Final advice on base rates SDE+ 2017

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Abstract

ECN and DNV GL have been commissioned by the Ministry of Economic Affairs to study the cost of renewable energy production. This cost assessment for various categories is part of the advice on the subsidy base rates for the SDE+ feed-in support scheme. A draft version of this advice has been discussed with the market in an open consultation round. This report contains the final advice on the cost of projects in the Netherlands targeted for realisation in 2017, covering installation technologies for the production of renewable electricity, renewable gas and renewable heat.

Contents

Executive Summary

The Dutch Ministry of Economic Affairs asked ECN and DNV GL to issue advice on the base rates for the SDE+ 2017 scheme. This report contains the Final Advice on the recommended base rates that have been determined following the consultation of market parties. For geothermal, the advice was provided by ECN, DNV GL and TNO.

The base rates have been calculated so as to be sufficient for the majority of the projects in the relevant category. However, due to project-specific circumstances, the implementation of some initiatives may turn out to be unprofitable despite the SDE+ allowance.

The resulting SDE+ 2017 base rates for the different categories are shown in Table 1 to Table 6. The designations E, G, H and CHP indicate which category is referred to, i.e. renewable electricity, gas, heat or combined heat and power plants. For comparison, the base rates from the SDE+ 2016 Base Rates and Final Advice[1] have also been included in the table. Base rates higher than 0.200 €/kWh have been calculated indicatively and are denoted as > 0.200 €/kWh.

The Ministry of Economic Affairs has asked for a calculation of the base rates for biomass categories for additional parameters. These parameters concern the biomass rates to be used and possibly a maximum rate of compensation for electricity production from a bio-CHP. Chapter 11 addresses these parameters in more detail and presents the resulting base rates.

[1] https://www.ecn.nl/publicaties/ECN-E--15-052.

Table 1: Advised base rates for SDE+ 2017: hydro-electric, wind and solar energy (amounts in €/kWh)[2]

Category	Energy carrier	Advised base rate for SDE+ 2017	Full load hours	Advised base rate for SDE+ 2016 (full load hours*)
Hydropower, height of fall ≥ 50 cm	E	0.156	5,700	0.173
Hydropower, height of fall ≥ 50 cm, renovation	E	0.100	2,600	0.108
Free tidal current energy, height of fall < 50 cm	E	0.192	3,700	>0.200
Osmosis	E	>0.200	8,000	>0.200
Photovoltaic solar panels, ≥ 15 kW_p and connection >3*80A	E	0.125	950	0.128
Solar thermal, aperture area ≥ 200 m^2 of > 140 kW	H	0.095	700	0.103
Onshore wind, ≥ 8 m/s	E	0.064	n/a	0.070
Onshore wind, ≥ 7.5 and < 8 m/s	E	0.070	n/a	0.076
Onshore wind, ≥ 7.0 and < 7.5 m/s	E	0.075	n/a	0.082
Onshore wind, < 7.0 m/s	E	0.085	n/a	0.093
Wind on primary water defences, ≥ 8 m/s	E	0.069	n/a	0.075
Wind on primary water defences, ≥ 7,5 and < 8 m/s	E	0.075	n/a	0.082
Wind on primary water defences, ≥ 7.0 and < 7.5 m/s	E	0.080	n/a	0.087
Wind on primary water defences, < 7.0 m/s	E	0.091	n/a	0.099
Wind on lake, water ≥ 1 km^2	E	0.104	n/a	0.114

* Full load hours shown if different from advice SDE+ 2017.

Table 2: Advised base rates for SDE+ 2017: geothermal energy (amounts in €/kWh)

Category	Energy carrier	Advised base rate for SDE+ 2017	Full load hours (power/heat)	Full load hours combined	Heat/power ratio	Advised base rate for SDE+ 2016 (full load hours*)
Geothermal heat, depth ≥ 500 metres	H	0.053	5,500	-	-	0.056
Geothermal heat, depth ≥ 3500 metres	H	0.057	7,000	-	-	0.062

* Full load hours shown if different from advice SDE+ 2017.

[2] No full load hours have been included for the categories relating to wind energy because the generic full load hours cap has been abolished since SDE+ 2015.

Table 3: Advised base rates for SDE+ 2017: water purification plants (amounts in €/kWh)

Category	Energy carrier	Advised base rate for SDE+ 2017	Full load hours (power/heat)	Full load hours combined	Heat/power ratio	Advised base rate for SDE+ 2016 (full load hours*)
Waste water treatment plant (WWTP) - thermophilic digestion of secondary sludge	CHP	0.048	8,000/4,000	5,729	0.66	0.060
WWTP - thermal pressure hydrolysis	E	0.084	8,000	-	-	0.093
WWTP (renewable gas)	G	0.031	8,000	-	-	0.032

* Full load hours shown if different from advice SDE+ 2017.

Table 4: Advised base rates for SDE+ 2017: incineration and gasification of biomass (amounts in €/kWh)**

Category	Energy carrier	Advised base rate for SDE+ 2017	Full load hours (power/heat)	Full load hours combined	Heat/power ratio	Advised base rate for SDE+ 2016 (full load hours*)
Biomass gasification (≥ 95% biogenic)	G	0.150	7,500	-	-	0.151
Existing capacity for direct and indirect co-firing	E	0.108	6,000/5,000	5,839	-	0.107
New capacity for direct co-firing	E	0.111	7,000	-	-	0.114
Boiler fired by solid or liquid biomass, 0.1-0.5 MW_{th}	H	0.057	3,000	-	-	-
Boiler fired by solid or liquid biomass, 0.5-5 MW_{th}	H	0.056	3,000	-	-	0.052 (4,000)
Boiler fired by solid or liquid biomass, ≥5 MW_{th}	H	0.044	7,000	-	-	0.043
Boiler fired by liquid biomass	H	0.070	7,000	-	-	0.071
Boiler fired by industrial steam from wood pellets	H	0.062	7,000	-	-	0.057
Thermal conversion of biomass, < 100 MW_e	CHP	0.062	8,000/5,000	7,500	8.00	0.077 (7,500/7,500)

* Full load hours shown if different from advice SDE+ 2017.

** See chapter 11 for base rates for additional parameters.

Table 5: Advised base rates for SDE+ 2017: digestion of biomass (amounts in €/kWh) **

Category	Energy carrier	Advised base rate for SDE+ 2017	Full load hours (power/heat)	Full load hours combined	Heat/power ratio	Advised base rate for SDE+ 2016 (full load hours*)
All-feedstock digestion (renewable gas)	G	0.061	8,000	-	-	0.060
Co-generation, all-feedstock digestion	CHP	0.069	8,000/7,000	7,436	1.13	0.087 (8,000 - 4,000)
Heat, all-feedstock digestion	H	0.062	7,000	-	-	0.060
Digestion and co-digestion of animal manure (renewable gas)	G	0.077	8,000	-	-	0.080
Co-generation, digestion and co-digestion of animal manure	CHP	0.090	8,000/7,000	7,433	1.15	0.121 8,000 / 4,000
Heat, digestion and co-digestion of animal manure	H	0.079	7,000	-	-	0.083
Digestion of more than 95% animal manure < 300 kW (renewable gas)	G	0.171	8,000	-	-	0.181
Co-generation, digestion of more than 95% animal manure < 300 kW	CHP	>0.200	8,000/1,000	5,200	0.08	>0.200 8,000 / 0
Heat, digestion of more than 95% animal manure < 300 kW	H	0.102	7,000	-	-	0.109 (8,000)

* Full load hours shown if different from advice SDE+ 2017.

** See chapter 11 for base rates for additional parameters.

Table 6: Advised base rates for SDE+ 2017: existing installations (amounts in €/kWh) **

Category	Energy carrier	Advised base rate for SDE+ 2017	Full load hours (power/heat)	Full load hours combined	Heat/power ratio	Advised base rate for SDE+ 2016 (full load hours*)
Extended lifespan all-feedstock digestion, co-generation	CHP	0.071	8,000/7,000	7,464	1.01	0.086 8,000 / 4,000
Extended lifespan co-generation, digestion and co-digestion of animal manure	CHP	0.082	8,000/7,000	7,464	1.01	0.108 (8,000/4,000)
Extended lifespan all-feedstock digestion (renewable gas)	G	0.058	8,000	-	-	0.059
Extended lifespan all-feedstock digestion (heat)	H	0.059	7,000	-	-	0.056
Extended lifespan digestion and co-digestion of animal manure (renewable gas)	G	0.066	8,000	-	-	0.071
Extended lifespan digestion and co-digestion of animal manure (heat)	H	0.069	7,000	-	-	0.071

* Full load hours shown if different from advice SDE+ 2017.

** See chapter 11 for base rates for additional parameters.

1 Introduction

ECN and DNV GL advise on the level of the base rates for the SDE+ 2017 scheme

The SDE+ in general

The Stimulation of Sustainable Energy Production scheme (SDE) is used by the Ministry of Economic Affairs to stimulate the production of renewable energy in the Netherlands. This scheme has been opened annually by the Ministry[3] since 2008 and is opened to applicants in phases, with the lowest cost technologies being eligible for subsidies first. The SDE+ scheme reimburses the difference between the *base rate* (the production costs of renewable electricity, renewable heat and renewable gas) on the one hand and the *correction amount* (the market price of renewable electricity, renewable heat or renewable gas) on the other hand. For each technology, a *base price for energy* is also set. This represents the lower limit for the correction amount. For more details of the scheme and terms used, see Appendix C.

Research assignment

The Ministry asked the Energy research Centre of the Netherlands (ECN) and DNV GL for advice on the level of the base rates for the SDE+ scheme for 2017. ECN and DNV GL advise the Ministry on the level of the base rates for the categories prescribed by the Ministry. Ultimately, the Minister of Economic Affairs decides on the opening of the SDE+ scheme in 2017, which categories will be opened and the base rates for new SDE+ allowances in 2017.

In consultation with the Ministry it was decided to present a draft advice to the market. A round of consultations took place in June 2016. This report contains the Final Advice on the recommended base rates that have been determined after consultation with market parties and in coordination with the Ministry in the summer period. ECN and DNV GL explain in the *Consultatiedocument Basisbedragen SDE+ 2017* (Consultation Document on Base Rates SDE+ 2017) (ECN-E--16-030) how they dealt with the reactions from the market consultations.

[3] The implementation of the SDE+ scheme is the responsibility of the Netherlands Enterprise Agency (RVO). For more information about the SDE+ scheme itself, see http://www.rvo.nl/subsidies-regelingen/stimulering-duurzame-energieproductie-sde.

Structure of this report

Chapter 2 describes the process of creating this report and the general principles. The findings are then detailed for hydroelectric power (Chapter 3), solar energy (Chapter 4), wind energy (Chapter 5), geothermal energy (Chapter 6), water purification (Chapter 7), thermal conversion of biomass (Chapter 8), digestion (Chapter 9) and existing installations for digestion and thermal conversion (Chapter 10). Each category in the SDE+ has its own section setting out the technical and economic parameters. Chapter 11 ends with conclusions which are translated to base rates.

This report includes the 2017 base rates and the calculation method for the 2017 provisional correction amounts for each category. Appendix B includes an overview of all categories and the accompanying 2017 base prices and 2017 provisional correction amounts. The base rates are explained in more detail in the report *Basisprijzen SDE+ 2017* (Base prices for SDE+ 2017) (Kraan and Lensink, 2016), while the calculations for the correction amounts are in the report *Correctiebedragen t.b.v. bevoorschotting 2017 (SDE+)* (Correction amounts for advances for 2017 [SDE+]) (Lensink, 2016).

2

Frameworks

This chapter describes the process followed and the working method used in section 2.1. The general and financial starting points for this advice are discussed in sections 2.2 and 2.3.

2.1 Process and working method

Process

On 1 June 2016, a draft advice on the SDE+ base rates was presented for the purpose of a public market consultation. To this end, an information meeting was held for sector organisations at the Ministry of Economic Affairs. Market parties were invited to submit their responses to this draft report to the Energy research Centre of the Netherlands (ECN). Approximately 40 consultation discussions were held in response to the reactions received.

This report by ECN and DNV GL contains the Final Advice on the recommended base rates that have been determined after consultation with market parties and in coordination with the Ministry during the summer period. The advice for geothermal energy was drawn up by ECN, DNV GL and TNO. In the *Consultatiedocument Basisbedragen SDE+ 2017* (Consultation Document on Base Rates SDE+ 2017) (ECN-E--16-030), ECN and DNV GL explain how they dealt with the reactions from the market consultations. This consultation document was used when compiling this Final Advice.

Fraunhofer ISI, Karlsruhe has performed an external review of this Final Advice. The authors would like to thank Mr M. Ragwitz and Mr G. Resch, and their colleagues for their valuable comments. The review is included in Appendix D. ECN and DNV GL respond to the review commentary in the afterword.

Working method

The advised base rates comprise the production costs of renewable energy carriers plus any scheme-specific additional costs related to the signing of electricity, heat or gas contracts. The Ministry defined the categories in its original request for advice. For all categories, ECN and DNV GL have calculated the production costs of renewable electricity, renewable gas or renewable heat. The Minister of Economic Affairs makes the final decision on when categories are opened. Neither the inclusion nor the absence of a category in this report may be interpreted as a recommendation for a potential opening.

2.2 General starting points

Legislative and regulatory framework

The starting points for the calculation of the base rates were determined in discussions between the Ministry, ECN and DNV GL. The effectiveness and efficiency of the SDE+ incentive scheme were taken into account. The SDE+ allowances, and hence the base rates, must be high enough to enable production of renewable electricity, renewable heat and renewable gas, but need not be sufficient for all planned projects. The rule of thumb is that the majority of the projects in each category should be able to proceed with these base rates.

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Existing laws and regulations must be taken into account when calculating the production costs, insofar as these apply generally in the Netherlands. The advice is thus based on policy that will be in force in 2017, in accordance with decisions taken up to this point. The production costs relate to projects that are eligible for SDE+ in 2017 and can begin as construction projects in 2017 or early 2018. The Ministry ensures that the calculated production costs comply with the provisions of the European Commission on state subsidies.

Reference installation and system delineation

ECN and DNV GL have defined a reference installation for each category. The reference installation consists of a particular technology or combination of technologies combined with a typical number of full load hours. A reference fuel or substrate is included for bio-energy categories. In the opinion of ECN and DNV GL, the reference installation has a typical configuration for new projects in the category to be investigated. The technical-economic parameters are quantified for the defined biomass-technology combinations. Based on these parameters, the production costs and base rates are calculated with the help of a simplified cash flow model, which can be consulted on the ECN website[4].

The SDE+ scheme reimburses the difference between the correction amount and the base rate. The correction amount is a measure of the market price of the renewable electricity, heat or gas. The base rate is a measure of the production costs of renewable electricity, renewable heat and renewable gas. The production costs are the (additional) costs involved in generating renewable energy.

[4] https://www.ecn.nl/nl/samenwerking/sde/.

The definition of 'additional costs,' i.e. the system boundary, can significantly influence the calculated biomass costs, especially in systems that derive the biomass from waste flows or residual products. In these systems, calculations are made of the additional costs of utilising these flows or products for the production of renewable electricity or renewable gas. Biomass costs are based on the prices that need to be paid to get the biomass delivered to the installation. Additional costs are determined by calculating the difference between the biomass prices referred to above and the price of biomass if it were not used for the production of renewable electricity, renewable heat or renewable gas. All prices stated in this report exclude VAT.

A heat grid is not included in the costs eligible for subsidy, but heat transport pipes are included.

For renewable heat categories, the costs relating to the production of renewable heat are considered for subsidy. The cost of an optional heat distribution pipe is regarded as part of the project investment costs. The heat infrastructure on the demand side, such as a heat grid, is not part of the costs eligible for subsidy. The heat production considered in this advice relates to the heat throughput directly behind the gate of the installation, but before the heat distribution pipe. This means that an SDE+ allowance may also apply to internal use of renewable energy, as long as it is not intended for the production process itself.

A new Ministerial Decree on Gas Quality (*Ministeriële Regeling Gaskwaliteit*) was published in July 2014. For the purpose of the investment and O&M costs of gas upgrading, the extra gas analyses that have been necessary since 1 October 2014 to comply with this Ministerial Decree on Gas Quality have been taken into account for new projects.

2.3 Financial frameworks

The financing of renewable energy projects fluctuates. Not only do the renewable energy technologies change as a result of learning and innovation, but practical experience can also cause the perceived risk of projects to change. In principle, higher risk means higher capital costs. The cost of attracting loan capital is moreover subject to increased economic fluctuations over which the renewable energy sector has no control.

The financial parameters that are used to calculate the base rates are shown in Table 7 and explained further in the text below. In the opinion of ECN and DNV GL, the results of these parameters provide a general picture of the capital costs of SDE+ projects. This does not mean that SDE+ projects cannot be financed differently in practice.

Table 7: Financial parameters used for SDE+ 2017

Financial parameter	Value used	Explanations
Interest with green funding	2.0 %	Solar PV, solar thermal, geothermal, gasification, hydropower
Interest without green funding	2.5 %	Other categories
Ratio of loan capital (LC)/equity (E)	80% LC / 20% E	Solar PV, onshore wind, wind on dyke
	75 % LC / 25 % E	Wind on lake
	70 % LC / 30 % E	Other categories
Return on equity	14.5 %	Categories with a high risk profile
	11.5 %	Other categories
Inflation in biomass prices and O&M costs	1.5% / year	

Interest

Project interest rates usually comprise three separate components: the Euribor interest, a commercial interest margin and an interest rate swap to convert the interest margin into a 10-year interest rate (for example based on 10-year IRS). The developments on the financial market are such that projects for renewable energy can acquire capital at considerably more favourable rates than in the past. Whereas last year ECN and DNV GL followed the fall in interest rates with caution because there were signs that they would start to rise, market consultation for this year seems to indicate that the costs of capital will remain lower than in previous years. The commercial interest margins are just under 2%, (and widely spread), which means that an interest rate of approximately 2.5% for loans for many projects is achievable. Green funding offers the project developer a discount of approximately 0.5 %.

This yields a 2.5% interest rate on loans for projects without green funding. For projects with green funding, a 0.5% reduction has been assumed, bringing down the effective interest rate to 2.0%. The market consultation has revealed that there are indeed opportunities to utilise the benefits of green funding for new projects. This also applies to most smaller wind projects. The market consultation reveals a mixed picture regarding the use of green funding for large wind projects.

Ratio of loan capital/equity

Financial institutions are demanding a larger contribution in terms of equity than in the years before the crisis. This increased contribution is not due to the method of risk assessment for the renewable energy projects itself, but rather a policy on risk exposure. The equity shares seen in sustainable energy projects in the Netherlands, which have recently been financed or for which finance has recently been agreed, range from 10% to just over 40%. A target value of 30% equity has been used in the calculations, except for the wind energy and solar PV categories, for which the market consultation has revealed that 20% equity is a typical value for financing.

Return on equity

The required return on equity is affected by the yields from alternative capital expenditure. The fall in inflation also has an impact on the required nominal return. In

The apportionment of risks and returns between the lender and project developer has no bearing on the base rates.

this Advice, the nominal returns have been adjusted in line with an expected inflation rate of 1.5%. The return on equity used for calculation purposes has therefore been lowered from 12% to a nominal 11.5%. For a few categories with a significantly higher operational or regulation-based risk, the return on equity has been lowered from 15% to 14.5%. These are projects for which it is difficult or impossible to conclude long-term biomass contracts, innovative categories and categories whose cash flow is less predictable, such as wind energy. The financial return must also cover the preparation costs. The preparation costs have not been included in the total investment amount.

Depreciation period

For biomass categories, a subsidy period of twelve years is assumed, compared to fifteen years for the other categories. The term of the loan and depreciation periods are assumed to be equal to the subsidy period. Any payments of the SDE+ allowance after twelve or fifteen years, as a consequence of any banking[5] in the SDE+, have not been included in the calculation. In practice, some of the components of particular technologies have a much longer lifespan than fifteen years. In such cases, their investment costs have been corrected for the remaining value of the components after fifteen years. In the case of project financing, the lender may want the loan to be repaid over a shorter period in practice, e.g. eleven or fourteen years. This offers the lender greater certainty that the loan will be repaid in full.

Capital costs

The total financial return is considered to be reasonable compensation for the total risk of the project. The manner in which the risks and returns are divided between the lender and the project developer has no bearing on the base rates advised under the stated research starting points. Table 8 shows the resulting capital costs (clustered categories) for each theme.

5 It is possible to transfer eligible production that has not been utilised to a subsequent year. This is known as 'banking'. After the regular subsidy period, the producer of renewable energy can be given one more year to make up for any production not utilised.

