CODE2

Cogeneration Observatory and Dissemination Europe

D5.1 - Cogeneration Roadmap

Member State: **Sweden**

October 2014

Leading CODE 2 Partner: KWK kommt U.G.

Sweden is part of the non-pilot Member States of the Northern Europe CODE2 Region.

The CODE2 Region 'Northern Europe' comprises the following Member States: Austria, Denmark, Finland, Germany, Sweden

Co-funded by the Intelligent Energy Europe Programme of the European Union

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Introduction and Summary

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 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 Sweden is written by CODE2 partner KWK kommt U.G. based on a range of studies and consultations (see list of sources in the Annex). It has been developed through a process of discussion and exchanges with experts. The roadmap was developed over the period from beginning to the middle of 2014. The national policy framework around CHP continues to evolve in Sweden and at the time of publication of this roadmap (December 2014) some items are under discussion. This should be taken into account when using the material in the roadmap.

Acknowledgement

KWK kommt U.G. and the CODE2 team would like to thank all experts involved for their contributions to develop this roadmap, which has been valuable regardless of whether critical or affirmative. It has to be stressed that the statements and proposals in this paper do not necessarily reflect those of the consulted experts.

Summary

Most of the municipalities in Sweden have local district heating networks and more than half of all homes and business premises are heated with district heating, however the CHP share in total electricity production at 10 % is below the European average. Low shares of CHP in district heat production and industrial heat production mean that there is still huge additional CHP potentials which in combination with increased power-to-heat ratios of bio energy CHP would allow Sweden to more than double CHP electricity production from 16 TWh/a to 40 TWh/a in 2030.

The high shares of hydropower, bio energy and nuclear power in Sweden's energy mix mean that decarbonisation of electricity is already extremely high. Together with an increasing supply of wind power, developing CHP further could assist in the substitution of up to 50 % of current nuclear power production up to 2030. This is to be a step by step process as nuclear power plants reach their end of life in the next decades.

The roadmap suggests potential minimum Primary Energy Savings to the Swedish economy of 62 TWh/a according to the EED calculation method. Using a substitution method to estimate the savings a value of 52 TWh/a Primary Energy Savings and 3 Million tonnes/a additional CO_2 savings by 2030 are possible. These savings can be meaningful contributions to Swedens overall energy and Climate goals.

A key proposal of the roadmap is to take the implementation of the EU-Energy Efficiency Directive as an inducement to put an active CHP support policy on the agenda and to remove still existing indirect barriers.

1. Where are we now? Background and situation of cogeneration in Sweden

1.1 Current status: Summary of currently installed cogeneration

From 2005 to 2011 cogenerated power in Sweden increased from 10.7 to 15.1 TWh. Though most of the municipalities in Sweden have local district heating networks and more than half of all homes and business premises are heated with district heating, the CHP share in total electricity production is only 10 %. This is mainly due to the relative low shares of CHP in district heat and industrial heat production.

According to the figures published by Eurostat 2013, the installed CHP electric capacity of cogeneration plants was 4.0 GW in 2011, the cogenerated power was 15.1 TWh, thereof 9.3 TWh from main activity producers (utilities) and 5.7 TWh from autoproducers (industry). The heat produced was 47.6 TWh, thereof 24.7 TWh from utilities and 22.9 TWh from industry. The CHP share in total electricity production was 10 %, hydro power providing 44.1%, nuclear 40.5% and wind 4%.

In the space heating market, district heating is the leading heating method for multi-dwelling buildings and nonresidential premises, accounting for 93% and 83% of the market shares respectively. 270 of the 290 municipalities in Sweden have local district heating networks. More than half of all homes and business premises are heated with district heating. In 2011, district heat supply accounted for around 60 TWh, thereof only 41 % was CHP heat, but with a steady increase since 2001 (24 %).

Since the 1970s, there has been a major transition towards the use of renewable fuels leading to considerable emissions reductions. District heat is now produced mostly from wood fuel and other biofuels (39.2%), waste (18.2%), mainly renewable organic waste, peat (3.8%) and waste heat (6.1%). Oil, natural gas and coal have minor shares. The supply of waste has increased over the past decade, and in some Swedish cities, heat from waste incineration forms the basis of district heating.

1.2. Energy and Climate Strategy of Sweden

By 2020, Sweden aims to phase out fossil fuels in heating; Sweden is committed to develop a third pillar in electricity supply, next to hydro and nuclear power, with increased co-generation, wind and other renewable power production to reduce vulnerability and increase security of electricity supply; and by 2050, the vision is that Sweden will have a sustainable and resource-efficient energy supply with zero net emissions of Greenhouse gases.

Between 1990 and 2010 Swedish greenhouse gas emissions decreased by 9 per cent while GDP increased by 51 per cent. This has been achieved through the use of carbon dioxide taxes in combination with an electricity certificate scheme and other policy measures and ambitious targets for energy efficiency and renewable energy.

General energy tax is levied on most fuels based on their energy contents. The carbon dioxide tax was introduced in Sweden in 1991. Over the years the tax rate has been significantly increased, in order to take account of the need to fight climate change. At present, the general CO_2 tax rate corresponds to more than 100 EUR/tonne. Industry has generally faced a considerably lower tax rate due to the risk of carbon leakage.

Sweden's energy policy is guided by two bills from 2009. The bill on "integrated climate and energy policy" sets out ambitious targets in support of and beyond the 20/20/20 objectives of the EU, in pursuit of a sustainable policy for the environment, competitiveness and long-term stability.

Short- to medium-term targets for 2020:

- 40% reduction in greenhouse gases or about 20 million tonnes of carbon dioxide equivalent, compared to 1990, to be achieved outside the EU Emissions Trading Scheme with two-thirds in Sweden and one-third by investments in other EU countries or the use of flexible mechanisms;
- at least 50% share of renewable energy in the gross final energy consumption;
- at least 10% share of renewable energy in the transport sector; and
- 20% more efficient use of energy compared to 2008.

