Allocation of Fuel Energy and Emissions to Heat and Power in CHP

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Contents

Abbreviations

CHP	Combined heat and power
DH	District heating
GHG	Greenhouse gases

1. General

This report is based on the assignment of SITRA, the Finnish Innovation Fund, to find out the various practices available for allocating the GHG emissions of the CHP plants. The assignment is a small part of the Energy Programme of SITRA amounting to €20 million during the years 2008-2012.

The CHP – combined heat and power- production is the unique technology to generate both heat and power from any fuel such as natural gas, oil, coal, biomass, peat and even nuclear at as high as 85%-95% fuel efficiency. Any other method of fuel based power generation reaches low efficiencies ranging from 30% to 45% only, while the huge losses are directed to the surrounding atmosphere, in a way or another through river, lake and sea water or with cooling towers directly to the air.

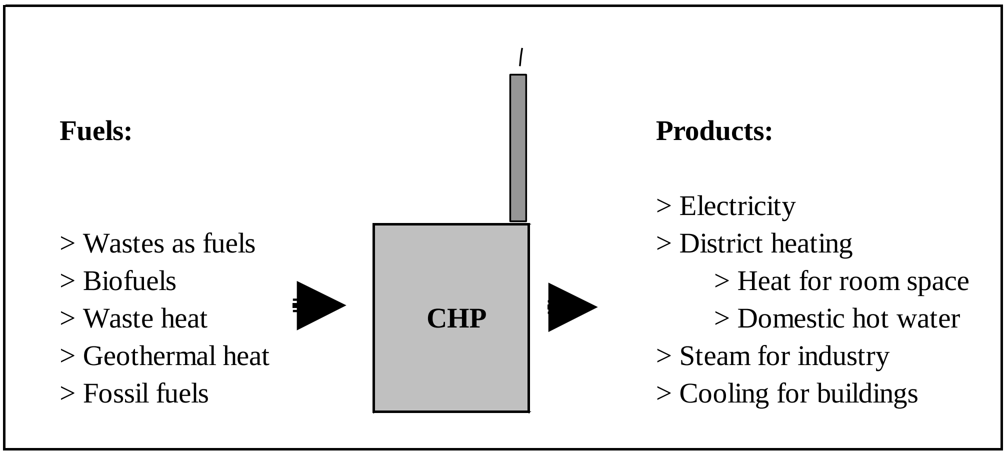

Figure 1: Possible fuels and products of CHP.

The CHP is still defined in various ways. In some countries all power and heat produced by a CHP plant is considered as CHP, whereas in the other countries CHP power and heat is only when their generation depends on each other. In other words, the CHP power is only that part of electricity generation that depends on the heat load, and likewise, the CHP heat is only when it comes out from the turbines and not directly from the boilers.

The CHP Directive[1] offers a sophisticated way to define what is CHP and how to calculate the energy savings of CHP. By year 2011, the member countries should unify their approaches to CHP definition. Article 12 of the Directive states that until the end of 2010 and subject to prior approval by the Commission, Member States may use other methods than the one provided for in Annex II of the Directive to subtract possible electricity production not produced in a cogeneration process from

[1] DIRECTIVE 2004/8/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC

the reported figures. Electricity production from cogeneration shall be considered equal to total annual electricity production of the unit measured at the outlet of the main generators;

- in cogeneration units of type of combined cycle and steam condensing extraction plants of the annual efficiency at least 80 %; and,.
- in cogeneration units of other types with an annual overall efficiency at a level of at least 75 %.

In cogeneration units with an annual overall efficiency below the values referred to above the cogeneration is calculated according to the following formula:

$$E_{CHP} = H_{CHP} . C$$

where:

E_{CHP} is the amount of electricity from cogeneration

C is the power to heat ratio

H_{CHP} is the amount of useful heat from cogeneration (calculated for this purpose as total heat production minus any heat produced in separate boilers or by live steam extraction from the steam generator before the turbine).

The calculation of electricity from cogeneration must be based on the actual power to heat ratio. If the actual power to heat ratio of a cogeneration unit is not known, the following default values may be used, notably for statistical purposes provided that the calculated cogeneration electricity is less or equal to total electricity production of the unit:

Type of the unit Default power to heat ratio, C

- Combined cycle gas turbine with heat recovery 0,95
- Steam backpressure turbine 0,45
- Steam condensing extraction turbine 0,45
- Gas turbine with heat recovery 0,55
- Internal combustion engine 0,75

In order to have CHP, and cogeneration, the prerequisite is to have the heat load in the form of district heating (DH) and /or industrial process load. Therefore, a short introduction to the DH situation in the world is given in the following Chapter 2.

In Chapter 3, the allocation methods are introduced, their use demonstrated and the outcomes compared. In Chapter 4, the main methods will be applied for the CHP systems of Denmark, Finland and Sweden to allocate the CO_2 emissions. In the last Chapter 5 the conclusions are presented.

2. District Heating Market in Europe and Asia

The DH market is growing in Italy, U.K. , Serbia and Germany but it is rather stable in Finland, Sweden and Denmark. In Russia, Ukraine and other transition economies in the Central Europe, the market is even little declining due to closing down excess and outdated capacity, while the customers have started to reduce their DH consumption. This reduction covers disconnections, conversions from DH to other heat modes as well as energy and capacity savings caused by thermal renovation measures.

