Energy Research Centre of the Netherlands

The potential for high-efficiency cogeneration in the Netherlands

Report to the Ministry of Economic Affairs

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Background

This study of the cogeneration potential in the Netherlands has been carried out at the request of the Ministry of Economic Affairs. The aim of the project is to assess the technical and economic feasibility of modernising and expanding the existing cogeneration facilities to save primary energy and reduce CO_2 emissions.

The calculations followed the rules laid down in the EU Cogeneration Directive and the methodology of the CBS (the Dutch Central Statistics Office) for reporting on high-efficiency cogeneration. The results are set out in accordance with the reporting template supplied by the European Commission. The three spreadsheets for the scenarios are enclosed.

The study project forms part of the Ministry's annual cogeneration research budget for ECN (the Energy Research Centre of the Netherlands), registered under number 5.0168. The contact person for this research at the Ministry of Economic Affairs is A.J. Vermeer. The contact person at ECN is S.J.G Dijkstra (Tel: 0224 - 56 4858; e-mail: s.dijkstra@ecn.nl).

Abstract

The Dutch Ministry of Economic Affairs has asked ECN to analyse the potential for high-efficiency cogeneration in the Netherlands. This will inform their national report on the cogeneration potential to the European Commission, as required by the European Cogeneration Directive (2004/8/EC). This report describes the methodology used and briefly states the main findings. The accompanying spreadsheet shows the full results.

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Summary

The European Cogeneration Directive (2004/8/EC) requires the EU Member States to analyse the additional potential for cogeneration. This report sets out the results for the Netherlands. The enclosed spreadsheets show the full results.

The report follows the template supplied by the European Commission. The projections are based on the calculations made using the ECN's modelling system for the Ministry of Economic Affairs and the Ministry of Housing, Spatial Planning and the Environment (*VROM*), which were used for the 2010 Reference Projections (ECN/PBL[*], 2010). The share of high-efficiency cogeneration has been determined using the method applied by the *Centraal Bureau van de Statistiek – CBS* (the Dutch Central Statistics Office).

The report distinguishes between the technical and the economic potential. The suitable heat demand per sector determines the technical potential, while the economic potential indicates the proportion of that which can operate on the energy market cost-effectively.

The results indicate that, from a technical point of view, a maximum of 7.7 GW_e of new cogeneration could be added to the existing 12.9 GW_e in the period up to 2020. The economic potential for new cogeneration is between 2.3 and 3.4 GW_e on top of the existing capacity in 2020, and varies more with the CO_2 price. The realisation of 3.4 GW_e of additional cogeneration would provide primary energy savings of 39 PJ and 2.2 Mt of CO_2 emission reduction and cost €4.8 billion.

[*] PBL = Netherlands Environmental Assessment Agency.

1. Introduction

The European Commission has requested the Member States to provide three scenarios for the national report on the potential for high-efficiency cogeneration[1] (see enclosed spreadsheets). The three scenarios vary as regards CO_2 price developments, see Table 1.1. A sensitivity analysis for other parameters is not required.

Table 1.1 *CO_2 price scenarios used in the analysis*

	2010 [€/t]	2015 [€/t]	2020 [€/t]
Scenario 1	15	15	15
Scenario 2	15	25	25
Scenario 3	15	50	50

The scenarios must include the following:
- Projections of both the technical and the economic potential
- Projections for 2010, 2015 and 2020

The projections are broken down by sector, fuel and technology, and a distinction has been made between new installations and the modernisation of existing installations, as required.

The resultant potentials must be quantified in terms of:
- Electrical capacity [GW]
- Electricity generation [TWh]
- Thermal capacity [GW]
- Useful heat generation [TWh]
- Fuel input [PJ]

At the request of the Ministry of Economic Affairs, ECN has worked out the three CO_2 price scenarios. The value of CO_2 has an impact on the cogeneration potential via energy demand, electricity prices and the attractiveness of cogeneration compared to competing technologies. A higher CO_2 price, for example, can make cogeneration cheaper than the separate generation of heat and electricity and leads to a slight fall in heat demand.

For each scenario ECN has determined the technical and economic potential for high-efficiency cogeneration. The method used by the CBS for reporting cogeneration statistics to Eurostat[2] has been adapted to determine the share of high-efficiency cogeneration. The projections are based on the calculations in ECN's modelling system for the Ministry of Economic Affairs and the Ministry of Housing, Spatial Planning and the Environment, which were used for the 2010 Reference Projections (ECN/PBL, 2010). The assumptions about economic development, energy policy and electricity prices have been copied over from this and adapted to the CO_2 price scenarios.

