# CODE2

**Cogeneration Observatory and Dissemination Europe**

# *D5.1 - Final Cogeneration Roadmap*

# Member State: **The Netherlands**

**Date: July 2014**

Leading CODE 2 Partner: COGEN Vlaanderen

*The Netherlands is part of the non-pilot Member States of the North-Western Europe CODE2 Region.*

*The CODE2 Region 'North-Western Europe' comprises the following Member States: Belgium, Ireland, Luxembourg, Netherlands and United Kingdom*

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**The CODE2 project**[1]

This roadmap has been developed in the frame of the CODE2 project, which is co-funded by the European Commission (Intelligent Energy Europe – IEE) and will launch and structure an important market consultation for developing 27 National Cogeneration Roadmaps and one European Cogeneration Roadmap. These roadmaps are built on the experience of the previous CODE project (www.code-project.eu) and in close interaction with the policy-makers, industry and civil society through research and workshops.

The input of all experts has informed these roadmaps. The content of the roadmaps, and opinions of the roadmaps presented reflect the conclusions of the CODE2 project only.

The project aims to provide a better understanding of key markets, policy interactions around cogeneration and acceleration of cogeneration penetration into industry. By adding a bio-energy CHP and micro-CHP analysis to the Member State projections for cogeneration to 2020, the project consortium is proposing a concrete route to realise Europe's cogeneration potential.

**Draft roadmap methodology**

This roadmap for CHP in the Netherlands is written by CODE2 partner COGEN Vlaanderen based on a range of studies and consultations. It has been developed through a process of discussion and exchanges with experts.[2]

[1] For more details and other outcomes of the CODE2 project see: http://www.code2-project.eu/.

[2] First discussions with policy authorities and experts took place in Januari 2014. The first draft roadmap has been discussed on a webex workshop on 13 March 2014 with 4 experts from the Netherlands.

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# 1 Executive Summary

**The Netherlands had historically a very active CHP market, which resulted in a large installed CHP capacity. The CHP capacity is mainly located in the industry, horticulture and district heating plants. But due to the lack of sufficient support from 2008 onwards, the CHP market in the Netherlands has stagnated and a decline in installed CHP capacity is expected for the following years.**

**The roadmap proposes several actions to realise the potential of CHP in 2030. A long-term energy and climate policy should be developed, which would improve the support for CHP. Furthermore, the Dutch policy should focus on primary energy consumption instead of final energy consumption. The ETS system should be improved at EU level so it will stimulated energy efficiency investments.. Additionally, a CO2-tax could create a stable investment climate for energy efficiency investments, with a return of the revenues to the companies in the form of support for energy saving measures. An alternative is to evaluate permissions of heat and power plants based on emission and efficiency requirements. Most important, the benefits of CHP should be compensated by a sufficient financial support system and existing plants should be supported to modernise with advantages for energy efficiency and electricity grid support. At last, heat networks should be developed further.**

**With measures proposed in the roadmap it should be possible to realize the economic potential of 16,1 GWe installed CHP capacity in 2030. This will result in primary energy savings of 42 TWh per year and CO2 savings between 12 and 15 Million tons per year in 2030.**

# 2 Where are we now?: Background and situation in the Netherlands

## *2.1* Current status: Summary of currently installed cogeneration in the Netherlands

**In 2012, cogeneration in the Netherlands had an installed electrical capacity of 12,73 GWe. High efficiency CHP generated half of the total amount of electricity. The CHP capacity is mainly located in industrial plants, horticulture and district heating. The CHP market in the Netherlands has been stable from 2008 but is expected to decline to half by 2020/2023 under business as usual conditions.**

According to Eurostat data[3], as shown in Table 1, approximately 33,6% of all generated electricity in 2008 was produced by CHP installations in high efficiency mode. The latest statistics published by the Dutch Central Statistics Office[4] shows that in 2012 51,8% of the electricity in the Netherlands was produced by CHP. The electrical installed capacity was 12,73 GWe, representing 43% of the total installed capacity. The difference between these statistics can be accounted for in the different definitions used by different bodies, e.g. regarding production in high efficient CHP mode only (Eurostat) or total production (Dutch CBS) of the CHP unit.

[3] Combined Heat and Power (CHP) in the EU, Turkey, and Norway - 2008 Data. EU: Environment and Energy, 2010.

[4] CBS Statline (http://statline.cbs.nl/StatWeb/selection/?DM=SLNL&PA=37823WKK&VW=T)
Figures from CBS include also CHP in non-highly efficient mode

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Table 1: Eurostat data for CHP in the Netherlands

| Year | Installed capacity electricity (MW) | Total cogenerated electricity generated (MWh) | Total heat supplied (MWh) | Total electricity generated (MWh) | Total share on electricity |
|---|---|---|---|---|---|
| 2008 | 8.970 | 36.410.000 | 68.417.000 | 108.363.000 | 33,6% |

The Dutch CHP sector saw rapid growth in the 1990s, as the legislative framework created a supportive environment for long-term investments in combination with the low gas prices. Installed capacity more than doubled between 1990 and 2000. Abundant and secure supply of natural gas combined with the prominence of energy intensive industry with a high heat demand contributed to this success. After 2000, growth slowed down as the transition to a liberalised energy market fuelled uncertainty, rewarding short-term investments. Between 2005 and 2008, CHP capacity tripled in the horticulture sector driven by the ability of these applications to follow the electricity market price signal using storage of heat to maintain high efficiency. From 2009, the installed CHP capacity in the Netherlands is stable caused by the loss of SDE+[5] support for CHP. Due to unfavourable market conditions and lack of compensating support CHP production and savings are in decline since 2010. The 2013 Dutch National Energy Agreement reconfirmed the halt to CHP support in the Netherlands, leading to an expectation in the sector of a halving of CHP s energy savings by 2020.

According to the Dutch Central Statistics Office, centralised CHP plants represented 39,8% of the total installed electrical CHP capacity in 2012. Together with the agriculture and horticulture sector (24,1%) and the industry (26,0%) it forms 90% of the total installed electrical CHP capacity. The agriculture and horticulture sector and services represent respectively 63,7% and 28,3% of the 4.408 CHP installations in the Netherlands. Most CHP plants are fired with natural gas (66%). Fuels like industrial gas, waste gas, biomass and waste accounted for 23,8% of the CHP energy mix and doubled between 2004 and 2012.

## *2.2* Energy and Climate Strategy of the Netherlands

**Under the EU Effort Sharing Decision, the Netherlands has to achieve a 16 per cent emission reduction in 2020 from the 2005 levels. The National Energy Agreement has as target to achieve an average yearly final energy consumption reduction of 1,5 per cent and 100 PJ final energy consumption reduction in 2020 in the sectors outside the Emission Trading System. The National Energy Agreement reconfirms that no additional measures are taken for CHP.**

The EU Effort Sharing Decision (No. 406/2009/EC) establishes binding annual greenhouse gas (GHG) emission targets for EU Member States for the period 2013–2020. These targets concern emissions from most sectors not included in the EU Emissions Trading System (EU ETS), such as transport (except aviation), buildings, agriculture and waste. The target for the Netherlands is a 16% emission reduction in 2020 from 2005 levels[6].

In September 2013, several Dutch stakeholders (government, unions, employer and environmental organisations) signed the SER National Energy Agreement (NEA) for a sustainable growth. The Energy Agreement contains agreements extending until 2020/2023 as a step towards an 80 to 95 per cent

[5] Stimulering Duurzame Energieproductie

[6] Source: http://ec.europa.eu/clima/policies/package/

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greenhouse gas emission reduction in 2050. They agreed on an average yearly final energy consumption reduction of 1,5 per cent and 100 PJ final energy consumption reduction in 2020. The target for renewable energy is 14 per cent in 2020 and 16% per cent in 2023. The greenhouse farming sector has agreed with an additional energy saving of 11 PJ in 2020 relative to the 2012 baseline. Furthermore, five coal plants will be closed by 2016-2017[7]. The National Energy agreement states that no subsidy for CHP will be given. As all targets are defined on final energy only, the expected CHP decline to halve will not affect these targets. However, Cogen Nederland expects the loss of primary energy savings due to CHP decline to exceed all other NEA savings to be realised.

ECN/PBL[8] calculated the effects of the Energy Agreement. They calculated that the effect of measures would result in a 22 to 60 PJ final energy reduction instead of 100 PJ to obtain the EU 2020 target.

## *2.3* Policy development in the Netherlands

**CHP is supported by energy investment allowances and energy tax exemption but necessary additional support was withdrawn in 2011 leaving an inadequate structure to compensate for market failures. Bioenergy CHP receives a feed-in-premium and residential micro CHP is uniquely supported by a subsidy in the province of Gelderland. A decline in CHP production and capacity is expected in the coming years due to the lack of sufficient financial support.**

The National Energy Agreement[9] parties expect a decline of installed CHP capacity the following years through the lack of policy and sufficient support. At the moment CHP in the Netherlands realizes a primary energy saving of 150 PJ. COGEN Netherlands expect a decrease of CHP related primary energy savings of 75-100 PJ, which is more than the 28-86 PJ primary energy savings implemented in the National Energy Agreement.[10] Although there is no specific support for the primary energy savings delivered by CHP, some schemes could also be of interest to CHP.