Long-term priorities:

- by 2020, Sweden aims to phase out fossil fuels in heating;
- by 2030, Sweden should have a vehicle stock that is independent of fossil fuels;
- Sweden is committed to develop a third pillar in electricity supply, next to hydro and nuclear power, with increased co-generation, wind and other renewable power production to reduce vulnerability and increase security of electricity supply;
- by 2050, the vision is that Sweden will have a sustainable and resource-efficient energy supply with zero net emissions of GHGs.

Sweden sees a role for natural gas as a transition fuel in industry and co-generation.

1.3. Policy development

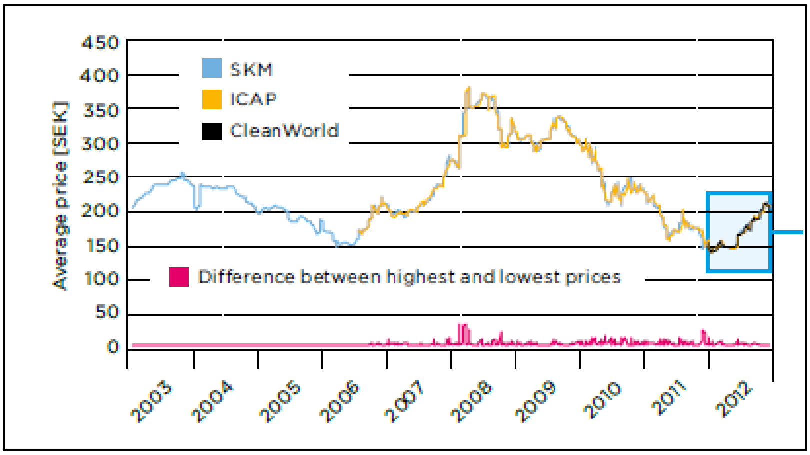
Sweden does not have any direct support specifically for cogeneration. But the electricity certificate scheme encourages cogeneration, particularly with bio energy. Energy and CO_2 taxation have also had an indirect impact on the development of cogeneration.

In its 2nd progress report to the Commission the Swedish Government has reported that Sweden does not have any 'direct' investment aid specifically for cogeneration, but that the electricity certificate scheme encourages cogeneration, particularly with bio energy; Energy and CO_2 taxation would have also had an indirect impact on the development of cogeneration.

In 2003, Sweden introduced the electricity certificate system (Electricity Certificates Act), on the basis of a quota obligation, as the primary policy instrument for promoting renewable electricity. This technology-neutral scheme is designed to encourage investments in cost-effective RES technologies. All renewable energy technologies are eligible for certificates, including solar, wind, geothermal, tidal and hydro power, and solid biofuels. From 2004, the system has also supported the use of peat in CHP plants, though peat is a fossil fuel.

Under the Swedish electricity certificate system, the demand for certificates is created by an obligation on electricity suppliers, certain electricity consumers and some industries to annually acquire renewable energy certificates (REC) in proportion to their electricity sales and consumption to prove that a certain proportion or quota of the electricity supplied by them was generated from renewable energy sources.

Figure 1 Development of average price of electricity certificates



In order to achieve the target of 25 TWh/a additional electricity produced from renewable sources in 2020, the quota has to increase over time. For 2012 the quota obligation was 17.9%. Figure 1 shows the development of certificate proves.

Another aid with an indirect effect on cogeneration is conversion aid from oil boilers and direct effect electricity for small buildings, multi-occupancy dwellings and premises. The aid was granted for conversions to district heating, as well as to biofuel boilers and hot water boilers and it operated during the period 2006-2010. Payments used for conversions from direct-electricity amounted to SEK 455 million, of which the majority was paid for district heating conversions.

The Local Investment Programme (LIP) was another aid form that had a positive impact on the development of district heat between 1998-2002 as does its successor, the Climate Investment Programme (KLIMP). These have enabled municipalities and other operators to apply for aid to take measures increasing ecological sustainability and reduce greenhouse gas emissions. Against this background, the expansion of district heating was considered a good option. During the years in which LIP and KLIMP funding was paid out, approximately 260 district heating projects were granted funds.