The results are set out using the European Commission's template for cogeneration potentials. The associated spreadsheets are enclosed.

[1] Under the European Cogeneration Directive, cogeneration installations producing primary energy savings of at least 10% compared to separate generation of heat and electricity qualify as highly efficient.

[2] As prescribed in Eurostat's Electricity and Heat Annual Questionnaire.

2. Methodology

2.1 Introduction

The analysis of the potential for new cogeneration is in three parts. Firstly an examination was made of existing cogeneration in the Netherlands, serving as the baseline for the future expansion of cogeneration. The second step was to evaluate the possibility of modernising existing cogeneration installations. Lastly, the potential for new cogeneration installations was analysed. This resulted in the projections for cogeneration capacity, energy generation and fuel consumption for 2010, 2015 and 2020 (Figure 2.1). The primary energy savings and avoided CO_2 emissions were also calculated for the total cogeneration potentials and are indicated together with the investment costs.

1

Existing cogeneration

(CBS statistics)

2

Modernisation and re-investment

(CBS statistics & ECN calculations)

3

Potential for new cogeneration

(ECN modelling system and sector analysis)

Cogeneration capacity, energy generation and fuel consumption

Costs

Primary energy savings

CO_2 emissions

Figure 2.1 *Steps of the potential analysis*

Firstly, the analysis covered a basic scenario with a CO_2 price of €15 per tonne in 2010 and €25 per tonne in 2015 and 2020, the same as scenario 2 in Table 1.1. On that basis the other two CO_2 price scenarios were then developed with the aid of a sensitivity analysis. Sections 2.2 to 2.7 describe the steps in detail:

- Section 2.2 – reports on existing cogeneration according to the CBS methodology
- Section 2.3 - methodology for the analysis of the potential for upgrading existing cogeneration
- Section 2.4 - methodology for the analysis of the potential for new cogeneration
- Section 2.5 – reports on the cost of realising the cogeneration potential
- Section 2.6 – calculation of the primary energy savings and CO_2 emission reduction of the cogeneration potential
- Section 2.7 – sensitivity analysis

2.2 Existing cogeneration

The data on existing cogeneration in 2008 are based on the data reported by the CBS for that year (CBS, 2010a). They indicate the electrical and heat capacity of cogeneration in 2008, and the electricity and heat generation and fuel consumption.

The CBS applies the following method to take account of the share of high-efficiency cogeneration in existing installations:

1. All electricity generation is considered to be high-efficiency generation where the reported efficiency of an installation is higher than 80% for CCGTs and steam condensing turbines, or higher than 75% in the case of other technologies (in accordance with Annex II to Directive 2004/8/EC).
2. Where the efficiency is below these figures a distinction is made on the basis of the ratio of power to heat generation:
   A. Where the realised power to heat ratio is between the minimum and maximum values given in the Eurostat Electricity and Heat Annual Questionnaire (Eurostat, 2009), the generation of electricity is considered to be 100% high-efficiency cogeneration since the useful heat production per kWh of electricity is greater than the minimum value needed to meet the requirements of the Cogeneration Directive.
   B. Where the requirements under point A are not met, the standard power to heat ratio in Annex III to Directive 2004/8/EC is used.
      i. Where the heat production multiplied by the standard power to heat ratio is greater than the electricity generation, all the generated electricity is considered to be 100% high-efficiency cogeneration.
      ii. Where the requirements under point i are not met, the cogeneration electricity is the product of heat generation and the standard power to heat ratio. The resultant quantity of cogeneration power then depends on the proportion of the heat generation that can be used.