Table 8: Weighted average cost of capital (WACC) per theme for SDE+ 2017

Theme	Weighted average cost of capital (WACC) [nominal]	Weighted average cost of capital (WACC) [actual]
Photovoltaic solar panels	3.5 %	2.0 %
Onshore wind energy	4.4 %	2.9 %
Wind energy on interconnecting water defences	4.4 %	2.9 %
Hydropower	4.5 %	3.0 %
Free tidal current energy	4.5 %	3.0 %
Solar thermal	4.5 %	3.0 %
New or existing capacity for direct co-firing	4.8 %	3.3 %
Boiler fired by solid or liquid biomass	4.8 %	3.3 %
All-feedstock digestion	4.8 %	3.3 %
Digestion of more than 95% animal manure	4.8 %	3.3 %
WWTP	4.8 %	3.3 %
Wind energy on lake	5.0 %	3.5 %
Osmosis	5.4 %	3.9 %
Geothermal heat	5.4 %	3.9 %
Biomass gasification	5.4 %	3.9 %
Digestion and co-digestion of animal manure	5.7 %	4.2 %
Boiler fired by industrial steam from wood pellets	5.7 %	4.2 %
Thermal conversion of biomass	5.7 %	4.2 %

2.4 Scheme-specific deductions

The nature of the SDE+ scheme implies additional costs for project owners for the duration of the project. These additional costs arise due to choices as to how the SDE+ scheme is structured. For example, the SDE+ scheme basically covers price risks, provided that the parties sell their renewable energy on comparable exchanges. For electricity, this is the day-ahead market, whereas for gas it is the year-ahead market. The trading on these exchanges involves transaction costs, which are charged at 0.0007 €/kWh. This value is derived from trading on the APX. In addition, while the SDE+ scheme does remove the price risk of fluctuating gas and electricity prices, it does so only to a lower limit. If electricity or gas prices are very low, the SDE+ scheme will no longer compensate the full financial gap. Accordingly, the risk of very low energy prices lies with the projects themselves. The price of this risk, or the costs of insuring this risk within private energy sale contracts, is referred to in this report as the base price premium. As described in Kraan and Lensink, 2016, the basic rate premiums amount to 0.002 €/kWh for electricity options (including solar and wind) and 0.000 €/kWh for gas and heat. The costs for real constant are included in the O&M costs for the individual categories.

3

Hydropower findings

This chapter describes the findings for the following categories related to hydropower:

- Hydropower, height of fall ≥ 50 cm (3.1)
- Hydropower, height of fall ≥ 50 cm, renovation (3.2)
- Free tidal current energy, height of fall < 50 cm (3.3)
- Osmosis (3.4).

3.1 Hydropower, height of fall ≥ 50 cm

The Netherlands is a relatively flat country, which means that the fall of rivers in the Dutch delta is small. Nevertheless, existing civil works and engineering constructions in rivers can create sufficient heights of fall to be used for electricity generation in hydroelectric power stations. In practice, this generally ranges from three to six metres, but it can rise to eleven metres in exceptional situations, e.g. in a number of sluices.

Potential projects within the hydropower category are characterised by a wide range of investment costs and corresponding base rates. For this reason, the base rates in this advice report are based on specific projects, with the potential to implement the project as well as the costs of the project being decisive in being selected for a reference project. For the 'hydropower, height of fall ≥ 50 cm' category, the reference installation is based, as before, on a height of fall of less than five metres, as this would appear to apply to the majority of projects.

The base rate is above 15 €ct/kWh. The technical-economic parameters on which this base rate is based are provided in Table 9. These have not changed compared to the advice issued last year.

Table 9: Technical-economic parameters for Hydropower, height of fall ≥ 50 cm

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Installation size	[MW]	1.0	
Full load hours	[h/a]	5,700	
Investment costs	[€/kW$_e$]	8,000	€ 8.0 million
Fixed O&M costs	[€/kW$_e$/a]	100	€ 100,000 / year

Table 10 shows the base rate and several other subsidy parameters.

Table 10: Summary of subsidy parameters for Hydropower, height of fall ≥ 50 cm

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.156
Base price for SDE+ 2017	[€/kWh]	0.031
Provisional correction amount in 2017	[€/kWh]	0.032
Calculation method for correction amount	APX	

3.2 Hydropower, height of fall ≥ 50 cm, renovation

The cost of generating electricity from hydropower comprises not just the cost of the technical energy installation, but also additional provisions required by laws and regulations in the construction of a hydropower installation. This section 3.2 ‘Hydropower, height of fall ≥ 50 cm, renovation’, covers renovation work on existing hydropower installations, such as implementing fish protection measures, in order to comply with laws and regulations.

For the 'hydropower, height of fall ≥ 50 cm, renovation' category, it is assumed that for a reference installation, existing turbines will be replaced by models that are more fish-friendly. At present, an innovative fish-friendly turbine of this kind would appear to be the primary manner of meeting the stricter requirements in terms of fish kill. It is very likely that, during such a renovation, some or all of the electrical infrastructure such as the generator, transformers and controls, will need to be modified. It is assumed that there will be no required modifications to the civil engineering structures. The lower number of full load hours compared with the 'hydropower, height of fall ≥ 50 cm' category, is based on the number of full load hours of existing installations suitable for renovation.

The parameters for this category have not changed in relation to the final advice for SDE+ 2016. A summary of the technical-economic parameters for the reference installation is shown in Table 11.

Table 11: Technical-economic parameters for hydropower, height of fall ≥ 50 cm, renovation

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Installation size	[MW]	1.0	
Full load hours	[h/a]	2,600	
Investment costs	[€/kW$_e$]	1,600	€1.6 million
Fixed O&M costs	[€/kW$_e$/a]	80	€80,000 / year

Table 12 shows the base rate and several other subsidy parameters.

Table 12: Summary of subsidy parameters for hydropower, height of fall ≥ 50 cm, renovation

Hydropower, height of fall ≥ 50 cm, renovation	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.100
Base price for SDE+ 2017	[€/kWh]	0.031
Provisional correction amount in 2017	[€/kWh]	0.032
Calculation method for correction amount	APX	

3.3 Free tidal current energy, height of fall < 50 cm

In addition to building dams in rivers (as described in the section above 3.1 Hydropower, height of fall ≥ 50 cm and in section 3.2 Hydropower, height of fall ≥ 50 cm, renovation) to generate electricity from the fall created in the water flowing in one direction, it is also possible to generate energy in free tidal current. The 'free tidal current energy, height of fall < 50 cm' category is intended for methods such as energy from tidal currents/undercurrents and wave energy, whereby the energy generated is not so much the result of the fall, but rather of the current in the water. This also includes tidal currents from dam water with bidirectional generation (inshore free tidal current energy), if the height of fall is limited to less than half a metre.

The final advice is mainly based on inshore free tidal current energy: projects being realised in or close to engineering constructions such as sea defences or semi-permeable dams that use the existing tidal movement, because these have the greatest chance of realisation in the short term. For example, two permits have been issued for the Eastern Scheldt storm surge barrier based on utilisation of tidal energy from free tidal movement. In addition, there are plans to make the Brouwersdam permeable again because of the quality of the water in Lake Grevelingen. The possibility of adding a tidal power plant to the new construction is being examined.

The base rate for this category is just under 20 ct/kWh. Table 13 shows the technical and economic parameters used for energy from free tidal current. These have not changed compared to the final advice issued last year.

Table 13: Technical-economic parameters for free tidal current energy, height of fall < 50 cm

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Installation size	[MW]	1.5	
Full load hours	[h/a]	3,700	
Investment costs	[€/kW$_e$]	5,100	€7.7 million
Fixed O&M costs	[€/kW$_e$/a]	155	€233,000 / year

Table 14 shows the base rate and several other subsidy parameters.

Table 14: Summary of subsidy parameters for free tidal current energy, height of fall < 50 cm

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.192
Base price for SDE+ 2017	[€/kWh]	0.031
Provisional correction amount in 2017	[€/kWh]	0.032
Calculation method for correction amount	APX	

3.4 Osmosis

For this category, a base rate is calculated for an osmosis power plant, in which electricity is generated from the difference in the saline concentration of seawater and freshwater. This makes use of saline industrial process water or seawater. As the technology is still in the developmental stage, there is still much uncertainty about costs in this category. Given that there are still steps in innovation that must be completed before the technology can be used on a commercial scale, the top of this bandwidth has been chosen to calculate the base rate. The advised base rates from the SDE+ 2016 final advice have been adopted in their entirety and are therefore based on the same techno-economic parameter values.

Table 15 shows the techno-economic parameters for osmosis.

Table 15: Technical-economic parameters for osmosis

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Installation size	[MW]	1.0	
Full load hours	[h/a]	8,000	
Investment costs	[€/kW$_e$]	37,000	€37.0 million
Fixed O&M costs	[€/kW$_e$/a]	213	€213,000 / year

Table 16 shows the base rate and several other subsidy parameters.

Table 16: Summary of subsidy parameters for osmosis

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	> 0.200
Base price for SDE+ 2017	[€/kWh]	0.031
Provisional correction amount in 2017	[€/kWh]	0.032
Calculation method for correction amount	APX	

4

Solar energy findings

This chapter describes the findings for the following categories related to solar energy:

- Photovoltaic solar panels, ≥ 15 kWp and connection > 3x80A (4.1)
- Solar thermal, aperture area ≥ 200 m^2 or > 140 kW (4.2).

4.1 Photovoltaic solar panels, ≥ 15 kW_p and connection >3×80A

Reference installation

The reference installation for photovoltaic systems (PV systems) ≥ 15kWp is a 250-kilowatt peak (kWp) roof-based system, as described in the final advice for SDE+ 2016.

PV systems are modular in nature and as a result, can be set up in a wide range of system sizes, from a few kWp to several MWp. The total peak capacity depends on the capacity of each panel and the number of solar panels that are set up on the available area. The modular character of the technology allows for economies of scale in purchase and installation. However, the specific costs of installing larger PV systems (such as the costs of connecting to the network and building) play a greater role than for smaller systems. For the purposes of this advice, systems of 2 MWp and 5 MWp were analysed, and the results show no reason to split the solar PV category into two separate categories.

This advice assumes that a location is chosen in which panels can be set up in their optimum position, without negative production effects caused by shade, for example. This advice is therefore based on a system with an initial annual production of 990 kWh/kWp at the start of the project, as a typical average for current new systems. An annual decrease in capacity of 0.7% has also been factored in, with a sharper decrease in the first year of operation. This decrease in capacity has been incorporated into a decrease in the number of full load hours per year, resulting in a weighted yield of 950 kWh/kWp per year.

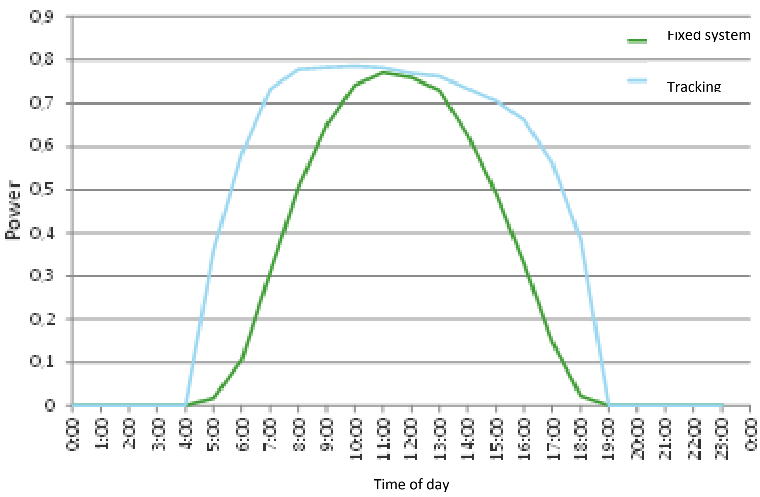
Field-based systems

The Netherlands is gradually gaining experience with large field-based systems, but the available data for these systems is still limited. This advice assumes that the selected reference installation is also representative for field-based systems. Compared to roof-based systems, field-based systems are associated with both cost benefits and drawbacks. As the area available for field-based systems is generally larger than for roof-based systems, field-based systems generally have a higher capacity and corresponding cost benefits. However, field-based systems sometimes have drawbacks due to additional costs for mounting, building costs, network connection, and security.

PV system on water

The technology that will enable PV systems to float on water is still being developed and the application is being tested at various locations in the Netherlands (and beyond). By using a simple solar tracking system, possibly in combination with double-sided solar panels and the possibility of lower effective temperatures, the yield could be up to 25% higher than that of standard field-based or roof-based systems with a fixed orientation. See Figure 1. A system with double-sided solar panels and a solar tracking system would cost more. In view of the innovative character of this technology, the as yet uncertain cost structure and the limited application in the Netherlands, the costs of this technology have not been quantified separately in this advice. To ensure that the number of full load hours for systems of this kind are not limited by the SDE+ scheme (which may influence design choices), a mark-up of approximately 25% is advised in relation to the maximum number of full load hours for systems with a fixed orientation. If floating PV systems are to compete optimally with regular PV systems in terms of kWh price, ECN and DNV GL advise setting the maximum number of full load hours eligible for subsidy for floating PV systems to 1190 full load hours.

Figure 1: Solar PV systems that track the sun can produce up to 25% more yield per year (single-axis tracking system). The figure shows that the additional yield compared to a south-facing fixed system is mainly generated in the morning and evening (figure represents a clear day in June).



Network connection

In the chosen reference case, it is assumed that the project can make use of an existing network connection and that no costs will be incurred for using the roof surface. For larger systems, there is not always a suitable connection directly in the building or on the site where the system is built. In these cases, it is assumed that a suitable connection is used in a neighbouring building. Where this is not the case, it will result in additional costs. Market consultation shows that these additional costs may be considerable for large systems in the Netherlands, although international experiences show a mixed picture. These costs have not been included in the base rate.

Price developments

To be granted a subsidy under the SDE+ 2017 scheme, the applicant must place the orders for the supply of components and for the construction of the production installation within one year after the decision. As the order process for solar PV systems has a limited throughput time, this calculation is based on the expected price level for orders placed in 2018.

The development of prices for PV systems in the years to come is uncertain. In 2011 and 2012, there was an extremely sharp fall in the price of PV modules, but since then prices have been decreasing more moderately. Recent information, partly from public sources and partly from the market consultation, was used to determine the current prices of modules and transformers. Based on the historic growth curve, a learning effect of approximately 19% may be assumed if the worldwide production of solar panels were doubled (Fraunhofer ISE, 2015). This learning curve based on capacity installed worldwide is used for the price projection of the module prices in 2018. The assumed cost reduction for transformers is slightly less (20%).

In mid-2013, the European Union agreed a minimum price and a maximum trading volume with Chinese PV manufacturers for solar panels from China. Parties that do not comply with this agreement will be subject to an anti-dumping import levy. Since the levy was introduced, the prices of modules from Europe and Japan have come ever closer to meeting the Chinese module prices. The minimum price was amended as of 1 April 2014 on the basis of price changes in the market from 0.56 €/Wp to 0.53 €/Wp. As of 1 April 2015, the minimum price was raised again to 0.56 €/Wp, owing to the weak euro. The European Commission started an evaluation on 5 December 2015. This process could take more than a year and the outcome is uncertain. In 2016, PV module prices worldwide varied from less than 0.5 €/Wp to more than 0.6 €/Wp. Taking these prices into account, for this SDE+ advice for 2017, a module price of 0.55 €/Wp has been set for 2016, whereby the learning effect will be applied to determine the price for 2018.

Prices of other components, such as transformers, have also fallen in recent years. The price of the transformer is highly dependent on the size of the system; for the chosen reference size, the price in 2018 is around 0.09 €/Wp. For the transformer, we see a learning effect of almost 20% each time capacity is doubled. The price of other components, such as mounting equipment, cabling and labour, is assumed to fall as a result of the increased efficiency of solar panels. In this draft advice, it is assumed that the prices of the different components will fall further along the learning curve compared to last year's advice. This means an annual price fall of approximately 6% for modules and transformers and almost 2.5% for installation equipment and labour costs.

Cost parameters

The total investment costs of roof-based turnkey systems with a size of approximately 250 kWp were approximately 1.1 €/Wp in 2015. Taking a modest further price fall and inflation into account, this advice assumes a price level of approximately 1.025 €/Wp, or 1025 €/kWp in 2018.

As a rule, a figure of between 1 to 2% of the investment sum is used for operating and management (O&M) costs. The advice assumes an amount of seventeen euros per kWp for O&M. This amount should cover all maintenance, cleaning, insurance of the installation, extension of the guarantee period of the transformer and the management and other operational costs of the installation. As stated above, building and security costs, possibly relevant for ground-based systems, have not been explicitly included. Costs related to the existing or future connection are assumed to remain constant.

The technical-economic parameters are summarised in Table 17.

Table 17: Technical-economic parameters for roof-based solar PV

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Installation size	[MW_p]	0.25	
Full load hours	[MWh/MW_p per year]	950 (1190 for floating PV)	
Investment costs	[$€/kW_e$]	1,025	€ 256,250
Fixed O&M costs	[$€/kW_e/a$]	17	€4,250 / year

Table 18 shows the base rate and several other subsidy parameters. The base rate has been calculated using expected electricity prices (basic load), with an allowance also being made for profile and imbalance costs.

Table 18: Summary of subsidy parameters for photovoltaic solar panels, ≥ 15 kWp and connection >3x80A

	Unit	SDE+ 2017 advice
Base rate	[€/kWh]	0.125
Base price for SDE+ 2017	[€/kWh]	0.026
Provisional correction amount in 2017	[€/kWh]	0.033
Calculation method for correction amount	APX x "profile and imbalance factor"	

4.2 Solar thermal, aperture area 200 m² or ≥ 140 kW

An aperture area of 200 m^2 is the lower limit of the system size for solar thermal systems for SDE+. Systems below this lower limit may be eligible for an investment grant via the ISDE. The SDE+ encourages renewable energy production via an annual production allowance in euros per kWh of heat; the ISDE awards a one-off grant depending on the annual yield of the solar boiler system. The 200 m^2-limit must be identical in both schemes so that subsidy is available in all cases and there is no overlap between the schemes.

For the SDE+, the 'solar thermal' category is based on a thermal system for hot tap water for large-scale consumers, equipped with covered (through a transparent layer) solar collectors. Systems that use solar thermal collectors solely for regenerating thermal energy storage are not the intended recipients of subsidy from the SDE+. This is why uncovered collectors are not eligible.

For the SDE+ 2017 final advice, the idea of defining new categories for solar thermal was explored, and/or adjusting the minimal surface area requirement for certain types of collector (particularly evacuated tube collectors with a relatively small aperture area in relation to the gross dimensions). This analysis did not give rise to any changes in the categories or the surface area requirement. In the opinion of ECN and DNV GL, the ISDE/SDE+ pairing is in principle a coherent and solid incentive package for renewable heat from solar thermal collectors.

Some high-yield collectors (such as evacuated tube collectors or sheet collectors) may be at a disadvantage because the production being subsidised can exceed the maximum number of claimable full load hours, i.e. 700 kWh/kW. As of 1 January 2015, the SDE+ allows over-production in one year (to a maximum of 25% of the maximum annual production being subsidised, i.e. 175 kWh/kW in the case of solar thermal) to be entered for the next year (backward banking), if the annual production being subsidised in that year has not already been achieved. Compensating under-production through forward banking has been possible for some time now. After the regular subsidy period of 15 years, producers of solar heat are given one more year to make up for any production not utilised. These mechanisms provide an extra safeguard to ensure that the intended annual production being subsidised can be claimed for the entire duration of the project, but is not a solution for collector systems that are structurally more efficient. Over-production can be restricted through choices in the design of solar thermal systems; in general, the number of full load hours for hot tap water systems decreases as the coverage ratio increases. In other words: with a low solar coverage ratio, the number of full load hours is rather a limiting factor; the SDE+ serves as an incentive to opt for a higher coverage ratio.

Table 19 shows the technical-economic parameters for a system with a 200 m^2 collector surface area or 140 kW, which is substantively unchanged in relation to last year.

Table 19: Technical-economic parameters for energy from solar thermal, aperture area of 200 m^2 or ≥ 140 kW

Parameter	Unit	Advice for 2017	Total amount for reference
Installation size	[MW]	0.14	
Full load hours	[h/a]	700	
Investment costs	[€/kW_{th_output}]	600	€ 84 thousand
Fixed O&M costs	[€/$kW_{th\_output/a}$]	1.9	€268 / year

Table 20 shows the base rate and several other subsidy parameters.

Table 20: Summary of subsidy parameters for solar thermal, aperture area of ≥ 200 m^2 or > 140 kW

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.095
Base price for SDE+ 2017	[€/kWh]	0.028
Provisional correction amount in 2017	[€/kWh]	0.029
Calculation method for correction amount	(TTF [Title Transfer Facility] + energy load)/gas boiler efficiency	

5
Wind energy findings

This chapter describes the findings for the following categories related to wind energy:

- Onshore wind (5.1)
- Wind on primary water defences (5.2)
- Wind on lake, water ≥ 1 km^2 (5.3).