1.4 Exchange of information and awareness

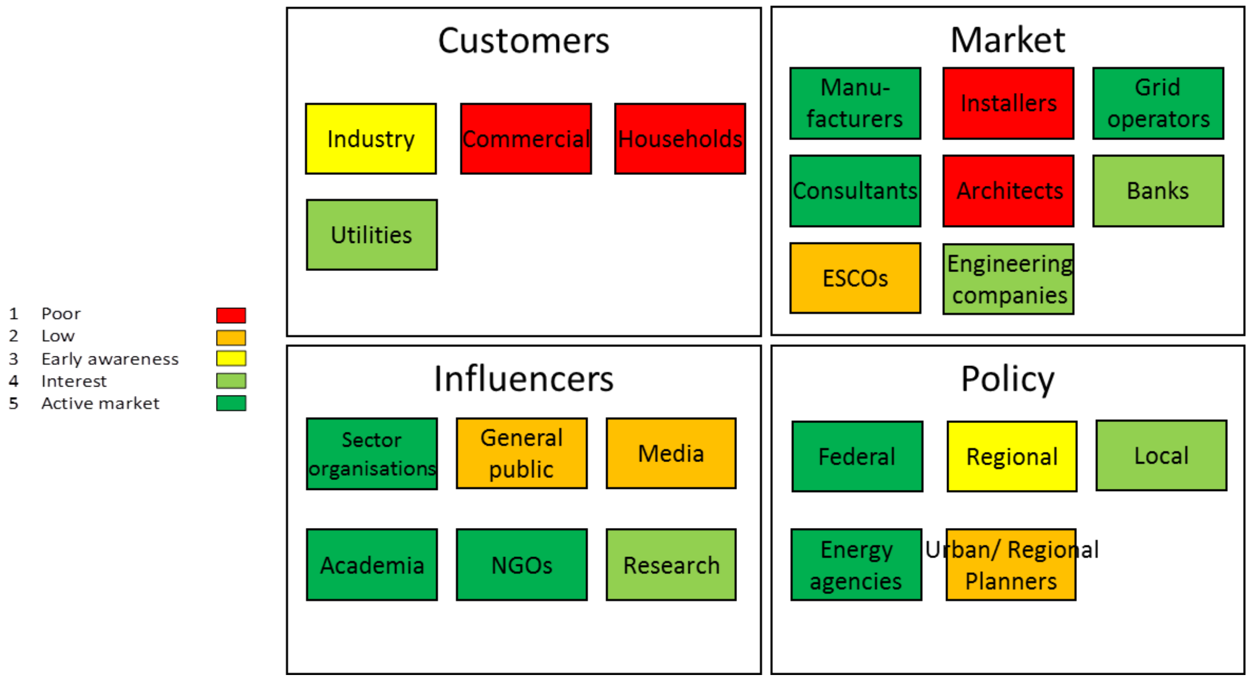
Compared to a general high interest in environment and energy issues in Sweden, knowledge and awareness on the role of CHP are rather low in the general public. The public discussion on decarbonizing the energy supply system is focused on renewable energy growth, mainly disregarding the issue of efficiency in transforming it into heat and power.

The interest in and awareness of environmental, energy and climate issues are very distinct in Sweden. Today it is one of the core values of the Swedish self-image to be a leading nation in climate and environmental protection. This extends to all areas of life, be it waste, the purchase of organically produced foods, wearing pollution-free clothes that toxic-free weed control and the use of public transport or hybrid cars. For the economy, the climate and energy friendliness has become a selling point. Thus, the environment and climate in the Swedish life, in politics and in the economy is omnipresent.

The concept of environmentally friendly energy supply is connected largely in the citizens mid to renewable energy only and the question of how efficiently e.g. bioenergy is transformed into useful energy is an issue for only a rather small circle of experts in industry and policy. The awareness of CHP and its potential role in environment protection seems to be rather low in the general public – see Table 1.

The rating of awareness of CHP in Table 1 by different societal and economic groups is based on discussions with energy experts, in which they gave their personal assessment of awareness in the different groups. This assessment has been further supported by indirect information from literature, which has been additionally considered.

Table 1 Ratings of the awareness of CHP in the different groups



1.5. The economics of CHP

Currently there is no application of CHP in Sweden which under normal economic conditions yields sufficient profits for investments in new CHP (mid-2014.) For micro CHP there is currently only a very small beginning market

From the start of the green certificates scheme in 2003 investments in bio energy based CHP had good economic benefits and CHP power production increased steadily up to 2011. Since then the development is stagnating. This seems to be partly due to lower average temperature, but it also reflects a less favorable economic perspectives for investments in new CHP. In Sweden, unlike in some other European countries, this is less directly caused by the decrease of electricity prices than by the background of the high share of bio energy already used in CHP. In principle the green certificates scheme as a quota system with a fix volume target of 25 TWh additional renewable electricity up to 2020 compared to 2002 is capable to compensate any cost and revenue factor developments. But in recent years investments in new wind energy plants have emerged as serious competitors to bio energy based CHP inside the green certificated scheme. Whilst the share of biofuels in renewable power production between 2010 and 2012 fell from 62 5 to 49 %, wind power grew from 19 % to 33 %. In fossil based CHP the economy of natural gas fired CHP is suffering from the current low power prices (see also chapter 1.6.). At the Nord Pool power exchange the spot prices fell from a peak of 80 €/MWh in December 2010 to 26 €/MWh in June 2014.[2]

Regarding the current economic situation of CHP in major user groups the following table shows that, with some exemptions in industry and district heating based on bio energy (RES) and natural gas, there is insufficient profit for investors, according to the assessment of Swedish CHP experts.

For micro CHP there is currently only a very small beginning market in small scale heat grids and in the commercial & service sector.

Table 2 Economic situation of CHP in major user groups

	Micro		**Small & Medium**		**Large**		
	up to 50kW		*up to 10 MW*		*more than 10 MW*		
	NG	**RES**	**NG**	**RES**	**NG**	**Coal**	**RES**
Industry	[grey]	[grey]	[red]	[green]	[yellow]	[red]	[green]
District heating	[red]	[red]	[red]	[green]	[green]	[red]	[green]
Services	[red]	[red]	[red]	[red]	[grey]	[grey]	[grey]
Households	[red]	[red]	[grey]	[grey]	[grey]	[grey]	[grey]

Legend:

- [green] **"normal"** — CHP 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.
- [yellow] **"modest"** — CHP Investment has **modest/limited economic benefits** and return on investment, **limited interest for new investments**.
- [red] **"poor"** — CHP Investment has **poor or negative return on investment or is not possible due to other limitations, no interest/possibilities for new investments**.
- [grey] — **Not applicable** for the sector

1.6. Barriers to CHP

Though there are reportedly no direct barriers to the expansion of CHP, in Sweden there do exist some important indirect barriers: lack of awareness of the important role of CHP for an efficient sustainable use of energy resources and decreasing electricity market prices in the last years

[2] http://www.nordpoolspot.com/Market-data1/Elspot/Area-Prices/ALL1/Hourly/

According to the Second progress report by the Swedish government to the European Union, DG Energy, 2011[3], there are no barriers in Sweden to high efficiency cogeneration production in terms of administrative procedures or other barriers. It stresses that:

- *the electricity market has been deregulated and made competitive with electricity offered (mainly) by Nordpool.*
- *there are no large vertically-integrated operators that 'squeeze out' cogenerated electricity by selling to their own companies in instalments.*
- *with regard to small-scale cogeneration installations, the main barrier is high investment costs, particularly for incinerating solid fuels. Small-scale cogeneration installations also have fairly low electric efficiency and alpha values, which poses challenges for the development of the technology.*
- *Potential barriers to the expansion of (high efficiency) cogeneration in Sweden are mainly exogenous by nature and it is not possible to influence them directly. Examples of potential barriers to the expansion of cogeneration include rising steel and biofuel prices. The price of electricity is particularly significant with regard to continued development. A decreasing demand for heat as the result of energy efficiency improving measures for energy consumption can have a negative impact on the development of cogeneration. A barrier of this kind must be overcome by the district heating companies themselves with the development of technology and compensation in the form of a widened customer base.*

Though it may be true that there are no direct barriers against CHP in Sweden , two important indirect barriers have been identified.

Barrier 1: The general lack of awareness of the important role of CHP for an efficient sustainable use of energy resources may impede a more resolute development of CHP in district heating, industry and commercial sector

The general lack of discussion and awareness of the importance of CHP for climate protection mentioned in chapter 1.4. may result in the overall value of energy efficiency and schedulable power not being fully taken into account in the development of the energy system. The lack of awareness of the sustainability and efficiency advantage of using efficient transformation for bio energy into heat and power may be one of the reasons of the low share of CHP in district heat production of only 41 %.

Barrier 2: Decreasing electricity market prices impede investments in new larger natural gas fired CHP plants and even threaten the continued operation of existing gas CHP plants

Due to the fast rising share of fluctuating RES in the power market in combination with the extremely low ETS carbon prices in the last years, the economic situation of existing and new natural gas fired CHP plants and the uncertainty for investments in cogeneration plants has become worse. Investments in such cogeneration plants are considered more and more to be unattractive against the background of expectation of further decreasing average power exchange prices and persistently low ETS carbon prices.

A further effect of the decreasing power price level is the increasing number of hours where power exchange prices are lower than the marginal cost of electricity generation (operating cost per kWh el). The result is that natural gas CHP plants are shut down in a growing amount of hours per year and the

[3] Swedish Energy Agency, Second progress report SE to the EU commission according to the CHP directive, 2011

heat demand is covered by growing shares of its inefficient production in simple gas boilers. This effect is inhibiting further development towards a growing CHP share in district heat production.

There is clear evidence that the low power exchange prices do not reflect the long term electricity production cost, hence the price signal is not triggering appropriate investments with regards to long term security of supply.

2. What is possible? Cogeneration potential and market opportunities

The economically feasible CHP electricity potential in the year 2020 was estimated 27.5 to 33 TWh/a in the analysis reported by the Swedish Government to the EU commission 2007. The base value was 10 TWH in 2005.

In its first report to the EU Commission referring to the CHP directive 2004 the Swedish government, based on a study made by Öhrlings Pricewaterhouse Coopers (ÖPWC) 2005[4], reported an economically feasible CHP power potential in the year 2020 of 27.5 to 33 TWh/a. Actually in 2011 a production of 15.1 TWh has be achieved, based on 10 TWH in 2005.

Table 3 Development and potential of CHP power production

TWh	2005 (SEA)	2010 (SEA)	2011 (SEA)	2012 (SEA)	2020 (ÖPWC)	2025 (ÖPWC)
District heating	5	9.8	10.5	9.3	17	20
Industry	5	6.1	6.0	6.3	10 – 15	15
Small and micro CHP	-	-	-	-	0.5 – 1	1
total	**10**	**15.9**	**16.5**	**15.6**	**27.5 – 33**	**36**

The economic cogeneration potential within district heating systems has been estimated by ÖPWC at over 14 TWh for 2010, approximately 15.5 TWh for 2015 and 17 TWh for 2020.

Regarding the industry a comparison was made between Sweden and the EU-15, which showed that industry in Sweden produced only little of its own electricity in proportion to its fuel consumption, compared to other countries. Based on the international benchmark, ÖPWC has estimated that the industry CHP potential could amount to 10-15 TWh up to 2020. Most of this potential exists in the paper and pulp industry. According to the ÖPWV study the remainder exists in the chemical and petrochemical industry[5]. Other industry secors have not been mentioned.

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[4] Öhrlings PricewaterhouseCoopers, An assessment of the potential for high-efficiency cogeneration in Sweden, 2005.

[5] Considering developments in some other EU countries it can be supposed that also relevant CHP potentials in other branches exist (e.g. food & beverage, metal processing, hospitals, hotels, …).

Bio energy

Bio energy is already the most important primary energy in Sweden, but it is mainly used for heat production only, particularly in industry. If the bio CHP potentials based on the district heating and industry heat demands and the related technologies were further developed, the bio share in electricity generation could be raised substantially from currently only 12.8 TWh/a (8.5 %; 2011)[6]. According to the Swedish energy balance, in 2012 the total bio energy supply was 127 TWh. From this only 36 TWh have been used in CHP plants. In the industry the CHP input was 8 TWh/a, thereof 5 TWh black liquor which is a by-product of pulp & paper production. But the total bio energy input of the industry was 54 TWh.

In the last decade new waste-to-energy methods to recover and use the energy in the black liquor have been developed. Also solid biomass gasification technologies have made big progress[7]. The use of biomass and black liquor gasification has the potential to achieve much higher overall energy efficiency than the conventional steam boilers combined with steam turbines while generating an energy-rich syngas. This gas can be used in engines in a combined cycle gas turbines (CCGT) to produce cogenerated electricity with an efficiency of up to 50 %, compared to 15 to 25 % in conventional steam based CHP.