Table 2.1 *Reference values for evaluating high-efficiency cogeneration in accordance with Directive 2004/8/EC and the Eurostat Annual Questionnaire*

	Minimum efficiency [%]	Power / Heat Industry Min	Max	Standard	District heating Min	Max	Standard
CCGT	80	0.5	1	0.95	0.7	1.2	0.95
Steam backpressure turbine	75	0.15	0.45	0.45	0.3	0.6	0.45
Steam condensing turbine	80	0.15	0.45	0.45	0.3	0.6	0.45
Gas turbine	75	0.2	0.6	0.55	0.35	0.75	0.55
Internal combustion engine	75	0.4	0.8	0.75	0.55	0.95	0.75

The CBS reports the installed cogeneration capacity, generation and fuel consumption per sector (CBS, 2010a). In a number of cases ECN has adapted the breakdown of the CBS data to bring them into line with the European Commission template (see enclosed Excel spreadsheets):

· Sheet ‘Overview’ – data reported directly by the CBS.
· Sheet ‘Sectors’ – data reported directly by the CBS, broken down as follows:
  - Industry: cogeneration installations in all industrial sectors and the energy sector (extraction and refining).
  - District heating: cogeneration installations operated by distribution companies and energy suppliers (these categories make up the vast majority of district heating cogeneration in the Netherlands).
  - Non-district heating: cogeneration installations in health care, waste incineration and other producers.
  - District cooling: assumed to be 0 (in 2008).
  - Micro-cogeneration: assumed to be 0 (in 2008).

- Other: cogeneration installations in agriculture and horticulture.
- Sheet ‘Fuels’ - the fuel input comes directly from the CBS while the electricity and heat generation have been calculated using the share of various fuels per technology. For example: if internal combustion engines use 98% natural gas and generate 13.1 TWh of electricity, then 13.1*0.98 TWh = 12.838 TWh of the cogeneration power is from natural gas.
- Sheet ‘Technologies’ – data reported directly by the CBS.

The cogeneration data reported by the CBS do not distinguish between the various sustainable fuels. Therefore ECN has calculated the breakdown from the cogeneration heat generation from sustainable fuels in the CBS report on sustainable energy generation (CBS, 2010b).

Assumptions about the power to heat ratio and the annual number of operating hours were made in order to determine the sustainable cogeneration electricity generation and capacity (Table 2.2). These assumptions are based on historical CBS data (CBS, 2010b) and ECN’s projections of the reference forecast, and therefore take account both of the technical parameters of the installations and the market conditions. They are lower than the number of operating hours in the financial gap calculation for biomass and biogas because the latter also relate to periods where installations only generate electricity.

Table 2.2 *Assumptions for sustainable cogeneration for determining electricity generation and capacity*

Application	Power/heat	Indicative operating hours per year
Waste incineration	5.0	4 800
Waste water treatment	1.5	4 000
Sewage treatment	1.5	4 100
Fermentation	1.5	4 000
Landfill gas	1.5	4 000
Biomass – small	4.0	5 300
Biomass – large	4.0	5 300

2.3 Upgrading of existing cogeneration

ECN used a projection of the number of installations that could be upgraded on the basis of the added cogeneration capacity per year since 1980. Two sources were used for this:
- The ECN basic list of cogeneration installations – this provides information on all decentral cogeneration installations which came on stream from 1980 to 2003, including information on the technology used and the anticipated year of decommissioning.
- CBS statistics on the development of cogeneration capacity per technology since 1998.

Table 2.3 *Assumptions for lifetime and modernisation for upgrading existing cogeneration*

Technology	Lifetime	Technical	Economic potential		
		potential	€15/t CO_2	€25/t CO_2	€50/t CO_2
Internal combustion engine	15 years	100%	85%	90%	95%
Steam turbine	25 years	100%	20%	40%	60%
CCGT	20 years	100%	80%	85%	90%
Gas turbine	20 years	100%	80%	85%	90%
Other	20 years	100%	70%	80%	90%

The projection of the number of installations that will have to be replaced and the expected lifetime, specified per technology, forms the basis for the potential for upgrading existing cogeneration. In the case of the technical potential, it is assumed that all cogeneration installations can be replaced, while in the case of the economic potential only some of the installations will be modernised, depending on how high the CO_2 price is. Table 2.3 shows the percentage of existing installations in which re-investment will be made under the various scenarios. These assumptions are based on projections of existing cogeneration facilities from the reference forecast and ECN's financial gap calculations for these technologies.

Both the technical and the economic potential for upgrading existing cogeneration are set out in the report, both expressed as electrical and thermal capacity, energy generation and fuel input.

2.4 New cogeneration

2.4.1 Relationship between the technical and economic potential

The technical potential limits the scope for expanding cogeneration facilities. The decisive factor here is the heat demand, together with the maximum share of production that can be achieved with cogeneration technologies from a technical point of view. The technical potential has been derived from projections of the heat demand per sector taken from the ECN modelling system for national energy exploration, including the following:

- Save-Production – projections of energy developments in industry and agriculture, including all decentral cogeneration (Daniëls & Van Dril, 2007)
- POWERS model (Seebregts et al., 2005) – use of cogeneration for district heating
- Save-Utiliteit (Volkers, 2006) – heat and refrigeration use in utility buildings
- SAWEC – simulation and analysis model for residential property energy consumption and CO_2 emissions (Boerakker, Menkveld & Volkers, 2005).