Entrepreneurs investing in CHP qualify for the Energy Investment Allowance[11]. Up to 41,5% of the investment costs in equipment and/or production costs can be deducted from the company's taxable profits in the calendar year of the purchase. In this way the deduction can add up to approximately 10% of the investment costs. Most categories have to meet an efficiency threshold. There is a maximum to the investment in €/kWe depending on the category of CHP.

Natural gas used for electricity production, including CHP, is exempted from energy tax. The installations must have an electrical efficiency of at least 30% and an installed capacity of 60 kWe or higher.

Renewable CHP is promoted through the Sustainable Energy Incentive Scheme Plus[12] (SDE+), which supports renewable electricity, gas and heat by means of a feed-in-premium. The SDE+ supports renewable energy by compensating the financial gap between production costs and the market price of renewable energy. It is a sliding feed-in-premium and is equal to the difference between a base rate and

[7] Energieakkoord voor duurzame groei (SER, 2013): http://www.energieakkoordser.nl/energieakkoord.aspx

[8] Het Energieakkoord: wat gaat het betekenen? Inschattingen en gemaakte afspraken (ECN/PBL, 2013)

[9] Energieakkoord voor duurzame groei (SER,2013): http://www.energieakkoordser.nl/energieakkoord.aspx

[10] Letter from COGEN Nederland at September 10, 2013

[11] Energie Investeringsaftrek: http://www.agentschapnl.nl/subsidies-regelingen/energie-investeringsaftrek-eia

[12] SDE+: http://www.agentschapnl.nl/subsidies-regelingen/sde/biomassa

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a correction rate, determined retroactively every year for certain technologies. The maximum annual budget is allocated in five phases, with the cheapest technologies having priority in the early phases. The scheme allows all technologies to compete against each other rather than pre-allocating a certain share of the budget for each technology.

Heat delivery through district heating is regulated under the new Heat Act[13], which came into force in January 2014. It will protect small-scale consumers (<100 kW) connected onto a heat network. The Heat Act will ensure the heat consumers a high quality service for a reasonable (maximum) price. In exchange the heat producers can qualify for a subsidy.

From 2014, the Province of Gelderland support up to 10.000 house owners that buy or rent a micro CHP with a subsidy of maximum 2000€. The condition is that the micro CHP will have an electrical capacity of maximum 3 kWe. Furthermore, small enterprises can ask Gelderland for micro CHP support if the payback period is larger than five years. The support is limited to 100.000€.[14]

## *2.4* Exchange of information and awareness in the Netherlands

**The Netherlands had historically a very active CHP market, which corresponds to a high awareness among most of the market players and customers.**

Good awareness about the benefits of cogeneration, among the different actors, is one of the basic conditions to create an active CHP market. This is necessary to achieve the full potential of CHP. Good awareness implies well-informed customers, enough qualified market players, policy makers that provide the correct framework for a functioning market and influencers that inform and advise the other groups. The actors on the CHP market, classified into four social-economic groups, are shown in Figure 1. The level of awareness was assessed for each of the actors and rated 1-5 , (1 poor and 5 Active market) , as shown below. The detailed comments on each group are described in 1.

[13] Warmtewet: https://zoek.officielebekendmakingen.nl/stb-2013-325.html

[14] Source: http://www.gelderland.nl/4/Home/Home-Actueel/Nieuws/Subsidieaanvraag-voor-HRe-ketel-in-Provincie-Gelderland.html and http://www.gelderland.nl/4/Energietransitie,-subsidies.html

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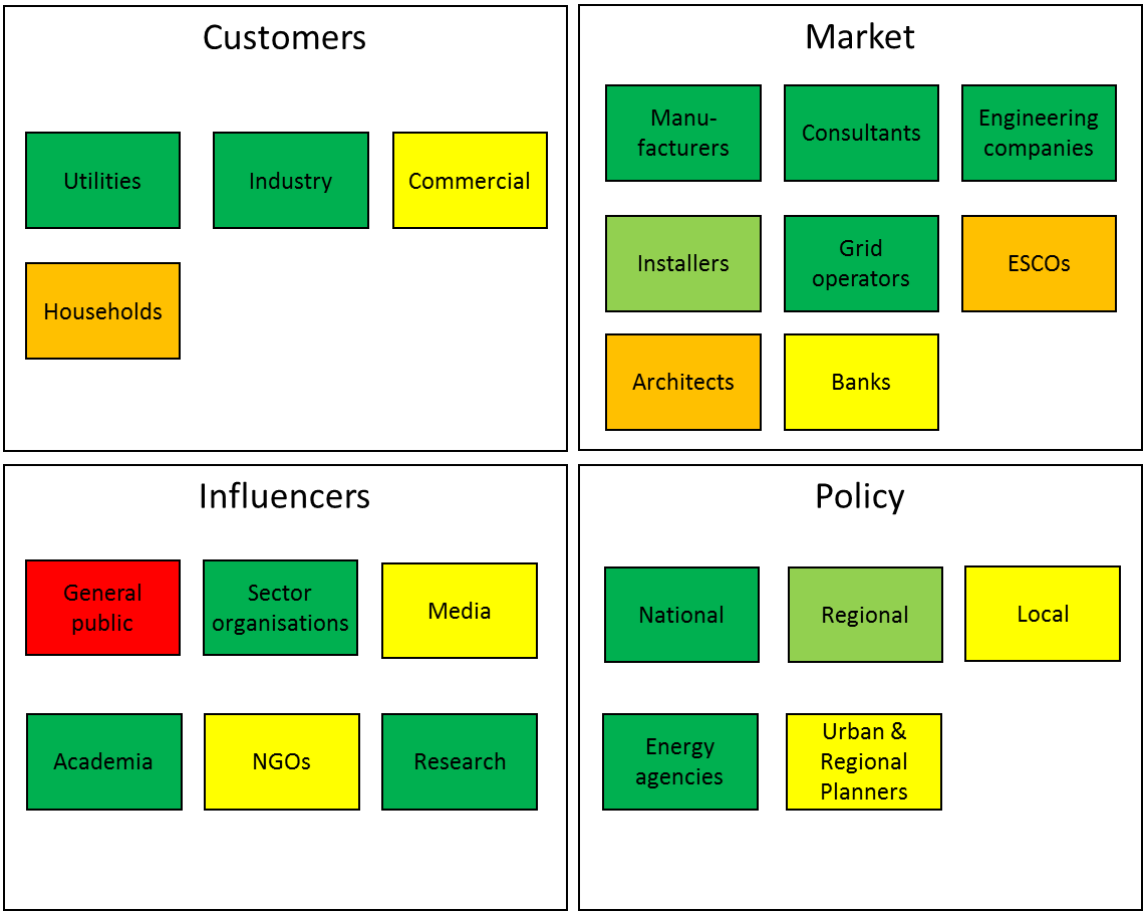


Figure 1: Level of awareness among key actors under the four socio-economic groups

| | | |
|---|---|---|
| 1 | Poor | |
| 2 | Low | |
| 3 | Early awareness | |
| 4 | Interest | |
| 5 | Active market | |

***Customers***

Figures of the installed electrical capacity, discussed in Chapter 2.1, show us that there is a very active market in the utility, industrial and horticulture sector. Also in the health sector (hospitals and retirement homes), there is a high penetration of cogeneration. The penetration in commercial premises is only limited. Manufacturers in recent years have started to advertise domestic micro-CHP cogeneration units, under the name HRe boilers, to households.

***Market players***

The large installed CHP capacity proves that most market players (manufacturers, consultants, engineering companies, installers and grid operators) are aware of cogeneration. Although some of the heating and electricity installers in the segment of the micro-installations lack the necessary knowledge. There are little well-known Energy Service Companies who provide CHP solutions. Banks are aware of

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possibilities of CHP but do not accept the CHP related risks (the long-term investment cost, high maintenance costs, fluctuating fuel prices and electricity prices) in this economic climate.

***Influencers***

The sector organisations (COGEN Nederland, Energy2GO, LTO Noord Glaskracht) are very active in promoting CHP. On TV, there are discussions about energy transition (WattNu?) based on public available simulation tools on the internet (energietransitiemodel.nl ) where CHP is mentioned occasionally. Specialised media like Energeia spend time on cogeneration. Most NGOs are more focused on off-shore wind and energy saving other than CHP although Milieucentraal[15] domestic micro-CHP units, better known as HRe boilers, promotes on its website. There is only a limited amount of CHP related research and at the moment no specific CHP training courses. The awareness of the opportunities of CHP in the era between 'fossil' and 'sustainable' is generally poor.

***Policy makers***

Policy makers in the Netherlands are familiar with CHP at many capacities as the technology is widely used in the economy. The relevant sectors of government know cogeneration but view it as a mature technology that does not need support because it has reached technological maturity. There is therefore a lack of awareness at policy maker level of the market failures which challenge the progress of CHP as a tool to improve energy efficiency and reduce CO2 emissions.