5.1 Onshore wind

5.1.1 Starting points and calculation method

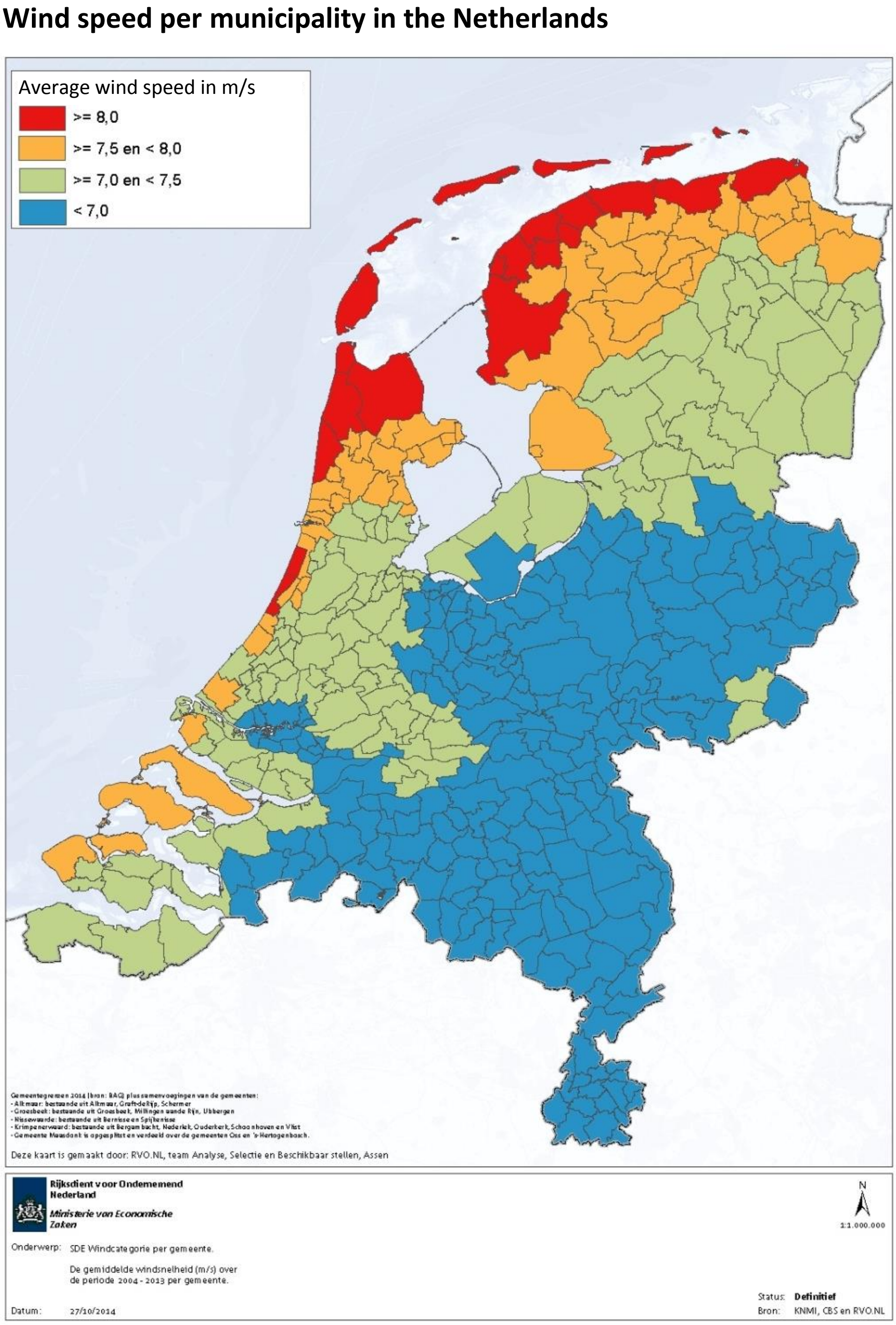
The Ministry's starting points

The Ministry of Economic Affairs has issued the following general starting points for the SDE+ 2017 in respect of the categories related to wind energy:

- Wind differentiation according to municipal boundaries, as introduced for the SDE+ 2015;
- No generic full load hours cap;
- A further 10% reduction in land costs compared to last year's advice SDE+ 2016;
- Participation costs and preparation costs are not included in the calculation of the base rate.

The wind differentiation is based on the wind map generated for the SDE+ by KNMI in 2014 (Geertsema and Van den Brink, 2014). Based on The Royal Netherlands Meteorological Institute's (KNMI) wind map, four wind speed categories have been defined for municipalities, as shown in Figure 2.

Figure 2: Classification of municipalities according to wind speed[6]



Source: KNMI, Statistics Netherlands, Netherlands Enterprise Agency (2014).

6 *Exception: Division of Rotterdam municipality*
Based on large differences in wind speeds for Rotterdam municipality, ECN and DNV GL advise making an exception and dividing this municipality into two areas on the basis of municipal district numbers: A) municipal districts 1323, 1318 and 1327; B) other municipal districts in Rotterdam.

Table 21: Definition of wind speed categories for wind energy

Category	Wind speed at 100 metres [m/s]
I	≥ 8.0
II	7.5 - 8.0
III	7.0 - 7.5
IV	< 7.0

Calculation method and assumptions

Different starting points have been used and assumptions made for the wind energy calculations for the SDE+ 2017. The resulting technical-economic parameters are shown in Table 22. The parameters are explained further in the text below.

Table 22: Technical-economic parameters for wind energy on land

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Size of the reference wind farm	[MW]	50.0	
Investment costs	[€/kW$_e$]	1,290	€ 64.5 million
Fixed O&M costs	[€/kW$_e$/a]	12.4	620,000 euros/year
Variable O&M costs	[€/kWh]	0.0166	

General starting points

Similar to last year, an average-sized wind farm of 50 MW has been assumed for all four wind speed categories for the onshore wind calculations. ECN and DNV GL calculated a reference size, representative of both the smaller wind farms (15MW) and the large-scale RCR projects (>100MW).

Investment costs: turbine prices and additional costs

In order to determine the base rates for the onshore wind energy categories, different wind turbine types with corresponding investments have been used (including the cost of transport, construction and cranes). Once again, ECN and DNV GL note a fall in turbine prices of a few percent this year.

Besides the turbine price, there are additional costs of foundations (including piles), electrical infrastructure on the wind farm, connection to the grid, civil infrastructure, building interest and CAR (Construction All Risk) insurance during construction. The absolute additional costs have been kept the same as last year. This year, it comes to 33% of the turbine costs. This brings the total investment costs to 1,290 €/kW.

O&M costs: variable and fixed operating costs

The variable costs (except land costs), which include guarantee and maintenance contracts, have also decreased this year. The variable costs are approximately 0.0095 €/kWh. It is becoming more common for turbine manufacturers to offer a choice of maintenance contracts at a fixed price per turbine. On average, these prices lie within the range of 20-30 €/kW. Both the variable and fixed costs of guarantee and maintenance contracts are calculated in the model, depending on the turbine.

The land costs are additional to the stated variable costs. Since the SDE+ 2014, ECN and DNV GL have assumed an annual reduction in land costs of 10% on the Ministry's instructions. As a result, land costs have been set at 0.0035 €/kWh for the SDE+ 2017. This brings the total variable O&M costs for this category to 0.0166 €/kWh.

The fixed annual costs are those of public liability insurance, machinery breakdown insurance, standstill insurance, network maintenance, energy use, property tax, and management and maintenance of land and roads. In this advice, ECN and DNV GL have assumed the same annual costs as in the SDE+ 2016, i.e. 12.4 €/kW.

For total maintenance costs, including land costs, inflation is assumed to be 1.5% per year.

Other costs
Last year, ECN and DNV GL took a closer look at the costs of participation. The intention is that with the code of conduct by NWEA (the Dutch wind energy association), which incorporates a reference amount of 0.4-0.5 €ct/kWh, participation costs will play a role in all projects. However, ECN and DNV GL have again been instructed not to include these costs in the base rate. The Ministry of Economic Affairs sees participation as being allowed to share the returns on investment, so these costs are already included in the returns from equity.

Additional costs of wind projects, such as non-statutory levies to local government and costs resulting from the preparation process (including financing costs and costs resulting from legal proceedings) have also not been included in the calculation of production costs by ECN and DNV GL. These additional costs – like incidental benefits such as purchasing discounts on large projects – are not generic in nature and in accordance with the research assignment are therefore not to be considered by ECN and DNV GL as costs (or income) eligible for subsidy. These costs are assumed to be earned back through the financial return on equity.

Income: returns from turbines
The base rate was established by combining the costs referred to above with the energy output of the wind turbines. These returns are largely determined by the wind resources and the power curve of the wind turbine. The energy output has been calculated for all turbines separately with the help of the specific power curve per wind turbine at the annual average wind speeds indicated in Figure 2. The model corrects the wind speed from the table (at an altitude of 100 metres) for the actual height of the axis of the turbine in question. In addition, the model only makes calculations for wind turbines which, based on the IEC classification, are actually permitted to be installed for the specific wind speed.

Like last year, ECN and DNV GL have assumed 13% output losses for a 50 MW reference wind farm. These losses are caused, among other things, by wake losses, non-availability, electrical losses, turbine performance, environmental losses and curtailment.

5.1.2 Overview of base rates

The resulting base rates are shown in Table 23 and should be read in conjunction with Figure 2, in which the Dutch municipalities are differentiated by wind speed categories. The map determines which maximum base rate a project in a particular municipality may apply for.

Example: a project in a municipality coloured red may submit an application for the 'onshore wind, ≥ 8.0 m/s' category (with a base rate of 0.064 €/kWh) at a project-specific maximum number of full load hours.

Table 23: Base rates for onshore wind

Category	Base rate (€/kWh)	Colour of municipalities which may submit applications
Onshore wind, ≥ 8.0 m/s	0.064	Red
Onshore wind, ≥ 7.5 and < 8.0 m/s	0.070	Orange
Onshore wind, ≥ 7.0 and < 7.5 m/s	0.075	Green
Onshore wind, < 7.0 m/s	0.085	Blue

Table 24 shows the base rate and several other subsidy parameters.

Table 24: Summary of subsidy parameters for onshore wind

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.064-0.085
Base price for SDE+ 2017	[€/kWh]	0.025
Provisional correction amount in 2017	[€/kWh]	0.028
Calculation method for correction amount	APX x “profile and imbalance factor”	

5.2 Wind on primary water defences

5.2.1 Starting points and calculation method

For the 'wind on primary water defences' category, ECN and DNV GL have assumed that the wind turbines are situated within the protection zones of a primary water defence as referred to in section 2.7 of Appendix 1 of the Regulations for the safety of primary water defences, or within the key zone or the protection zone on the waterside of a primary water defence bordering the North Sea, the Western Scheldt, the Eastern Scheldt, the Wadden Sea, the Dollard or the Eems.

Table 25 shows the technical-economic parameters for 'wind on primary water defences'. These parameters are the same as those for the 'onshore wind' category, except for the investment costs. Explanatory notes may be found in the text below. For an explanation of the other parameters (and the calculation method used), the reader is referred to section 5.1 on onshore wind energy.

Table 25: Technical-economic parameters for 'wind on primary water defences'

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Installation size	[MW]	50.0	
Investment costs	[€/kW$_e$]	1,460	€73 million
Fixed O&M costs	[€/kW$_e$/a]	12.4	€620,000/year
Variable O&M costs	[€/kWh]	0.0166	

Higher investment costs for 'wind on primary water defences'
Placing a wind turbine in the 'wind on primary water defences' category results in the following extra costs compared to the normal 'onshore wind energy' category:

- Foundation costs: the erection of a wind turbine must not cause the dykes to weaken. To ensure this, extra sheet pile walls need to be installed in some cases.
- Civil engineering works: sheet pile walls may also be required for the crane sites and access roads.
- Network connections: potential connection points for wind on primary water defences are often a large distance away. Moreover, additional drilling is often required under the water's surface.

The absolute additional costs for wind on primary water defences have been kept the same as the absolute additional costs from last year. This represents 50% of the turbine prices. Due to the fall in turbine prices (see section 5.1), an adjustment to the total investment costs has also been made for onshore wind. The investment costs have fallen to 1,460 €/kW.

5.2.2 Overview of base rates

The resulting base rates for wind on primary water defences are shown in Table 26 and should be read in conjunction with Figure 2, in which the Dutch municipalities are differentiated by wind speed categories. This is because wind differentiation applies to this category (similar to onshore wind). The wind map determines what maximum base rate may be submitted for a project in a particular municipality.

Example: a project in a municipality coloured red may submit an application for the 'wind on primary water defences, ≥ 8.0 m/s' category (with a base rate of 0.069 €/kWh) at a project-specific maximum number of full load hours.

Table 26: Base rates for 'wind on primary water defences'

Category	Base rate [€/kWh]	Colour of municipalities permitted to submit applications
Wind on primary water defences, ≥ 8.0 m/s	0.069	Red
Wind on primary water defences, ≥ 7.5 and < 8.0 m/s	0.075	Orange
Wind on primary water defences, ≥ 7.0 and < 7.5 m/s	0.080	Green
Wind on primary water defences, < 7.0 m/s	0.091	Blue

Table 27 shows the base rate and several other subsidy parameters.

Table 27: Overview of subsidy parameters for 'wind on primary water defences'

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.069-0.091
Base price for SDE+ 2017	[€/kWh]	0.025
Provisional correction amount in 2017	[€/kWh]	0.028
Calculation method for correction amount	APX x "profile and imbalance factor"	

5.3 Wind on lake, water ≥ 1 km²

5.3.1 Starting points and calculation method

Table 28 shows the technical-economic parameters for wind on lake. These parameters (apart from the fixed O&M costs) differ from the parameters used for onshore wind. An explanation of the differing parameters may be found in the text below. For an explanation of the fixed O&M costs, the reader is referred to section 5.1 on onshore wind.

Table 28: Technical-economic parameters for wind on lake

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Installation size	[MW]	150.0	
Investment costs	[€/kW$_e$]	2,510	€381 million
Fixed O&M costs	[€/kW$_e$/a]	12.4	€1,860,000/year
Variable O&M costs	[€/kWh]	0.0236	

For wind on lake, a wind farm size of 150 MW has been assumed. Due to the size of the wind farm, the wake losses are higher than for the 50 MW wind farm. In this category, a total of 17% project losses has been assumed instead of the 13% which applies to the 'onshore wind' category. The wind speed has been set at 8.5 m/s, because it has been assumed that 'wind on lake' projects will be located in water subject to high wind speeds.

Due to the fall in turbine prices (see section 5.1), an adjustment to the total investment costs has also been made for onshore wind; these have decreased to 2,510 €/kW. Contrary to the 'onshore wind' and 'wind on primary water defences' categories, the maintenance costs for 'wind on lake' have not fallen. So as in previous years, variable O&M costs of 0.0201 €/kWh have been assumed for this category. In addition, there are land costs of 0.0035€/kWh, in accordance with the description in Section 5.1.1., bringing the total variable O&M costs to 0.0236 €/kWh.

5.3.2 Overview of base rates

The resulting base rate for 'wind on lake' and several other subsidy parameters is shown in Table 29. As for the other wind energy categories, the full load hours cap has been removed for 'wind on lake', but a project-specific full load hours cap does apply. Wind differentiation does not apply to 'wind on lake'. It is anticipated that 'wind on lake' projects will only be developed in the windier parts of the Netherlands.

Table 29: Overview of subsidy parameters for 'wind on lake'

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.104
Base price for SDE+ 2017	[€/kWh]	0.025
Provisional correction amount in 2017	[€/kWh]	0.028
Calculation method for correction amount	APX x “profile and imbalance factor”	

6

Geothermal findings

This chapter describes the findings for the following categories related to geothermal energy. The following sections will be discussed in order:

- Geothermal heat at a depth of ≥ 500 metres (6.1)
- Geothermal heat at a depth of ≥ 3,500 metres (6.2).

At the request of the Ministry of Economic Affairs, this year no advice has been issued about:

- the SDE+ category 'geothermal co-generation at a depth of ≥ 500 metres',
- the possibilities of expanding geothermal sources,
- geothermal sources using existing oil or gas wells.

The Ministry has confined its request for information to ECN, DNV GL and TNO to the categories for geothermal heat at depths of more than 500 metres and more than 3,500 metres.

6.1 Geothermal heat at a depth of ≥ 500 metres

This section explains the advice on the geothermal energy category for low-temperature heat in more detail. This makes this category representative of the scope of many geothermal heat projects, particularly in the greenhouse horticulture sector.

District heating projects differ from greenhouse horticulture projects and are therefore less relevant to this category; a higher return temperature and fewer full load hours are often characteristic of projects that focus mainly on district heating. Many geothermal projects aimed solely at supplying district heating grids will therefore be more expensive than the reference installation.

For geothermal projects in this category, parameters with a great impact on the thermal source capacity are (among other things) the source temperature (in relation to aspects such as the drilling depth of the doublet) and the flow rate of the liquid streams (in relation to aspects such as the aquifer characteristics and the diameter of the production and injection source). Both drilling depth and well diameter have a great impact on the investment sum for geothermal projects.

To calculate the base rate, four separate reference projects were configured for low-temperature heat derived from geothermal energy, whereby different drilling depths and well diameters were assumed. The depth of the well for the reference projects was set at 2,300 and 3,000 metres. In addition, two borehole diameters were used: 5.5 and 8.5 inches. As a result, the source capacity for the various cases varies between 7 and 22 MW, but the depth takes precedence for the SDE+ subsidy, and projects with smaller and larger capacities may apply for subsidy in this category. For the purposes of these four reference projects, a heat distribution pipe was assumed, varying in length from one kilometre for smaller projects, to four kilometres for the project with the highest source capacity.

The cost price for each of the configurations was calculated for the reference projects. The base rate for this category was set on the basis of the reference case described in Table 30 and Table 31, whereby the following characteristics are important:

- The interest during construction for a two-year construction period has been factored into the investment cost;
- Remaining value of 20% of the investment sum at the end of the SDE+ duration of 15 years has been included. Experience in other countries shows that geothermal sources often continue to produce heat after the 15 years of the SDE+.
- Costs have been earmarked for installations for capturing oil and gas;
- The geological report required for the SDE+ scheme comes under project preparation costs and has therefore not been included in the reference case.

Table 30 shows the technical-economic parameters for the reference case for this category, with a drilling depth of 3,000 metres and source capacity of 12 MW.

Table 30: Technical-economic parameters for geothermal heat at a depth of ≥ 500 metres

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Thermal output capacity	[MW]	12	
Full load hours heat supply	[h/a]	5,500	
Investment costs	[€/kW$_{th_output]}$	1,622	€19.5 million
Fixed O&M costs	[€/kW$_{th_output/a]}$	59	€708,000/year
Variable O&M costs	[€/kW$_{th_output}$]	0.0080	

Table 31 shows the base rate and several other subsidy parameters.

Table 31: Overview of subsidy parameters for geothermal heat at a depth of ≥ 500 metres

Parameter	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.053
Base price for SDE+ 2017	[€/kWh]	0.012
Provisional correction amount in 2017	[€/kWh]	0.012
Calculation method for correction amount	TTF x 70%	

6.2 Geothermal heat at a depth of ≥ 3500 metres

This category is focused particularly on higher temperature applications for industrial processes and it is characterised by the greater drilling depth of the doublet. Once again, several configurations have been calculated for this category. Three reference projects were examined, with drilling depths of 3700, 4000 and 6000 metres and a well diameter of 8½ inches. The source capacity for the various cases varies between 15 and 27 MW, but the depth takes precedence for the SDE+ subsidy, and projects with smaller and larger capacities may apply for subsidy in this category. For the purposes of these three reference projects, a heat distribution pipe was assumed, varying in length from 0.5 kilometres for the smallest project, to four kilometres for the project with the highest source capacity. Due to the greater drilling depth, the costs of reservoir stimulation were also included at € 4 million per doublet.

The cost price for each of the configurations was calculated for the reference projects. These show very similar costs prices per kWh. The base rate for this category was set in line with the reference case described in Table 32 and Table 33, whereby the following characteristics are important:

- The interest during construction for a two-year construction period has been factored into the investment cost;
- Remaining value of 20% of the investment sum at the end of the SDE+ duration of 15 years has been included. Experience in other countries shows that geothermal sources often continue to produce heat for longer.
- Costs have been earmarked for installations for capturing oil and gas;
- The geological report required for the SDE+ scheme comes under project preparation costs and has therefore not been included in the reference case.

Table 32 shows the technical-economic parameters for the reference case for this category, with a drilling depth of 3,700 metres and source capacity of 15 MW. See also Table 33 for other subsidy parameters.

Table 32: Technical-economic parameters for geothermal heat at a depth of ≥ 3500 metres

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Thermal output capacity	[MW]	15	
Full load hours heat supply	[h/a]	7,000	
Investment costs	[€/kW_{th_output}]	2,393	€35.9 million
Fixed O&M costs	[€/kW_{th_output}/a]	86	€1,290,000/year
Variable O&M costs	[€/kW_{th_output}]	0.0057	

Table 33 shows the base rate and several other subsidy parameters.