Additionally there is considerable potential to increase forest fuel extraction without decreasing possibilities of achieving other environmental and forest production objectives, according to a report on bioenergy feedstock research published by the Swedish Energy Agency 2014.[8]

Regarding heat supply to the economy a bio CHP potential analysis carried out in the CODE2 project shows that under current conditions the heat related input of bio fuels in CHP and district heating is estimated to decrease slightly up to 2030.[9]

A simple calculation

shows roughly the additional potential: if only half of the bio fuel currently used in industry for heat only production (50 % x 46 TWh/a = 23 TWh/a) could be transposed into CHP with an electric efficiency of 30 %, then 23 x 0.3 = 6.9 TWh/a additional CHP electricity could be produced – only in the industry and only from bio energy already used.

Swedish biogas production and policy is focused on upgrading biogas to compressed natural gas (CNG) for use as vehicle fuel. This limits the application of it as a potential fuel for CHP. Biomethan transported over the gas network to consumers anywhere in Sweden would create additional potentials for high efficient use in CHP in appropriate applications.

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[6] IEA Energy Policies of IEA Countries, Sweden, 2013, p.105.

[7] D. Bräkow and I. Rickert, Fördergesellschaft Erneuerbare Energien E.V.: Positionsbestimmung für Anlagen mit thermochemischer Vergasung von Biomasse im sich wandelnden Energiesystem, presentation on a DGMK-conference 2014 in Rotenburg a.d. Fulda

[8] Consequences of an increased extraction of forest biofuel in Sweden, https://energimyndigheten.a-w2m.se/Home.mvc?ResourceId=2912

[9] 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 2 for the Swedish bio-CHP potential analysis or http://www.code2-project.eu/wp-content/uploads/130712_Bio_CHP_EU-27.pdf for the complete EU-27 analysis).

Small-scale cogeneration

The potential within small or medium-scale cogeneration has been estimated by ÖPWC on the basis of the heating infrastructure which is not connected to conventional cogeneration, either inside or outside the existing district heating systems. Since development of small-scale cogeneration plants relies mainly on natural gas as a source of fuel, access to natural gas is considered as a requirement for small scale CHP. The estimated potential amounts to 0.5-1 TWh/a.

According to the CODE2 Micro CHP analysis, in 2030 there is only a market potential for residential and small scale commercial applications of 100 and 380 units per year (see annex 1).

Long term energy forecast

According to the Swedish Energy Agency's long-term forecast[10], net production of electricity in Sweden will increase from 145 TWh in 2007 to 177 TWh in 2020 and 2030. Model calculations show that biofuel cogeneration and waste cogeneration are expected to increase between 2020-2030, while peat cogeneration is expected to decrease and gas cogeneration reach zero in 2030. According to the long-term forecast, biofuel cogeneration in district heating networks will produce 8.4 TWh in 2020 and this will have increased to 9.9 TWh in 2030.

In industry, biofuel-based electricity production will increase to just 7 TWh by 2020 and just over 7 TWh by 2030, while waste cogeneration is expected to produce around 3 TWh of electricity in 2020 and 2030.

According to the forecast, the composition of input fuel for cogeneration production will change. The predominant type of energy is biofuel, and expansion will be considerable until 2020, after which it will level off, but waste fuel will increase significantly during this period.

3. How do we arrive there? : The Roadmap

3.1. Overcoming existing barriers and creating a framework for action

Key proposal is to take the implementation of the EU-Energy Efficiency Directive as an inducement to put an active CHP expansion policy on the agenda in Sweden and to remove still existing indirect barriers. The most important drivers of CHP electricity increase up to 2030 are: higher CHP share in DH and higher electric efficiency of CHP plants.

3.1.1. The European Energy Efficiency Directive 2012 EED should be taken as an impulse to trigger an active CHP development policy

Regarding the relative low awareness on the importance of CHP as one of the most important opportunities to boost energy efficiency, the implementation of the EED requires revisiting the positive efficiency and sustainability role of CHP and to put an active CHP expansion policy on the agenda. Besides specific support mechanisms as described below, the requirement to link CHP directly to the

[10] Cited from: Swedish Energy Agency, Second progress report SE to the EU commission according to the CHP directive, 2011.

national energy efficiency target and quantify its contribution should be linked to clear reporting of the cogeneration role and its significance for heat production in all appropriate energy policy publications, thus opening discussion on topic in the context of not just 2020 but also 2030 targets. Naming numeric targets for future CHP development is further recommended.

Besides the energy efficiency advantages of transforming any fuel into cogenerated heat and electricity, also the socio-economic advantages should be considered. In the "comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling" according to Art. 14 of the EED a cost-benefit analysis shall be carried out based on socio-economic and ecologic criteria. Regarding the high capital intensity of CHP it is also important that the discount rate used in the economic analysis for the calculation of net present values shall be chosen at a low value according to Annex IX of the EED and be nearby the discount rate as defined by the European Central Bank[11]. Generally the cost-benefit analysis should be based on a socio-economic consideration and not on common business level criteria (e.g. discount rate 2 to 3 % instead of > 10 %).

Even if additional electricity from bio energy CHP will in the short run not reduce CO_2 emissions, its development is important regarding the option to phase out nuclear power in the next two decades. It has been reported that income from electricity sales for at least three reactors of totally ten operated in Sweden was below production costs in two of the past four years[12]. However the Swedish Energy Minister has stated in November 2013 to not be willing to provide any subsidies for new nuclear power production in Sweden[13].

3.1.2. Policy makers should

- ***consider suitable instruments to increase the CHP share in district heat production***

The aim should be to increase the share of CHP in district heat production from currently only 41% to at least 80% (as e.g. in Finland and Germany) up to 2030. The advantages of switching bio energy use from heat only plants to CHP should be re-visited as part of the EED comprehensive assessment and CBA and "reasonable measures "[14] put in place appropriately. In parallel the electric efficiency of bio CHP should be raised by the introduction of gasification technologies combined with high efficient CHP based on engines and CCGT.