[15] Source: http://www.milieucentraal.nl/themas/energie-besparen/energiezuinig-verwarmen-en-warm-water/nieuwe-cv-of-combiketel-kopen/hre-ketel

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## *2.5* The economics of CHP in the Netherlands

**In general, it is hard to make cogeneration financially interesting in the Netherlands. This is the result of the several external costs that CHP carries and that are not financially validated in the market. In some applications, however, like swimming pools and hospitals, it is possible to achieve a good economic case.**

A cogeneration plant is a large investment and its feasibility is most of the time measured by its financial parameters, such as internal rate of return (IRR), return on investment (ROI) or payback period. An important factor is the capital cost of the cogeneration unit and its maintenance compared to a standard boiler. The most significant parameter however, is the spark spread. This is the theoretical gross margin of a gas-fired CHP from selling a unit of electricity, having bought the fuel required to produce this unit of electricity. The support systems described in Chapter 2.3 should improve the business case for CHP installations.

An economic analysis is made on four CHP cases, which are standardized within the CODE2 project to compare the economic situation of CHP between the Member States. The cases are:

- a 50 kWe internal combustion engine (ICE) installed in a hotel
- a 1 MWe internal combustion engine installed (ICE) in an industrial plant
- a 10 MWe combined cycle (CC) CHP producing district heat and power in a public utility
- a 500 kWe biogas engine cogeneration placed at a farm, where the heat is sold to a client.

The details of this economic analysis can be found in Annex 4: Assumptions used in the economics of CHP. The results are shown in Figure 2.

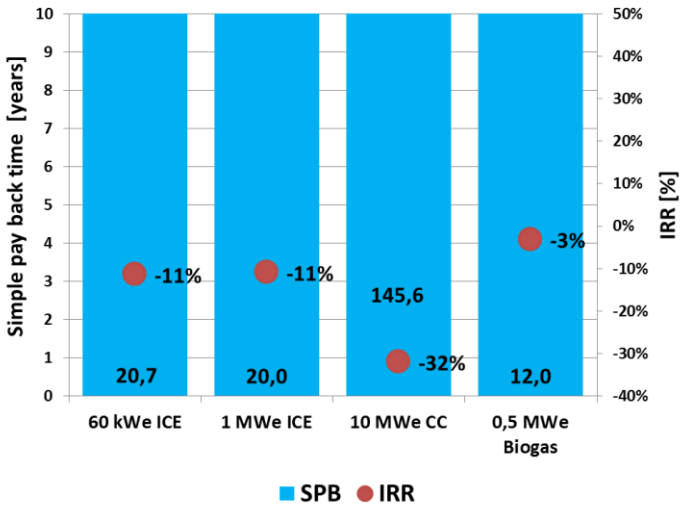


Figure 2: Economic calculations of four standard CHP plants

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The internal rate of return (IRR) over 10 years is currently negative or close to zero for all cases. Although, the cases are not truly tyical for the Netherlands, the modelling describes the economic situation of CHP in Netherlands.

For an economic analysis of eight typical Dutch CHP plants, we use figures of 'unprofitable tops' calculations based on a 2009 ECN study[16] and updated by COGEN Nederland. The cases are a 250 and 60 MWe combined cycle gas turbine CHP, a 45 and 8 MWe gas turbine CHP, a 25 MWe steam turbine CHP, 2 and 0,4 MWe internal combustion CHP in agriculture and 250 MWe CCGT CHP connected to a district heating network. The details can be found in Annex 4: Assumptions used in market extrapolation. Five of the eight installations have a negative payback time because of the marginal costs (fuel and operational & maintenance) are larger than the revenues of heat and electricity. The other three cases have a negative IRR, because of the payback time is larger than ten years.

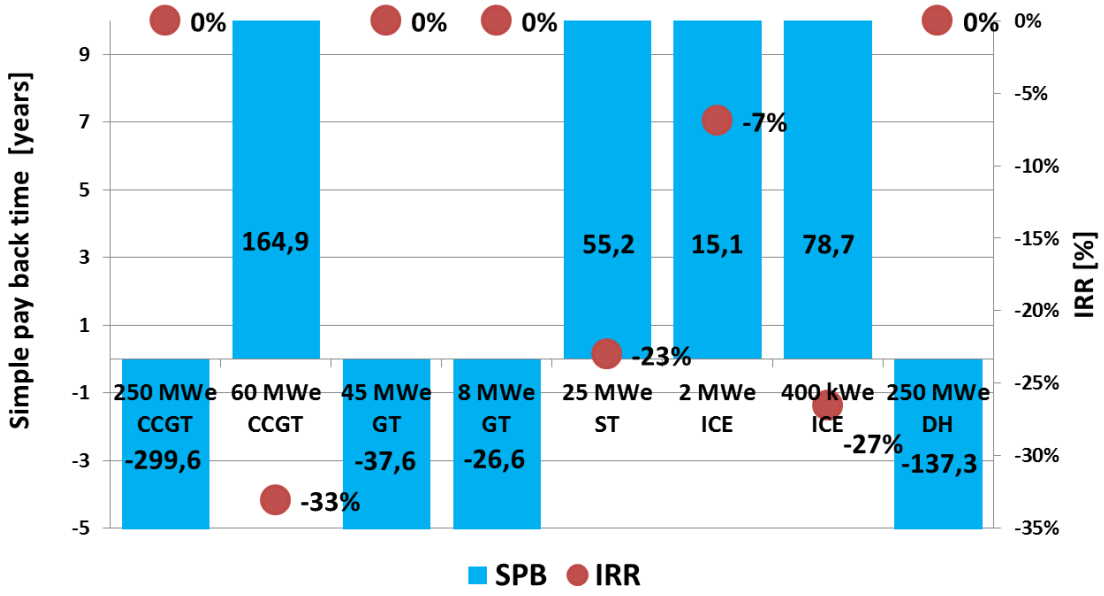


Figure 3: Economic calculations of eight Dutch reference CHP plants

Despite of difficult economic situation of the large CHP plants, there seem to be some opportunities for small CHP units of a few tens or hundreds kWe, in sectors with large hot water demand and a sufficient high electricity demand to use the electricity produced by the CHP. Good examples of those sectors are swimming pools and hospitals.

An overview of the economic situation of cogeneration in the main market segments is given in Table 1. In general, it is hard to make cogeneration financially interesting in the Netherlands, which are also the conclusions of the rapport of CE Delft in 2009.[17] This is only because external costs are not paid for by the polluter, nor is avoiding external costs rewarded. With an external cost of 100€/ton$CO_2$ the economic situation would change completely. Gas fuelled CHP would be cost-effective, while coal fired power plants would not be.

[16] Onrendabele top berekeningen voor nieuw WKK-vermogen(ECN, 2009)

[17] Rentabiliteit van WKK - Second opinion op conclusiesmodelberekeningen ECN en Ministerie EZ,ten behoeve van de Tweede Kamer (CE Delft, 2009)

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Table 1: CHP economics matrix

| Netherlands | Micro *up to 50kW* | | Small & Medium *up to 10 MW* | | Large *more than 10 MW* | | |
|---|---|---|---|---|---|---|---|
| | NG | RES | NG | RES | NG | Coal | RES |
| SME/Industry | | | | | | | |
| District heating/cooling | | | | | | | |
| Services | | | | | | | |
| Households | | | | | | | |

**Legend:**

| | |
|---|---|
| **"normal"** | Cogeneration Investment has **good economic benefits**, return on investment acceptable for the investors, **interest for new investment exists**; there are no significant economic barriers for the implementation. |
| **"modest"** | Cogeneration Investment has **modest/limited economic benefits** and return on investment, **limited interest for new investments**. |
| **"poor"** | Cogeneration Investment has **poor or negative return on investment or is not possible due to other limitations, no interest/possibilities for new investments**. |
| | Inapplicable, the technology is not used in this market segment. |
| **NG** | **Natural Gas** or appropriate fossil fuel |
| **RES** | **Renewable energy sources** (wood biomass, biogas, etc.) |

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## 2.6 Barriers to CHP in the Netherlands

**The major barrier for CHP in the Netherlands is the low electricity price, which decreases the revenues of the CHP plants combined with the halting of important government support. Furthermore, as result of various market failures, it is still more interesting to build condensing power plants and waste heat instead of using CHP plants. Investments in interesting CHP project are deferred as because companies give priority to investing in their core business instead of energy saving measures. At last, most existing industrial CHP plants are configured for base load operation, which means they face low revenue from electricity in the near term and their continued use is threatened.**

As discussed in previous Chapters, the Netherlands have/had a very active CHP market. Chapter **Error! Reference source not found.** shows that most actors know the benefits of CHP. Still, the current outlook for CHP is not very promising. The most important barrier is the current bad economic case as shown in Chapter 2.5. Further significant barriers exist which are ordered in descending order of importance:

***Barrier 1: Exceptionally low prices in the wholesale electricity market for extended and intermittent periods are currently removing the profitability of electrical sales to the grid. This presents a barrier to profitable operation of existing plant and an unattractive investment opportunity for new plant.***

The price of an emission allowance in the EU emission trading system (ETS) swings at the time of writing around 4-5 €/tCO2[18] and projections estimate that the price in 2020 will be between 8 €/tCO2 and 15 €/tCO2.[19] In combination with the oversupply of coal caused by the switch from coal to shale gas in the US, this result in coal power plants producing electricity at low prices. Because of this electricity from old coal fired power plants with high CO2-emissions take a large share in the electrical energy mix while highly efficient gas fire power plants are being decommissioned.

The low spark spread is not only a barrier for the installation of new CHP plants but also for the operation of existing CHP plants.