In Table 1 statistical information from the selected countries has been presented in order to emphasize the DH sector importance in the northern globe. The CHP in particular, plays an important role in the countries, as given the percentage that the CHP generated electric energy comprises in the national electricity generation balance. The individual numbers are not fully comparable to each other, because the definition of CHP still varies among the countries.

Table 1: District heating statistics of Europe and Asia[2].

Country	Production capacity GW	Length of networks Mm	DH floor space Mm2	Total DH delivered PJ	Share of CHP in electricty production
China	224,6	88,9	3006	2250	
Czech Republic	36,1	6,5	109	144	10 %
Denmark	**17,3**	**27,6**	**204**	**103**	**53 %**
Estonia	2,8	1,4	30	26	8 %
Finland	**20,4**	**11,0**	**297**	**108**	**34 %**
France	17,4	3,1		80	
Germany	57,0	100,0	440	267	13 %
Japan	4,4	0,7	49	10	
Korea (South)	13,3	4,7	142	199	23 %
Latvia		2,0	38	24	40 %
Lithuania	8,3	2,5	34	29	21 %
Norway	1,4	0,9		11	
Poland	67,8	18,8	540	425	16 %
Romania	53,2	7,6	70	67	11 %
Russia		176,5			
Sweden		**17,8**	**215**	**169**	**5 %**

Table comprises all significant DH countries in the world except Ukraine, the statistics of which is not available. In USA and Canada the DH is still rather undeveloped even though the origin of district energy is traced back to the USA.

[2] District Heating and Cooling, Country by Country/2009 Survey, Euroheat & Power

3. Allocation Theory in Brief

3.1 Variable and Fixed Costs

The costs of energy production can be divided to the fixed and the variable costs, for instance, as follows:

- The fixed costs comprise capital costs, insurance, permanent maintenance staff salaries, guarding; and,
- The variable costs comprise fuels, electricity, water, lubricants, chemicals, spare parts, temporary man power and operation staff salaries

There are company specific variations how the salary costs are divided, sometimes all staff costs are considered fixed, for instance.

For CHP it is necessary to have the heat load such as district heating, industrial steam or even cooling of premises as heat load. Therefore, competitiveness on the heating / cooling market is essential to the success of CHP.

3.2 Allocation Options

Allocation of the costs of a CHP plant has been an eternal subject for discussion, since several thermodynamic and economic methods are available to make such an allocation. Apart from the thermodynamics, the idea is actually very simple. The cost allocation problem is analogous to any production unit, which generates two or more products from the same input, for instance, like an oil refinery which produces gasoline, oil for heating, heavy fuel oil, and asphalt for roads, etc. from the same process and all based on the same major resource: crude oil. The market defines the price of each product, not the non-existing or insignificant differences in production costs.

Basically, the problems and possible solution are illustrated in Fig. 2, where the selected allocation method only shifts costs from one to the other product while keeping the total costs constant.

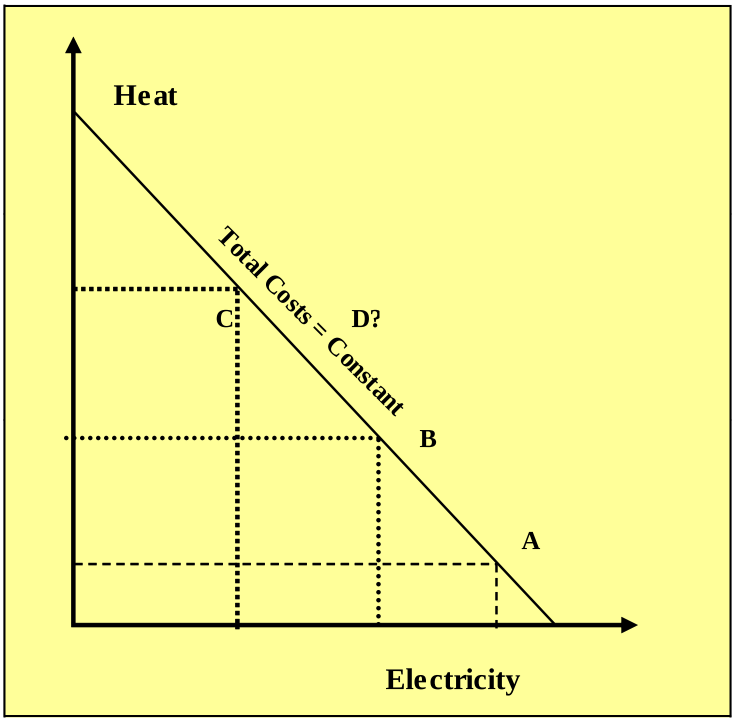

Figure 2: CHP cost allocation methods.

Selection of the allocation methods shall follow the requirements of the actual energy market as follows:

> A: Production of DH used to begin with extracting steam from the condensing power plants at low incremental costs and such allocation was used quite long time to compete with gas heating (used to be in Germany, the Netherlands and Denmark).
>
> B: DH and power operate on a saturated market and the costs are allocated to power and heat in a market price based way (Finland and Sweden).
>
> C: Heat covers most of the costs of CHP and electricity is based on incremental costs (used to be in Poland, the Baltic countries and Russia, for instance)
>
> D: Any method without regulation: when both heat and power sectors are unbundled and competition works perfectly on both sides, no central regulation is needed but the market takes care of fair allocation of the CHP costs.

In cases where the municipality is an owner of the CHP plants it might have an influence on the allocation of the costs of CHP between the products, DH, industrial steam and electric power. But in many instances, municipalities do not own CHP, and therefore, CHP cost allocation and thereby bulk sales tariffs of electric power are determined by national power regulators.

