation, defining the system boundaries is an essential step; even more so than in other categories. It determines how the various yields and costs can be charged. As with waste incineration plants, it seems obvious to consider the digester as an additional option, next to the core activity of the company. This means that:

- At the front side of the digester feedstock costs are charged at a tariff that would apply at the factory gate for the alternative deployment.
- It is assumed that green gas will be generated and fully fed back into the grid.
- The cost for removing the digestate is included in the feedstock costs in the same manner as in the category co-digestion of animal manure.

Crude biogas and green gas hub

A producer of green gas must upgrade the quality of the gas before the biogas can be fed into the natural gas grid as green gas. However, in case of a green gas hub the production of crude biogas and its upgrading are done at different locations. The produced crude biogas of different digestion installations must be transported to the hub by means of separate biogas pipes, after which the biogas will be upgraded to green gas. A production system for crude biogas consists of the following components:

- Digester.
- Limited gas scrubbing. this step consists mainly of deeper sulphide-removal than in direct on-site use of the biogas in a CHP plant and of ammonia removal.
- Heat for the digester: part of the biomass will be used in a boiler to supply the required heat to the digester; it needs electricity from the grid.
- Gas drying: the biogas must be dehydrated prior to transport through crude biogas pipes.
- Transport to external application: the biogas (CH_4 en CO_2) is supplied to another installation where it is used to replace natural gas.

The main assumptions in establishing the techno-economic parameters for the production of crude biogas are:

- The cost of CO_2 separation is not charged.
- The cost of sulphide or ammonia removal, if comparable to the direct on-site use of biogas in a CHP, is discounted in the cost of the digester. Moreover, extra costs are included for additional sulphide removal, gas drying, extra investment for better gas measuring than in CHP applications and a compressor to pump crude biogas in pipes. In landfill gas additional gas purification is included.
- The heat demand of the digester is covered by firing part of the crude biogas in the boiler.
- The electricity for the installation is obtained from the grid.

This chapter presents the techno-economic parameters for the reference systems in accordance with the green gas options and the corresponding production costs. The production costs are an indication of the costs of crude biogas ‘at the gate’ of the installations. As biogas consists of 50% carbon dioxide, its calorific value is much lower than that of biogas that has been upgraded to natural gas quality. Therefore the production cost is expressed in €ct per Nm^3 natural gas equivalent (standard quality). This way the data are made comparable to the production cost of green gas. The base rate for crude biogas must be considered in the light of possible support for installations that are linked to the green gas hub.

8.2 Landfill gas/waste water treatment plants

Description of reference installation

The reference system for this category has a crude biogas production of 150 NM^3/h (or 80 Nm^3/h green GAS). That is comparable to a CHP capacity of 300 kW_e, which makes the reference consistent with the reference in the advice for renewable electricity for these categories.

Based on the cost indications and technical considerations (see Van Tilburg *et al.,* 2008a) membrane separation was selected as the reference technology for gas purification in landfill gas. This is a proven technology. This installation does not require heat and the required electricity is taken from the grid. Gas scrubbing is the reference technology for gas purification in water treatment plants. The heat that is required for this technique is generated by firing part of the crude biogas in a boiler. The residual heat that is released in this process can be used for covering part of the heat demand of the digester. The required electricity is obtained from the grid.

Tables 8.1a and 8.1b show the techno-economic parameters for landfill gas and water treatment plants.

Table 8.1a *Technical economical parameters for landfill gas (biogas)*

		Draft advice 2011		Final advice 2010	
		Green gas	Crude biogas	Green gas	Crude biogas
Reference volume	[Nm^3/h biogas]	150	150	150	150
Full load hours	[hour/year]	6500	6500	6500	6500
Digestion part:					
Investment cost	[Nm^3/h biogas]	-	-	-	-
Fixed O&M costs	[Nm^3/h biogas]	-	-	-	-
Energetic efficiency digester	[%]	100	100	100	100
Energy content substrate mix	[GJ/tonne]	3	3	3	3
Feedstock costs	[€/tonne]	0	0	0	0
Green gas production:					
Investment cost	[Nm^3/h biogas]	5350	1400	5350	1400
Fixed O&M costs	[Nm^3/h biogas]	360	140	360	140
Methane efficiency gas purification	[%]	80	-	80	-
Electricity and heat generation					
Heat demand (biogas use)	[%]	-	-	-	-
Electricity demand (gas scrubbing)	[kWh/Nm^3 biogas]	0.15	0.05	0.15	0.05
Electricity tariff	[€/kWh]	0.14	0.14	0.14	0.14