***Barrier 2: Lack of well-targeted and appropriate financial support compensating for market failure for CHP means that currently there is an unacceptable economic case for CHP operators, preventing the wider deployment of CHP***

Cogeneration in the Netherlands is considered a mature technology. For large installations, this is definitely the case. Because of this, the Dutch government concludes that CHP has to compete, without support, with conventional technologies in the market. The problem with this point of view is that the benefits of CHP are not sufficiently reflected as value in the energy market. This market failure results in an uneconomic case for CHP without further measures from the market or from public support.

***Barrier 3: The Netherlands Energy saving targets under Article 3 of the EED is based on final energy consumption which means that primary energy saving by CHP is not valued towards the Netherlands energy efficiency target, resulting in less political interest in CHP.***

The energy targets for 2020 in the National Energy Agreement are defined in final energy savings. The EED does require that however the target is set the member state must report also in primary energy savings. Defining the energy saving targets on final energy use is a heavily flawed approach in dealing

[18] Source: http://www.eex.com/en/Market%20Data/Trading%20Data/Emission%20Rights

[19] Source: http://www.icis.com/resources/news/2013/10/09/9713881/eu-2020-oversupply-forecast-exceeds-analyst-expectations/ ; http://www.icis.com/resources/news/2013/10/24/9718673/co2-price-for-coal-to-gas-switch-exceeds-2020-forecasts/

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with energy efficiency in the energy transformation sector. Climate change and fossil fuel dependency are directly related to primary energy use. By defining the energy targets on final energy consumption instead of primary energy consumption, possible efficiency gains in the transformation sector, such as CHP, are not stimulated.

***Barrier 4: There is currently insufficient dis-incentive in the Netherlands to building condensing power stations. This presents a barrier to the wider deployment of CHP, which is a different type of project requiring a more complex business proposition.***

CHP plants know an increased complexity with respect to condensing power stations. Besides the technical complexity, the economic case of a CHP plants does not only depended on the gas market and the electricity market but also on the heat demand. Since the additional costs of the CHP plants are only compensated by uncertain revenues of the heat sale and there are no dis-incentives to build condensing power stations in the Netherlands, the business case for investors to waste the heat is better than to build a CHP plant.

***Barrier 5: CHP and energy savings are not part of the core business of most companies, which results in CHP related investments having a low priority when choices between investments are taken, which is a barrier to achieve the full economic potential for CHP.***

Companies have only a limited capital available for investments, which obliges them to make choices. Investments in the core business generally take priority. Since CHP and energy savings are not of the core business for most companies, it is hard to get the necessary financial resources for investments in CHP, even when a CHP project is profitable.

***Barrier 6: Because most existing industrial CHP plants designed under another policy framework are configured for base load operation, they are not able to decrease their power production when the electricity prices are below the operational costs.***

The off-peak whole sale electricity prices in the Netherlands are lower than the operational costs of industrial cogeneration plants. Industrial cogeneration plants are designed and configured for continuous operation, which allows them to modulate their electrical power output during off-peak only in a small operating range. Minimum load is determined by the process demand.

In an energy market with a large share of intermittent renewable energy sources like wind and PV, flexibility is important. This need for flexibility will increase further when planned large offshore wind capacity is installed.

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# 3 What is possible? Cogeneration potential and market opportunities in the Netherlands

**In 2010, ECN estimated the potential for high-efficiency CHP between 15,2 and 16,1 GWe in 2020. Based on the heat demand, COGEN Nederland representing the industry estimates a technical potential of 20 and 25 GWe in respectively 2020 and 2030.**

In 2010, the Ministry of Economic Affairs commissioned ECN to update the 2007 report on the potential for high-efficiency cogeneration in the Netherlands. Based on 12,9 GWe installed capacity in 2008, ECN estimated a technical potential of 20,7 GWe high-efficient CHP in 2020. The economic potential was estimated between 15,2 and 16,1 GWe, which was calculated based on a CO2 price between 15 and 50€/ton CO2.[20] The costs required to achieve this potential are expected to be between € 3,5-4,8 bn. Higher CO2 prices are likely to benefit CHP growth in the industrial sector, especially for agriculture, while central power plant capacity is likely to decrease. Taking into account the uncertainty in the European carbon markets, the current economic potentials may be even lower than what was projected by ECN in 2010.

In January 2011, COGEN Nederland, the Dutch CHP association, published a Cogeneration Roadmap for the Netherlands[21]. The Roadmap outlines the significant energy savings and CO2 emission reductions that can be achieved by CHP investments in 2020 and 2030, if the right incentives are put in place. In terms of installed capacity, under an optimum policy scenario, CHP could reach up to 20 GWe and 25 GWe by 2020 and 2030 respectively. By 2020 and 2030, energy savings coming from CHP could reach 205 PJ and 300 PJ respectively, up from 125 in 2010 as shown in Table 2.

**Table 2: Primary energy saving potential of CHP in the Netherlands in 2020 and 2030**

| Sector | Primary energy savings (PJ) | | |
|---|---|---|---|
| | 2010 | 2020 | 2030 |
| District heating | 30 | 50 | 100 |
| Industrial sector | 50 | 80 | 100 |
| Glasshouse horticulture | 35 | 45 | 50 |
| Built environment | 10 | 30 | 50 |
| **Total** | **125** | **205** | **300** |

***Micro-CHP***

In 2011, Energy Matters investigated the energy savings potential of mini-CHP in services and collective housing, which confirms the 50 PJ/y energy savings for the built environment[22].

[20] The potential for high-efficiency cogeneration in the Netherlands (ECN, 2010)

[21] Cogeneration Roadmap for the Netherlands (COGEN Nederland, 2011)

[22] Energiebesparing en CO2-emissiereductie in de utiliteitsbouw en collectieve woningbouw door gaswarmtepompen en mini-wkk potentieel 2010-2030 (EnergyMatters, ECN and BDH, 2011)

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The CODE2 micro-CHP potential analysis expects a potential for 2.250.000 household micro-CHP units, with an electrical capacity of 1 kWe, in the Netherlands in 2030. This will deliver a 38 PJ/year primary energy saving. The potential for micro-CHP in collective housing systems and SMEs is estimated 23.000 units with an 18 PJ/year primary energy saving. More information can be found in Annex 2: Micro CHP potential assessment.

***Bio-energy CHP***

In 2009, bio-energy had a share of 3,7% in the CHP fuel consumption. According the CODE2 bio-energy CHP potential analysis which is based on member states own reporting on bio-based fuels, in 2020 and 2030, bio-energy will have a share of respectively 9,5% and 14% of the CHP fuel consumption. Solid biomass is burned in a boiler to produce steam for a steam turbine. Bio-energy in the form of biogas from digestion, can be used in a gas engine or gas turbines. More information can be found in Annex 3: Bio-CHP potential assessment.

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# 4 How do we arrive there? The Roadmap

## *4.1* Overcoming existing barriers and creating a framework for action in the Netherlands

**With the current Netherlands CHP policy, it will not be easy to keep the current CHP capacity in the Netherlands. The actions that must be taken to maintain existing CHP capacity and to realise the remaining CHP potential in 2030 are:**

***General policy action***

- **Developing an integral long-term energy and climate policy would improve the support for CHP**
- **Focusing on primary energy reduction instead of final energy consumption would stimulate energy efficiency gains in the transformation sector**

***Actions related to emission reduction would stimulate CHP for its emissions savings***

- **Improve the EU emission trading system (ETS) at the European level**
- **Introduce a CO2 - tax on energy**
- **Put overall efficiency and/or emission requirements on power and heat generation**

***Specific CHP related actions***

- **Perform an assessment of the high-efficiency CHP and efficient district heating potential**
- **Set binding targets for high efficiency CHP through the target reporting process of the EED and NEEAPs**
- **Increase the awareness of the benefits of CHP installations among policy makers**
- **A well designed support scheme for high efficiency CHP**
- **Extend the preferential access to the grid for renewable energy sources to CHP**
- **Support the upgrade and modernisation of existing CHP, so it can play a broader role in the future energy services market and electricity network support functions.**

***Specific heat networks related action***

- **Further development of heat networks**

### General policy actions

***Action 1: Developing an integral long-term energy and climate policy would improve the support for CHP***

In terms of energy and climate policy, we are facing enormous challenges. Decisions made today will have an enormous impact in the future and should be taken wisely. The Netherlands National Energy Agreement, as discussed in Chapter 2.2, does include neither CHP nor an energy policy beyond 2020. An integral long-term energy and climate policy should be developed, with a policy view on 2030 and 2050. This energy and climate policy should be based on simulations, combining both heat and electricity demand, and taking into account a large (and as complete as possible) array of criteria (investment costs; operating costs; network costs; environmental costs; reliability; manageability of the overall system balance; energy storage; the vulnerability of large systems, both technically and politically …).

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The "*Energy Transition Model*"[23] can be regarded as a first step in this direction: the model is a comprehensive simulation tool for creating future energy scenario's.

***Action 2: Focusing on primary energy reduction instead of final energy consumption would stimulate energy efficiency gains in the transformation sector***

The Dutch energy savings targets, under the EED, as discussed in Chapter 2.2, are defined by the final energy consumption. Climate change and fossil fuel dependency are directly related to primary energy use, whereas final energy consumption leaves out possible efficiency gains in the transformation sector. Even energy savings through cogeneration at the end user's site is currently not included. Therefore, the targets should be defined by primary energy consumption instead of final energy consumption.