3.1 Thermodynamic Allocation Methods

From the thermodynamic point of view, two main principles can be defined for allocating the variable cost of CHP, namely the exergy and the energy method. The exergy is the part of energy which can be converted to mechanical power, electricity, and the balance is called anergy.

The exergy method values electricity as the main product (exergy) and the heat is the by-product (anergy). Therefore, electricity shall cover the main part of the CHP costs, whereas the heat the remaining small part. Thus, the heat product benefits from the exergy allocation. The exergy method is very close, even equal to the so called working method, according to which the power product has to cover all costs that are needed to generate power and the rest allocated to costs of heating.

According to the energy method, both products shall share the variable costs relative the output energies. In this way the electricity receives all the benefits of the CHP cost allocation.

3.2 Economic Allocation Methods

Most economic allocation methods are close to the thermodynamic ones depending on whether low power or low heat costs are in priority, except one: the benefit distribution method, which in Sweden is called as the alternative method, because it compares the CHP with its alternatives.

In the benefit distribution method (Fig. 3), first the total costs of the CHP plant are allocated to the total costs of heat and power relative their alternatives, the power-only production and the heat –only production. As physical alternatives, a heat-only boiler plant and a condensing power plant using the same fuel as the CHP and having the same power and heat production capacities as the CHP plant are applied.

Second, the total costs of the alternatives will be calculated for the same period of time, usually several years, in order to have the comparable costs of the alternatives available.

Third, the variable costs of the power and heat will be determined either by means of the energy or exergy method. The selection does not influence on the total benefit allocation anymore, but may prevent negative fixed costs to come to either product.

Forth and at last, the variable costs of power and heat will be subtracted from the total costs of power and heat, respectively, and the remainders will be the fixed costs of power and heat, respectively. In such a way the total costs of CHP have been allocated to both variable and fixed costs of power and heat product.

The benefit distribution method, while fairly allocating the CHP benefits to both products, is suited to market conditions in which both power and heat are offered at a saturated market without strong regulation on either side.

The benefit allocation method was developed by a team in Ekono Energy Ltd[3] about 15 years ago.

[3] S.-L. Viirola and A. Nuorkivi

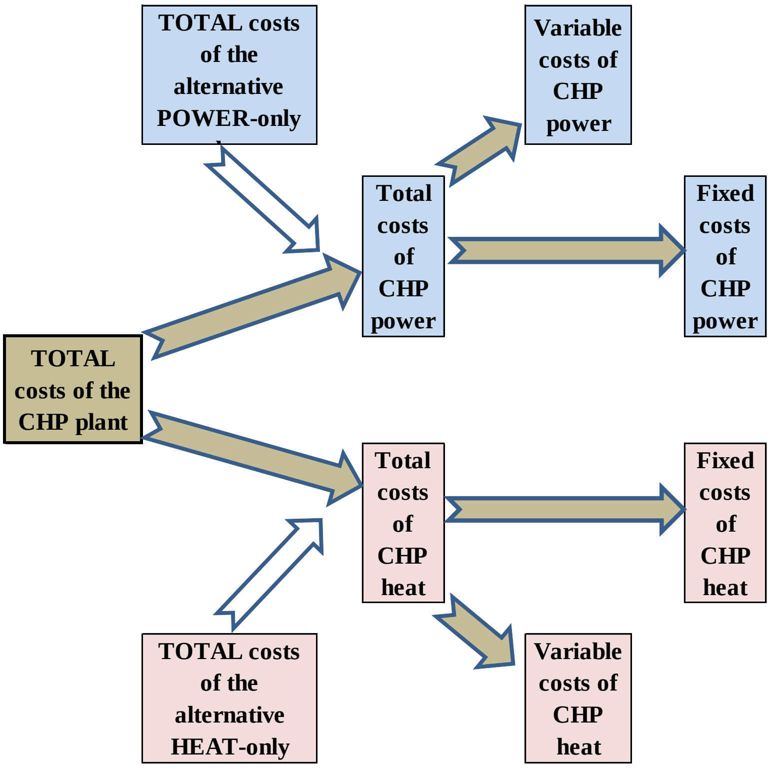

Figure 3: Benefit distribution method.

Another economic method is the penalty method, in which the heat product covers the incremental fuel needed for heat production compared to optimal power-only production at the similar condensing power plant. In Sweden the penalty method is called as power bonus method, because heat only covers the incremental costs of heat production, thus enjoying the bonus from electricity generation. In a solid fuel fired plant the incremental fuel consumption of heat is about 20% and in a gas fueled combined cycle plant 0% of the total fuel consumption.

3.3 Outcome of Various Allocation Methods

The Swedish Energy has carried out a simple an indicative calculation of the relative impacts of the various allocation methods on fuel consumption in two types of CHP plants. The two CHP plants are:

- A back-pressure CHP plant using solid fuel and generating 45 units of electricity and 90 units of DH while using 150 units of fuel. Thus the losses of 15% are based on the boiler efficiency of 90%. The supply and outdoor temperature are assumed at 90and +5 ^{o}C on average in the exergy method.
- A combined cycle gas and steam turbine plant having the overall efficiency of 90% and generating 45 units of power and another 45 units of heat while consuming 100 units of gas fuel. In the bonus method, if the primary energy factor of 2,5 is used for electricity generation as is typical in the condensing power plants using solid fuels, the fuel consumption of power generation would amount to 113 units, equal to 13 units more than

the fuel consumption 100 in the first place. Therefore, the incremental fuel consumption of heat would become negative, but is given as zero% in Table below.