The economic potential is derived from the technical potential following an economic feasibility analysis for each technology carried out in the modelling system (Figure 2.2). The orange cells represent the breakdown of the potential as required for the report to the European Commission.

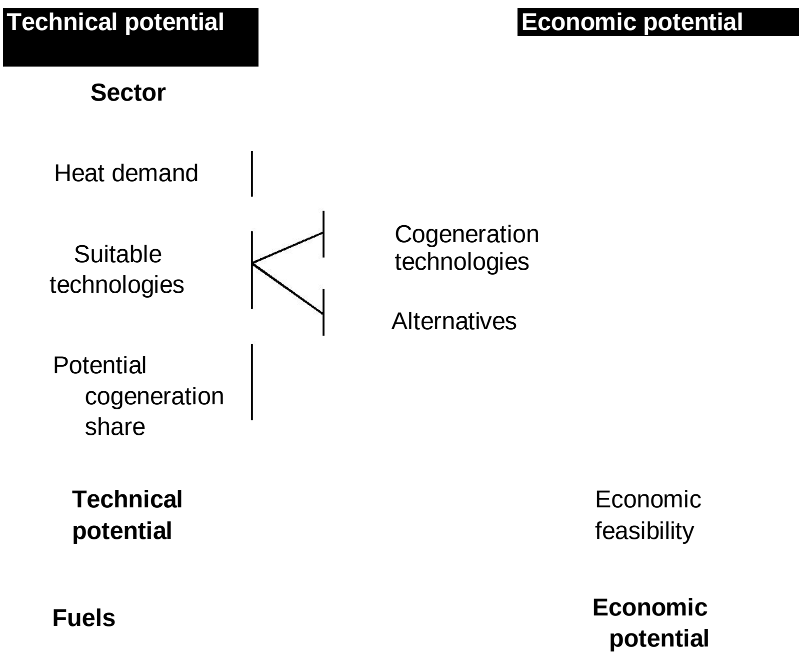

Figure 2.2 *Relationship between the technical and the economic cogeneration potential*

2.4.2 Sources used for calculations

The projections of the development of new cogeneration installations are based on the calculations made in ECN's system for the Ministry of Economic Affairs and the Ministry of Housing, Spatial Planning and the Environment used for the 2010 Reference Forecast (ECN/PBL, 2010). The policy variant including *Schoon en Zuinig* ('Clean and Economical') and *Voorgesteld beleid* ('Proposed policies') (RR2010 VV) was used as the basic scenario since that variant takes account of existing and planned policy and thus contains the most recent policy information. Sheet 6 in the enclosed spreadsheets describes the assumptions made for policy instruments in this basic scenario.

ECN adopted the assumptions in full, with the exception of the assumptions for electricity prices. The electricity prices in the Reference Forecast are based on long-term projections; for example, the RR2010 VV scenario uses a CO_2 price of €13 per tonne in 2010, rising to €20 in 2020. Therefore existing projections in the RR2010 VV scenario have been adapted to develop the scenarios for a CO_2 price of €15, €25 and €50 per tonne by means of a sensitivity analysis of existing CO_2 price scenarios in the 2010 Reference Forecast. This also has an impact on the electricity price used for calculating the economic potential (Table 2.4).

Table 2.4 *Assumptions for the electricity price in the three CO_2 price scenarios*

	2010		2015		2020	
CO_2 price scenario [€/t]	Peak	Low	Peak	Low	Peak	Low
2010-2015-2020	[€/MWh]	[€/MWh]	[€/MWh]	[€/MWh]	[€/MWh]	[€/MWh]
15 - 15 - 15	58	42	55	37	58	40
15 - 25 - 25	58	42	58	42	59	43
15 - 50 - 50	58	42	62	51	64	55

The results of the 2010 Reference Forecast for the following parameters were used directly:

- Heat, electricity and cooling demand per sector
- Cooling demand and penetration of refrigeration technologies
- Heat generation, electricity generation and fuel input of cogeneration per sector, technology and fuel
- Installed cogeneration capacity per sector, technology and fuel
- Annual number of operating hours of cogeneration systems.