Re-establishing this primary energy savings target within the implementation of the EED is fundamental to achieving momentum on `CHP policy in the coming years. Without the visibility of the primary energy losses and savings, the value of CHP to energy policy remains invisible. Policy action becomes unnecessary.

The reporting requirements under the EED insist that however set the energy savings made should be expressed in primary energy. This should be a starting point for the Netherlands to revisit their target setting approach.

## Actions related to emission reduction would stimulate CHP for his emissions savings

***Action 3: Improve the EU emission trading system (ETS) at the EU level***

As discussed in Barrier 3 the EU emission trading system (ETS) was installed to combat climate change and reduce industrial greenhouse gas emissions cost-effectively. The low emission allowances price impedes a switch to low carbon technologies in the heat and electricity market. Actions should be taken to restore the EU emission trading system, so it can achieve the objectives for which it was designed. As changes to the ETS-system have to be brought about on EU level, this action really requires adopting and defending a clear stance in the European parliament and council, rather than taking direct actions on member state level.

The structure for EU ETS is set clearly until 2020. However the Netherlands should work within the council to prepare the way for a significant review of the functioning of the ETS in the period 2015-2020.

***Action 4: Introduce a $CO_2$- tax on energy***

In the absence of a properly functioning ETS system, an additional $CO_2$-tax on (fossil) energy use could be introduced on member state level. This $CO_2$ -tax would support investments in primary energy savings. A similar approach exists today in the UK, where a carbon price floor is set, currently at £16 per tonne of carbon. This carbon price floor increases steadily over the years and delivers a stable investment climate for low carbon technologies. The $CO_2$-tax, called the carbon support price, is equal to the difference of the carbon price floor and the ETS $CO_2$-price. The revenues of the $CO_2$-tax could be used to support energy saving measures.

***Action 5: Put overall efficiency and/or emission requirements on power and heat generation***

A set of efficiency and/or emission requirements can be a valuable alternative for a CO2-tax on energy, especially in sectors where competitiveness is important. This is already the case in Belgium where in

[23] http://energietransitiemodel.nl/?locale=en

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2011 an environmental permission for a coal-fired power plant in Antwerp is refused because of its emissions.[24] Similar, the permit of a thermal power plant can be evaluated on the facility to provide waste heat, as aimed for by EED Article 14.5.a. Particularly biomass fuelled power plants should operate in CHP mode since electrical efficiencies are typically lower for biomass.

### Specific CHP related actions

***Action 6: Perform an assessment of the high-efficiency CHP and efficient district heating potential***

The Energy Efficiency Directive (EED) Article 14 paragraph 1 states that "*by 31 December 2015, Member States shall carry out and notify to the Commission a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling, [..]"*. A thorough analysis of the potential of high-efficiency CHP (taking into account "*External benefits such as environmental and health benefits", EED Annex IX, part 1)* allows for defendable yet ambitious targets for primary energy savings through high efficiency CHP.

***Action 7: Set binding targets for high efficiency CHP***

At the moment, the Netherlands have no targets for high efficiency CHP. Targets are useful, however, for both policy makers and market players. Article 3 of the European Energy Efficiency Directive (EED) states that each Member State has to set indicative energy efficiency targets. As cogeneration forms an important part of the EED. There should be a clear link between the Article 3 targets and the actions under article 14 and 15 with an explicitly calculated savings attributed to growth in CHP. A vision should be formed on how cogeneration will contribute to energy efficiency targets of the Netherlands. The above mentioned assessment of the CHP potential can act as a guideline. As mentioned under Action 2, the efficiency target should be based on primary energy use.

***Action 8: Increase the awareness of the benefits of CHP installations***

As shown in the awareness study, most market parties (the customers and the suppliers of CHP goods and services) are aware of the possibilities of CHP. There is, however, a lack of awareness about the benefits of CHP at the policy level. The possible role of CHP in the future energy mix of the Netherlands is not fully understood. The CHP sector has already put quite some effort in pointing out the possibilities and advantages of CHP, but there is a clear need for sustaining this effort. CHP should be regarded as a sustainable technology.

Industry should work with policy makers to develop this better understanding and awareness.

***Action 9: Support for high efficiency CHP***

As discussed in Barrier 1, the benefits of CHP are not sufficiently rewarded in the market. This should be compensated to create a level playing field. Depending on which benefit of CHP should be supported, several options are available. The first and easiest option is to reinstate the SDE+ support for CHP, which is based on a feed-in system. A second option is that the level of support is proportional with the primary energy savings (e.g. Flanders) or with the $CO_2$ emissions savings (e.g. Wallonia and Brussels). Another option is that the CHP is supported for the available capacity of flexible electricity generation. The last option is by increasing the tax reductions. By doing so, the Dutch government can comply with requirements of Article 14.2 of the EED on encouraging the CHP potential.

***Action 10: Extend the preferential access to the grid for renewable energy sources to CHP***

[24] Geen milieuvergunning voor E.ON-steenkoolcentrale in Antwerpse haven (De Morgen, 2 december 11)

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Renewable energy plants get priority for the connection to the grid, transport over the grid and in the market. 25 Those priority rights should also be implemented for CHP, as required by EED Article 15.5. Although access to the grid is not a barrier at the moment, explicit priority for CHP will act as a positive signal from the Dutch government, fostering a more positive investment climate.

***Action 11: Modernize and flexibilize CHP, so it will play in the future energy optimal role***

In a future with a large share of electricity produced by intermittent renewables, power plants have to operate in a much more flexible way to compensate for both expected and unexpected power drops and peaks of solar and wind. In high RES scenarios, there are periods in which the total electricity demand can be met by renewables alone. At such times, additional CHP electricity does not contribute any primary energy savings. Even now already, fluctuating short term market prices can force CHP installations to change production levels for certain periods. Both facts indicate that CHP users will have to adapt their view on how to operate the CHP installation in a constantly evolving energy market.

Article 14 of the EED requires member states to put "adequate measures in place" to support the development of CHP where it has proved advantageous under a socio-economic cost benefit analysis. With a high installed base of CHP in industry in the Netherlands a full implementation of the EED Article 14 suggests that the Netherlands government should consider measures to support industrial plants to modernise and upgrade their design to fit the emerging high RES market needs.

## Specific heat networks related action

***Action 12: Further development of heat networks***

In 2030 and later there will still be a large amount of old build buildings, however, which have a high heating demand. The easiest way to decarbonise those heat demands is to connect them to heat networks. The first generation low carbon heating generation plants can be gas CHP installations. As the decarbonisation process evolves, renewable CHP plants or other low carbon heat generators can replace gas CHP plants. This action complies with the obligation of Article 14 of the EED to take adequate measures so that an efficient infrastructure for district heating and cooling will be developed.

[25] „Voorrang voor Duurzaam"

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## *4.2* Possible paths to growth in the Netherlands

**The technical potential CHP capacity is twice the size of what is of currently installed (12,73 GWe). With the actions proposed in the roadmap, the CHP capacity could expand up to 16,1 GWe in 2030. The business as usual scenario, however, predicts a large decline.**

All CHP experts predict a decrease in installed CHP capacity and generated electricity under current market conditions. This decline is already visible in the CBS statistics, with an average of 5% annual decrease of electricity produced by CHP. This trend is not yet visible in the production capacity but we expect this will nevertheless occur, but to a lesser extent. The business as usual (BAU) scenario expects a yearly decrease of 3% until 2030, as shown in Figure 4. In 2030, this will result in half of the currently installed CHP capacity.

The 2010 ECN study[26] estimates a technical potential for CHP in 2020 at an additional 7,7 GWe high-efficient CHP 2020 on top of the 12,9 GWe installed capacity in 2008. For 2030, we assume a further increase of CHP capacity with 1% growth. This is in line with the roadmap[27] of COGEN Nederland which estimates a technical potential to double the primary energy savings delivered by CHP.

Our (conservative) growth path is based on the economic potential of the ECN study. The study estimates an economic CHP potential in 2020 of 2,3 and 3,4 GWe with respectively a $CO_2$-price of 15€/ton $CO_2$ and 50€/ton $CO_2$. With measures we propose in the roadmap it is possible to realize the economic potential of 15,2 GWe installed CHP capacity in 2020 and 16,1 GWe in 2030.