Table 2: Relative comparison of allocation methods.

	Fuel allocation		
	Heat	Power	Total
Back-pressure CHP with solid fuel			
Energy method	67 %	33 %	100 %
Benefit distribution method	50 %	50 %	100 %
Exergy method	30 %	70 %	100 %
Power bonus method	25 %	75 %	100 %
Combined cycle gas and steam turbine CHP			
Power bonus method	0 %	100 %	100 %

The table shows that the bonus method would be most supportive to DH regardless the type of the CHP plant.

3.4 Example of Three Main Allocation Methods

In the following and example of three ultimate allocation methods has been quantitatively described.

The basic data of the case are given in Table 3 below.

Table 3: Data of CHP plant.

Capacity of CHP Plant	
Electric power	100 MW
Heat	200 MW
Peak load duration	5000 h
Energy production	
Electricity	500 GWh
Heat	1000 GWh
Fuel consumption rates	
Electric power	1,2
Heat	1,1
Fuel price	10 €/MWh

The annual variable costs of the CHP plant are

(1,1*1000+1,2*500) GWh * 10 €/MWh = 17 M€

The annual fixed costs of the CHP plant are estimated here as 13 M€

Therefore, the total costs of the CHP plant amount to 30 M€

In order to allocate the costs with any method, one has to define the alternative methods of producing heat and power:

For heat production a heat-only-boiler with same fuel, capacity and efficiency will be used, as described in Table 4.

Table 4: Alternative heat production plant

Alternative heat production		
Heat only boilers		
Capacity	200	MW
Heat production	1000	GWh
Fuel cons. rate	1,1	
Variable costs	11	M€
Fixed cost estimate	8	M€

The variable costs are based on the product of fuel consumption rate, heat production and the fuel price. The fixed costs are estimated using 40 €/kW.

In a condensing power plant the fuel consumption rate is assumed as 3, which is high due to the inevitable condensing losses. The condensing power plant is specified in Table 5.

Table 5: Alternative power generation plant

Alternative power generation		
Condensing power plant		
Capacity	100	MW
Production	500	GWh
Fuel cons. Rate	3,0	
Variable costs	15	M€
Fixed cost estimate	10	M€

The fixed costs, e.g. the capital expenses, of the condensing power plant are estimated at 10 M€, a little lower than the CHP plan of the same capacity and fuel of 13 M€.

The results of the cost allocation methods are in alternatives A, B and C as follows:

A: Alternative power generation method:

Total costs of the CHP plant	30 M€
Total costs of the condensing power plant	25 M€
Total costs of CHP heat (=30-25)	5 M€
Heat, variable	0 M€
Heat, fixed	5 M€

B: Benefit distribution method

Division of total costs of CHP relative to its alternatives

Total cost of power (25/(25+19))*30 =	17 M€
Total cost of heat ((19/25+19) * 30 =	13 M€

Variable costs of CHP power: 500*10*1,2 =	6 M€
Variable cost of CHP heat: 1000*10*1,1 =	11 M€

As a result,

Fixed costs of power: 17 – 6 =	11 M€
Fixed costs of heat: 13 -11 =	2 M€

C: Alternative heat production method

Total cost of the CHP plant	30 M€
Total cost of heat only boiler	19 M€
Remaining costs of CHP power: 30-19 =	11 M€
Power, variable: 1,2*500*10 =	6 M€
Power, fixed: 11 - 6 =	5 M€

The above fixed and variable costs of the alternatives A, B, C are summarized as unit costs in Table below. Table shows how heat benefits from the Alternative power generation method whereas electric power from the Alternative heat generation method.

Table 6: Results of the CHP cost allocation example.

Method of total cost allocation	€/MWh
Power	
A) Alternative power generation method	**48**
B) Benefit distribution method	**34**
C) Alternative heat production method	**22**
Heat	
A) Alternative power generation method	**6**
B) Benefit distribution method	**13**
C) Alternative heat production method	**19**

Fig. 6 illustrates possible cost allocation of heat and power in a CHP system. One should bear in mind that CHP may not exist without the heat demand offered by the DH systems, and therefore the DH price should incorporate some of the benefits associated with CHP production.

In conclusion, the total costs of heat must be always lower than the costs of the alternative for the DHE and the customers in order to ensure sustainable development of the local DH/CHP system.

In the following, for better understanding the method names are simplified as the Energy method, which allocates the emissions according to the produced energies, the Finnish-Swedish method that uses benefit distribution method to allocate the emissions to the products relative to their alternatives, condensing power and heat only boilers, and finally, the Danish method, which is close to the exergy and power bonus method.

4. CHP Allocation in Three Nordic Countries

4.1 Denmark

The basic features of the cost and emission allocation in Denmark is based on the interview and information received from VEKS[4] and the web pages of the Danish Energy Authority.

Denmark has a long history in emission accounting. VEKS, for instance, has had emission accounting since year 1994 already.