- ***consider suitable instruments to make investments in new CHP and modernisation or replacement of old CHP and the CHP share in DH production independent from power exchange prices.***

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[11] Foot note 1 at part 1 of Annex IX EED: "The national discount rate chosen for the purpose of economic analysis should take into account data provided by the European Central Bank."

[12] Mycle Schneider and Antony Froggatt: The World Nuclear Industry Status Report 2014, July 2014.

[13] The Swedish Energy Minister has Reuters, "Sweden rejects British model for new nuclear plant deals", 20 November 2013, see http://uk.reuters.com/article/2013/11/20/uk-sweden-nuclear-idUKBRE9AJ0O820131120.

[14] EED Article 14, 4

A suitable instrument could e.g. be a minimum electricity price attained by a (windfall) tax on the difference between power exchange prices (future and day ahead markets) and politically defined sustainable power prices. It may also be useful to consider possibilities to „repair“ the power exchange market. Maybe also a European discussion on an appropriate EU body about the reasons of the obviously wrong market signals from the power exchange with regards to CHP investments could be useful and appropriate.

With regards to economic benefits of CHP, in this context also EED Article 15, should be taken into account, requiring national energy regulatory *authorities "to ensure, through the development of network tariffs and regulations … provide incentives for grid operators to make available system services to network users permitting them to implement energy efficiency improvement measures in the context of the continuing deployment of smart grids."*

3.1.3. Government and industry should

- support the development and market introduction of biomass gasification for use in CHP

As described in chapter 2, the further development of biomass gasification technologies would pave the way to huge additional CHP power potentials.

This final development of technologies up to market maturity could be done in cooperation with other countries with important Pulp &Paper industries such as Austria and Finland[15]. Appropriate political measures as either market, policy or regulation based should be considered.

- strengthen the implementation and operation of CHP by energy service companies (ESCOs)

Energy service companies (ESCOs) can play a key role in mobilising additional CHP potentials by creating a service and mobilising finance, particularly in industry and commercial sector. This is possible in principle everywhere in the heating market, . The ESCO business model uses longer financial payback times than industrial companies. As a consequence ESCOs in many cases are able to bring cogeneration potentials into reality, where otherwise "business as usual" would apply: inefficient heat and steam production in boilers.

As specialised experts on efficiency ESCOs do have or can develop the necessary know-how on technical and legal issues and many of them can offer cogeneration solutions by "contracting" even as a part of an integrated efficiency package including other energy saving measures regarding the supply of power, heat and cold. CHP related energy services may be offered either by existing energy supply companies or by new suppliers.

The implementation of Article 18 EED, requiring that "Member States shall promote the energy services market …" could be a core element for bringing the cogeneration potentials of the industry outside pulp

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[15] Corresponding proposals have been made in the CHP roadmaps of the CODE2 project for these countries.

& paper and chemical industry into the reality. The same may apply for many other energy users e.g. the food and commercial sector who aren´t able or do not wish to invest in cogeneration devices and operate them. It is important to make sure that cogeneration implementation by external ESCOs is explicitly supported throughout CHP policy.

3.2. Possible paths to growth

With the proposed roadmap it is estimated, that up to 2030 CHP electricity production could increase by 23 TWh/a to 40 TWh/a and cover 23 % of total net electricity production in Sweden. In the business-as-usual case cogenerated power production will achieve only 22 TWh/a.

It is proposed to align the CHP roadmap targets to the values of the ÖPWC study, as shown in Table 4. Regarding the year 2030 it is estimated, that also after 2025 CHP power production can further increase to 40 TWh, considering the enormous potentials from raising the electric efficiency of biomass use particularly in the industry.

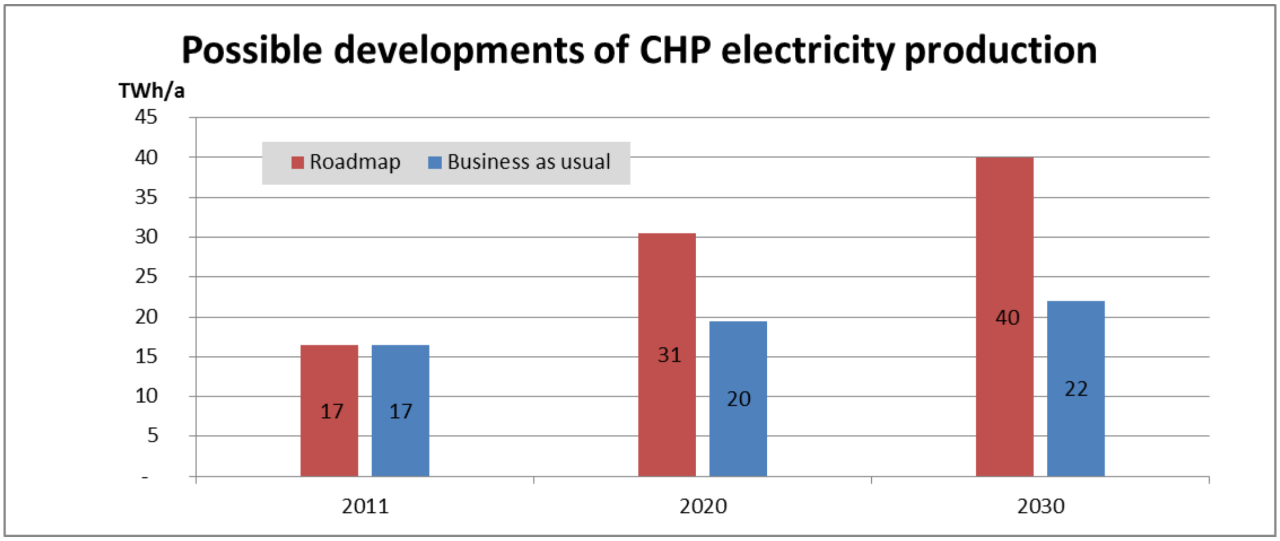
Table 4 Past development and future potentials of CHP electricity in Sweden