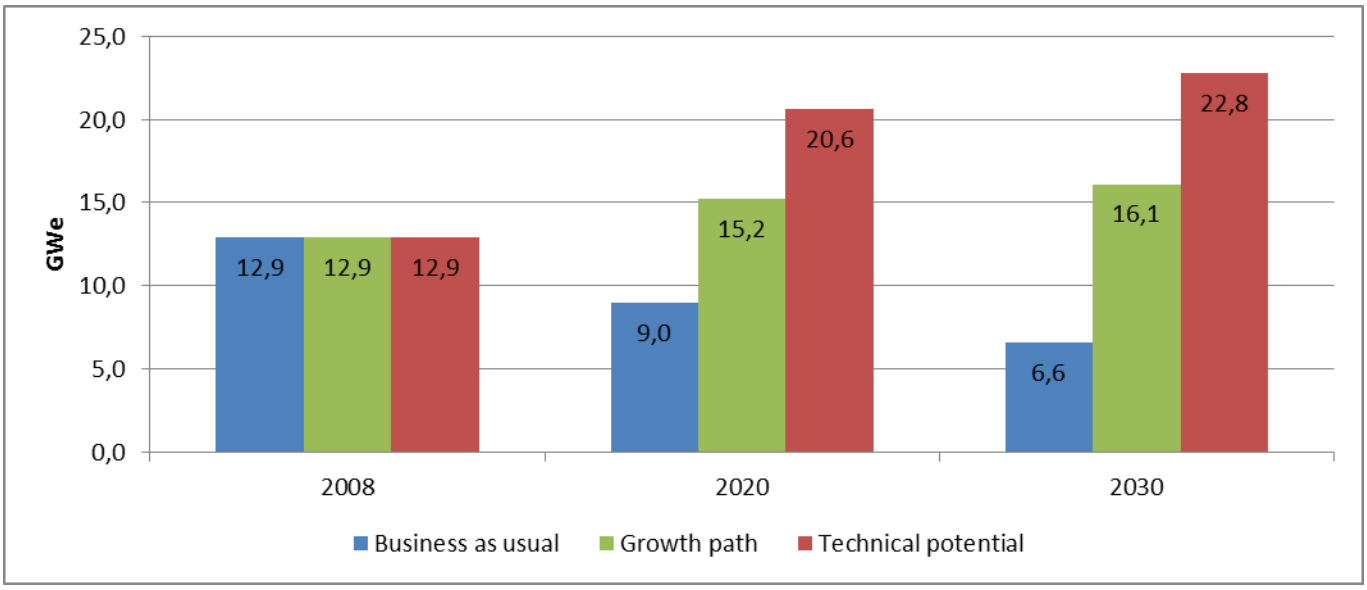


Figure 4: Growth path for CHP to 2030

[26] The potential for high-efficiency cogeneration in the Netherlands (ECN, 2010)

[27] Cogeneration Roadmap for the Netherlands (COGEN Nederland, 2011)

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## 4.3 Saving of primary energy and CO2 emissions by the CHP roadmap of the Netherlands

Primary energy saving (PES) and CO2 emissions saving projections resulting from increased use of CHP require assumptions about not just what types of fuel and technology are displaced, but also their operation on the market. Within CODE2 two approaches are developed. These represent two different analytic considerations which are summarised here and more fully explored in Annexe 5.

1) **Methodology according to Annexes I and II of the EED**. This method is used at a member state level today for national reporting to the European Commission and at project level for determining if a specific CHP plant is highly efficient. In the methodology, the efficiency of each cogeneration unit is derived by comparing its actual operating performance data with the best available technology for separate production of heat and electricity on the same fuel in the market in the year of construction of the cogeneration unit using harmonized reference values which are determined by fuel type and year of construction.

2) **Substitution method.** This method has been developed within the project and estimates the amounts of electricity, heat and fuel which are actually replaced by additional new CHP based on a projection of the supply base changes in the member state supply over the period are calculated. The situation in 2030 is compared to the current status. With this method PES for the Netherlands through implementing the roadmap for CHP is estimated at 42 TWh per year and CO2 savings are estimated to be between 12 and 15 Million tons per year in 2030. The actual saving is particularly dependent on the efficiency increase through upgrading both current power plant and CHP technology efficiencies. The final share of bio energy in additional CHP has a major impact on the CO2 savings which can be anticipated. The CO2 reduction achieved is due to both higher energy efficiency and fuel switching towards low carbon (natural gas) or non-carbon (bio energy) fuel, but CHP development and fuel switching are anticipated to be an integrated process driven by policy objectives.

**Table 3: Saving of primary energy and CO2 by the Dutch CHP roadmap**

| | Substitution method | | EED method | |
|---|---|---|---|---|
| | **low case** | **high case** | **low case** | **high case** |
| PE saving (TWh/a) | 42 | 42 | 45 | 49 |
| $CO_2$ saving (Mt/a) | 12 | 15 | 9 | 7 |
| - per kWh el* (kg/kWh el) | 0,69 | 0,87 | 0,51 | 0,4 |

* This value represents the $CO_2$ reduction of the power generation. It includes the avoided $CO_2$ emissions from fuel savings for separate heat generation in boilers; it must not be confused with the considerably lower $CO_2$ emissions of the substituted condensation electricity or with even lower emissions of compared power production according to the BAT approach in accordance with the EU CHP directive reference values.

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# ANNEXES

## 1. Stakeholder group awareness assessment

| | | |
|---|---|---|
| 1 | Poor | |
| 2 | Low | |
| 3 | Early awareness | |
| 4 | Interest | |
| 5 | Active market | |

| Group | Comments |
|---|---|
| **Customers** | |
| Industry | The industry is aware of CHP but with the current spark spread (2014), they tend to switch to heat production with boilers.<br>There is also a large installed capacity in the horticulture sector, but there are looking to alternative low carbon technologies, like gas driven heat pumps, because of the low spark spread. |
| Utilities | Utilities have several CHP plants in joint ventures with large industrial companies. |
| Commercial | The penetration in commercial premises is only limited. |
| Households | Manufacturers start to advertise domestic micro-CHP cogeneration units, under the name HRe boilers, to households. |
| **Market and supply chain** | |
| Manufacturers | There are sufficient manufactures of CHP units and CHP related equipment. |
| Installers | There is enough knowledge and experience among installers. |
| Grid operators | Grid operators are convinced of the benefits of CHP. |
| Consultants | There is enough knowledge among installers. |
| Engineering companies | There is enough knowledge and experience among engineering companies . |
| Architects | Micro-CHP is not yet seen as a common heating option. |

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| | |
|---|---|
| Banks | In the current economic climate and with and overcapacity of electricity generation, banks will not accept the risks of CHP (the long-term investment cost, high maintenance costs, fluctuating fuel prices and electricity prices. |
| ESCOs | There are no well-known Energy Service Companies who provide CHP solutions. |
| **Policy** | |
| National | The government sees cogeneration as a mature technology that does not need support anymore. They believe the market has to play his role. |
| Regional | Micro-CHP is supported by only one province, Gelderland. |
| Local | |
| Urban & Regional planners | CHP is not seen as a key technology for heat networks. |
| Energy agencies | The CHP technology is known but there is a lack of knowledge about the benefits of CHP. |
| **Influencers** | |
| Sector organisations | The sector organisations COGEN Nederland, Energy2GO and LTO Noord Glaskracht are very active to promote CHP. |
| General public | |
| Media | There are discussions about energy transition on TV (WattNu?) based on public available simulation tools on the internet (energietransitiemodel.nl ) where CHP is mentioned briefly. Specialised media like Energeia spend more time on cogeneration. |
| Academia | There are no CHP specific cogeneration courses or trainings. |
| Research | There is only a limited amount of CHP related research. |
| NGOs | NGOs do not mention CHP, they are more focused on off-shore wind and energy saving other than CHP |

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## 2. Micro CHP potential assessment

### *Country statistics*

Population: 16 850 000 (2010)
Number of households: 7 660 000 (2010)
GDP per capita: € 32 900 (2010)
Primary energy use: 54 000 ktoe/year (2010)
GHG-emissions: 210 Mton $CO_{2,eq}$/year (2010)

### *Household systems (±1 kWe)*
***Boiler replacement technology***

**Present market (2013)**
Boiler stock: 5 470 000 units
Boiler sales: 455 000 units/year

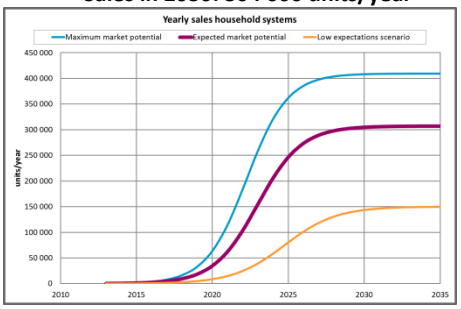
### *Potential estimation*

| *Indicator* | *Score* |
|---|---|
| Market alternatives | 3 |
| Global CBA | 3 |
| Legislation/support | 2 |
| Awareness | 1 |
| Purchasing power | 3 |
| **Total** | **9 out of 12** |

**Expected final market share: 68% of boiler sales in Household sector**

### *Yearly sales*

Sales in 2020: 35 000 units/year*
**Sales in 2030: 304 000 units/year***




### *Stock*

Stock in 2020: 72 000 units*
**Stock in 2030: 2 250 000 units***
Stock in 2040: 3 070 000 units*

### *Potential savings in 2030*

**Primary energy savings:**
38 PJ/year*
910 ktoe/year*
**GHG-emissions reduction:**
1,9 Mton $CO_{2,eq}$/year*

### *SME & Collective systems (±40 kWe)*
***Boiler add-on technology***

**Present market (2013)**
Boiler stock: 95 000 units
Boiler sales: 7 900 units/year

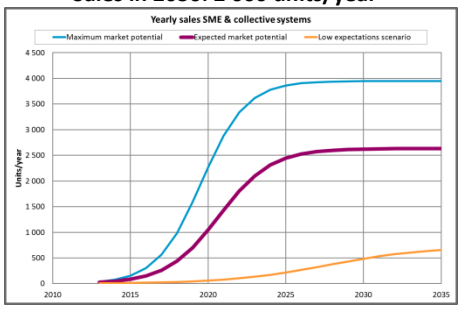
### *Potential estimation*

| *Indicator* | *Score* |
|---|---|
| Market alternatives | 3 |
| Global CBA | 3 |
| Legislation/support | 2 |
| Awareness | 1 |
| **Total** | **6 out of 9** |

**Expected final market share: 33% of boiler sales in SME & Coll. sector**

### *Yearly sales*

Sales in 2020: 1 000 units/year*
**Sales in 2030: 2 600 units/year***




### *Stock*

Stock in 2020: 6 000 units*
**Stock in 2030: 23 000 units***
Stock in 2040: 27 000 units*

### *Potential savings in 2030*

**Primary energy savings:**
18 PJ/year*
435 ktoe/year*
**GHG-emissions reduction:**
0,9 Mton $CO_{2,eq}$/year*

*Corresponding to the expected potential scenario.