For allocation of fuel energy and emissions, two separate approaches are according to the needs used as follows:

- The Danish Energy Authority has stipulated that the energy efficiency of 200% will be used when allocating the fuel costs of CHP to the heat product in the energy and emission statistics. This means that in order to produce two units of heat energy, for instance, one unit of real fuel must be used and the other unit will be recovered from the heat otherwise directed to the turbine condenser. From the condenser the heat unit would have been wasted

[4] Director Lars Gullev, VEKS, Copenhagen, June 14 and Sep 7, 2010

to the environment if not recovered to district heating. Once the principle was established, a strong debate preceded the Energy Authority decision, because the electricity sector had to take over substantial costs and responsibilities of the CHP business in Denmark. This 200% principle is used in DH marketing and labeling, in other words in the green account of DH, but not in financial transactions. The green labeling of DH together with strong regulation is the reason for that DH has been and still is very successful in the heating market.

- In emission and tax calculation, another approach is used. The heat efficiency of the particular plant has to be used when calculating the taxes and GHG emissions of the CHP generated heat energy. Such efficiency of heat production is now considered constant 125% for all CHP plants in Denmark. Until Dec. 31, 2009, however, the efficiency used to vary from 125% to 280% depending on the particular plant, but at the moment it is constant for all plants.

The CHP plants using waste fuel collected from the municipality, hospitals or industry, will act as carbon sinks.

In order to create the energy balance of the CHP industry in Denmark, the publically available sources were used. Such sources were the web pages of Danish Energy Authority as well as those of Vattenfall and DONG energy companies.

The medium size CHP plants with electric capacity below 100 MW electric are assumed as back-pressure plants with boiler efficiency of 90% and the power to heat rate of 65%. There are however two exemptions, namely DTU and Hillerod plants that are with combined cycle having the power to heat ratio about 1.Regarding all small CHP plants producing DH, the peak load duration of the heat and power productions are assumed at 5000 and 6500 hours, respectively. This means they are operated at almost full CHP mode all year long. The small difference indicates that some little electric power has been generated without the heat load and leading the excess heat to the environment. The fuel of medium size CHP plants is either natural gas or renewable, but practically neither coal nor oil at all.

In order to meet the heat and power generation and fuel consumption of the medium size CHP plants indicated in the national CHP balance, a fictive CHP plant had been added to the list of Vattenfall and DONG operated plants. The fictive plant represents the other small CHP plants in the country with a power and heat capacity of 90MW electric and 90 MW heat while using a mixture of natural gas and biomass.

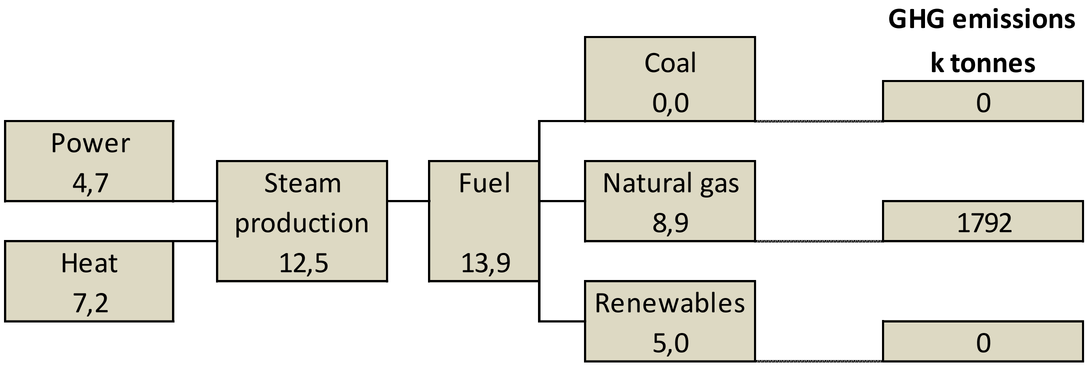

Figure 4: Medium size CHP in Denmark (TWh).

The large CHP plants with electric capacity higher than 100 MW are mainly condensing extraction with a few back pressure plants with boiler efficiency of 90%. For real CHP generation, according the CHP Directive, the power to heat ratio of 0,45, that is applicable to both types of CHP plants, has been used. Regarding all large CHP plants producing DH, the peak load duration of the heat and power productions are assumed at 4500 and 3400 hours, respectively. The difference indicates that the power plants may be run with reduced heat production in times when the market price of power is high. This is because reducing heat production will maximize power generation, which would be optimal from time to time. The fuel of large CHP plants is mainly coal with little natural gas and some oil that is used in starting up/shutting down the coal fired plant. Some renewable fuel (wood ships) is mixed with coal in the large CHP plants as well.

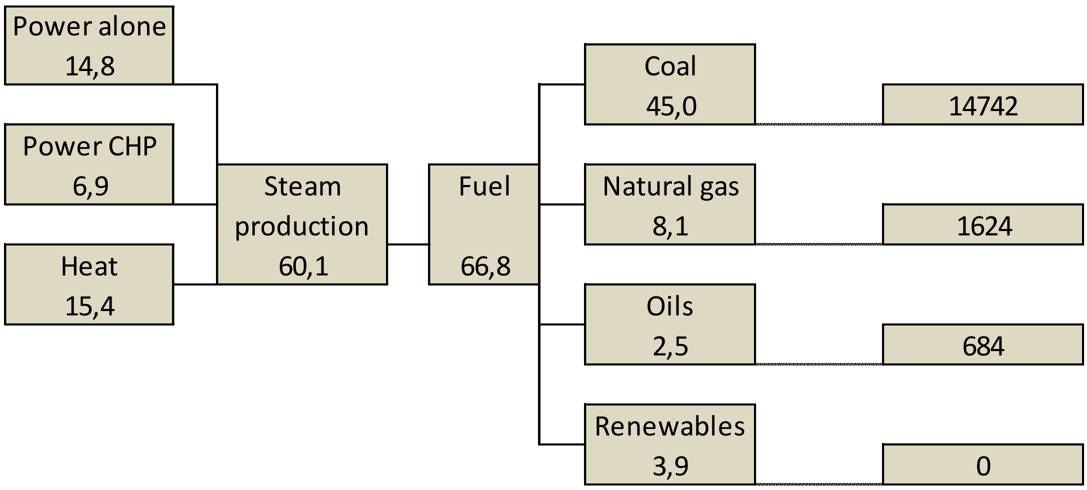

Figure 5: Large scale CHP in Denmark (TWh).