Table 33: Overview of subsidy parameters for geothermal heat at a depth of ≥ 3500 metres

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.057
Base price for SDE+ 2017	[€/kWh]	0.012
Provisional correction amount in 2017	[€/kWh]	0.012
Calculation method for correction amount	TTF x 70%	

7

Water treatment findings

This chapter describes the findings for the following categories related to water treatment (WWTP):

- Waste water treatment plants, centralised thermophilic digestion of secondary sludge (7.1)
- WWTP - thermal pressure hydrolysis (7.2)
- WWTP - renewable gas (7.3).

The categories have remained unchanged in relation to the SDE+ 2016. Reactions from the market consultation for a more technology-neutral approach to water treatment will be dealt with separately from this advice.

7.1 Waste water treatment plants, centralised thermophilic digestion of secondary sludge

Additional biogas production causes increased breakdown of sludge, resulting in lower sludge processing costs.

For this category, a base rate is calculated for thermophilic digestion installations in which secondary sludge, obtained from multiple waste water treatment plants, is centrally processed and the biogas converted into heat and electricity by means of a CHP installation. The advised base rate is based on the same technical-economic parameter values as the advice for 2016. The case has been calculated on the basis of a sludge processing price of 64 €/tonne, which is money saved from useful application in the form of digestion. This value has been selected as the lowest price: if even lower sludge processing prices are used for the calculation, the base rate will rise very sharply, while the water treatment process as a whole will become cheaper. This case is based on information provided by water boards. Breaking down secondary sludge from multiple sewage treatment plants using this technology saves on sludge processing costs. This saving is calculated with respect to the reference situation in which all the sludge has to be processed. This is shown as a negative amount for the O&M costs. In addition, the cost of the CHP gas engine has been included in the case.

Table 34: Technical-economic parameters for waste water treatment plants, thermophilic digestion of secondary sludge

Parameter	Unit	Advice for 2017	Total amount for reference
Input capacity	[MW_{th_input}]	1.90	
Electrical capacity	[MW_e]	0.70	
Thermal output capacity	[MW_{th_output}]	0.92	
Full load hours electrical supply	[h/a]	8,000	
Full load hours heat supply	[h/a]	4,000	
Maximum electrical efficiency	[%]	37%	
Investment costs	[€/kW_e]	6,485	€10.5 million
Fixed O&M costs	[€/kW_e]	-493	-€ 798,000/year

Table 35 shows the base rate and several other subsidy parameters.

Table 35: Overview of subsidy parameters for waste water treatment plants, thermophilic digestion of secondary sludge

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.048
Base price for SDE+ 2017	[€/kWh]	0.023
Heat/power ratio	H:E	0.66
Combined number of full load hours	hours/year	5,729
Provisional correction amount in 2017	[€/kWh]	0.024
Calculation method for correction amount	(APX + TTF x 70% x CHP)/(1 + CHP)	

7.2 WWTP - thermal pressure hydrolysis

Biogas production from water treatment plants can be increased by adding a thermal pressure hydrolysis installation to an existing purification plant. It is assumed that the existing purification plant already has a CHP gas engine with sufficient capacity.

In water purification plants, purification sludge is digested, with the gas produced in most cases being used to generate electricity using a CHP gas engine. In this way, part of the water purification plant's own energy consumption is covered. A new development in water purification plants is the addition of an installation for thermal pressure hydrolysis to the digestion installation. As a result, a higher gas yield per tonne of sludge is achieved. Upstream thermal pressure hydrolysis also serves to increase the sludge processing capacity of the existing installation. An additional benefit is that the sludge digestate, produced by the digestion of sludge pre-treated with thermal high-pressure hydrolysis, can be further dehydrated, thus reducing the cost of transportation.

The reference plant only includes the investment cost for the thermal pressure hydrolysis stage. The costs of dehydration and modification of the existing digestion tank are assumed to be compensated by the lower transportation cost for sludge removal.

The additional gas yield arising from an upstream thermal pressure hydrolysis stage can be used in various ways:

- Electricity production (more electricity generated for the installation’s internal use, making full use of the heat from the CHP plant for thermal pressure hydrolysis);
- Upgrading biogas to green gas quality;
- Crude biogas supply for external applications.

Hydrolysis has its own heat requirement, which can be met by the CHP plant based on the total gas yield of the digester (about 360 Nm3/h crude biogas). In the case of crude biogas or green gas outputs, more gas is needed to heat the hydrolysis than is supplied by the additional yield from the hydrolysis. Therefore, ECN and DNV GL conclude that a CHP option will generally be useful here, with a CHP plant of about 720 kWe supplying the required heat. In this configuration, all the heat is used for the internal process and only renewable electricity remains as a supplied product eligible for an SDE+ allowance.

This configuration will probably apply to the majority of waste water treatment plants because external heat is not usually available for sewage treatment plants. For situations in which this is the case, a new 'WWTP green gas – thermal pressure hydrolysis' category is recommended.

Table 36: Technical-economic parameters for WWTP - thermal pressure hydrolysis

Parameter	Unit	Advice for 2017	Total amount for reference
Sludge throughput	[tonnes of dry matter/year]	16,079	
Full load hours	[hours/year]	8,000	
CHP capacity (net)	[kW_e]	723	
Total investment	[€/kW_e]	6,100	€4.4 million
Total variable costs	[€/kW_e]	800	€578,000/year

Table 37 shows the base rate and several other subsidy parameters.

Table 37: Overview of subsidy parameters for WWTP - thermal pressure hydrolysis

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.084
Base price for SDE+ 2017	[€/kWh]	0.031
Provisional correction amount in 2017	[€/kWh]	0.032
Calculation method for correction amount	APX	

7.3 WWTP – renewable gas

The base rate for the 'renewable gas from waste water treatment plant digestion' category has been calculated for a larger digestion unit, based on data from the Netherlands foundation for applied water research (STOWA, 2011). In view of the limited application of biogas from waste water treatment plants for renewable gas and the large-scale application of CHP in waste water treatment plants (Statistics Netherlands, 2013), plus the heat required for thermal pressure hydrolysis and thermophilic digestion, producing renewable gas rather than using the biogas in a CHP plant would appear to make little sense from the point of view of the efficiency of the SDE+ scheme. In addition, there is a tendency to process sewage treatment sludge at central locations by means of digestion, and for this reason, too, a base rate based on a large plant is realistic.

Table 38: Technical-economic parameters for WWTP – renewable gas

Parameter	Unit	Advice for 2017	Total amount for reference
Reference size	[Nm^3/h green gas]	164.2	
Full load hours	[h/a]	8,000	
Internal heat requirement	[%]	25 %	
Internal electricity requirement	[kWh/Nm^3 crude biogas (net)]	0.15	
Electricity rate	[€/kWh]	0.10	
Investment costs	[€/Nm^3/hour crude biogas (gross)]	4,896	€1.5 million
Fixed O&M costs	[€/Nm^3/hour crude biogas (gross)]	504	€158,000/year
Energy content of substrate	[GJ/tonne]	22.0	
Efficiency of gas cleaning	[%]	99.9 %	

Table 39 shows the base rate and several other subsidy parameters.

Table 39: Overview of subsidy parameters for WWTP - renewable gas

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.031
Base price for SDE+ 2017	[€/kWh]	0.015
Provisional correction amount in 2017	[€/kWh]	0.016
Calculation method for correction amount	TTF	

8

Findings for incineration and gasification of biomass

This chapter describes the findings for the categories related to the incineration and gasification of biomass. Ahead of the findings for the different categories, Section 8.1 provides a summary of the biomass prices used. After that, the following categories are discussed in successive sections:

- Prices used for biomass incineration and gasification (8.1)
- Biomass gasification (≥ 95% biogenic) (8.2)
- Existing direct and indirect co-firing capacity (8.3)
- New capacity for direct co-firing (8.4)
- Boiler fired by solid or liquid biomass, 0.1 - 5 MWth (8.5)
- Boiler fired by solid or liquid biomass, ≥5 MWth (8.6)
- Boiler fired by liquid biomass (8.7)
- Boiler fired by industrial steam from wood pellets (8.8)
- Thermal conversion of biomass, < 100 MW_e (8.9).

8.1 Prices used for biomass incineration and gasification

Biomass as a fuel is available in different qualities. In this report, a number of reference fuels have been used. For solid biomass, the reference fuel used is pruning and thinning wood and wood pellets. For liquid biomass, the reference fuel used is animal fat.

Table 40 shows a summary of these different references for biomass as a fuel. More detailed explanation of the elements in the table is provided in the following subsections.

Table 40: Biomass prices used for plants applying for SDE+ in 2017

Biomass for incineration and gasification	Energy content	Price	Reference price
	[GJ/tonne]	[€/tonne]	[€/GJ]
Solid biomass			
Pruning and thinning wood	9	50	5.6
Wood pellets, direct co-firing	17	145	8.5
Wood pellets, boilers	17	155	9.1
B-grade wood	13	25	1.9
Liquid biomass			
Animal fat	39	600	15.4

8.1.1 Pruning and thinning wood

The reference fuel for new installations for thermal conversion of solid biomass and for boilers fired by solid biomass is pruning and thinning wood. The biomass consists of fresh wood chips from forests, landscapes and gardens. The energy content of fresh wood is about 7 GJ/tonne. However, a large part of the wood delivered to the installations will originate from stock. To allow for the natural drying processes of wood stocks, the annual average energy content has been taken as 9 GJ/tonne. The reference price is assumed to be 50 €/tonne or 5.6 €/GJ. The price is near the top of market prices for large-scale purchase and near the bottom of market prices for small-scale purchase[7]. A price increase of 2% has been used in relation to last year's advice, in line with market developments in the national and international price of wood chippings[8].

- Fuel price pruning and thinning wood: 50 €/tonne.
- Energy content: 9 GJ/tonne
- No fuel surcharge.

8.1.2 Wood pellets

For the 'direct co-firing' and 'boiler industrial steam from wood pellets' categories, the biomass fuel is assumed to be clean, white wood pellets with a heating value of 17.0 MJ/kg, in accordance with the trading definition. The cost of biomass fuel is assumed to be 145 €/tonne for the 'direct co-firing' category (delivered at the plant gate) and 155 €/tonne for the 'boiler industrial steam from wood pellets' category. This price is based on input obtained from the market (from both pellet producers and energy companies) and public sources such as the Argus index (current spot prices and forwards). The price of pellets has shown a downward trend on the spot market over the past two years (in American dollars per tonne). However, in 2015 this downward trend was fully compensated by a rise in the exchange rate of the dollar (both real and on the futures market for euro-dollar-futures). As a result, the price in euros per tonne remained quite

7 Based on a large number of confidential sources.

8 References: EUWID, Kaminholz-wissen.de.

stable. Last year, the spot prices in dollar/tonne for pellets fell further, but the futures expectations in €/tonne have not changed fundamentally in relation to previous years.

The price is made up of:

- for the 'direct co-firing' category: 145 €/tonne for delivery to the plant, comprising 135 €/tonne for the price of CIF ARA and 10 €/tonne for the logistical costs of transport from port to plant
- For the 'boiler fired by industrial steam from wood pellets' category: 155 €/tonne for delivery to the industrial user, comprising 135 €/tonne for the price of CIF ARA and 20 €/tonne for the logistical costs of transport from port to plant. These costs include additional storage costs (silos), an extra transhipment step and transport by lorry (max. 150 km).
- For the above-mentioned categories: 15 €/tonne fuel surcharge (for long-term contracting and currency risk).

In this price, a risk premium has been taken into account because this price is set for the eight-year subsidy period and only corrected for inflation, not for any structural price increases. Based on the information received during the market consultation, it was found that the prices for smaller-scale batches of pellets fall within the uncertainty margin of the prices used here.

The choice of biomass fuel and the corresponding price level can also be influenced by the sustainability criteria for biomass in direct co-firing. In early 2016, government, industry and NGOs reached an agreement about these sustainability criteria. Current insight into the effects of the sustainability criteria have been incorporated into this advice.

- Fuel price of wood pellets (including transhipment and logistics): 145 or 155 €/tonne
- Energy content: 17 GJ/tonne
- Fuel surcharge: 15 €/tonne.

8.1.3 B-grade wood

The fuel price for B-grade wood is assumed to be 25 €/tonne, with an associated energy content of 13 GJ/tonne. This price is lower than the price used in the advice for SDE+ 2016 and in line with current market developments.

- Fuel price B-grade wood: 25 €/tonne
- Energy content: 13 GJ/tonne
- No fuel surcharge.

8.1.4 Liquid biomass

After reaching a peak in 2011 and 2012, the prices of vegetable oil and animal fats are now displaying a downward trend. The most recent data appear to show this fall continuing; however, based on the five-year average it is small. For 2017, as for last year, an average price for liquid biomass of 600 €/tonne is assumed at a heating value of 39 GJ/tonne. The prices of animal fats track the prices of vegetable oils. Moreover, there is a well-developed international market for vegetable oils. By trading on the international market for vegetable oils, the risks of rising prices for animal fats can be successfully hedged.

- Fuel price for animal fat: 600 €/tonne.
- Energy content: 39 GJ/tonne
- No fuel surcharge.

8.2 Biomass gasification (≥95% biogenic)

A bio-SNG installation for green gas production by means of gasification consists of three components: gasification, gas cleaning and gas upgrading. In a gasification installation, solid biomass is converted into a gaseous fuel known as syngas. In the gas cleaning section, impurities are removed from the gas. In the final step, the gas is upgraded to natural gas quality (bio-SNG) after which the green gas can be fed into the natural gas grid.

The reference installation has a production capacity of approximately 1,479 Nm^3 of green gas/hour. The energy efficiency of gasification into bio-SNG is 65%. This efficiency has been lowered in relation to previous advice to take account of the ongoing innovative character. Higher efficiency should be feasible in the long term. Although the installation can fulfil its own internal heat requirement, the purchase of electricity for internal use has been included in the calculation of the base rate. Combining a wood-gasifier and a gas upgrading installation results in a complex production installation. Therefore, 7,500 full load hours per year have been assumed. Table 41 provides the technical-economic parameters.

Table 41: Technical-economic parameters for gasification of biomass (≥ 95% biogenic)

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Reference size	[Nm^3/h]	1,479	
Full load hours	[h/a]	7,500	
Investment costs	[$€/kW_{output}$]	5,248	€68.2 million
Fixed O&M costs	[$€/kW_{output}$]	262	€ 3.4 million/year
Energy content of substrate	[GJ/tonne]	9	
Feedstock costs	[€/tonne]	50	

Table 42 shows the base rate. In addition, this table also shows the base price, the contract costs and the correction amount.

Table 42: Overview of subsidy parameters for biomass gasification (≥95% biogenic)

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.150
Base price for SDE+ 2017	[€/kWh]	0.015
Provisional correction amount in 2017	[€/kWh]	0.016
Calculation method for correction amount	TTF	

8.3 Existing capacity for direct and indirect co-firing of biomass

8.3.1 General assumptions

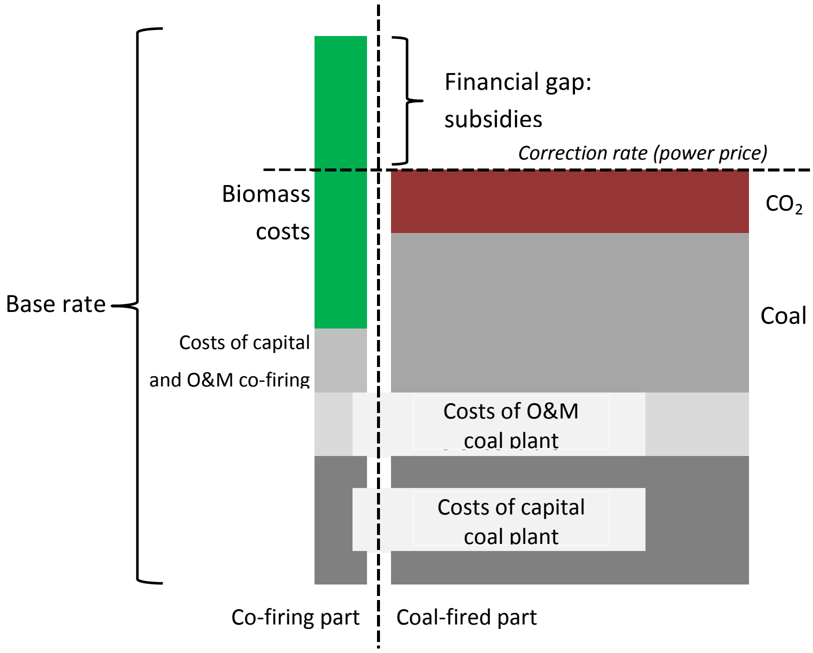
Part of the Netherlands' electricity and heat production comes from coal-fired power plants. Alongside coal, these power plants can also use biomass as a fuel. There are two ways of doing this:

- By direct replacement of coal by biomass, which is put into the boiler as solid fuel. This is called *direct* co-firing.
- By using biomass after a thermal pre-treatment, for example gasification. In this case, the biomass is used via an intermediate product. This is called *indirect* co-firing.

For all categories of direct co-firing, the calculations are based on clean white wood pellets. For indirect co-firing, the reference fuel is B-grade wood. The biomass prices used are explained in Sections 8.1.2 (wood pellets) and 8.1.3 (B-grade wood) respectively.

Delineation of direct/indirect co-firing in coal-fired power plant
In order to calculate the base rate for the use of biomass, the costs of the coal-fired power plant (capital costs and O&M) are allocated proportionately to the share of biomass used. Theoretically speaking, the calculations are based on a virtual biomass power plant the size of which is represented by this share. An illustration of this method is shown in Figure 3. Efficiency losses of the power plant as a whole caused by the use of biomass are also allocated to the biomass proportion. For example, if the yield of the plant as a whole decreases by half a percent with 25% direct co-firing, in the calculations an output decrease of 2% is allocated to the co-firing proportion.

Figure 3: Illustration of the SDE method for biomass co-firing in a coal-fired power plant. Costs in €/kWh$_e$. Stylised figure; the sizes of the cost bars do not correspond exactly to the data in this report.



Capital costs
When calculating the capital costs of the coal-fired power plant, account is taken of the difference between the economic life of the power plant and the duration of the SDE+ allowance for the use of biomass (eight years). The capital costs and operational costs of the coal-fired power plant are allocated proportionately to the part of the power plant that uses biomass. Given an economic lifetime of 30 years, the specific capital costs (€/kWe) of the coal-fired power plant are included in the calculations with a factor of 8/30. For specific investments required to enable the use of biomass, an economic lifetime of eight years is assumed.

Heat supply
In the MEP scheme (Environmental Quality of Electricity Production), the production of heat from using biomass in coal-fired power plants was not subsidised separately. The subsidy was based on the part of the electricity production that would be produced from biomass if there would have been no heat production.

In this SDE+ 2017 advice, the starting point is that the core of this approach will be maintained: there will not be a separate payment for heat; instead, the basis for the subsidy will remain the same as the electricity production from biomass that would be achieved without heat transfer.

8.3.2 Description of the reference installation

The text below describes the reference power plants for the 'existing capacity for direct or indirect co-firing' category, and specifies the parameters used.

Coal-fired power plant built in the 1990s with existing capacity for direct co-firing of biomass
The reference used for this category is a supercritical 600-650 MWe coal-fired power station built in the 1990s with a net efficiency of 41%, fitted with FGD, $DeNO_x$ and a fine particles removal system. The production time of electricity generated is assumed to be 6,000 full load hours a year.

It is assumed that the efficiency when burning biomass is 2% lower than when burning coal. Given the fact that the co-firing installation is already present, only limited replacement investments are assumed here.

For the performance of co-firing activities, a proportionate part of the capital and maintenance costs of the coal-fired power plant is allocated to the co-firing activities. The following principles are applied:

- The total investment costs of the coal-fired power plant built in the 1990s are set at 1,100 €/kW_e. Over the duration of the scheme (eight years), and taking the economic life of the coal-fired power station (30 years) into account, a percentage of this price, equal to the co-firing percentage (based on energy,) is factored into the base rate.
- The replacement investment needed to enable the existing co-firing installation to operate for another eight years is estimated at 30 €/kW_e (only calculated over the number of kW_e of co-firing).
- The O&M costs of the coal-fired power plant are 30 €/kW_e, using the same calculation method as for the investment costs.
- The additional O&M costs resulting from biomass co-firing amount to 5.7€/MWh_e (only calculated for the kilowatt hours generated using biomass). This includes base price premium and the contract costs.

Coal-fired power plant built in the 1990s with existing capacity for indirect co-firing of biomass
The reference used for this category is a supercritical coal-fired power station built in the 1990s with a net efficiency of 41%, fitted with FGD, $DeNO_x$ and a fine particles removal system. Adjacent to the plant is a biomass gasifier supplying product gas which is used in the coal-fired power plant for indirect co-firing. 5,000 full load hours are assumed for the biomass gasifier.

A thermal efficiency of 95% is assumed for the biomass gasifier. It is assumed that the efficiency when burning product gas is 1% lower than when burning coal.