TWh (rounded)	**2005** (SEA)	**2011** (SEA)	**2020** (ÖPWC)	**2025** (ÖPWC)	**2030** (CHP roadmap)
District heating	5	11	17	20	20
Industry	5	6	10 - 15	15	19
Small and micro CHP	-	-	1	1	1
total	**10**	**16.5**	**28 – 33**	**36**	**40**

Together with an increasing supply of wind power this development could provide the opportunity to substitute up to 50 % of nuclear power production up to 2030, depending also from the future development of power demand. The combination of electricity production from wind energy and weather independent and bio energy based CHP, which can be flexibly operated, would also fulfil the indispensable criterion of technical security of power supply. Based on wind and indigenous bio fuels if produced in a sustainable manner this strategy would also meet objectives of sustainability and strategic security of supply.

Regarding the alternative option of following a "business-as-usual" strategy it is assumed that up to 2030 only 22 TWh/a CHP electricity would be achieved, according to the long term forecast of the Swedish energy agency cited in chapter 2. The 2020 value of 20 TWh/a has been interpolated.

Table 5 The CHP roadmap path compared to the business-as-usual path



3.3. Saving of primary energy and CO_2 emissions by the CHP roadmap

Primary energy saving (PES) and CO_2 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. It 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 Sweden through implementing the roadmap for CHP is estimated at 52 or 53 TWh per year and CO_2 savings are estimated to be between 2 and 3 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. In Sweden the CO_2 saving induced by the CHP growth is striking low. This is due to the fact that Sweden's electricity supply is already almost carbon-free, as it is dominated by hydro and nuclear energy. It´s just the substitution of the small electricity production in the remaining fossil CHP and power plants which yields a CO_2 reduction. But it should be noted that without switching to carbon free heat and power production with bio energy the projected replacement of the nuclear power plants in the next decades would require the installation of new fossil power plants, as the increase of wind power alone would lead to a questionable weather dependence and weakening of security of supply.

The final share of bio energy in additional CHP has a major impact on the CO_2 savings which can be anticipated. The CO_2 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 6: Saving of primary energy and CO_2 by the Swedish CHP roadmap

	Substitution method				EED method			
	low case		high case		low case		high case	
PE saving	53	TWh/a	52	TWh/a	64	TWh/a	66	TWh/a
CO_2 saving	2	Mio t/a	3	Mio t/a				
- per kWh el*	0.07	kg/kWh el	0,15	kg/kWh el				

* 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.

The naming of the “low” and high” cases is related to CO_2-emission saving. In the Swedish case with the substitution method the PES is higher in the “low case” than in the “high case”. This is due to a higher share of new bio energy CHP in the “high case”, which leads to a lower PES, because bio CHP has lower electric efficiency compared to natural gas CHP, but also lower CO_2 emissions. The EED method results in higher PES than the substitution method as, regardless the real primary energy use development, the additional CHP is always compared to separated heat production with the same fuel, as described in Annex 5

Annex 1: Micro CHP potential

micro-CHP potential summary Sweden

Country statistics

Population: 9 400 000 (2010)
Number of households: 4 500 000 (2010)
GDP per capita: € 31 900 (2010)
Primary energy use: 34 400 ktoe/year (2010)
GHG-emissions: 66 Mton $CO_{2,eq}$/year (2010)

Household systems (±1 kWe)
Boiler replacement technology

Present market (2013)

Boiler stock: 22 600 units
Boiler sales: 1 300 units/year

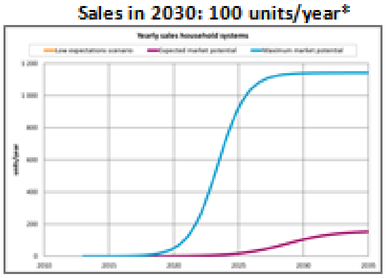
Potential estimation

Indicator	Score
Market alternatives	0
Global CBA	0
Legislation/support	0
Awareness	0
Purchasing power	3
Total	3 out of 12

Expected final market share: 12% of boiler sales in Household sector

Yearly sales

Sales in 2020: 1 units/year*
Sales in 2030: 100 units/year*



Stock

Stock in 2020: 3 units*
Stock in 2030: 360 units*
Stock in 2040: 1 500 units*

Potential savings in 2030

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

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

Present market (2013)

Boiler stock: 75 000 units
Boiler sales: 4 200 units/year

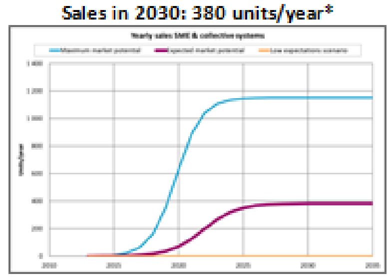
Potential estimation

Indicator	Score
Market alternatives	0
Global CBA	3
Legislation/support	0
Awareness	0
Total	3 out of 9

Expected final market share: 15% of boiler sales in SME & Coll. sector

Yearly sales

Sales in 2020:70 units/year*
Sales in 2030: 380 units/year*



Stock

Stock in 2020: 450 units*
Stock in 2030: 3 000 units*
Stock in 2040: 4 000 units*

Potential savings in 2030

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

*Corresponding to the expected potential scenario.

micro-CHP score card Argumentation

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

Scorecard

Indicator	Score
Market alternatives	0
Global CBA	0
Legislation/support	0
Awareness	0
Purchasing power	3
Total	3 out of 12