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The score card is used to assess the relative position of an EU country based on current regulations, markets and economics. The score itself functions as input to the implementation model to 2030.

| ***±1 kWe systems (Households)*** ***Boiler replacement technology*** | ***±40 kWe systems (SME & Collective systems)*** ***Boiler add-on technology*** |
|---|---|
| ***Scorecard*** | ***Scorecard*** |

| *Indicator* | *Score* |
|---|---|
| Market alternatives | 3 |
| Global CBA | 3 |
| Legislation/support | 2 |
| Awareness | 1 |
| Purchasing power | 3 |
| **Total** | **9 out of 12** |

| *Indicator* | *Score* |
|---|---|
| Market alternatives | 3 |
| Global CBA | 3 |
| Legislation/support | 2 |
| Awareness | 1 |
| **Total** | **3 out of 9** |

| ***Market alternatives*** | ***Market alternatives*** |
|---|---|
| *In existing buildings only competition of condensing boilers. Gas network is well developed. In new houses also some competition of heat pumps. District heating mainly in bigger cities.* | *In existing buildings only competition of condensing boilers. Gas network is well developed. In SME strong competition of heat pumps.* |
| ***Global CBA*** | ***Global CBA*** |
| *SPOT:* ***4.4 years*** | *SPOT:* ***5 years*** |
| ***Legislation/support*** | ***Legislation/support*** |
| *Micro-CHP is seen as an energy efficiency solution. For new buildings a way to optimize energy performance score. No financial support for microCHP available.* | *Micro-CHP is seen as an energy efficiency solution. For new buildings a way to optimize energy performance score. No financial support for microCHP available.* |
| ***Awareness*** | ***Awareness*** |
| *Field trials have been carried out. Homeowner become aware of micro-CHP. Some suppliers are active on the market.* | *Technology is quite well known by end-users. Several suppliers are active on the market. Strong history in CHP.* |
| ***Purchasing power*** | |
| *GDP:* ***€ 32 900 per year*** | |

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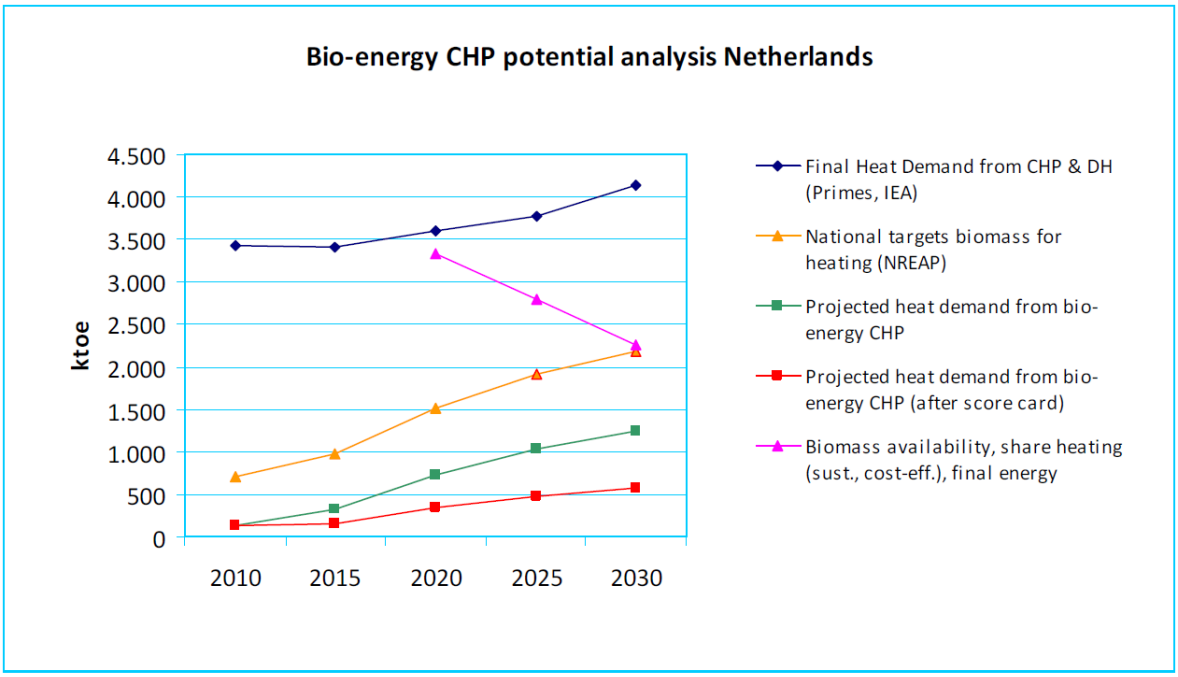
# 3. Bio-CHP potential assessment

| Bio-energy CHP potential analysis Netherlands | | | |
|---|---|---|---|
| **Figures (projections)** | **2010** | **2020** | **2030** |
| Final heat demand from CHP and DH (PRIMES, IEA), ktoe | 3.424 | 3.602 | 4.134 |
| (Projected) heat demand from bio-energy CHP and DH (after score card), ktoe | 126 | 343 | 579 |
| Bio-energy penetration rate in CHP markets (2009: EEA, Eurostat) | 3,7% (2009) | 9,5% | 14,0% |
| Biomass availability, share heating (sust., cost-eff.), final energy (Biom. Futures), ktoe | | 3.339 | 2.268 |




| Framework Assessment (Score card) | Score | Short analysis |
|---|---|---|
| Legislative environment | + 2 (of 3) | Both CHP types have good grid access, but only bio CHP gets financial support |
| Suitability of heat market for switch to bio-energy CHP | + 2 (of 3) | Industry has good CHP penetration but bio supply too little reliable. Bio CHP has biggest penetration in agricultural applications. |
| Share of Citizens served by DH | - 0 (of 3) | Based on the total installed DH capacity the DH penetration is estimated to be 9% |

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| | | |
|---|---|---|
| National supply chain for biomass for energy | o 1 (of 3) | Little domestic biomass supply possible vs. big energy demand. We lobby for an CHP obligation to be applied to all bio fuels burned. |
| Awareness for DH and CHP | + 2 (of 3) | |

The national bio-CHP potential analysis is based on figures from the PRIMES database, Eurostat, the National Renewable Energy Action Plan (NREAP), and the project Biomass Futures. The analysis has been discussed and, where necessary, refined in consultations with national energy experts (see Annex for the detailed bio-CHP potential analysis).

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# 4. Assumptions used in the economics of CHP

| Sector | | Heating in services and multifamily houses | Industry and service process heat and heating supply | District heating | Bio gas CHP (agriculture, w aste, industrial w astew ater or sew age treatment) |
|---|---|---|---|---|---|
| | | 60 kWe ICE | 1 MWe ICE | 10 MWe CC | 0,5 MWe Biogas |
| **Technology** | | **ICE** | **ICE** | **STEG** | **ICE** |
| **Power** | **$MW_{El}$** | **0,05** | **1** | **10** | **0,5** |
| **Efficiency-el.** | $Eff_{EL}$ | 34% | 40% | 35% | 38% |
| **Efficiency-th.** | $Eff_{H}$ | **51%** | **45%** | **45%** | 37% |
| **Efficiency-sum.** | $Eff_{SUM}$ | 85% | 85% | 80% | 75% |
| **Operation** | **h/a** | **3.000** | **6.000** | **3.500** | **7.000** |
| Fuel | MWh | 441 | 15.000 | 100.000 | 9.211 |
| Fuel | m³ | 50.153 | 1.705.185 | 11.367.902 | 1.047.044 |
| Electricity | MWh | 150 | 6.000 | 35.000 | 3.500 |
| Heat | MWh | 225 | 6.750 | 45.000 | 3.408 |
| Electricity + Heat | MWh | 375 | 12.750 | 80.000 | 6.908 |
| **Investment** | **EUR** | **115.000** | **770.000** | **13.000.000** | **2.700.000** |
| | **€/kWel** | 2.300 | 770 | 1.000 | 5.400 |
| **O&M costs** | % of Inv. | 3,7% | 13,0% | 2% | 9% |
| | €/MWh | 28,2 | 16,7 | 7,4 | 69,4 |
| **Price of fuel** | €/MWh | 34,1 | 30,3 | 28,0 | 14,7 |
| **Value of electrcity** | €/MWh | 72 | 60 | 46 | 46 |
| **Other market revenues** | €/MWh | | | | |
| **Value of heat** | €/MWh | 61 | 34 | 34 | 10 |
| **Support** | | | | | |
| Electricty | €/$MWh_{El}$ | | | | |
| Electricity + Heat | €/GJ | | | | 15,7 |
| Other support or benefits | €/a | | | | |
| Investment subsidy | € | 7.781 | 62.250 | 1.348.750 | 224.100 |
| **Costs & revenues** | | | | | |
| Fuel | €/a | -15.044 | -454.383 | -2.800.000 | -135.796 |
| Electricty | €/a | 10.809 | 360.372 | 1.610.000 | 161.000 |
| Heat | €/a | 13.640 | 229.500 | 1.530.000 | 34.079 |
| Support | €/a | 0 | 0 | 0 | 390.434 |
| Other market revenues | €/a | 0 | 0 | 0 | 0 |
| O&M costs | €/a | -4.230 | -100.100 | -260.000 | -243.000 |
| **TOTAL** | **€/a** | **5.175** | **35.389** | **80.000** | **206.717** |
| **SPB** | **years** | **20,7** | **20,0** | **145,6** | **12,0** |
| **IRR** | **%** | **-11%** | **-11%** | **-32%** | **-3%** |