The emissions are calculated according to Table 7 below:

Table 7: CO2 emission factors

Fuel	g/MJ	k ton/TWh
Coal	91	328
Natural gas	56	202
Oil	76	274

In the Table below the CHP emissions of Denmark have been approximated in four ways as follows:

- Energy method allocates the GHG emission relative to the produced heat and electricity energies;
- Danish method using 200% efficiency for heat production and leaving the remaining emission to electricity which corresponds to the power bonus method as well.
- Finnish –Swedish method using 115% efficiency for heat production and leaving the remaining emission toe electricity. The method is close to the benefit distribution method.
- Alterative power method allocating all emissions to electric power, which corresponds to the exergy method as well.

Table 8: CHP emission allocation option in Denmark.

		Energy method	Fin-Swedish practise 115% eff.	Danish practise 200% eff.	Alternative power method
Power	k tonnes CO2	10.152	12.042	14.932	18.842
		54 %	64 %	79 %	100 %
Heat	k tonnes CO2	8690	6800	3910	0
		46 %	36 %	21 %	0 %
	g/MJ of heat	107	84	48	0
	g/kWh of heat	384	301	173	0
Total	k tonnes CO2	18.842	18.842	18.842	18.842

In the above table the specific CO_2 emission according to the local Danish method are 48 g/MJ, whereas the national statistics gives 34 g/MJ for the entire DH sector. The difference is probably caused by the coal intensive CHP production compared to small and medium systems characterized by natural gas and renewable sources.

4.2 Sweden

The basic features of the cost and emission allocation in Sweden is based on two interviews, one at Swedish Power Association[5] and the other one at Swedish District Heating Association[6].

In Sweden in year 2008, the bulk of fuels used for DH production were renewable. For instance, 48%, 16% and 6% of DH fuels were bio mass, waste fuel and peat, respectively, amounting to 70% in total. Moreover, some 20% of fuel consumption of DH was from heat pumps, industrial waste heat, and electricity, the latter one being mainly hydro and nuclear. Therefore, those energy sources did not provide any CO_2 emissions to be paid for.

While having almost half of the fuel consumption based on bio mass, there are19 CHP plants using bio fuel, mainly pellets and wood ships but a large variety of biomass is used.

Regarding waste driven CHP, there are 24 locations involved with waste but power not always based in waste fuel. In 19 CHP plants waste is used to generate power as well.

The balance of only 10% of the DH fuel consumption was fossil in year 2008. Practically all DH that was based on fossil fuels was generated in three CHP plants located as follows: a coal fuelled CHP plant with back pressure turbines in Stockholm (Värtan), a natural gas driven combined cycle plant in Gothenburg (Rya) and a gas fired plant with back pressure turbines in Malmö (Heleneholm). In the Stockholm and Malmö plants there are condensing heat recovery units in the boilers to increase the efficiency while using fuel other than coal.

The number of CHP plants is expanding fast in Sweden, but using mainly renewable fuels. During the years 2009-2015 the number of CHP plants is expected to increase by 35 plants. Likewise, the electricity production based on DH load is expected to increase from 9,5 TWh in 2009, having had been 28% more than in 2008 already, to almost 13 TWh in 2015.

Simultaneously, the relative CO_2 emissions would fall from the current 22 g/MJ of the delivered DH energy to about 14 g/MJ. The declining trend is impressive, since the value used to be about even 42 g/MJ for some ten years ago.

By year 2015, the share of fossil fuels in DH is expected to fall further to the level of 5 TWh, equal to about 8% of the total fuel consumption of DH.

Due to increasing share of renewable fuels in overall, and in CHP in particular, the question of CHP allocation is becoming rather marginal in Sweden.

The energy and emission balance of the three fossil fuel driven CHP plants of Sweden has been approximated in Figure below (a). The fuel consumptions are from the 2008 statistics and the capacities from the CHP plant brochures available in the web.

The energy balance of the renewable driven CHP plants is approximated in the same figure in (b). From the CHP fuel statistics separated for electricity and heat, the fuels needed for CHP electricity

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[5] Mr. Folke Sjöbohm, Svensk Energi,Stockholm, May 18,2010
[6] Mr. Erik Larsson and Ms. Sonya Trad, Svensk Fjärrvärme, Stockholm, June 22, 2010

generation have been recorded from each site, altogether from 42 sites, with 9,1 TWh of electricity in total. In many of the cases all fuel consumption for heat reported from the CHP location is not really CHP heat but produced by water boilers instead. Therefore, in order to make the fuel of CHP heat realistic, either the real power to heat ratio of the CHP plant or the value 0,4 has been used, which ever lower. In such a way the reported CHP heat fuel of 19,1 TWh has been adjusted to 16,0 TWh as a realistic estimate. Consequently, the produced electricity and heat from the CHP using renewable energy are 7,2 and 14,5 TWh, respectively.