For the indirect co-firing of biomass, a proportionate part of the capital and maintenance costs of the coal-fired power plant is allocated to the co-firing activities. The following principles are applied:

- The total investment costs of the coal-fired power plant built in the 1990s are set at 1,100 €/kW_e. Over the duration of the scheme (eight years), and taking into account the economic life of the coal-fired power station (30 years), a percentage of this price, equal to the co-firing percentage (based on energy,) is factored into the base rate.

- The cost of replacement investments needed to enable the biomass gasifier to operate for another eight years has been set at 75 €/kW_e (only calculated over the number of kW_e of co-firing).
- The O&M costs of the coal-fired power plant are 30 €/kW_e, using the same calculation method as for the investment costs.
- The additional fixed O&M costs for the biomass gasifier amount to €190/kW_e (only calculated over the number of kW_e co-firing). This also includes additional costs for removing all metal from the biomass.
- In addition, there are variable O&M costs for the gasifier amounting to 10.2 €/MWh_e (only calculated for the kilowatt hours generated using biomass). This includes base price premium and the contract costs.

Table 43 shows the technical-economic parameters for the two reference installations.

Table 43: Technical-economic parameters for existing biomass co-firing capacity

Parameters for reference installations	Unit	Direct co-firing value	Indirect co-firing value
Net electrical capacity of the power plant	[MW_e]	600-650	600-650
Direct/indirect co-firing percentage	[e/e%]	27	5
Thermal full load efficiency of coal	[%]	41	41
Full load hours of electricity production	[h/a]	6,000	5,000
Efficiency of biomass gasifier	[%]	-	95
Efficiency of biomass portion of plant	[%]	39*	38*/**
Cost of biomass	[€/tonne]	160	25
Duration of incentive scheme	[a]	8	8
Specific investment for use of biomass (extension of economic lifetime)	[€/kW_e]	30	75
Investment costs for coal-fired power plant	[€/kW_e]	1,100	1,100
Economic lifetime of coal-fired power plant	[a]	30	30
O&M costs for coal-fired power plant	[€/kW_e]	30	30
Additional O&M costs for direct co-firing (biomass MWh)	[€/MWh_e]	5.7	-
Additional fixed O&M costs for biomass gasifier	[€/kW_e]	-	190
Additional variable O&M costs for biomass gasifier	[€/MWh_e]	-	10.2

*: Output loss of the power plant as a whole resulting from indirect or direct co-firing of biomass is allocated entirely to the biomass portion.

**: Including the efficiency of the gasifier.

Table 44 shows the base rate. This is based on an average of direct and indirect co-firing weighted according to capacity. In addition, this table also shows the base price, the base price premium, the correction amount and the method used to calculate the correction amount.

Table 44: Overview of subsidy parameters for existing direct and indirect co-firing capacity

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2016	[€/kWh]	0.108
Base price for SDE+ 2016	[€/kWh]	0.031
Weighted number of full load hours	[hours/year]	5,839
Provisional correction rate in 2016	[€/kWh]	0.032
Calculation method for correction amount	APX	

8.4 New capacity for direct co-firing of biomass

The text below describes the reference power plant for the 'new capacity for direct co-firing' category and states the parameters used.

Coal-fired power plant with new capacity for direct co-firing of biomass
The reference for this category is a supercritical coal-fired power station in the range 700-1,100 MW_e with a net full load efficiency of 46 %, fitted with FGD, $DeNO_x$ and fine particles removal system. The production time of electricity generated is assumed to be 7,000 full load hours.

It is assumed that the efficiency when burning biomass is 2% lower than when burning coal. For the creation of the new direct co-firing plant, an investment amount of 350 €/kW_e is assumed (only calculated over the number of kW_e direct co-firing). This amount is lower than last year, because the market has indicated an intention to convert existing coal mills for flexible use instead of building additional hammer mills. This leads to lower investment costs.

For the performance of co-firing activities, a proportionate part of the capital and maintenance costs of the coal-fired power plant is allocated to the co-firing activities. The following principles are applied:

- The total investment costs of the coal-fired power plant are 2,000 €/kW_e. Over the duration of the scheme (eight years), and taking the economic life of the coal-fired power station (30 years) into account, a percentage of the costs, equal to the co-firing percentage (based on energy,) is factored into the base rate.
- The O&M costs of the coal-fired power plant are 30 €/kWe, This will also be included in the calculation in proportion to the co-firing capacity.
- The additional O&M costs resulting from biomass co-firing amount to 4€/MWh_e (only calculated for the kilowatt hours generated using biomass). In view of the above-mentioned change in strategy for the conversion that enables co-firing (see investment costs for biomass co-firing), the allocation of variable O&M has been reduced from 3 to 2 €/MWh. At the same time, the sum includes the base price premium of 2 €/MWh and the contract costs of 0.7 €/MWh. This brings the total amount for the additional O&M costs to 4.7 €/MWh.

The economic lifetime of the biomass co-firing installation is equal to the duration of the scheme (starting point for SDE system).

Table 45: Technical-economic parameters for new capacity for direct biomass co-firing in a coal-fired power plant

Parameter	Unit	SDE+ 2017 advice
Net electrical capacity of the power plant	[MW_e]	700-1,100
Thermal full load efficiency of coal	[%]	46%
Direct co-firing percentage	[e/e%]	20%
Full load hours of electricity production	[h/a]	7,000
Thermal full load efficiency	[%]	44%
Cost of biomass	[€/tonne]	160
Duration of incentive scheme	[a]	8
Specific investment for biomass direct co-firing	[€/kW_e]	350
Investment costs for coal-fired power plant	[€/kW_e]	2,000
Economic lifetime of coal-fired power plant	[a]	30
O&M costs of coal-fired power plant	[€/kW_e]	30
Additional O&M costs for biomass co-firing (including basic price premium)	[€/MWh_e]	4.7

*: The efficiency loss of the power plant as a whole resulting from biomass direct co-firing is entirely allocated to the biomass portion.

Table 46 shows the base rate and several other subsidy parameters.

Table 46: Overview of subsidy parameters for new direct co-firing capacity.

	Unit	SDE+ 2017 advice
Base rate SDE+ 2017	[€/kWh]	0.111
Base price SDE+ 2017	[€/kWh]	0.031
Provisional correction rate 2017	[€/kWh]	0.032
Calculation method for correction amount	APX	

8.5 Boiler fired by solid or liquid biomass, 0.5 - 5 MW_{th} and 0.1 – 0.5 MW_{th}

The reference installation for this category is a hot water boiler with a combustion grate, using wood from cutting and pruning as the reference fuel. Supplementary to this reference installation, allowance has been made for investments in flue gas cleaning equipment required by the Activities Decree. For example, the cost of a dust filter has been included for these installations. Due to the relaxation of the NO_x emission requirement for capacities between 1 and 5 MW_{th} in the Activities Decree, a $DeNO_x$ installation is not required for this category. To ensure that the category corresponds with the majority of the projects, the number of assumed full load hours has been reduced from 4,000 to 3,000 hours per year. In practice, 4,000 full load hours was not feasible for the services sector, whereas 3,000 full load hours should be. The investment costs for boilers in the capacity class 0.1 – 0.5 MW_{th} have been set at 510 €/$kW_{th,output}$ and for boilers in the capacity class 0.5 – 5 MW_{th} at 480 €/$kW_{th,output.}$ The difference between the two categories can be put down to the difference in economies of scale.

Reducing the number of full load hours causes a decrease in the O&M costs of 45 €/kW$_{th,output}$ to 34 €/kW$_{th,output}$.

Table 47 shows the technical-economic parameters for boilers fired by solid biomass.

Table 47: Boilers fired by solid biomass, 0.5-5 MW$_{th}$ and 0.1-0.5 MW$_{th}$

Parameter	Unit	SDE+ 2017 advice 0.5-5 MW$_{th}$	SDE+ 2017 advice 0.1-0.5 MW$_{th}$
Thermal output capacity	[MW$_{th_output]}$	0.75	0.30
Full load hours heat supply	[h/a]	3,000	3,000
Investment costs	[€/kW$_{th_output}$]	480	510
Fixed O&M costs	[€/kW$_{th_output}$]	34	34
Energy content of fuel	[GJ/tonne]	9.0	9.0
Fuel price	[€/tonne]	50	50

Table 48 shows the base rate and several other subsidy parameters. A higher correction amount is advised for smaller boilers, on account of the greater potential benefit of avoiding energy tax.

Table 48: Overview of subsidy parameters for boiler fired by solid or liquid biomass, 0.5-5 MW$_{th}$ and 0.1-0.5 MW$_{th}$

	Unit	SDE+ 2017 advice 0.5-5 MW$_{th}$	SDE+ 2017 advice 0.1-0.5 MW$_{th}$
Base rate for SDE+ 2017	[€/kWh]	0.056	0.057
Base price for SDE+ 2017	[€/kWh]	0.028	0.052
Provisional correction amount in 2017	[€/kWh]	0.029	0.053
Calculation method for correction amount	(TTF + energy tax)/gas boiler efficiency		

8.6 Boiler fired by solid or liquid biomass, ≥5 MW$_{th}$

In previous years, the reference installation for this category was a hot water boiler for supplying heat. In practice, the installations are often steam boilers. The reference installation for the advice SDE+ 2017 is therefore a steam boiler with a combustion grate, using wood from cutting and pruning as reference fuel. Supplementary to this reference installation, allowance has been made for investments required by the Activities Decree. The flue gas cleaning equipment for this category calls for higher investments than for the 0.5 - 5 MW$_{th}$ category. We have assumed that NO_x emissions can be reduced sufficiently with the use of an SNCR system. In addition, allowance has been made for higher investments in supplementary biomass storage and dust filters for the 0.5 - 5 MW$_{th}$ category than for the reference installation. The investment costs have been increased in relation to the final advice SDE+ 2016 to 580 €/kW$_{th,output}$.

In this category, it is possible to achieve heat or steam supply with a boiler fired by solid biomass instead of a gas-fired CHP. For this reason, the number of full load hours has been set at 7,000 hours per year for this category.

An overview of the technical-economic parameters for boilers fired by solid biomass (≥5 MW) is shown in Table 49.

Table 49: Technical-economic parameters for boilers fired by solid or liquid biomass, ≥5 MW_{th}

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Thermal output capacity	[MW_{th_output}]	10	
Full load hours heat supply	[h/a]	7,000	
Investment costs	[€/kW_{th_output}]	580	€5.8 million
Fixed O&M costs	[€/kW_{th_output}]	62	€620,000/year
Energy content of fuel	[GJ/tonne]	9.0	
Fuel price	[€/tonne]	50	

Table 50 shows the base rate and several other subsidy parameters.

Table 50: Overview of subsidy parameters for boiler fired by solid or liquid biomass, ≥5 MW_{th}

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.044
Base price for SDE+ 2017	[€/kWh]	0.012
Provisional correction amount in 2017	[€/kWh]	0.012
Calculation method for correction amount	TTF x 70%	

8.7 Boiler fired by liquid biomass

In some cases, gas-fired boilers can be replaced relatively quickly and easily by boilers fired by liquid biomass, for example pyrolysis oil or animal fat. The selected reference fuel is animal fat. It is expected that in 2017, the market will still be interested in boilers fired by animal or vegetable fats (residues). Given the relatively small contribution of the investment costs to the base rate and the option for initiators to further reduce these investment costs by installing modified burners in existing boilers, the investment amount has been set at zero in this advice. This makes the calculation representative for the use of liquid biomass in new bio-boilers as well as for the use of liquid biomass in modified, existing boilers. Table 51 shows the parameters for a boiler fired by liquid biomass.

Table 51: Technical-economic parameters for boiler fired by liquid biomass

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Thermal output capacity	[MW_{th_output}]	10	
Full load hours heat supply	[h/a]	7,000	
Investment costs	[€/kW_{th_output}]	0	€0.0 million
Fixed O&M costs	[€/kW_{th_output}]	24	€240,000/year
Energy content of fuel	[GJ/tonne]	39.0	
Fuel price	[€/tonne]	600	
Fuel surcharge	[€/tonne]	0	

Table 52 shows the base rate and several other subsidy parameters.

Table 52: Summary of subsidy parameters for boiler fired by liquid biomass

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.070
Base price for SDE+ 2017	[€/kWh]	0.022
Provisional correction amount in 2017	[€/kWh]	0.023
Calculation method for correction amount	(TTF + energy tax)/gas boiler efficiency	

8.8 Boiler fired by industrial steam from wood pellets > 5 MW_{th}

For this category, the reference installation is a water tube boiler, supplying steam at 35 bar, in which wood pellets are used as reference fuel. The fuel is stored in silos.

The market consultation in 2016 revealed that in addition to boilers with a capacity of approximately 30 $MW_{th,}$ there is also interest in capacities below 10 MW_{th}. The market consultation generated two analyses, both based on the ETS data for various industrial sectors. The conclusion from these analyses is that at a lower limit of 10 $MW_{th,}$ it is possible to achieve approximately 80% of the potential energy production in industry. At a lower limit of 5 $MW_{th,}$ approximately 90% of potential energy production can be achieved. From this perspective, we advise lowering the lower limit to 5 MW_{th}.

It is assumed that the installation can operate autonomously and be controlled remotely. The output of the boiler is 30 MW_{th} and the boiler is assumed to have an efficiency of 90%. The number of full load hours of heat supply is 7,000 hours per year, which corresponds with the 'boiler fired by solid or liquid biomass > 5 MW_{th}' category. The investment costs for the reference installation amount to 560 €/$kW_{th, output}$ with associated O&M costs of 36 €/$kW_{th, output}$. This means the investment costs are the same as for the 'pruning and thinning wood' category. The more expensive steam boiler and steam appendages for the pellet category are compensated by the simpler fuel storage and transport associated with this type of installation. The O&M costs for this category are lower than those for the category based on pruning wood. This is because the storage and transport of fuel can be performed on a smaller scale and more easily, which means fewer staff and replacement parts are needed to operate and maintain the installation.

The technical-economic parameters are shown in Table 53. In view of the duration of wood pellet contracts, we would advise a subsidy term of eight years, as for the direct/indirect co-firing categories.

Table 53: Technical-economic parameters for boiler fired by industrial steam from wood pellets

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Thermal output capacity	[MW_{th_output}]	30	
Full load hours heat supply	[h/a]	7,000	
Investment costs	[€/kW_{th_output}]	560	€ 16.8 million
Fixed O&M costs	[€/kW_{th_output}]	36	€1,080/year
Energy content of fuel	[GJ/tonne]	17.0	
Fuel price	[€/tonne]	155	
Fuel surcharge	[€/tonne]	15	

Table 54 shows the base rate and several other subsidy parameters.

Table 54: Overview of subsidy parameters for boiler fired by industrial steam from wood pellets

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.062
Base price for SDE+ 2017	[€/kWh]	0.012
Provisional correction amount in 2017	[€/kWh]	0.012
Calculation method for correction amount	TTF x 70%	

8.9 Thermal conversion of biomass, <100 MW_e

After several market consultations, the decision has been made to recommend a scaled down, simpler, more flexible reference installation for thermal conversion (CHP). The reference installation is based on pruning and thinning wood as fuel with an installed thermal capacity of 9.6 $MW_{th, output}$ and installed electrical capacity of 1.6 $MW_{e,output}$, and thermal load (biomass input) of 10 $MW_{th,input}$. The reference installation is designed to supply flexible heat and electricity, making the heat available for a centralised or decentralised district heating grid. The boiler can generate electricity using a condensing steam turbine. The determining factor for the scale is that the steam turbine must be able to supply an electrical capacity of 1.6 MW_e. The installation is fitted with an SNCR system and cyclone+bag filter.

The installation comprises a condensing steam turbine with electrical efficiency of 16%. In addition, other technologies that generate electricity from heat (such as a back pressure turbine or ORC) with a minimum efficiency of 10% are also allowed. Although they might have a lower capacity (typically 1 MW_e), unlike a condensing steam turbine, they usually supply electricity continuously and can generate a constant volume of electricity on an annual basis. This relatively simple, flexible set-up reduces investment costs to 1,250 €/kW_{th_input}. The number of full load hours of heat supply has been taken to be 8,000 hours (at 8 $MW_{th,output}$). The number of full load hours of electricity supply has been taken to be 5,000 (at 1.6 MW_e).

The technical-economic data for these reference plants are summarised in Table 55.

Table 55: Technical-economic parameters for thermal conversion of biomass, <100 MW_e_

Parameter	Unit	SDE+ 2017 advice	Total amount for reference
Input capacity	[MW_{th_input}]	10	
Electrical capacity	[MW_e]	1.6	
Thermal output capacity	[MW_{th_output}]	8	
Full load hours electrical supply	[h/a]	5,000	
Full load hours heat supply	[h/a]	8,000	
Maximum electrical efficiency		16%	
Electricity loss in heat supply		-	
Investment costs	[€/kW_{th_input}]	1,250	€12.5 million
Fixed O&M costs	[€/kW_{th_input}]	100	€1 million/year
Energy content of fuel	[GJ/tonne]	9.0	
Fuel price	[€/tonne]	50	

Table 56 shows the base rate and several other subsidy parameters. Section 11.1 calculates the base rate for situations in which the additional costs of electricity may not exceed 0.150 €/kWh.

Table 56: Overview of subsidy parameters for thermal conversion of biomass, <100 MW_e

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.062
Base price for SDE+ 2017	[€/kWh]	0.014
CHP ratio	[H:E]	8.00
Combined number of full load hours	[hours/year]	7,500
Provisional correction amount in 2017	[€/kWh]	0.015
Calculation method for correction amount	(APX + TTF x 70% * CHP)/(1 + CHP)	

9

Biomass digestion findings

This chapter describes the findings for the categories related to the digestion of biomass. Ahead of the findings for the different categories, section 9.1 provides a summary of the biomass prices used. After that, the following categories are discussed in successive sections:

- Prices used for biomass digestion (9.1)
- All-feedstock digestion (9.2)
- All-feedstock digestion (renewable gas) (9.2.1)
- Co-generation, all-feedstock digestion (9.2.2)
- Heat, all-feedstock digestion (9.2.3)
- Digestion and co-digestion of animal manure (9.3)
- Digestion and co-digestion of animal manure (renewable gas) (9.3.1)
- Co-generation, digestion and co-digestion of animal manure (9.3.2)
- Heat digestion and co-digestion of animal manure (9.3.3)
- Digestion of more than 95% animal manure (9.4)
- Digestion of more than 95% animal manure < 300 kW (renewable gas) (9.4.1)
- Co-generation, digestion of more than 95% animal manure < 300 kW (9.4.2)
- Heat digestion of more than 95% animal manure < 300 kW (9.4.3).
- Large-scale digestion of more than 95% animal manure (9.4.4).

Alongside the technical-economic parameters, these sections also give the base rate, base price, correction amount for 2017 and the method used to calculate the correction amount for each category.

9.1 Prices used for biomass digestion

Biomass as a fuel is available in different qualities. In this report, two reference fuels have been used for digestion: biomass for all-feedstock digesters and biomass for manure co-digesters. Table 57 shows a summary of these different references for biomass as a fuel. More detailed explanation of the elements in the table is provided in the following sub-sections.

Section 11.1 calculates the base rates on the basis of the biomass prices used in the advice for the SDE+ 2014.

Table 57: Biomass prices used for digestion plants applying for SDE+ in 2017

Biomass for digestion*	Energy content	Price (range)	Reference price
	[GJ/tonne]	[€/tonne]	[€/GJ]
All-feedstock digestion input	3.4	27.8	8.2
Co-digestion input	3.4	35.4	10.5

* The energy content of digestion input is given in GJ_{biogas}/tonne. The reference price for digestion input is given in €/GJ_{biogas}.

9.1.1 Digestion: biomass for all-feedstock digesters

The reference case used for the 'all-feedstock digestion' category is an installation that uses waste flows from the food and beverage industry or from biofuel production. The reference fuel is assumed to consist of waste products from the food and beverage industry, with the price level being determined by the animal feed markets. The reference price was established based on information from LEI regarding the 5-year average trend for animal feeds. The reference price for SDE+ 2017 has been set at 27.8 €/tonne at a biogas production of 3.4 GJ/tonne.