For micro-cogeneration energy generation and capacity, the results of the 2010 Reference Forecast have been supplemented by technology-specific projections from the 2008 update of the energy and CO_2 saving potential of micro-cogeneration in the Netherlands by ECOFYS, ECN and other organisations (ECOFYS et. al., 2008).

The report on the results has been adapted to the European Commission reporting requirements. ECN also compared the results with the results of previous analyses of cogeneration potential in the Netherlands, with which they are consistent:

- Daniëls, B.W. et. al. *High-efficiency cogeneration in the Netherlands*. ECN. November 2007
- ECOFYS, ECN, Cogen Projects, Gasunie, TNO, CE Delft. *Energie- en CO_2-besparingspotentieel van micro-WKK in Nederland (2010 - 2030) – Energy and CO_2 saving potential of micro-cogeneration in the Netherlands (2010 - 2030).* Update 2008.
- PriceWaterhouseCoopers. *Het potentieel van WKK in de Chemie • Enquête onder leden van de VNCI – The potential for cogeneration in the chemical industry • Survey of members of the VNCI (the Netherlands Chemical Industry Association).* May 2009 (confidential).
- Wetzels, W. et al. *WKK-potentieel in de chemische industrie – Cogeneration potential in the chemical industry*. ECN. November 2009 (not yet published).

2.4.3 Technical potential

The evaluation of the technical potential for cogeneration uses the expected heat demand in various sectors of the economy, taken directly from the 2010 Reference Forecast. This quantitative output was supplemented by a qualitative analysis in order to establish whether cogeneration is suitable for various applications.

The qualitative analysis distinguishes between the various sectors, since suitability for using cogeneration varies by sector. For example, a distinction can be made between the properties of the required heat (the temperature and pressure, for example), the availability of suitable cogeneration technologies and the extent to which the sector is familiar with cogeneration. Together with the share in the total potential already accounted for by cogeneration, these factors determine the size of the additional technical potential. Then each sector was given a score (see Table 2.5). Existing studies by ECN and other organisations into the potential of various sectors for various cogeneration applications were consulted for this (see paragraph 2.4.1).

Table 2.5 *Evaluation of the possible share of cogeneration in heat supply per sector*

Sector	Suitability of heat demand	Availability of cogeneration systems	Familiarity with cogeneration	Existing uptake of cogeneration potential
Industry				
Food/feed	High	High	High	Low/medium
Paper	Very high	High	High	High
Chemical industry	High	High	High	Medium/high
Metal	Medium	High	Medium	Low
Other	Variable[3]	High	Variable	Low
Energy				
Extraction	Low	Medium	Low	Low
Refining	High	High	High	High
Built environment				
Services	Medium/High	High	Medium	Medium
Domestic	Low/medium	Low	Low	Low
District heating	High	High	High	Medium
Agricult./horticulture	High	High	Very high	High

The maximum technical heat supply by cogeneration results from the total heat demand and the potential share of cogeneration per sector. The capacity, electricity generation and fuel input were calculated on the assumption that the power to heat ratio, the efficiency and the number of operating hours are the same as the values used in the ECN modelling system (Table 2.6).

[3] Depending on the industrial application.

Table 2.6 *Assumptions for determining the electricity generation, installed capacity and fuel input*

Sector	Maximum share of heat demand [%]	Power/Heat	Electrical efficiency [%]	Operating hours per year (indicative)[4]
Industry				
Food/feed	60	0.37	21	3 900
Paper	90	0.50	26	4 900
Chemical industry	55	0.50	27	4 700
Metal	10	0.39	23	2 400
Other	10	0.31	20	2 600
Energy				
Extraction	10	0.45	26	6 100
Refining	25	0.61	19	6 400
Built environment				
Services	20	0.74	31	3 900
Domestic	5	0.50	25	4 700
District heating	n/a[5]	2.16	43	4 000
Agricul./horticulture	80	0.71	35	3 500

2.4.4 Economic potential

The economic potential for cogeneration includes those installations which have been calculated to be both technically feasible and cost-effective. The projections for these have been calculated using the modelling system for National Energy Exploration (Volkers, 2006). The results for the technical potential were used to validate them because they determine the ceiling for the economic potential.