Market alternatives

Current national roadmaps on other technologies, ***DH, Heat pumps***

Development (local) gas grid ***low for heating in houses***

Global CBA

SPOT: ***22 years***

Legislation/support

Current incentives on micro-CHP: ***No***

Current incentives on other technologies as heat pumps and district heat: ***Strong***

Current regulation in favour of microCHP ***No***

Current legislation in favour of other technologies: ***Strong***

Awareness

Are stakeholders aware of the microCHP technologies

Homeowners? ***No***

*Consultants ?****No***

Installers? ***No***

Planners? ***No***

Government? ***Yes but no issue in SE***

Are manufacturers active in the market? ***No***

Purchasing power

GDP: ***€ 31 900 per year***

±40 kWe systems (SME & Collective systems)

Boiler add-on technology

Scorecard

Indicator	Score
Market alternatives	0
Global CBA	3
Legislation/support	0
Awareness	0
Total	3 out of 9

Market alternatives

Current national roadmaps on microCHP: ***No***

Current national roadmaps on other technologies: Yes: ***HP and district heat***

Global CBA

SPOT: ***5 years***

Legislation/support

Current incentives on microchip: ***No***

Current incentives on other technologies: ***HP***

Current regulation in favour of microchip: ***No***

Current legislation in favour of other technologies: ***Yes HP***

Awareness

Are stakeholders aware of the technology

Homeowners? ***No***

Consultants? ***low***

Installers? ***low***

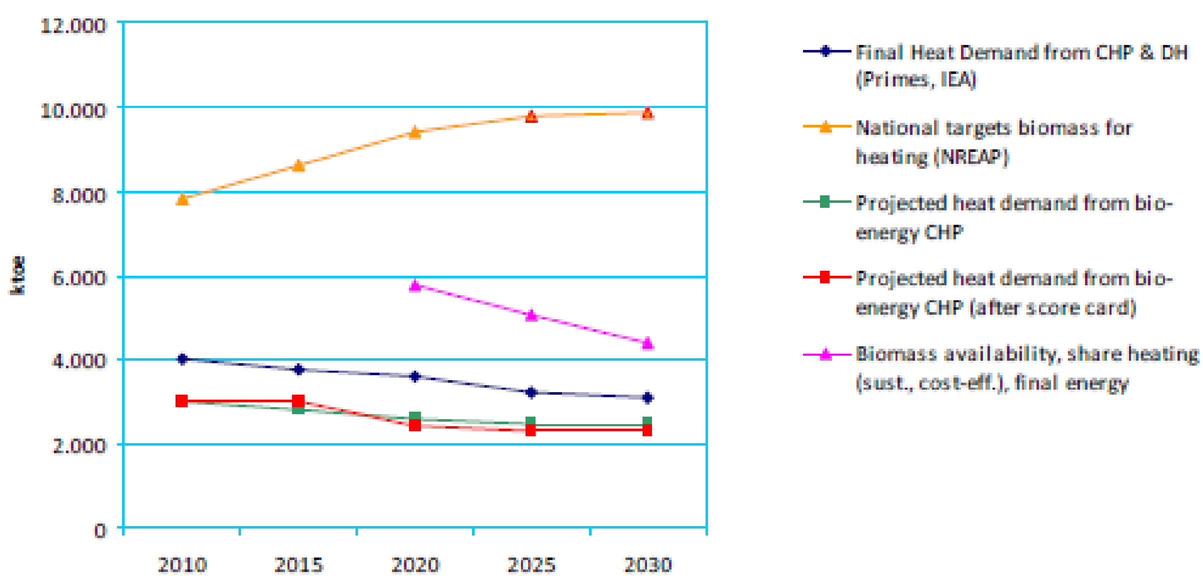
Planners? ***low***

Annex 2: Bio-energy CHP potential

Bio-energy CHP potential analysis Sweden

Figures (projections)	2010	2020	2030
Final heat demand from CHP and DH (PRIMES, IEA), ktoe	4.001	3.584	3.083
(Projected) heat demand from bio-energy CHP and DH (after score card), ktoe	2.996	2.408	2.299
Bio-energy penetration rate in CHP markets (2009: EEA, Eurostat)	74,9% (2009)	67,2%	74,6%
Biomass availability, share heating (sust., cost-eff.), final energy (Biom. Futures), ktoe		5.761	4.397

Bio-energy CHP potential analysis Sweden



Framework Assessment (Score card)	Score	Short analysis
Legislative environment	++ 3 (of 3)	High support by power quota system and investment grants
Suitability of heat market for switch to bio-energy CHP	++ 3 (of 3)	High interest of consumers on bio fuels in all market segments
Share of Citizens served by DH	+ 2 (of 3)	
National supply chain for biomass for energy	++ 3 (of 3)	
Awareness for DH and CHP	++ 3 (of 3)	

Annex 3: Assumptions used in the market extrapolations

- CHP potentials according to ÖPWC study (see chapter 2) will be achieved up to 2025; thereafter further growth by
  - DH CHP share increase from 41 to 80 %
  - average biofuel electric efficiency increase from estimated 20% to 30 %.
  - up to 2030 40 % of existing CHP will be replaced or retrofitted.
- additional CHP potentials in further industry branches outside pulp & paper, refineries and chemical industry (e.g. food & beverage, metal processing, ..) .
- additional CHP power which not substitutes old and retrofitted CHP replaces nuclear power.

Annex 4: Assumptions used in the economics of CHP

Detailed economic analysis of four standard CHP cases was implemented in all pilot roadmaps and optionally in non-pilot roadmaps.

As requested detailed economic data for economic analysis of four standard CHP cases were not available or are not sufficiently reliable for making objective conclusions about the CHP profitability and comparison of economics with other member states, detailed calculation table is not included in this report.

Annex 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[16]" 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[17], however this method has been considered as too simple. Therefore 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.

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

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

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,

- 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.

Annex 6: Sources

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