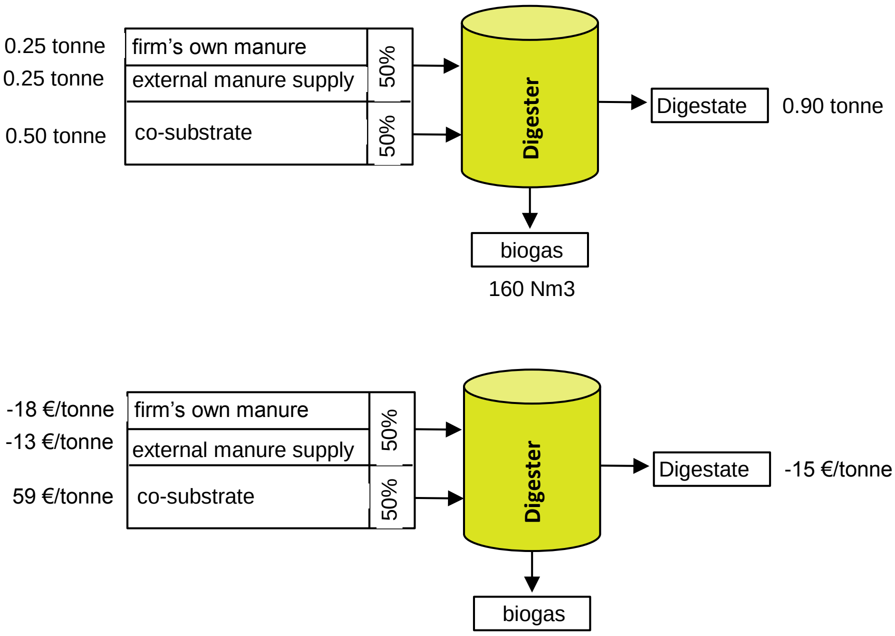
9.1.2 Digestion: biomass for manure co-digesters

Feedstock for manure co-digestion: fertiliser
The price of slurry displays regional differences, ranging from 0 to -5 € per tonne in areas with manure shortages up to a maximum of -15 to -20 € per tonne in manure surplus areas. The reference price is assumed to be -18 € per tonne for a firm's own manure. To make allowances for additional transportation costs, the reference price for external supply has been taken to be -13 €/tonne. About 90% of the total input remains as digestate. On average, the removal of digestate costs an additional 15 € per tonne.

Feedstock for manure co-digestion: co-substrate
In 2012, 80 new products that can serve as co-substrates were added to the so-called positive list of co-products. Permitting these co-products has resulted in a better alignment with regulations for foreign digesters. Co-products are subject to limits for the concentrations of heavy metals and organic impurities. However, expanding the list has not succeeded in easing the pressure on the market for co-products.

The market consultation of 2010 revealed that to prevent the annual fluctuations from having too great an impact on the calculated base rates, a long-term average is a more desirable starting point. In order to correct for fluctuations, the average of the last five years has been calculated, based on trade information from LEI (corrected for transport). ECN and DNV GL are upholding this policy in the advice for SDE+ 2017. Figure 4 provides a schematic overview of the assumed feedstock flows in the co-digester.

Figure 4: Flows and prices of digestion inputs and outputs[9]



The reference gas yield of co-substrate is assumed to be 291 Nm^3/tonne. The average price of co-substrate (including maize) is 9.7 €/GJ or 59 €/tonne at the start of the project, with a net energy content of 6.1 GJ/tonne. The total assumed feedstock costs, consisting of the purchase of co-substrate (including maize) and processing costs for manure and digestate, in the current mix amounts to 35.4 €/tonne, or 23 cent/Nm3 crude biogas, assuming a gas yield from the total input, manure and co-substrate of 3.4 GJ/tonne (excluding a 0.5 €/tonne fuel surcharge). An overview is shown in Table 58.

Table 58: Prices of manure and co-substrate

	Energy content	Price (range)	Reference price
	[GJ/tonne]	[€/tonne]	[€/GJ]
Supply of animal manure	*0.63*	*-13 (-25 to 0)*	*-21*
Removal of animal manure	*0.63*	*-18 (-30 to -5)*	*-29*
Co-substrate	*6.1*	*59.4*	*9.7*
Co-digestion input	3.4	35.4	10.5

9 The calculation methodology is based on the typical method used in the market of expressing the energy content of the manure input and co-substrates in gas yield in Nm^3/tonne or GJ/tonne for a particular energy content of the gas (21 MJ/m^3). In the calculation, the energy content of feedstock is expressed in GJ gas yield per tonne of input. For the sake of completeness: tonnes of input are based on the entire product and not just on the dry matter content.

9.2 All-feedstock digestion

9.2.1 All-feedstock digestion (renewable gas)

The reference technology for this category is a digester with a production capacity of 950 Nm^3/h crude biogas or 590 Nm^3/h renewable gas. The biogas produced is upgraded to renewable gas. The reference gas purification technology chosen is membrane technology, in view of the fact that this technology has been used for several recent renewable gas projects. This technology works at high pressures in order to achieve the separation between CH_4 and CO_2. For this reason, it is assumed that the renewable gas produced can be fed into the local 8-bar grid. With this technology, the CO_2 flow can be further cooled into the by-product liquid CO_2. However, when calculating the base rate, no account has been taken of the additional investment and O&M costs of this step.

The heat required to heat the digester is generated by firing part of the crude biogas in a boiler. The electricity required is obtained from the grid. See Table 59 for the technical-economic parameters of renewable gas production in all-feedstock digesters. It should be noted that the base rates have been calculated on the basis of a stand-alone installation and not a hub connection.

Table 59: Technical-economic parameters for energy from all-feedstock digestion (renewable gas)

Parameter	Unit	Advice for 2017	Total amount for reference
Reference size	[$Nm^3_{gross\ crude\ biogas}$/h]	950	
Full load hours	[h/a]	8,000	
Internal heat requirement	[% biogas]	5%	
Investment costs (digester)	[€ per $Nm^3_{gross\ crude\ biogas}$/h]	3,900	€6 million
Investment costs (gas upgrading)	[€ per $Nm^3_{net\ crude\ biogas}$/h]	2,327	combined
Fixed O&M costs (digester)	[€ per $Nm^3_{gross\ crude\ biogas}$/h]	232	€0.33 million/year
Fixed O&M costs (gas upgrading)	[€ per $Nm^3_{net\ crude\ biogas}$/h]	122	combined
Energy content of substrate	[GJ_{biogas}/tonne]	3.4	
Feedstock costs	[€/tonne]	27.8	

Table 60 shows the base rate and several other subsidy parameters.

Table 60: Overview of subsidy parameters for all-feedstock digestion (renewable gas)

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.061
Base price for SDE+ 2017	[€/kWh]	0.015
Provisional correction amount in 2017	[€/kWh]	0.016
Calculation method for correction amount	TTF	

9.2.2 Co-generation, all-feedstock digestion

In the 'all-feedstock digestion to electricity and heat' digestion option, an existing industrial installation is modified by integrating a production installation for electricity or heat into the existing installation. The feedstock is primarily released from the existing installation and the energy from the biogas produced is largely returned to the same existing installation in the form of heat and power.

For the reference installation, a scale of 3 MW_e (8.1 MW_{th_input}) has been assumed. The number of full load hours for heat has been increased from 4,000 to 7,000. This brings the number of full load hours of heat to the same number used in the 'heat from all-feedstock digestion' category and the categories for manure digestion.

Table 61 shows the technical-economic parameters for all-feedstock digestion for co-generation (CHP).

Table 61: Technical-economic parameters for energy from co-generation, all-feedstock digestion

Parameter	Unit	Advice for 2017	Total amount for reference
Input capacity	[MW_{th_input}]	8.1	
Electrical capacity	[MW_e]	3.0	
Thermal output capacity	[MW_{th_output}]	3.888	
Full load hours electrical supply	[h/a]	8,000	
Full load hours heat supply	[h/a]	7,000	
Maximum electrical efficiency		37 %	
Investment costs	[€/kW_{th_input}]	994	€8.1 million
Fixed O&M costs	[€/kW_{th_input}]	57	€462,000/year
Energy content of fuel	[GJ_{biogas}/tonne]	3.4	
Feedstock costs	[€/tonne]	27.8	

Table 62 shows the base rate and several other subsidy parameters.

Table 62: Overview of subsidy parameters for co-generation, all-feedstock digestion

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.069
Base price for SDE+ 2017	[€/kWh]	0.021
CHP ratio	[H:E]	1.13
Combined number of full load hours	[hours/year]	7,436
Provisional correction amount in 2017	[€/kWh]	0.022
Calculation method for correction amount	(APX + TTF x 70% x CHP)/(1 + CHP)	

9.2.3 Heat, all-feedstock digestion

In the 'all-feedstock digestion to heat' digestion option, an existing installation is modified by integrating a production installation for heat into the existing installation. The feedstock is primarily released from the existing installation and the energy from the biogas produced is largely returned to the same existing installation in the form of heat.

Table 63 shows the technical-economic parameters for all-feedstock digestion for renewable heat.

Table 63: Technical-economic parameters for energy from heat, all-feedstock digestion

Parameter	Unit	Advice for 2017	Total amount for reference
Input capacity	[MW_{th_input}]	8.1	
Full load hours heat supply	[h/a]	7,000	
Internal heat requirement	[%]	5	
Investment costs	[€/kW_{th_output}]	850	€5.9 million
Fixed O&M costs	[€/kW_{th_output}]	47	€324,000/year
Energy content of fuel	[GJ_{biogas}/tonne]	3.4	
Feedstock costs	[€/tonne]	27.8	

Table 64 shows the base rate and several other subsidy parameters.

Table 64: Overview of subsidy parameters for heat, all-feedstock digestion

	Unit	Advice 2017
Base rate for SDE+ 2017	[€/kWh]	0.062
Base price for SDE+ 2017	[€/kWh]	0.022
Provisional correction amount in 2017	[€/kWh]	0.023
Calculation method for correction amount	(TTF + energy tax)/gas boiler efficiency	

9.3 Digestion and co-digestion of animal manure

9.3.1 Digestion and co-digestion of animal manure (renewable gas)

For the reference installation for animal manure digestion, a production capacity has been assumed of 505 Nm^3/h crude biogas (or 315 Nm^3/h renewable gas). The size of the digester in an installation of this size is comparable to that of a digester in a 1.1 MW_e bio CHP plant. Economies of scale appear to be limited for digesters. The maximum size of a digestion tank is restricted by the fact that the material needs to be able to be homogenised; the diameter of the roof of a digester is also subject to a maximum size.

Consequently, for production at a larger scale, several tanks are often placed side by side.

The reference gas purification technology chosen is membrane technology, in view of the fact that this technology has been used for several recent renewable gas projects. This technology works at high pressures in order to achieve the separation between CH_4 and CO_2. For this reason, it is assumed that the renewable gas produced can be fed into the local 8-bar grid. With this technology, the CO_2 flow can be further cooled into the by-product liquid CO_2. However, when calculating the base rate, no account has been taken of the additional investment and O&M costs of this step.

The heat required to heat the digester is generated by firing part of the crude biogas in a boiler. The electricity required is obtained from the grid. Table 65 shows the technical-economic parameters for the production of renewable gas. It should be noted that the base rates have been calculated on the basis of a stand-alone installation and not a hub connection.

Table 65: Technical-economic parameters for energy from manure co-digestion (renewable gas)

Parameter	Unit	Advice for 2017	Total amount for reference
Reference size	[$Nm^3_{gross\ crude\ biogas}$/h]	505	
Full load hours	[h/a]	8,000	
Internal heat requirement	[% biogas]	5%	
Investment costs (digester)	[€ per $Nm^3_{gross\ crude\ biogas}$/h]	4,515	€4 million
Investment costs (gas upgrading)	[€ per $Nm^3_{net\ crude\ biogas}$/h]	2,876	combined
Fixed O&M costs (digester)	[€ per $Nm^3_{gross\ crude\ biogas}$/h]	366	€0.26 million/year
Fixed O&M costs (gas upgrading)	[€ per $Nm^3_{net\ crude\ biogas}$/h]	154	combined
Energy content of substrate	[GJ_{biogas}/tonne]	3.4	
Feedstock costs	[€/tonne]	35.4	

Table 66 shows the base rate and several other subsidy parameters.

Table 66: Overview of subsidy parameters for manure co-digestion (renewable gas)

	Unit	Advice for 2017
Base rate for SDE+ 2017	[€/kWh]	0.077
Base price for SDE+ 2017	[€/kWh]	0.015
Provisional correction amount in 2017	[€/kWh]	0.016
Calculation method for correction amount	TTF	

9.3.2 Co-generation, digestion and co-digestion of animal manure

For the reference installation, a scale of 1.1 MW_e (3 MW_{th_input}) has been assumed. An installation of this size remains well below the MER limit (MER = Environmental Impact Assessment) and can be supplied with manure by two large farms. In the first year, there will be additional costs for starting up the installation. These additional costs are included in the investment cost and result in a total investment cost of 1,145 €/kW_{th_input}.

Calculations for the SDE+ base rates are based on an electrical efficiency for converting the biogas into net electricity supply of 37%. For heat, it was assumed that all available heat (after deducting the internal heat requirement for the digester) is available for hygienisation of the digestate. The possibility of using the heat in the drying and hygienisation process of digestate means an increase in the number of full load hours for heat from 4,000 to 7,000.

Table 67 shows the technical-economic parameters for manure digestion for co-generation (CHP).

Table 67: Technical-economic parameters for energy from co-generation, digestion and co-digestion of animal manure

Parameter	Unit	Advice for 2017	Total amount for reference
Input capacity	[MW_{th_input}]	3.0	
Electrical capacity	[MW_e]	1.1	
Thermal output capacity	[MW_{th_output}]	1.44	
Full load hours electrical supply	[h/a]	8,000	
Full load hours heat supply	[h/a]	7,000	
Maximum electrical efficiency		37%	
Investment costs	[€/kW_{th_input}]	1,145	€3 million
Fixed O&M costs	[€/kW_{th_input}]	85	€255,000/year
Energy content of fuel	[GJ_{biogas}/tonne]	3.4	
Feedstock costs	[€/tonne]	35.4	

Table 68 shows the base rate and several other subsidy parameters.

Table 68: Overview of subsidy parameters for co-generation, digestion and co-digestion of animal manure

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.090
Base price for SDE+ 2017	[€/kWh]	0.21
CHP ratio	[H:E]	1.15
Combined number of full load hours	[hours/year]	7,433
Provisional correction amount in 2017	[€/kWh]	0.22
Calculation method for correction amount	(APX + TTF x 70% x CHP)/(1 + CHP)	

9.3.3 Heat, digestion and co-digestion of animal manure

An investment cost of 963 €/kW_{th_output} is assumed for manure co-digestion for renewable heat, including the cost of an additional boiler. The boiler supplies heat/steam at about 120°C. The cost of a gas pipe or a heat grid has not been included.

Table 69 shows the technical-economic parameters for manure co-digestion (heat).

Table 69: Technical-economic parameters for energy from manure co-digestion (heat)

Parameter	Unit	Advice for 2017	Total amount for reference
Input capacity	[MW_{th_input}]	3.0	
Full load hours heat supply	[h/a]	7,000	
Internal heat requirement	[%]	5	
Internal electricity requirement	[kWh/GJ_{output}]	5.41	
Electricity rate	[€/kWh]	0.10	
Investment costs	[$€/kW_{th\_output}$]	963	€2.5 million
Fixed O&M costs	[$€/kW_{th\_output}$]	74	€189,000/year
Energy content of fuel	[GJ_{biogas}/tonne]	3.4	
Feedstock costs	[€/tonne]	35.4	

Table 70 shows the base rate and several other subsidy parameters.

Table 70: Overview of subsidy parameters for manure co-digestion (heat)

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.079
Base price for SDE+ 2017	[€/kWh]	0.022
Provisional correction amount in 2017	[€/kWh]	0.022
Calculation method for correction amount	(TTF + energy tax)/gas boiler efficiency	

9.4 Digestion of more than 95% animal manure

Recent initiatives for the production of renewable gas through manure mono-digestion are on a larger to much larger scale than the SDE+ reference for 2016. For this reason, two sub-categories were examined for 2017:

- Small-scale manure mono-digestion similar to the reference system used for the SDE+ in 2016 for the production of renewable gas;
- Large-scale manure mono-digestion with a production capacity for crude biogas of around 2 million m^3 per year.

9.4.1 Digestion of more than 95% animal manure < 300 kW (renewable gas)

The reference system for this category has a crude biogas production of 20.5 Nm^3/h (or 11 Nm^3/h renewable gas). This is comparable to a CHP capacity of 39 kW_e, which makes the reference consistent with the reference in the advice for renewable energy for this category. The reference gas cleaning technique is based on a configuration of membranes. The heat required to heat the digester is generated by firing part of the crude biogas in a boiler. The electricity required is obtained from the grid.

Table 71 shows the technical-economic parameters for the production of renewable gas.

Table 71: Technical-economic parameters for energy from manure mono-digestion (renewable gas)

Parameter	Unit	Advice for 2017
Reference size	[$Nm^3_{gross\ crude\ biogas}$/h]	20.5
Full load hours	[h/a]	8,000
Internal heat requirement	[% biogas]	18%
Investment costs (digester)	[€ per $Nm^3_{gross\ crude\ biogas}$/h]	16,900
Investment costs (gas upgrading)	[€ per $Nm^3_{net\ crude\ biogas}$/h]	19,557
Fixed O&M costs (digester)	[€ per $Nm^3_{gross\ crude\ biogas}$/h]	807
Fixed O&M costs (gas upgrading)	[€ per $Nm^3_{net\ crude\ biogas}$/h]	1,892
Energy content of substrate	[GJ_{biogas}/tonne]	0.63
Feedstock costs	[€/tonne]	0

Table 72 shows the base rate and several other subsidy parameters.

Table 72: Overview of subsidy parameters for digestion of more than 95% animal manure (renewable gas)

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.171
Base price for SDE+ 2017	[€/kWh]	0.015
Provisional correction amount in 2017	[€/kWh]	0.016
Calculation method for correction amount	TTF	

9.4.2 Co-generation, digestion of more than 95% animal manure < 300 kW

The reference installation for the production of renewable heat and electricity is based on manure produced internally on the farm. Based on the energy content of the manure and the electrical efficiency of the gas engine, the reference installation delivers a net electrical output of 39 kW_e. Technically, electricity generation from digestion involves a CHP installation in which the 26 kW_{th} of heat is used entirely for the internal digestion process. Although a small part of the heat production can nevertheless be used outside the installation itself, in order to achieve a representative base rate, only electricity production has been considered as being eligible for an SDE+ allowance.

Table 73 shows the technical-economic parameters for manure mono-digestion for electricity and heat.

Table 73: Technical-economic parameters for energy from manure mono-digestion (CHP)

Parameter	Unit	Advice for 2017	Total amount for reference
Input capacity	[MW_{th_input}]	0.123	
Electrical capacity	[MW_e]	0.039	
Thermal output capacity	[MW_{th_output}]	0.026	
Full load hours electrical supply	[h/a]	8,000	
Full load hours heat supply	[h/a]	1,000	
Maximum electrical efficiency		32%	
Investment costs	[€/kW_{th_input}]	3,348	€0.4 million
Fixed O&M costs	[€/kW_{th_input}]	198	€24,000/year
Energy content of fuel	[GJ_{biogas}/tonne]	0.63	
Feedstock costs	[€/tonne]	0	

Table 74 shows the base rate and several other subsidy parameters.

Table 74: Overview of subsidy parameters for co-generation, digestion of more than 95% animal manure

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	>0.200
Base price for SDE+ 2017	[€/kWh]	0.030
CHP ratio	H:P	0.08
Combined number of full load hours	hours/year	5,200
Provisional correction amount in 2017	[€/kWh]	0.031
Calculation method for correction amount	(APX + TTF x 70% x CHP)/(1 + CHP)	

9.4.3 Heat, digestion of more than 95% animal manure < 300 kW

The reference installation for the production of renewable heat is based on manure that is produced internally on the farm. Table 75 shows the technical-economic parameters of manure mono-digestion for heat.

Table 75: Technical-economic parameters for energy from manure mono-digestion (heat)

Parameter	Unit	Advice for 2017	Total amount for reference
Input capacity	[MW_{th_input}]	0.123	
Full load hours heat supply	[h/a]	7,000	
Investment costs	[€/kW_{th_output}]	3,916	€0.4 million
Fixed O&M costs	[€/kW_{th_output}]	193	€18,000/year
Energy content of fuel	[GJ_{biogas}/tonne]	0.63	
Feedstock costs	[€/tonne]	0	

Table 76 shows the base rate and several other subsidy parameters.

Table 76: Overview of subsidy parameters for heat, digestion of more than 95% animal manure

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.102
Base price for SDE+ 2017	[€/kWh]	0.022
Provisional correction amount in 2017	[€/kWh]	0.023
Calculation method for correction amount	(TTF + energy tax)/gas boiler efficiency	

9.4.4 Large-scale digestion of more than 95% animal manure

There are very few large-scale digesters in operation, although interest in these installations appears to be growing. Initial investigations by ECN and DNV GL seem to indicate that the production costs for renewable energy from large-scale mono-digesters would be significantly lower than those involved in small-scale mono-digestion. The production costs for renewable energy from mono-digesters are more comparable with the production costs for renewable energy from manure co-digesters. It could be said that mono-digesters and co-digesters are the extremes in the same spectrum: installations that are technically very similar, but which need a greater or lesser amount of co-substrate to be added to the manure being digested. Instead of defining separate categories for manure co-digestion, small-scale manure mono-digestion and large-scale manure mono-digestion, ECN and DNV GL recommend that a broader analysis of the production of renewable energy from manure digestion be made, before deciding whether to create more or fewer extra categories. Based on the information available, ECN and DNV GL advise instigating a separate category for small-scale manure digestion (without co-substrate). Pending the broader analysis mentioned above, ECN and DNV GL think it worth considering supporting large-scale manure digestion (without substrate) through the categories for manure co-digestion.