The model calculations give the cogeneration capacity that can be developed within the existing technical, economic and policy framework and conditions, and the quantities of electricity and heat which these cogeneration units can generate per year on an economical basis. Account was taken of factors such as energy prices, CO_2 prices, other operational costs and the development of alternative sources of electricity and heat such as new coal-fired power stations and heat pumps.

The installed capacity, the energy generation and the fuel input are reported for the calculated potentials (see enclosed Excel spreadsheets). They have been validated by comparing them with other studies (see paragraph 2.4.1).

2.5 Investment cost of realising the cogeneration potential

The European Commission requires a report on the investment costs for realising the cogeneration potential. The costs are derived from the projections per technology using the characteristic investment costs of the various systems. The technical parameters of Jacobs Consultancy for the financial gap calculation (Jacobs Consultancy, 2009) are the source of these costs, which are specified in the enclosed spreadsheet. For micro-cogeneration technologies, the projections of the existing potential study[6] and data from producers of these systems have been used.

4 The modelling system uses precise operating hours for all types of installation, with minor variations between the scenarios. These figures are used in the calculations of the potentials. The indicative figures are reported here because the exact future figures cannot be predicted with such great accuracy.

5 District heating installations do not have any intrinsic heat demand but supply part of the built environment (utility, domestic and industry) with heat. The production is therefore based on the demand by those end users.

6 ECOFYS, ECN, Cogen Projects, Gasunie, TNO, CE Delft. '*Energie- en CO_2-besparingspotentieel van micro-WKK in Nederland (2010-30)*' – The energy and CO_2 saving potential of micro-cogeneration in the Netherlands (2010-30). Update 2008.

2.6 Primary energy savings and CO_2 emission reduction

The report to the European Commission must also include the expected primary energy savings and CO_2 emission reduction of the cogeneration potential. The primary energy savings have been calculated using the definition in Annex III to Directive 2004/8/EC:

$$PES = \left(1 - \frac{1}{\frac{\eta heat\,(CHP)}{\eta heat\,(REF)} + \frac{\eta electr\,(CHP)}{\eta electr\,(REF)}} \right) \times 100\%$$

Where:

- PES: is the primary energy savings
- $\eta_{heat}(CHP)$: the efficiency of the installation's heat production
- $\eta_{heat}(REF)$: the reference value for the efficiency of heat production
- $\eta_{electr}(CHP)$: the efficiency of the installation's electricity generation
- $\eta_{electr}(REF)$: the reference value for the efficiency of electricity generation

This method uses different reference values from those in the Energy Saving Monitoring Protocol ('PME'). The PME compares cogeneration with the average efficiency of Dutch electricity supply in 1995, while the EU Directive uses a comparison with the best available commercial power station. As a result, the savings according to the EU Directive are lower than those according to the PME method.

The CO_2 emission reduction is then derived from the primary energy savings:

$$CO_2\ savings = PES \times emission\ factor\ (fuel)$$

For the emission factors for the fuels used, the standard values of the Intergovernmental Panel on Climate Change (IPCC) were used, as recommended by the Association of Issuing Bodies, including Certiq, for the application of the EU Directive for calculating Guarantees of Origin for cogeneration. Table 2.7 shows these for the relevant fuels.

Table 2.7 *Emission factors and energy content for each type of fuel*

Fuel	Emission factor [kg CO_2/GJ]	Energy content
Hard coal	94.6	24.5 MJ/kg
Biomass and biogas	0	15.1 MJ/kg
Oil	77.4	38.79 MJ/l
Natural gas	56.1	31.65 MJ/m^3
Waste	0	15.1 MJ/kg
Refining gas	66.7	21.12 MJ/m^3

2.7 Sensitivity analysis and CO_2 price scenarios

The projections were made for various CO_2 prices in line with the scenarios in Table 1.1. For this ECN identified the main primary effects of the CO_2 price on various relevant factors for the economic exploitation of cogeneration, and tested their sensitivity using the SaveProduction model in the modelling system (Table 2.8).

Table 2.8 *Impact of CO_2 price on factors for the cogeneration potential*

Factor	Effect of rising CO_2 price
Electricity price	Increase
Heat demand	Decrease
Electricity demand	Neutral
Cogeneration capacity	
Industry	Sharp increase
Energy	Decrease
Utility	Increase
Agriculture and horticulture	Sharp increase
Domestic	Neutral
Fuel for cogeneration	
Hard coal	Decrease
Oil	Decrease
Natural gas	Sharp increase
Sustainable	Increase

3. Results

3.1 The cogeneration potential

The enclosed spreadsheets contain the complete results for the cogeneration potential. Only the main points are referred to here.