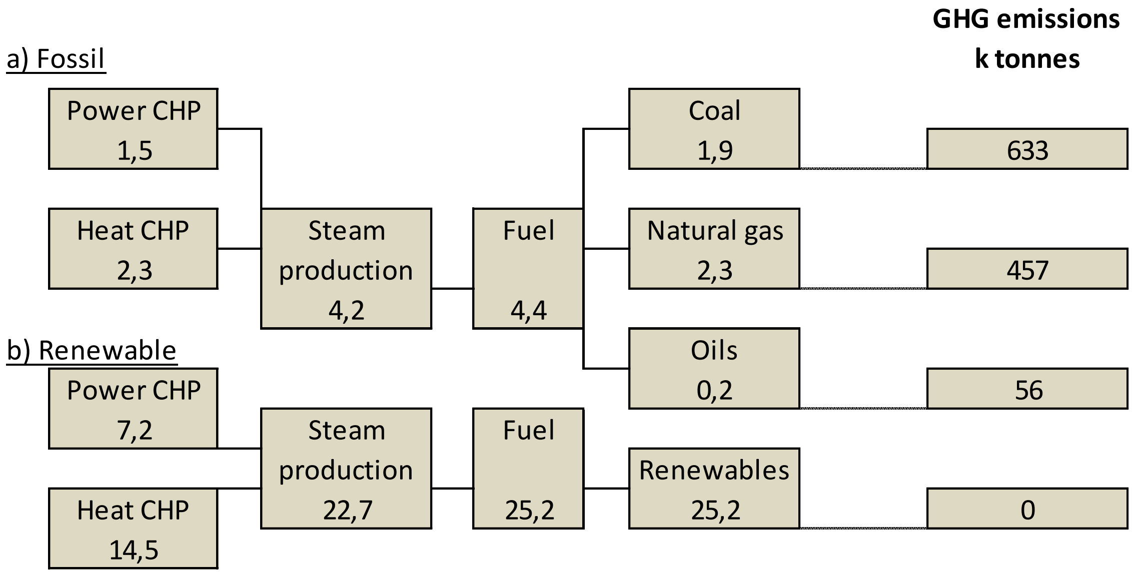

Figure 6: CHP plants of Sweden separated to (a) fossil and (b) renewable fuels (TWh).

The GHG emissions of the plants can be allocated to power and heat in four ways as presented in Table below.

Table 9: CHP emission allocation option in Sweden

		Energy method	Fin-Swedish practise 115% eff.	Danish practise 200% eff.	Alternative power method
Power	k tonnes CO2	393	557	808	1.147
		34 %	49 %	70 %	100 %
Heat	k tonnes CO2	754	590	339	0
		66 %	51 %	30 %	0 %
	g/MJ of heat	8	7	4	0
	g/kWh of heat	30	23	13	0
Total	k tonnes CO2	1.147	1.147	1.147	1.147

Thanks to the comprehensive use of renewable in CHP, the specific emissions of DH are very low, regardless the method applied.

There is not a mandatory way to allocate the fuels and emissions to power and heat in Sweden at the moment. On one hand, the bonus method which is close to the Danish practice above is used when calculating the primary energy factor, because electricity would need to be generated anyway. The DH association would like to use it for taxation and emission calculations as well, but not any method has been officially chosen at the moment. The bonus method would be the most effective way to promote DH on the market.

In the energy statistics, on the other hand, the benefit distribution method, or the Finnish-Swedish method, has been used, but not the energy method to allocate CHP fuel consumption.

The taxation is based on the bonus method. For electricity zero taxation but for heat full taxes 20% tax rate of DH fuel: 100% of 20% of fuel is equal to 20% of 100% fuel needed for DH (energy method).

The DH Association has carried out numerous calculations about applying the power bonus method, but without any official approval received so far.

The CHP directive calculates according to the alternative formula, telling how much savings achieved from CHP compared to its alternatives but does not go further to support any method to be used in tariff or emission calculations.

The CO_2 tax as paid by DH in Sweden is high, about 107 Euro per metric ton. In addition to high taxes, the DH companies have to buy CO_2 allowances, which is another reason that has raised the DH prices.

4.3 Finland

The basic features of the cost and emission allocation in Finland is based on the interview and information received from the Finnish Energy Industries[7].

The Finnish CHP producing DH is fossil fuel intensive, equal to 67% of all fuel consumption covered mainly by coal and natural gas. Peat as a slowly renewable fuel covers 19% of the total consumption and the balance of 13% is covered by the real renewable like wood and various wastes.

The largest coal fired CHP plants in the fuel consumption order of 2008 statistics are located in Helsinki, Naantali, Espoo, Lahti and Vantaa, whereas the gas fired CHPs in Helsinki, Tampere, Vantaa, Espoo and Hämeenlinna. The largest peat fuelled CHP plants are situated in Oulu, Kuopio, Tampere, Pori, Rovaniemi, Mikkeli, Joensuu and Seinäjoki. In the plants of Mikkeli and Joensuu in particular, wood is an important fuel component.

In 2008, the CHP with DH covered 18% of the total electricity consumption in Finland.

[7] Ms. Mirja Tiitinen, M. Sc. (Tech), Finnish Energy Industries, Helsinki, June 23, 2010

In the official Statistics of Finland (Tilastokeskus), both the energy and the benefit distribution method have been applied to allocate the CHP power and heat in the energy statistics. The allocation has been calculated company by company, but only the summary information is publically available. The national emission statistics, on the other hand, does not differentiate the emissions of the CHP plants to their products.