Table 8.1b *Technical economical parameters for WWTP (biogas)*

		Draft advice 2011		Final advice 2010	
		Green gas	Crude bio-gas	Green gas	Crude bio-gas
Reference volume	[Nm^3/h biogas]	150	150	150	150
Full load hours	[hour/year]	8000	8000	8000	8000
Digestion part:					
Investment cost	[€/Nm^3/h biogas]	-	-	-	-
Fixed O&M costs	[€/Nm^3/h biogas]	-	-	-	-
Energetic efficiency digester	[%]	67	67	67	67
Energy content substrate mix	[GJ/tonne]	22	22	22	22
Feedstock costs	[€/tonne]	0	0	0	0
Green gas production:					
Investment cost	[€/Nm^3/h biogas]	6390	700	6390	700
Fixed O&M costs	[€/Nm^3/h biogas]	430	50	430	50
Methane efficiency gas purification	[%]	99.9	-	99.9	-
Electricity and heat generation					
Heat demand (biogas use)	[%]	15	10	15	10
Electricity demand (gas scrubbing)	[kWh/Nm^3 biogas]	0.13	0.02	0.13	0.02
Electricity tariff	[€/kWh]	0.14	0.14	0.14	0.14

8.3 Manure co-digestion

Description of reference installation

Based on the scale-size of new initiatives the production capacity of new installations has been projected at 900 Nm^3/h of crude biogas (or 500 Nm^3/h green gas). The size of the digester of an installation of this capacity is comparable to a digester of a bio-CHP plant of 2 MW_e. Scale effects appear to be limited for digesters. The maximum size of a digester tank is limited because the material must be homogenised; the diameter of the roof of a digester is also bound to a maximum value. Therefore several tanks are often placed next to each other.

The reference gas purification technique is gas scrubbing. The heat that is required for this technique is generated by firing part of the crude biogas in a boiler. The residual heat released during gas scrubbing is sufficient to heat the digester. The required electricity is obtained from the grid. Gas separation and upgrading can bring benefits of scale compared to the current reference scales for green gas production.

Additional comments

It is assumed that the produced green gas can be fed into the local grid. See Table 8.2 for an overview of the techno-economic parameters.

Table 8.1 *Techno-economic parameters manure co-digestion (biogas)*

		Draft advice 2011		Final advice 2010	
		Green gas	Crude biogas	Green gas	Crude biogas
Reference size	[Nm^3/h biogas]	900	900	270	270
Full load hours	[hour/year]	8000	8000	8000	8000
Digestion part:					
Investment cost	[€/Nm^3/h biogas]	3980	3980	4490	4490
Fixed O&M costs	[€/Nm^3/h biogas]	225	225	295	295
Energetic efficiency digester	[%]	67	67	67	67
Energy content substrate mix	[GJ/tonne]	2.9	2.9	2.9	2.9
Feedstock costs	[€/tonne]	18	18	19	19
Green gas production:					
Investment cost	[€/Nm^3/h biogas]	2400	280	3880	450
Fixed O&M costs	[€/Nm^3/h biogas]	240	26	385	45
Methane efficiency gas purification	[%]	99.9	-	99.9	-
Electricity and heat generation					
Heat demand (biogas use)	[%]	10	5	10	5
Electricity demand (digester and gas purification)	[kWh/Nm^3 biogas]	0.25	0.12	0.25	0.12
Electricity tariff	[€/kWh]	0.14	0.14	0.14	0.14

8.4 VFG digestion

Description of reference installation

The reference installation is assumed to have a crude biogas production of 550 Nm^3/h or 305 Nm^3/h of green gas (comparable to a CHP of 1.2 MW_e). The starting point is that the VFG is composted. Only additional investments and annual additional costs of digestion compared to composting of VFG are included in the calculation of the base rate. The feedstock cost is therefore nil by definition.

Additional comments

It is assumed that the produced green gas can be fed into the local grid. See Table 8.3 for an overview of the techno-economic parameters.