The results show that, from a technical point of view, a maximum of 7.7 GW_e of new cogeneration could be added to the existing 12.9 GW_e in the period up to 2020, at a CO_2 price of €15 per tonne (Table 3.1). The CO_2 price only has an impact on this result by changing the demand for heat – a higher price leads to greater savings being made and thus lower heat demand and less cogeneration. The differences between the scenarios are relatively small.

Table 3.1 *The technical cogeneration potential in the Netherlands*

	2010		2015		2020	
CO_2 price scenario [€/t]	Modern. [GW_e]	New [GW_e]	Modern. [GW_e]	New [GW_e]	Modern. [GW_e]	New [GW_e]
15 - 15 - 15	0.6	10.5	2.0	7.7	3.8	7.7
15 - 25 - 25	0.6	10.5	2.0	7.4	3.8	7.6
15 - 50 - 50	0.6	10.5	2.0	7.6	3.8	7.5

The economic potential for new cogeneration is between 2.3 and 3.4 GW_e on top of the existing capacity in 2020 and varies more with the CO_2 price (Table 3.2, last column). A higher CO_2 price results in higher electricity prices. This makes it attractive for businesses to generate their own power by cogeneration, leading to an increase in investment in the development of new cogeneration and the modernisation of existing installations. A high CO_2 price is therefore important for realising the existing potential.

Table 3.2 *The economic cogeneration potential in the Netherlands*

	2010		2015		2020	
CO_2 price scenario [€/t]	Modern. [GW_e]	New [GW_e]	Modern. [GW_e]	New [GW_e]	Modern. [GW_e]	New [GW_e]
15 - 15 - 15	0.5	2.0	1.6	2.4	3.0	2.3
15 - 25 - 25	0.5	2.0	1.8	2.2	3.2	2.6
15 - 50 - 50	0.5	2.0	1.9	3.4	3.4	3.4

3.2 The costs, primary energy savings and CO_2 emission reduction of the cogeneration potential

The costs of realising the economic cogeneration potential in 2020 are estimated at €3.5 billion in the scenario with the lowest CO_2 price, and at €4.8 billion in the highest CO_2 price scenario (Table 3.3). In the high CO_2 price scenario, this can provide a primary energy saving of 39 PJ and a CO_2 emission reduction of 2.2 Mt (Table 3.4).

Table 3.3 *Investment costs required for realising the economic cogeneration potential*

CO_2 price scenario [€/t]	2010 [€bn]	2015 [€bn]	2020 [€bn]
15 - 15 - 15	2.2	3.0	3.5
15 - 25 - 25	2.2	3.8	3.9
15 - 50 - 50	2.2	4.1	4.8

Table 3.4 *Primary energy savings (PES) and CO_2 emission reduction of the economic cogeneration potential*[7]

	2010		2015		2020	
CO_2 price scenario [€/t]	PES [PJ]	Em. red. [Mt CO_2]	PES [PJ]	Em. red. [Mt CO_2]	PES [PJ]	Em. red. [Mt CO_2]
15 - 15 - 15	17	0.7	27	1.5	26	1.5
15 - 25 - 25	17	0.7	20	0.9	30	1.7
15 - 50 - 50	17	0.7	39	2.2	39	2.2

7 The PES was calculated in accordance with the formula in the EU Cogeneration Directive and is thus lower than if the Energy Saving Monitoring Protocol had been used.

4. Comments on the methodology

4.1 The modelling system for national energy exploration

The calculations made in the modelling system for national energy exploration analyse cogeneration in the context of other developments on the energy market. For example, account is taken of an increase in electricity generation from (new) coal-fired power stations and new gas power stations, and the impact on electricity prices. In reality such factors shape the investment decisions of companies, so that they are highly relevant for determining the economic feasibility. The results of the modelling system are aggregated nationally, which in some cases can lead to simplification for specific technologies or individual installations. In the case of micro-cogeneration, for example, the overall effect on electricity generation is small, making it difficult to make a distinction between individual technologies and applications. ECN has tried to avoid oversimplification by comparing the results with existing potential calculations and, where necessary, adapting them. Data compiled by cogeneration technology developers and an analysis of a limited number of individual installations were also used to validate the results.