10

Findings for existing installations

This chapter describes the findings for the following categories related to existing installations:

- Extended lifespan, all-feedstock digestion (CHP) (10.1)
- Extended lifespan, digestion and co-digestion of animal manure (CHP) (10.2)
- Extended lifespan, all-feedstock digestion (renewable gas and heat) (10.3)
- Extended lifespan, digestion and co-digestion of animal manure (renewable gas and heat) (10.4).

The biomass prices used in this category have already been provided in section 9.1.

10.1 Extended lifespan, all-feedstock digestion (CHP)

The 'extended lifespan, all-feedstock digestion' category relates to digestion installations whose MEP allowance has ended. A heat supply of 7,000 full load hours has been assumed, equal to the heat supply in new CHP projects. The participants in the consultation round asked for a greater focus on the cost of renovating digesters. In view of the assumed lifespan of 12 years, ECN and DNV GL have based their calculations on major maintenance of the digestion installation, including the replacement of mixers, gas roof and CHP engine. These costs have been factored into the O&M costs. Replacing the gas engine increases electrical efficiency. The net efficiency of a renovated digester is lower than a newly built installation, given the smaller scale of the MEP digesters.

Table 77 shows the technical-economic parameters for extended lifespan, all-feedstock co-digestion (CHP).

Table 77: Technical-economic parameters for energy from extended lifespan of all-feedstock digestion (CHP)

Parameter	Unit	Advice for 2017	Total amount for reference
Input capacity	[MW_{th_input}]	2.2	
Electrical capacity	[MW_e]	0.8	
Thermal output capacity	[MW_{th_output}]	0.925	
Full load hours electrical supply	[h/a]	8,000	
Full load hours heat supply	[h/a]	7,000	
Maximum electrical efficiency		37%	
Electricity loss in heat supply		-	
Investment costs	[€/kW_{th_input}]	0	€0 million
Fixed O&M costs	[€/kW_{th_input}]	158	€0.3 million/year
Energy content of substrate	[GJ/tonne]	3.4	
Feedstock price	[€/tonne]	27.8	

Table 78 shows the base rate and several other subsidy parameters.

Table 78: Overview of subsidy parameters for extended lifespan of all-feedstock digestion (CHP)

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.071
Base price for SDE+ 2017	[€/kWh]	0.021
CHP ratio	[H:E]	1.01
Combined number of full load hours	[hours/year]	7,464
Provisional correction amount in 2017	[€/kWh]	0.022
Calculation method for correction amount	(APX + TTF x 70% x CHP)/(1 + CHP)	

10.2 Extended lifespan, digestion and co-digestion of animal manure (CHP)

The 'extended lifespan, digestion and co-digestion of animal manure' category relates to digestion installations whose MEP allowance has ended. A heat supply of 7,000 full load hours has been assumed, equal to the heat supply in new CHP projects. The participants in the consultation round asked for a greater focus on the cost of renovating digesters. In view of the assumed lifespan of 12 years, ECN and DNV GL have based their calculations on large-scale maintenance of the digestion installation, including the replacement of mixers, gas roof and CHP engine. These costs have been factored into the O&M costs. Replacing the gas engine increases electrical efficiency. The net efficiency of a renovated digester is lower than a newly built installation, given the smaller scale of the MEP digesters.

Table 79 shows the technical-economic parameters for extended lifespan, digestion and co-digestion of animal manure.

Table 79: Technical-economic parameters for energy from extended lifespan of manure co-digestion (CHP)

Parameter	Unit	Advice for 2017	Total amount for reference
Input capacity	[MW_{th_input}]	2.2	
Electrical capacity	[MW_e]	0.8	
Thermal output capacity	[MW_{th_output}]	0.925	
Full load hours electrical supply	[h/a]	8,000	
Full load hours heat supply	[h/a]	7,000	
Maximum electrical efficiency		37%	
Electricity loss in heat supply		-	
Investment costs	[€/kW_{th_input}]	0	€0 million
Fixed O&M costs	[€/kW_{th_input}]	158	€0.3 million/year
Energy content of substrate	[GJ/tonne]	3.4	
Feedstock price	[€/tonne]	35.4	

Table 80 shows the base rate and several other subsidy parameters.

Table 80: Overview of subsidy parameters for extended lifespan for digestion and co-digestion of animal manure (CHP)

	Unit	SDE+ 2017 advice
Base rate for SDE+ 2017	[€/kWh]	0.082
Base price for SDE+ 2017	[€/kWh]	0.021
CHP ratio	[H:E]	1.01
Combined number of full load hours	[hours/year]	7,464
Provisional correction amount in 2017	[€/kWh]	0.022
Calculation method for correction amount	(APX + TTF x 70% x CHP)/(1 + CHP)	

10.3 Extended lifespan, all-feedstock digestion (renewable gas and heat)

Installations for all-feedstock digestion can also opt not to replace the gas engine but to connect the installation to a green gas or heat hub, so that instead of electricity, renewable gas is produced or heat is supplied.

Reference systems for the production of crude biogas

When determining the technical-economic parameters for the production of crude biogas, the costs of CO_2 separation are not included, whereas the costs of limited gas cleaning to remove hydrogen sulphide or ammonia are included. In addition, it has been assumed that part of the crude biogas in a boiler is fired to supply heat for the digester. In order to extend the lifespan, analogous to the CHP option, the costs of renovation (excluding the CHP replacement) have been included in the O&M costs.

Table 81 shows the technical-economic production parameters for a green gas or heat hub based on existing all-feedstock digesters. In the case of supply to a heat hub (see

Appendix A), the number of full load hours is limited by the full load hours of the heat supplied by the hub, i.e. 7,000 hours/year.

Table 81: Technical-economic parameters for energy from extended lifespan of all-feedstock digestion (crude biogas)

Parameter	Unit	Advice for 2017	Total amount for reference
Reference size	[$Nm^3_{gross\ crude\ biogas}$/h]	370	
Full load hours	[h/a]	8,000*	
Internal heat requirement	[% biogas]	5%	
Investment costs (digester)	[€ per $Nm^3_{gross\ crude\ biogas}$/h]	0	€0 million combined
Investment costs (gas upgrading)	[€ per $Nm^3_{net\ crude\ biogas}$/h]	385	
Fixed O&M costs (digester)	[€ per $Nm^3_{gross\ crude\ biogas}$/h]	480	€0.19 million/year combined
Fixed O&M costs (gas upgrading)	[€ per $Nm^3_{net\ crude\ biogas}$/h]	38	
Energy content of substrate	[GJ_{biogas}/tonne]	3.4	
Feedstock costs	[€/tonne]	27.8	

* 7,000 full load hours for delivery to a heat hub.

Table 82 shows the base rate and several other subsidy parameters. This includes the cost of crude biogas production and the cost of the supply hub (see Appendix A).

Table 82: Overview of subsidy parameters for extended lifespan, all-feedstock digestion (renewable gas and heat)

	Unit	Advice for SDE+ 2017 renewable gas	Advice for SDE+ 2017 heat
Base rate for SDE+ 2017	[€/kWh]	0.058	0.059
Base price for SDE+ +2017	[€/kWh]	0.015	0.012
Provisional correction amount in 2017	[€/kWh]	0.016	0.012
Calculation method for correction amount		TTF	TTF x 70%

10.4 Extended lifespan, digestion and co-digestion of animal manure (renewable gas and heat)

Installations for digestion and co-digestion of manure can also opt not to replace the gas engine but to connect the installation to a hub, so that instead of generating electricity, it produces renewable gas or it supplies heat.

Reference systems for the production of crude biogas

When determining the technical-economic parameters for the production of crude biogas, the costs of CO_2 separation are not included, whereas the costs of limited gas cleaning to remove hydrogen sulphide or ammonia are included. In addition, it has been assumed that part of the crude biogas in a boiler is fired to supply heat for the digester. In order to extend the lifespan, analogous to the CHP option, the costs of renovation (excluding the CHP replacement) have been included in the O&M costs.

Table 83 shows the technical-economic production parameters for a green gas or heat hub based on existing manure co-digesters. In the case of supply to a heat hub, the number of full load hours is limited by the full load hours of the heat supplied by the hub, i.e. 7,000 hours/year.

Table 83: Technical-economic parameters for energy from extended lifespan of manure digestion and co-digestion (crude biogas)

Parameter	Unit	Advice for 2017	Total amount for reference
Reference size	[$Nm^3_{gross\ crude\ biogas}$/h]	370	
Full load hours	[h/a]	8,000	
Internal heat requirement	[% biogas]	5%	
Investment costs (digester)	[€ per $Nm^3_{gross\ crude\ biogas}$/h]	0	€0 million combined
Investment costs (gas upgrading)	[€ per $Nm^3_{net\ crude\ biogas}$/h]	385	
Fixed O&M costs (digester)	[€ per $Nm^3_{gross\ crude\ biogas}$/h]	480	€0.19 million/year combined
Fixed O&M costs (gas upgrading)	[€ per $Nm^3_{net\ crude\ biogas}$/h]	38	
Energy content of substrate	[GJ_{biogas}/tonne]	3.4	
Feedstock costs	[€/tonne]	35.4	

Table 84 shows the base rate and several other subsidy parameters. This includes the cost of crude biogas production and the cost of the supply hub (see Appendix A).

Table 84: Overview of subsidy parameters for extended lifespan of digestion and co-digestion of animal manure (renewable gas and heat)

	Unit	Advice for SDE+ 2017 renewable gas	Advice for SDE+ 2017 heat
Base rate for SDE+ 2017	[€/kWh]	0.066	0.069
Base price for SDE+ 2017	[€/kWh]	0.015	0.012
Provisional correction amount in 2017	[€/kWh]	0.016	0.012
Calculation method for correction amount		TTF	TTF x 70%

11

Additional parameters

The technical-economic parameters from the previous chapters are important information for calculating the base rates based on the stylised ECN cash flow model, which was also used for the advice in previous years. The cash flow model, completed for each category, can be downloaded from the ECN website: https://www.ecn.nl/nl/samenwerking/sde/.

The base rates advised by ECN and DNV GL are calculated on the basis of insight into market prices, on the condition that the rates must be viable for the majority of the projects. These base rates are shown in the tables in the summary and in the sections relevant to the various categories. In addition, the Ministry of Economic Affairs has asked for a calculation of base rates for additional parameters. These are shown in this chapter.

11.1 Base rates for additional parameters

In order to ensure that SDE+ does not encourage a further rise in the price of biomass, the Ministry has asked for the base rates to also be calculated on the basis of the biomass prices used for the SDE+ 2014. Table 85 shows these biomass prices and Table 86 the base rates based on these biomass prices.

Table 85: Biomass prices as an additional parameter

Biomass	Price advice for SDE+ 2017	Price advice for SDE+ 2014
Pruning and thinning wood	5.6 €/GJ	5.3 €/GJ
Animal fat	15.4 €/GJ	15.4 €/GJ
All-feedstock digestion input	8.2 €/GJ	7.4 €/GJ
Co-digestion input	10.5 €/GJ	9.5 €/GJ

Table 86: Base rates for additional parameters

Category	SDE+ 2017 advice [€/kWh]	SDE+ 2017 for additional parameters [€/kWh]
Biomass gasification (≥ 95% biogenic)	0.150	0.149
Boiler fired by solid or liquid biomass, 0.1-0.5 MW_{th}	0.057	0.056
Boiler fired by solid or liquid biomass, 0.5-5 MW_{th}	0.056	0.055
Boiler fired by solid or liquid biomass, ≥ 5 MW_{th}	0.044	0.043
Boiler fired by liquid biomass	0.070	0.070
Thermal conversion of biomass, < 100 MW_e	0.062	0.061
All-feedstock digestion (renewable gas)	0.061	0.058
Co-generation, all-feedstock digestion	0.069	0.065
Heat, all-feedstock digestion	0.062	0.058
Digestion and co-digestion of animal manure (renewable gas)	0.077	0.074
Co-generation, digestion and co-digestion of animal manure	0.090	0.085
Heat, digestion and co-digestion of animal manure	0.079	0.075
Extended lifespan all-feedstock digestion, co-generation	0.071	0.067
Extended lifespan co-generation, digestion and co-digestion of animal manure	0.082	0.077
Extended lifespan all-feedstock digestion (renewable gas)	0.058	0.055
Extended lifespan all-feedstock digestion (heat)	0.059	0.055
Extended lifespan digestion and co-digestion of animal manure (renewable gas)	0.066	0.063
Extended lifespan digestion and co-digestion of animal manure (heat)	0.069	0.064

With a view to optimising costs, the Ministry has also asked for a calculation of the base rates for bio-CHP on the condition that additional costs of a heat boiler for electricity production for CHP may not exceed 0.13 €/kWh or 0.15 €/kWh for the biomass prices for the SDE+ 2014. The resulting base rates are shown in Table 87.

Table 87: Base rates [€/kWh] co-generation with a maximum additional price for electricity of 0.013 €/kWh or 0.015 €/kWh. The base rates were calculated based on biomass prices from the SDE+ 2014

Category	Heat reference	Base rate CHP	Base rate heat	Additional costs electricity	Base rate SDE+ 2017 with additional costs of € 0.015 /kWh	Base rate SDE+ 2017 with additional costs of €0.013 /kWh
Thermal conversion of biomass, < 100 MW_e	Boiler fired by solid or liquid biomass, ≥5 MW_{th}	0.061	0.043	0.205	0.055	0.053
Co-generation all-feedstock digestion	Heat, all-feedstock digestion	0.065	0.058	0.073	0.065	0.065
Co-generation, digestion and co-digestion of animal manure	Heat, digestion and co-digestion of animal manure	0.085	0.075	0.096	0.085	0.085
Co-generation of more than 95% animal manure < 300 kW	Heat digestion of more than 95% animal manure < 300 kW	0.227	0.102	0.237	0.146	0.128

Abbreviations

APX	Amsterdam Power eXchange, market index for electricity (day ahead)
WWTP	Waste water treatment plant
BEC	Bio-energy plant
CAPEX	Capital Expenditures, investment costs
CAR	Construction all risk insurance
EZ	Dutch Ministry of Economic Affairs
IRS	Interest Rate Swap
LEI	Agricultural Economics Research Institute
MEP	Environmental Quality of Electricity Production
O&M	Operation and Maintenance
OPEX	Operating Expenditures
ORC	Organic Rankine Cycle
RED	Reversed Electrodialysis
FGD	Flue gas desulphurisation installation
RVB	Central Government Real Estate Agency (*Rijksvastgoedbedrijf*)
RWZI	Waste Water Treatment Plant *(Rioolwaterzuiveringsinstallatie*)
SDE	Dutch Renewable Energy Production Support Scheme
SNCR	Selective non-catalytic reduction installation
SNG	Substitute Natural Gas or Synthetic Natural Gas
TTF	Title Transfer Facility, market index for gas (futures market)
WACC	Weighted Average Cost of Capital
CHP	Combined Heat and Power

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Appendix A. Hubs and production of crude biogas

A.1. Introduction

Unlike renewable gas, biogas does not comply with the specifications for feeding into the natural gas grid. Primarily consisting of methane and carbon dioxide, which is produced by various digestion installations, crude biogas can be transported to a central point through a low-pressure pipeline. In these so-called hubs, the biogas is used for the production of electricity and/or heat. It can also be purified to produce renewable gas. For most categories, the cost of processing to produce electricity and/or heat or renewable gas at the location itself is included. For a few categories, processing via a hub is more reasonable (as for extended lifetime of all-feedstock digesters, manure co-digesters and agricultural digesters which can choose to not merely replace the CHP). For this reason, this section shows the technical-economic parameters of hubs by way of explanation of the parameters in the chapter on digestion.

Most base rates are calculated using the cost structure of an independent installation, i.e. without a hub connection.

A.2. Description of reference heat hub

The technical-economic parameters for the reference heat hub including biogas pipeline are shown in Table 88. These parameters result in a cost price for a heat hub of 0.003 €/kWh.

Table 88: Technical-economic parameters for heat hub

Parameter	Unit	Advice 2017	Total amount for reference
Input capacity	[MW_{th_input}]	12.7	
Full load hours heat supply	[h/a]	7,000	
Internal heat requirement	[%]	0	
Investment costs	[€/kW_{th_output}]	60	€0.7 million
Fixed O&M costs	[€/kW_{th_output}]	1.3	€15,000/year

A.3. Description of reference green gas hub

The reference system for a green gas hub has a crude biogas input of 2,200 Nm^3/h (or 1,440 Nm^3/h renewable gas). The reference gas purification technology chosen is membrane technology, in view of the fact that this technology has been used for several recent renewable gas projects. This technology works at high pressures in order to achieve the separation between CH_4 and CO_2. With this technology, the CO_2 flow can be further cooled into the by-product liquid CO_2. However, when calculating the base rate, no account has been taken of the additional investment and O&M costs of this step. The required electricity is purchased externally.

The technical-economic parameters for the reference green gas hub, including biogas pipeline and green gas compression to 40 bar, are shown in Table 89. These parameters result in a cost price for a green gas hub of 0.017 €/kWh.

Table 89: Technical-economic parameters for green gas hub

Parameter	Unit	Advice 2017	Total amount for reference
Reference size	[$Nm^3_{gross\ crude\ biogas}/h$]	2,200	
Full load hours	[h/a]	8,000	
Investment costs (digester)	[€ per $Nm^3_{gross\ crude\ biogas}/h$]	0	€4 million
Investment costs (gas upgrading)	[€ per $Nm^3_{net\ crude\ biogas}/h$]	1,750	combined
Fixed O&M costs (digester)	[€ per $Nm^3_{gross\ crude\ biogas}/h$]	0	€0.187 million/year
Fixed O&M costs (gas upgrading)	[€ per $Nm^3_{net\ crude\ biogas}/h$]	85	combined

Appendix B. Overview of base rates and correction amounts

The base rates and provisional correction amounts for 2017 are represented in the following tables. The calculation methods for these base rates are included in Kraan and Lensink, 2016, and for the correction amounts in Lensink, 2016. For the heat categories, the heat production of the reference installation is usually taken to be normative in terms of achieving the benefits of avoiding energy tax and sustainable energy storage (ET and SES). Apart from the exceptions specified, an independently-operating installation is assumed when determining the correction amount. Table 90 shows how the energy tax benefit is determined for the purpose of calculating the correction amounts.

Installations producing less than the equivalent of 170,000 m^3 of natural gas heat per year are assumed to save on energy tax in the 0-170,000 m^3 band in natural gas/year. The correction amount is determined on the basis of natural gas not used in a gas boiler with 90% efficiency, and energy tax not paid (as well as avoiding sustainable energy surcharge) in the 0 to 170,000 m^3/year band. This correction amount is referred to as correction amount 'small'.

Installations producing less than the equivalent of 1 million, but more than 170,000 m^3 of natural gas heat per year, are also assumed to save on energy tax in the 170,000-1 million m^3 band in natural gas/year. The correction amount is determined on the basis of natural gas not used in a gas boiler with 90% efficiency, and energy tax not paid (as well as avoiding sustainable energy surcharge) in the 170,000 - 1 million m^3/year band. This correction amount is referred to as correction amount 'medium/small'. In the advice for the SDE+ 2016, the 'boiler fired by solid biomass < 5 MW' category came in the 'medium' category, but the advice for the SDE+ 2017 is to allocate it to the 'medium/small' category.

Installations producing less than the equivalent of 10 million, but more than 1 million m^3 of natural gas heat per year, are also assumed to save on energy tax in the 1-10 million m^3 band in natural gas/year. The correction amount is determined on the basis of natural gas not used in a gas boiler with 90% efficiency, and energy tax not paid (as well as avoiding sustainable energy surcharge) in the 1-10 million m^3/year band. This correction amount is referred to as correction amount 'medium'.

Installations that produce more than the equivalent of 10 million m^3 of natural gas heat are assumed to replace a CHP. For the producer an average net heat price of 70% of the TTF gas price is assumed. All categories with co-generation are also assumed to be replacing a gas CHP. This correction amount is referred to as 'large'.