Table 8.2 *Techno-economic parameters VGF digestion (biogas)*

		Draft advice 2011		Final advice 2010	
		Green gas	Crude biogas	Green gas	Crude biogas
Reference size	[Nm^3/h biogas]	550	550	225	225
Full load hours	[hour/year]	8000	8000	8000	8000
Digestion part:					
Investment cost	[€/Nm^3/h biogas]	7130	7130	7800	7800
Fixed O&M costs	[€/Nm^3/h biogas]	815	815	890	890
Energetic efficiency digester	[%]	67	67	67	67
Energy content substrate mix	[GJ/tonne]	2.5	2.5	2.5	2.5
Feedstock costs	[€/tonne]	0	0	0	0
Green gas production:					
Investment cost	[€/Nm^3/h biogas]	3700	420	5300	600
Fixed O&M costs	[€/Nm^3/h biogas]	290	38	410	50
Methane efficiency gas purification	[%]	99.9	-	99.9	-
Electricity and heat generation					
Heat demand (biogas use)	[%]	10	5	10	5
Electricity demand (digester and gas purification)	[kWh/Nm^3 biogas]	0.25	0.12	0.25	0.12
Electricity tariff	[€/kWh]	0.14	0.14	0.14	0.14

8.5 Other digestion

Description of reference installation

The reference technique for this category is a mono-digester with residual flows from the food and feeds industry with a production capacity of crude biogas of 950 Nm^3/h. The size of such installations is comparable to a bio-CHP of 2 MW_e. The produced biogas is upgraded to green gas by means of gas scrubbing technology. Calculations are based on a feedstock price of 23 €/tonne. The energy content of the substrate is 5 GJ/tonne, see also Section 6.4.

Additional comments

The fact that the produced green gas can be used within the company is not taken into account in this advice. After all, the SDE scheme is based on a subsidy for feeding back into the grid. Internal use is therefore not included in the advice on the base rate. Particularly green gas can offer significant technical benefits for internal use. In case of direct use the biogas often need not be purified to natural gas quality, but can be used directly, for example for underfiring in a steam boiler. Additional costs, for example for adjusting gas burners to make them suitable for firing crude biogas, also need to be taken into account. But these costs are expected to be relatively low. See Table 8.4 for an overview of the techno-economic parameters.

Table 8.3 *Techno-economic parameters other digestion (biogas)*

		Draft advice 2011		Final advice 2010	
		Green gas	Crude biogas	Green gas	Crude biogas
Reference size	[Nm^3/h biogas]	950	950	950	950
Full load hours	[hour/year]	8000	8000	8000	8000
Digestion part:					
Investment cost	[€/Nm^3/h biogas]	3900	3900	4500	4500
Fixed O&M costs	[€/Nm^3/h biogas]	220	220	250	250
Energetic efficiency digester	[%]	67	67	67	67
Energy content substrate mix	[GJ/tonne]	5	5	5	5
Feedstock costs	[€/tonne]	23	23	27	27
Green gas production:					
Investment cost	[€/Nm^3/h biogas]	2400	275	3000	350
Fixed O&M costs	[€/Nm^3/h biogas]	200	25	250	30
Methane efficiency gas purification	[%]	99.9	-	99.9	-
Electricity and heat generation					
Heat demand (biogas use)	[%]	10	5	10	5
Electricity demand (digester and gas purification)	[kWh/Nm^3 biogas]	0.25	0.12	0.25	0.12
Electricity tariff	[€/kWh]	0.14	0.14	0.14	0.14

9. Advised base rates

Chapter 7 and 8 provide an overview of the techno-economic parameters for electricity and green gas. Chapter 5 provides an overview of the financial parameters. Together with the calculation method of a stylised cash flow model, the production costs can be calculated from these data. Details of the calculation method can be found in the cash flow models that are available on the ECN internet site.

To arrive at the base rates, several scheme-specific costs are added to the production cost. These are the transaction costs that arise from trading electricity on the APX market and the price floor premium. The price floor premium can be considered an insurance premium for covering low electricity prices. If the annual average electricity price drops below the price floor, the SDE payments do not cover the entire unprofitable gap. The price floor premium depends partly on the flexibility of electricity production and the difference between the production costs in the category and the long-term electricity price.