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| | | 250 MWe CCGT | 60 MWe CCGT | 45 MWe GT | 8 MWe GT | 25 MWe ST | 2 MWe ICE | 400 kWe ICE | 250 MWe DH |
|---|---|---|---|---|---|---|---|---|---|
| **Technology** | | **Big CCGT** | **Small CCGT** | **Big GT** | **Small GT** | **ST** | **Big ICE** | **Small ICE** | **District Heating** |
| **Power** | **$MW_{El}$** | **250** | **60** | **45** | **8** | **25** | **2** | **0,4** | **250** |
| **Efficiency-el.** | $Eff_{EL}$ | 46% | 40% | 36% | 30% | 25% | 43% | 36% | 49% |
| **Efficiency-th.** | $Eff_{H}$ | 34% | 43% | 49% | 55% | 65% | 49% | 52% | 29% |
| **Efficiency-sum.** | $Eff_{SUM}$ | 80% | 83% | 85% | 85% | 90% | 92% | 88% | 78% |
| **Operation** | **h/a** | **6.500** | **6.500** | **6.500** | **6.500** | **7.500** | **4.000** | **3.200** | **4.500** |
| **Investment** | **EUR** | **235.000.000** | **75.600.000** | **45.450.000** | **12.320.000** | **26.250.000** | **1.156.000** | **336.000** | **258.500.000** |
| | **€/kWel** | 940 | 1.260 | 1.010 | 1.540 | 1.050 | 578 | 840 | 1.034 |
| **O&M costs** | % of Inv. | 4,1% | 4,1% | 7,1% | 5,5% | 5,0% | 5,5% | 4,6% | 2,6% |
| | €/MWh | 6,0 | 8,0 | 11,0 | 13,0 | 7,0 | 7,9 | 12,0 | 6,0 |
| **Price of fuel** | €/MWh | 29,7 | 29,7 | 29,7 | 31,0 | 31,0 | 30,3 | 30,3 | 29,7 |
| **Value of electrcity** | €/MWh | 45 | 46 | 43 | 45 | 44 | 49 | 50 | 45 |
| **Other market revenues** | €/MWh | | | | | | | | |
| **Value of heat** | €/MWh | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 |
| **Support** | | | | | | | | | |
| Electricty | $€/MWh_{El}$ | | | | | | | | |
| Electricity + Heat | €/GJ | | | | | | | | |
| Other support or benefits | €/a | | | | | | | | |
| Investment subsidy | € | 15.562.500 | 3.735.000 | 2.801.250 | 498.000 | 1.556.250 | 72.625 | 24.900 | 15.562.500 |
| **TOTAL** | **€/a** | **-732.320** | **435.707** | **-1.133.329** | **-444.257** | **447.204** | **71.539** | **3.951** | **-1.769.667** |
| **SPB** | **years** | **-299,6** | **164,9** | **-37,6** | **-26,6** | **55,2** | **15,1** | **78,7** | **-137,3** |
| **IRR** | **%** | **#GETAL!** | **-33%** | **#GETAL!** | **#GETAL!** | **-23%** | **-7%** | **-27%** | **#GETAL!** |

# 5. Methodologies used to calculate the saving of primary energy and CO2 emissions under the roadmap

**Substitution method**

This method has been developed in the CODE2 project. In doing this, two other approaches have been considered: 1) the "replacement mix method[28]" from the Munich FfE institute, which however cannot be used directly for a long term comparison as needed in CODE2; 2) a method used to calculate the $CO_2$ saving resulting from a voluntary commitment of the German industry for $CO_2$ reduction[29], however this method has been considered as too simple. Therefor the following more differentiated approach has been developed:

Based on an estimate of the increase in cogeneration electricity the thereby caused decrease of $CO_2$ emissions and primary energy consumption is estimated. In this approach, an attempt is made to determine the actual quantities saved compared to the base year (e.g. 2010). Hence it refers to the actual saving of fuels for the production of the amounts substituted by modern CHP plants

a) of electricity and heat in the replaced or retrofitted old CHP plants

b) of electricity in power plants

c) of heat in boilers.

The savings result from a combination of three effects:

- CHP effect

- Technology effect (improved CHP technologies)

- Fuel switching (e.g. lower carbon content of natural gas compared to coal, $CO_2$ neutrality of bioenergy)

The results show the savings actually induced by the expansion of CHP compared to the situation in the base year.

This approach differs fundamentally from the methods for checking the high-efficiency according to the CHP Directive or in accordance with ANNEX II of the EED (Directive 2012/27/EU on energy efficiency), in which a comparison between CHP and the best available Technology (BAT) of separate production of electricity and heat produced is carried out strictly on a same-fuel basis.

This procedure is considered to be inappropriate to deliver an estimate of the actual fuel saving quantities by CHP over a longer period, which is considered relevant value, representing meaningful the contribution of CHP to the long-term objectives of the EU to reduce $CO_2$ emissions and primary energy consumption. The BAT approach of the CHP Directive has been developed to verify the high efficiency of individual plants, but not to determine actual saved $CO_2$ emissions and primary energy quantities by CHP expansion.

In fact, the CHP expansion is closely associated with a replacement of old by new cogeneration technologies and a change in the structure of fuel away from coal to natural gas and bio-energy. These three developments,

[28] 10. FfE Forschungsstelle für Energiewirtschaft e.V., Energiezukunft 2050; http://www.ffe.de/die-themen/erzeugung-und-markt/257

[29] The calculation has been made by the VIK Verband der Industriellen Energie- und Kraftwirtschaft e.V., 2010, Unpublished.

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- replacement of separate generation by cogeneration

- replacement of old by new cogeneration technologies

- replacement of carbon-rich by low-carbon fuels,

can be usefully seen only as an integrated process.

To account for the uncertainties in particular with regard to fuel shares and technology development, a window of possible developments with an upper value and a lower value of emission reduction and savings has been determined. The different levels of results are due to assumptions about key parameters such as current share of electricity from cogeneration, which is replaced by electricity from new or retrofitted units, fuel shares in the replaced CHP plants, power plants and boilers as well as in the new CHP plants.

The results have been calculated based on the following input values: growth of CHP power production, share of current old CHP to be replaced by new installations and retrofitting, fuel efficiency and electric efficiency of new CHP and replaced CHP for different fuels, electric efficiency of replaced power from conventional power plants for different fuels, heat efficiency of replaced heat from boilers, corresponding fuel shares.

**EED method**

The Primary Energy Savings methodology of the EED is used at a country level for national reporting to the Commission, and at project level for determining if CHP is highly efficient. In the methodology, each cogeneration unit is compared with the best technology for separate production of heat and electricity on the same fuel on the market in the year of construction of the cogeneration unit and the harmonized reference values are determined by fuel type and year of construction.

The underlying principle is that, knowing that regularly new investments have to be made in new energy production units, it is necessary to compare CHP with the centralized production installation which could be built using the same fuel rather than assuming a displacement of a different fuel or introduction of a new fuel. It is a logical approach when looking at the decision making process of investors or a member state government. By investing in or supporting CHP, a certain electricity generating capacity will be produced by CHP and NOT by centralized production based on the same fuel (= principle of 'avoided production').

For the timeframe of the roadmap (between 2010 and 2030), and especially in countries where there is no overcapacity, it is relevant to compare installing a certain capacity (at national level) of CHP compared to installing new capacity with another technology (power plant + gas boiler). Older installations being replaced with state-of-the-art technology.is a typical reinvestment decision. New CHP-plant (or combination of smaller installations) would not necessarily lead to less production in older production installations, but would rather preempt investments in e.g. new CCGT investments.

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# 7. Contacts

## Project partners

The project consortium exists of the following partners that have a solid expertise on cogeneration:

- COGEN Europe, the European Association for the promotion of cogeneration, is the project coordinator (Belgium) – contact: fiona.riddoch@cogeneurope.eu
- Hellenic Association for the Cogeneration of Heat and Power (HACHP) (Greece) – contact: hfa@heatflux.eu
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