Table 90: Energy tax benefit for the purpose of calculating the correction amounts

Category	Energy carrier	Heat output capacity	Heat full load hours	Amount of natural gas replaced	Calculated energy tax band	Advice correction amount
		[kW]	[h/a]	[m^3/year]	[m^3/year]	
Solar thermal ≥ 140 kW	H	140	700	**11,147**	0-170,000	Medium-small
Geothermal heat, depth ≥ 500 m	H	12,000	5,500	**7,507,109**	1 -10 million	Large
Geothermal heat, depth ≥ 3500 m	H	15,000	7,000	**11,943,128**	> 10 million	Large
Boiler fired by solid or liquid biomass, 0.1-0.5 MWth	H	300	3,000	**102,370**	0-170,000	Small
Boiler fired by solid or liquid biomass, 0.5-5 MWth	H	750	3,000	**255,924**	170,000 -1 million	Medium-small
Boiler fired by solid or liquid biomass, ≥5 MWth	H	10,000	7,000	**7,962,085**	1 -10 million	Large
Boiler fired by liquid biomass	H	10,000	7,000	**7,962,085**	1 -10 million	Medium
Boiler fired by industrial steam from wood pellets	H	30,000	7,000	**23,886,256**	> 10 million	Large
Heat, all-feedstock digestion	H	6,885	7,000	**5,481,896**	1 -10 million	Medium
Heat, digestion and co-digestion of animal manure	H	2,550	7,000	**2,030,332**	1 -10 million	Medium
Heat, digestion of more than 95% animal manure < 300 kW	H	91	7,000	**72,455**	0-170,000	Medium
Extended lifespan digestion and co-digestion of animal manure (heat)	H	2,025	7,000	**1,612,598**	1 -10 million	Large
Extended lifespan all-feedstock digestion (heat)	H	2,025	7,000	**1,612,598**	1 -10 million	Large
Waste water treatment plant (WWTP) - thermophilic digestion of secondary sludge	E+H	919	4,000	**418,123**	170,000 -1 million	Large
Thermal conversion of biomass, < 100 MWe	E+H	8,000	8,000	**7,279,621**	1 -10 million	Large
Co-generation, all-feedstock digestion	E+H	3,888	7,000	**3,095,659**	1 -10 million	Large
Co-generation, digestion and co-digestion of animal manure	E+H	1,440	7,000	**1,146,540**	1 -10 million	Large
Co-generation, digestion of more than 95% animal manure < 300 kW	E+H	26	1,000	**2,957**	0-170,000	Large
Extended lifespan all-feedstock digestion, co-generation	E+H	925	7,000	**736,493**	170,000 -1 million	Large
Extended lifespan co-generation, digestion and co-digestion of animal manure	E+H	925	7,000	**736,493**	170,000 -1 million	Large

There are a few exceptions to the above-mentioned system. In general, solar thermal projects work in combination with other (natural gas) heat supplies, so the energy tax on natural gas effectively avoided often falls into a higher tax band. Most geothermal energy projects are realised in the horticulture sector, where they usually replace a gas CHP. With regard to the boiler fired by solid biomass > 5 MW, the reference installation is at the top of the tax band, so unlike with a boiler fired by liquid biomass, the installation is used for base load as much as possible, for district heating or other purposes. Generally speaking, large boilers replace a CHP. Exceptions to the system described above are found in the extended lifespan for digestion, where a connection to a major hub is assumed for heat, resulting in the 'large' correction amount, and digestion of more than 95% animal manure, where a connection to a medium-large hub is assumed for heat, resulting in the 'medium' correction amount.

Table 91: Base rate and provisional correction amount SDE+ 2017: hydropower, wind and solar energy

Category	Base price [€/kWh]	Correction amount [€/kWh]
Hydropower, height of fall ≥ 50 cm	0.031	0.032
Hydropower, height of fall ≥ 50 cm, renovation	0.031	0.032
Free tidal current energy, height of fall < 50 cm	0.031	0.032
Osmosis	0.031	0.032
Photovoltaic solar panels, ≥ 15 kWp and connection >3*80A	0.026	0.033
Solar thermal, aperture area ≥ 200 m^2 or > 140 kW	0.028	0.029
Onshore wind, ≥ 8 m/s	0.025	0.028
Onshore wind, ≥ 7.5 and < 8 m/s	0.025	0.028
Onshore wind, ≥ 7.0 and < 7.5 m/s	0.025	0.028
Onshore wind, < 7.0 m/s	0.025	0.028
Wind on primary water defences, ≥ 8 m/s	0.025	0.028
Wind on primary water defences, ≥ 7.5 and < 8 m/s	0.025	0.028
Wind on primary water defences, ≥ 7.0 and < 7.5 m/s	0.025	0.028
Wind on primary water defences, < 7.0 m/s	0.025	0.028
Wind on lake, water ≥ 1 km^2	0.025	0.028

Table 92: Base rate and provisional correction amount SDE+ 2017: geothermal energy

Category	Base price [€/kWh]	Correction amount [€/kWh]
Geothermal heat, depth ≥ 500 m	0.012	0.012
Geothermal heat, depth ≥ 3,500 m	0.012	0.012

Table 93: Base rate and provisional correction amount SDE+ 2017: water purification plants

Category	Base price [€/kWh]	Correction amount [€/kWh]
Waste water treatment plant (WWTP) - thermophilic digestion of secondary sludge	0.023	0.024
WWTP - thermal pressure hydrolysis	0.031	0.032
WWTP (renewable gas)	0.015	0.016

Table 94: Base rate and provisional correction amount SDE+ 2017: incineration and gasification of biomass

Category	Base price [€/kWh]	Correction amount [€/kWh]
Biomass gasification (≥95% biogenic)	0.015	0.016
Existing capacity for direct and indirect co-firing	0.031	0.032
New capacity for direct co-firing	0.031	0.032
Boiler fired by solid or liquid biomass, 0.1-0.5 MW_{th}	0.052	0.053
Boiler fired by solid or liquid biomass, 0.5-5 MW_{th}	0.028	0.029
Boiler fired by solid or liquid biomass, ≥ 5 MW_{th}	0.012	0.012
Boiler fired by liquid biomass	0.022	0.023
Boiler fired by industrial steam from wood pellets	0.012	0.012
Thermal conversion of biomass, < 100 MW_e	0.014	0.015

Table 95: Base rate and provisional correction amount SDE+ 2017: digestion of biomass

Category	Base price [€/kWh]	Correction amount [€/kWh]
All-feedstock digestion (renewable gas)	0.015	0.016
Co-generation, all-feedstock digestion	0.021	0.022
Heat, all-feedstock digestion	0.022	0.023
Digestion and co-digestion of animal manure (renewable gas)	0.015	0.016
Co-generation, digestion and co-digestion of animal manure	0.021	0.022
Heat, digestion and co-digestion of animal manure	0.022	0.023
Digestion of more than 95% animal manure < 300 kW (renewable gas)	0.015	0.016
Co-generation, digestion of more than 95% animal manure < 300 kW	0.030	0.031
Heat, digestion of more than 95% animal manure < 300 kW	0.022	0.023

Table 96: Base rate and provisional correction amount SDE+ 2017: existing installations

Category	Base price [€/kWh]	Correction amount [€/kWh]
Extended lifespan all-feedstock digestion, co-generation	0.021	0.022
Extended lifespan co-generation, digestion and co-digestion of animal manure	0.021	0.022
Extended lifespan all-feedstock digestion (renewable gas)	0.015	0.016
Extended lifespan all-feedstock digestion (heat)	0.012	0.012
Extended lifespan digestion and co-digestion of animal manure (renewable gas)	0.015	0.016
Extended lifespan digestion and co-digestion of animal manure (heat)	0.012	0.012

Appendix C. Basic information for SDE+

The following text has been taken virtually verbatim from the website RVO.nl (Netherlands Enterprise Agency) (2015) and the document *Nationaal actieplan voor energie uit hernieuwbare bronnen* (National action plan for energy from renewable sources) NREAP (Dutch Government, 2010).

Box 1: Basic information for SDE+

General
The Dutch Renewable Energy Production Support Scheme (SDE+) stimulates the production of sustainable energy. Sustainable energy is generated from clean, inexhaustible sources and is therefore also known as 'renewable energy'.

What is SDE+?
SDE+ is an operating incentive. In other words, producers receive a subsidy for the sustainable energy they generate and not for the purchase of the production plant, as in the case of an investment subsidy. SDE+ is focused on companies and institutions that want to produce sustainable energy. The Dutch Government is excluded from participating in SDE+. The cost price of sustainable energy is higher than that of grey energy. As such, the production of sustainable energy is not always profitable.

The SDE scheme reimburses the difference between the cost price of grey energy and that of sustainable energy over a period of 5, 8, 12 or 15 years, depending on the technology. How much subsidy you can receive depends on the technology and the quantity of sustainable energy you produce. The SDE+ has a single budget for all categories and is opened in phases. In the first phase, the 'cheaper' technologies can apply for subsidies. The subsidy increases per phase. In addition, in certain cases it is possible to submit an application in a so-called free category.

What does SDE+ apply to?
In 2015, SDE+ was opened for the production of:
- Renewable electricity;
- Renewable gas;
- Renewable heat or a combination of renewable heat and electricity (CHP).

For energy from:

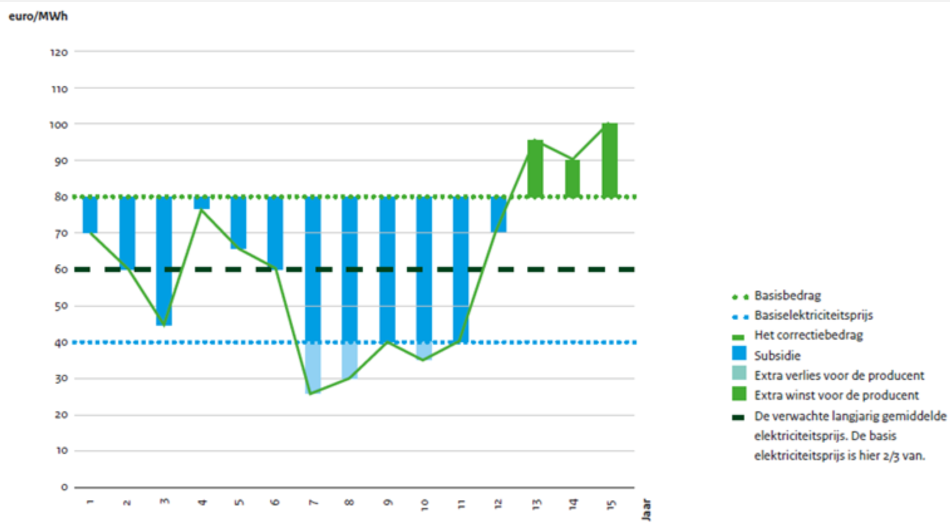
- Biomass
- Geothermal
- Water
- Wind
- Solar.

The SDE+ contribution
The cost price of the production of green energy is reflected in the base rate for the technology. The yield of the grey/other energy is reflected in the correction amount. SDE+ reimburses the difference between the cost price of green energy and the yield of the grey/other energy: SDE+ contribution = base rate – correction amount.

This means that the level of the SDE+ contribution is dependent on changes in the energy price. At a higher energy price, you receive less SDE+ but you receive more from your energy customer. At a lower energy price, you receive more SDE+ and less from your energy customer. The subsidy that the Netherlands Enterprise Agency (*Rijksdienst voor Ondernemend Nederland*) allocates to you in the decision is a maximum amount over the entire term of the subsidy (5, 8, 12 or 15 years). This maximum is based on the capacity submitted and the maximum number of full load hours for the technology. The base energy price is used to calculate the amount of the allowance. The base energy price is the lower limit for the correction amount. The correction amount cannot be lower than the base energy price. If the correction amount is equal to the base energy price, the maximum subsidy has been reached. The ultimate size of the subsidy is calculated each year on the basis of the quantity of energy you produce and the level of the energy price. The subsidy applies up to a maximum number of full load hours and has a maximum term, depending on the technology.

Source: RVO, 2015

Figure 5: SDE+ contribution = base rate – correction amount



Source: Dutch Government, 2010.

Pillars of the SDE+

1 Single integrated budget ceiling

A single subsidy ceiling has been set for all categories. In 2015, 3.5 billion euros is available for supporting projects. If more applications are received in a day than there is remaining budget available, the applications are ranked by order of base rate. The application with the lowest base rate is first on the list. If the budget limit falls between applications with the same base rates, lots are drawn between them.

2 Phased opening

The SDE+ is opened in phases. In 2015, nine phases will be opened in the period between 9:00 on 31 March and 17:00 on 17 December 2015. Each phase has a maximum base rate, rising from 0.070 €/kWh (0.055 €/kWh for renewable gas) in phase 1 to 0.150 €/kWh (0.118 €/kWh for renewable gas) in phase 9. Each technology has a maximum base rate above which no subsidy is paid. In phase 1, cost-effective technologies with a base rate lower than or equal to 0.070 €/kWh can submit applications. Compared to technologies with a higher maximum base rate, phase 1 applicants have a greater chance that there will be sufficient budget available.

3 Maximum base rate

The SDE+ 2015 is based on a maximum base rate of 0.150 €/kWh (0.118 €/kWh for renewable gas). Technologies that can produce sustainable energy for this amount or less are eligible for subsidy.

4 Free category

In each phase, there is a free category. This allows innovative entrepreneurs who are able to produce more cheaply than the base rate calculated for the technology in question to gain access to SDE+. Projects in the free category are subject to a base rate which is the same as the upper limit of the relevant phase in which subsidy was applied for. A condition is that this amount must be lower than the base rate for the technology in question. In this way, the free category also offers scope to a number of technologies whose costs are higher on average than 0.150 €/kWh (converted to 0.118 €/kWh for renewable gas).

Source: RVO, 2015

Appendix D. External review

Fraunhofer
ISI

Fraunhofer Institute for
Systems and Innovation Research
| Visions for Decisions

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Your Reference	Your Letter of	Our Reference	
		MR/bka	Karlsruhe, 23 September 2016

Review on the draft advice of SDE+

Dear Mr. Himbergen,

Fraunhofer ISI and TU Vienna has reviewed the advice of ECN/DNV GL on the Dutch renewable energy tariffs as proposed in the draft advice of 2016. The review included the following activities: discuss with ECN the results of the draft advice, give suggestion for further research where applicable, reflect whether ECN/DNV GL have addressed adequately the issues that were raised by market parties during the consultation round and give a limited review on the overall advisory process.
Fraunhofer ISI and TU Vienna have concluded the following. The research process by ECN/DNV GL was conducted in a manner that was sound and correct. Suggestions for improvements can be summarized as follows:

<u>Financing</u>
Although the interest rates assumed by ECN/DNV GL seem generally adequate, they could be moderately lowered taking into account currently low interest rates. This could be done by reducing WACC values by approximately 1% point for all technologies. The comparison with the results of the EU project DIA-CORE, which assessed country specific financing costs in detail is in line with such a slight reduction of WACC values.

At least a ±1% WACC sensitivity analyses should be included in the analysis. One should also keep in mind that other forms of financing are possible, such as intermediate loans and refinancing on the consumer market through wind shares.

Biomass incineration

A first impression was that the prices of wood pellet (30 €/MWh) have tended being on the high side. A comparison with an assessment taken by Utrecht University in the course of the DIA-CORE project confirms however that assumptions reflect recent trends: Despite a recent decline in spot prices of industrial pellets in US$, CIF ARA prices of industrial wood pellets have increased as a result of the weakening euro against the US dollar. To sum up, the combination of the weak euro, low CO2 price and low coal price results in comparatively high cost of biomass, weakening its competitiveness. Therefore we consider the current assumptions adequate.

For steam boilers and heat boilers, a comparison with experience from Austria indicates that cost assumptions appear being within the range of market observations. There are however tendencies for slightly higher costs / prices in recent year(s) under Austrian circumstances. How far this represents the impact of market power due to concentration effects is currently for example under discussion.

Pyrolysis oil, being an intermediate product (pretreatment), appears a promising fuel and technology option to be supported within the SDE+. As done by ECN/DNV GL the price of oil can be used as proxy for fuel price developments, if the fuel input is restricted to pyrolysis oil. It has been however discussed that this might cause some tension between indirectly subsidizing technological learning through the higher prices of pyrolysis oil.

As a general remark concerning the question whether production or investment-based support appears more useful in the case of biomass heating, specifically concerning small-scale installations, there are clear pros for remaining with a simple approach of providing up-front investment support instead of a more complicated generation-based support scheme. For example also the UK approach (Renewable Heat Incentive) despite the general impression that support is generation-based offers in practical terms investment-based up-front support in the case of small-scale installations.

PV

Large scale green-field systems receive the same base rate as all other systems > 15 kW due to a tradeoff regarding cost reductions caused by economies of scale and other costs for land lease etc. occurring for large scale systems. We think, however, that the impact of economies of scale should be stronger, which would justify a reduced base rate for MW-scale plants.

Wind-in-lake

These projects are very specific and individual. Therefore it is very difficult to estimate the specific investment and hence the generation costs for these plants. Therefore we would propose in the future to tender such projects in a central regime similar to the case of offshore wind, i.e. a public institution performs the pre-development of the project and the company assigned with the actual construction and operation of the plant is awarded based on competitive bidding.

Besides the issues listed above we do not have any additional suggestions for improvements and did not find any incorrect assumptions or calculations.

Kind regards,

Prof. Dr. Mario Ragwitz
(Fraunhofer ISI)

Dr. Gustav Resch
(TU Wien, EEG)

Afterword

The authors of this report would like to thank the reviewers from Fraunhofer ISI and TU Wien for the constructive, critical discussions. In this afterword, the authors will explain how they used the reviewers' comments.

With regard to lowering financing costs, ECN and DNV GL held further consultations in August 2016. The general impression is that there would seem to be sufficient opportunity to arrange even more competitive funding than proposed by the reviewers. However, there is no guarantee that interest rates will not rise again in the next few years. If interest rates rise, there is a realistic chance that the base rates will have to follow suit to ensure that subsidies continue to cover costs. To clarify the effect of changing interest rates, Table 8 shows the base rates if interest (on loan capital) were -2% points and +2% points compared with the advice of ECN and DNV GL.

Table 97: Sensitivity of the advised base rates to interest on loan capital

Category	-2% points	SDE+ 2017 advice	+2 % points
Hydropower, height of fall ≥ 50 cm	0.146	0.156	0.167
Hydropower, height of fall ≥ 50 cm, renovation	0.096	0.100	0.105
Free tidal current energy, height of fall < 50 cm	0.182	0.192	>0.20
Osmosis	>0.20	>0.20	>0.20
Photovoltaic solar panels, ≥ 15 kWp and connection >3*80A	0.116	0.125	0.135
Solar thermal ≥ 140 kW	0.089	0.095	0.102
Onshore wind, ≥ 8 m/s	0.061	0.064	0.068
Onshore wind, ≥ 7.5 and < 8 m/s	0.066	0.070	0.074
Onshore wind, ≥ 7.0 and < 7.5 m/s	0.071	0.075	0.080
Onshore wind, < 7.0 m/s	0.080	0.085	0.090
Wind on primary water defences, ≥ 8 m/s	0.065	0.069	0.073
Wind on primary water defences, ≥ 7.5 and < 8 m/s	0.071	0.075	0.080
Wind on primary water defences, ≥ 7.0 and < 7.5 m/s	0.076	0.080	0.085
Wind on primary water defences, < 7.0 m/s	0.085	0.091	0.097
Wind on lake, water ≥ 1 km2	0.099	0.104	0.110
Geothermal heat, depth ≥ 500 m	0.050	0.053	0.055
Geothermal heat, depth ≥ 3,500 m	0.054	0.057	0.060
Waste water treatment plant (WWTP) - thermophilic digestion of secondary sludge	0.039	0.048	0.057
WWTP - thermal pressure hydrolysis	0.079	0.084	0.090
WWTP (renewable gas)	0.030	0.031	0.032
Biomass gasification (≥95% biogenic)	0.145	0.150	0.155
Existing capacity for direct and indirect co-firing	0.107	0.108	0.108
New capacity for direct co-firing	0.110	0.111	0.112
Boiler fired by solid or liquid biomass, 0.1-0.5 MWth	0.056	0.057	0.058
Boiler fired by solid or liquid biomass, 0.5-5 MWth	0.055	0.056	0.057
Boiler fired by solid or liquid biomass, ≥5 MWth	0.043	0.044	0.045
Boiler fired by liquid biomass	0.070	0.070	0.070
Boiler fired by industrial steam from wood pellets	0.061	0.062	0.062
Thermal conversion of biomass, < 100 Mwe	0.061	0.062	0.063
All-feedstock digestion (renewable gas)	0.060	0.061	0.062
Digestion and co-digestion of animal manure (renewable gas)	0.076	0.077	0.078
Digestion of more than 95% animal manure < 300 kW (renewable gas)	0.165	0.171	0.177

The costs of firing boilers with solid biomass seem to have risen slightly in the Netherlands compared with last year, as they have in Austria. As a result of comments made by the reviewer, the authors redefined the reference installation for various biomass boiler categories. Although biomass boilers fired by pyrolysis oil are eligible for funding from SDE+, pyrolysis oil is not a reference fuel due to reasons put forward by the reviewers. ECN and DNV GL think that pyrolysis oil is slightly more expensive than animal fat, the fuel used as the reference fuel.

It is not possible to make an unequivocal distinction between large and small-scale solar projects (solar PV) on the basis of price. Information from the market consultations seemed to indicate that large-scale projects are more expensive than smaller ones. At the same time, international literature supports the opinion of the reviewers: that economies of scale will make large-scale parks cheaper than small parks. At present, perhaps because of the limited experience with large-scale solar projects in this country, the Netherlands cannot unequivocally state whether large-scale projects are cheaper or more expensive than small-scale projects; see also chapter 4.

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