Costs for feeding green gas into the natural gas grid are charged by means of contract costs. The base rate is increased with a surplus corresponding to the mentioned contract costs. The production cost of green gas and crude biogas and the base rate for green gas are expressed in Nm^3 natural gas equivalents, calculating with an energy content (*LHV*) of 31,65 MJ/m^3. This value can be used to calculate the base rates into €ct/GJ. The correction rates are based on the prices of G+ gas. The *Wobbe Index*[6] of G+ gas is approximately 1% higher than G-gas that corresponds to the assumed natural gas equivalents.

See Table 9.1 for the resulting base rates for electricity and Table 9.2 for the base rates for green gas.

[6] The Wobbe Index is a measure for the energy content , see (N.V. Nederlandse Gasunie, 1988).

Table 7.1 *Breakdown of base rates for 2010 (electricity)*

	Subsidy duration [year]	Production costs [€ct/kWh]	Transaction costs [€ct/kWh]	Basic rate premium [€ct/kWh]	**Base rate [€ct/kWh] Draft advice 2011**	Base rate [€ct/kWh] Final advice 2010
Wind energy						
Onshore wind < 6 MW	15	9.32	0.09	0.20	**9.6**	9.6
Onshore wind ≥6 MW	15	9.33	0.09	0.20	**9.6**	-
Digestion options						
Landfill gas	12	8.22	0.09	0	**8.3**	8.3
WWTP	12	5.91	0.09	0	**6.0**	6.0
Manure co-digestion	12	16.68	0.09	0.25	**17.0**	18.3
VFG digestion	12	12.73	0.09	0.25	**13.1**	13.4
Other digestion	12	14.28	0.09	0.25	**14.6**	15.8
Thermal conversion of biomass						
Solid biomass <10 MW_e	12	20.72	0.09	0.25	**21.1**	19.8
Solid biomass 10-50 MW_e	12	11.66	0.09	0.25	**12.0**	12.1
Liquid biomass <10 MW_e	12	17.25	0.09	0	**17.3**	15.7
Liquid biomass 10-50 MW_e						12.3
Waste incineration plants						
Standard efficiency	15	5.11	0.09	0	**5.2**	5.2
Increased efficiency	15	5.52	0.09	0	**5.6**	5.6
High efficiency	15	6.12	0.09	0	**6.2**	6.2
Hydropower						
Height of the fall < 5 metres	15	11.88	0.09	0.25	**12.2**	12.3
Height of the fall ≥5 metres	15	6.89	0.09	0.15	**7.1**	7.2
Free tidal current energy	15	33.65	0.09	0.25	**34.0**	-
Solar PV						
1-15 kW_p	15	31.80	0	0	**31.8**	47.4
15-100 kW	15	26.45	0.09	0.25	**26.8**	43.0

Table 7.2 *Breakdown of base rates for 2011 (green gas)*

	Subsidy duration [year]	Production costs [€ct/ Nm^3]	Contract costs [€ct/ Nm^3]	**Base rate [€ct/ Nm^3] Draft advice 2011**	Base rate [€ct/ Nm^3] Final advice 2010	Production costs crude biogas [€ct/ Nm^3 a.e.]
Landfill gas	12	36.1	1.0	**37.1**	37.1	9.0
WWTP	12	27.7	1.0	**28.7**	28.7	3.2
Manure co-digestion	12	69.5	1.8	**71.3**	83.1	53.9
VFG digestion	12	61.9	1.8	**63.7**	73.8	43.3
Other digestion	12	59.1	1.8	**60.9**	74.1	44.9

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List of abbreviations

a.e.	Natural Gas equivalent
AVI	Waste incineration plant
BAT	Best Available Technique
BEMS	Decree on emission regulation mid-sized combustion plants
BoS	Balance of System
BREF	BAT-Reference
BVA	Decree on waste incineration
CHP	Combined Heat and Power
EB	Energy Tax
GFT	Vegetable, fruit and garden waste
O&M	Operation and Maintenance.
ORC	Organic Rankine Cycle.
SDE	Decree on incentives for renewable energy production
VAT	Value Added Tax (turnover tax)
WACC	Weighted Average Cost of Capital.
WWTP	Waste water treatment plant