4.2 High-efficiency cogeneration

The 2010 Reference Forecast contains all installations supplying both heat and power, but these are not completely high-efficiency installations in cases where only part of the heat is used[8]. However, the analysis of potential required by the European Commission is confined to high-efficiency cogeneration. Therefore, in this study, power generation in installations in which the heat is not fully used has been scaled back to that part of generation qualifying as high-efficiency. The overall electricity generation of cogeneration power stations may therefore be greater than that indicated in the results of this study.

ECN expects the number of cogeneration power stations which are only partly high-efficiency to increase as a result of rising electricity prices and the growing share of unpredictable energy sources such as wind energy. This is because high electricity prices stimulate greater electricity generation, resulting in a decline in heat generation. A large supply of electricity from unpredictable sources may lead to greater fluctuations between peak and low prices. As a result of this financial incentive, cogeneration operators may restrict the use of installations to peak times on the electricity market so that the annual number of operating hours decreases.

The 2010 Reference Forecast and this study take this trend into account, but in the case of district heating this led to extremely negative results which are due more to the aggregated approach taken in the modelling system than to actual developments. Therefore, in the case of district heating ECN used the thermal capacity as a guide for evaluating the economic potential, because the use of heat from these installations is laid down (contractually) in agreements with customers and is thus a deciding factor.

8 This scaling back is a direct result of the methodology prescribed in the Cogeneration Directive and the approach applied by the CBS.

References

Boerakker, Y.H.A, M. Menkveld, C.H. Volkers (2007): *'Een blik op the toekomst met SAWEC' – Looking towards a future with SAWEC ('Simulation and analysis model for residential energy consumption and CO_2 emissions')*. ECN. July 2007.

Buck, A. de, *et al*. (2009): *'Rentabiliteit van WKK - Second opinion op modelberekening ECN en Ministerie EZ, ten behoeve van de Tweede Kamer' – The cost-effectiveness of cogeneration – Second opinion on the model calculations of ECN and the Ministry of Economic Affairs, for the Lower House of Parliament.* ECN. September 2009.

Centraal Bureau voor de Statistiek (2010a). '*Productiemiddelen electriciteit en warmte' – Means of generating electricity and heat*. Statline databank. March 2010.

Centraal Bureau voor de Statistiek (2010b): '*Duurzame energie productie, verbruik en capaciteit' – Sustainable energy generation, consumption and capacity*. Statline databank. March 2010.

Commission of the European Communities (2008): *Commission decision establishing detailed guidelines for the implementation and application of Annex II to Directive 2004/8/EC of the European Parliament and the Council.* 19 November 2008.

Daniëls, B.W. et. al. (2007): *High-efficiency cogeneration in the Netherlands*. ECN. November 2007.

ECN. '*Basislijst WKK' – Basic list of cogeneration.* April 2007 (confidential spreadsheet).

ECN/PBL (2010): '*Referentieramingen Energie en Emissies 2010-2020' – Reference Forecasts for Energy and Emissions 2010-20.* ECN and PBL, Petten/Bilthoven, ECN-E-010-004, April 2010 (not yet published).

ECOFYS, ECN, Cogen Projects, Gasunie, TNO, CE Delft. *'Energie- en CO_2-besparingspotentieel van micro-WKK in Nederland (2010 - 2030)' – The energy and CO_2 saving potential of micro-cogeneration in the Netherlands (2010-30).* Update 2008.

European Parliament and the Council of the European Union. *Directive 2004/8/EC on the promotion of cogeneration based on a useful eat demand in the internal energy market.* 11 February 2004.

Eurostat (2009): International Energy Agency and UN Economic Commission for Europe. *Electricity and Heat Annual Questionnaire 2008 and Historical Revisions*. July 2009.

Jacobs Consultancy (2009): '*Techno-economische parameters SDE 2009' – Technical and economic parameters for the SDE 2009*. 3 September 2009.

PriceWaterhouseCoopers. '*Het potentieel van WKK in de Chemie • Enquête onder leden van de VNCI' – The potential for cogeneration in the chemical industry • Survey of members of the VNCI (the Netherlands Chemical Industry Association).* May 2009 (confidential).

Volkers, C.H. '*NEV-RekenSysteem. Technische Beschrijving' – The National Energy Exploration Modelling System. Technical description*. ECN. November 2006.

Wetzels, W. et al. '*WKK-potentieel in de chemische industrie' – Cogeneration potential in the chemical industry*. ECN. November 2009 (not yet published).