On the company level, the CHP allocation has been done individually, and the selection of the allocation method has not been publically announced. Nevertheless, the companies likely apply more or less the benefit distribution method, the Finnish-Swedish method in other words, since there is a strong concern around that neither product shall subsidize the other one. In order to address the concern, both products shall benefit from the CHP. The Competition Office, however, is entitled to request any CHP company to inform the office about the cost allocation method used. Moreover, the Energy Market Authority requires a clarification to the subsidy issue from the companies once a year according to the respective Act.

The Finnish legislation stipulates that the costs have to be allocated to power and heat but does not say in which way but leaves it open for the companies to choose.

In practice, the fuel allocated for heat in CHP will be calculated by multiplying the heat energy by 90%, which equals to the heat production efficiency of 100-120%. In this document, 115%¤ efficiency has been used for the heat generated by the CHP as Finnish-Swedish practice.

In the Finnish taxation, there is a kind of CO_2 tax that is called the “excise tax” (valmistevero). According to the legislation, the fuel mix has to be equal on both energy and heat side of the CHP.

At present, peat is excluded from the CO_2 tax and natural gas enjoys a reduced tax level of 2.1 €/MWh of fuel consumption. In 2011, however, the tax for gas will rise to the same level as is with the coal, at the moment being about 7.4 €/MWh, but the future of the tax exemption of peat is unlikely to stay and an excise tax has been already suggested by the government to peat already.

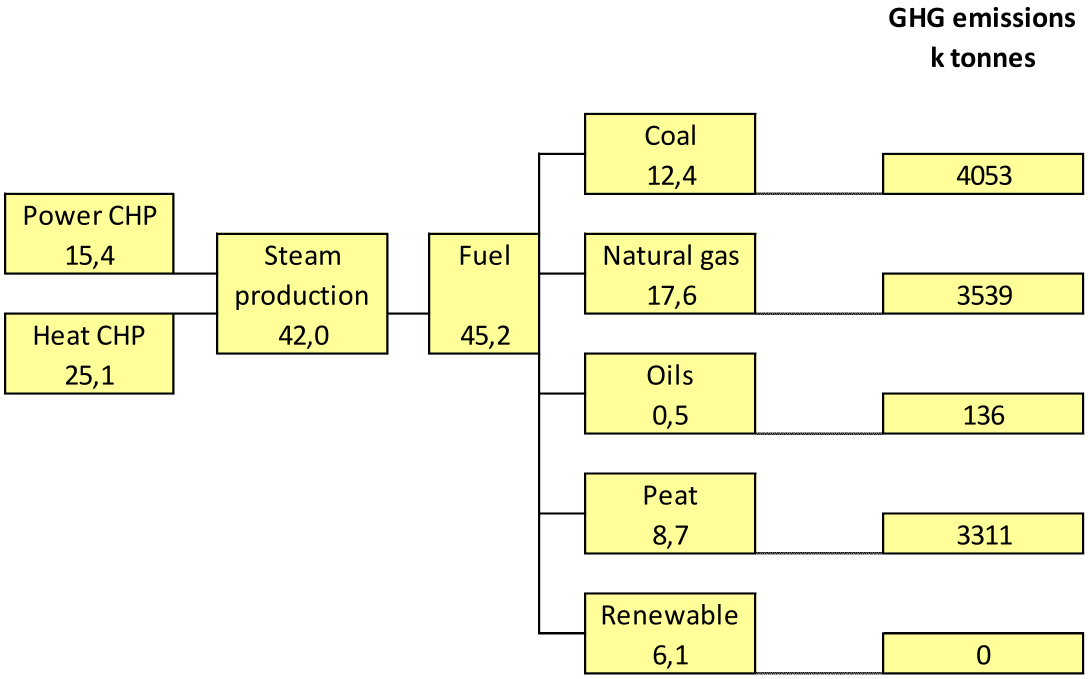

Figure 7: CHP in Finland (TWh).

In Finland, the bulk of CHP is a mixture of back-pressure and combined cycle plants. Therefore, the power-to-heat ratio of 0,6 is realistic and in accordance with the CHP Directive.

Table 10: CHP emission allocation options in Finland.

		Energy method	Fin-Swedish practise 115% eff.	Danish practise 200% eff.	Alternative power method
Power	k tonnes CO2	4.203	5.689	7.963	11.040
		38 %	52 %	72 %	100 %
Heat	k tonnes CO2	6.836	5.350	3.076	0
		62 %	48 %	28 %	0 %
	g/kWh of heat	76	59	34	0
	g/MJ of heat	273	213	123	0
Total	k tonnes CO2	11.040	11.040	11.040	11.040

5. Recommendation

The CHP directive is expected to uniform the CHP fuel and emission allocation in Europe from January 2011 on. In such a way the CHP statistics are expected to become comparable.

It will depend on the country, whether for energy political reasons, the taxation will be different to CHP power and heat. There is actually a physical reason to tax heat lighter than the power in CHP, because the heat load is the prerequisite of CHP existence. Therefore, promoting DH would support the success of CHP, which further would enable the fuel savings of about 30% achieved compared to the alternative ways to produce power and heat, in the alternative power and heat alone plants.

In all three countries both CHP and DH are well justified as a means to save energy and emissions as well as to use reneable energy sources in an effective and sustainable way. Based on the different allocation methods, the summary of specific CO_2 emission of DH in CHP can be presented in Table below.

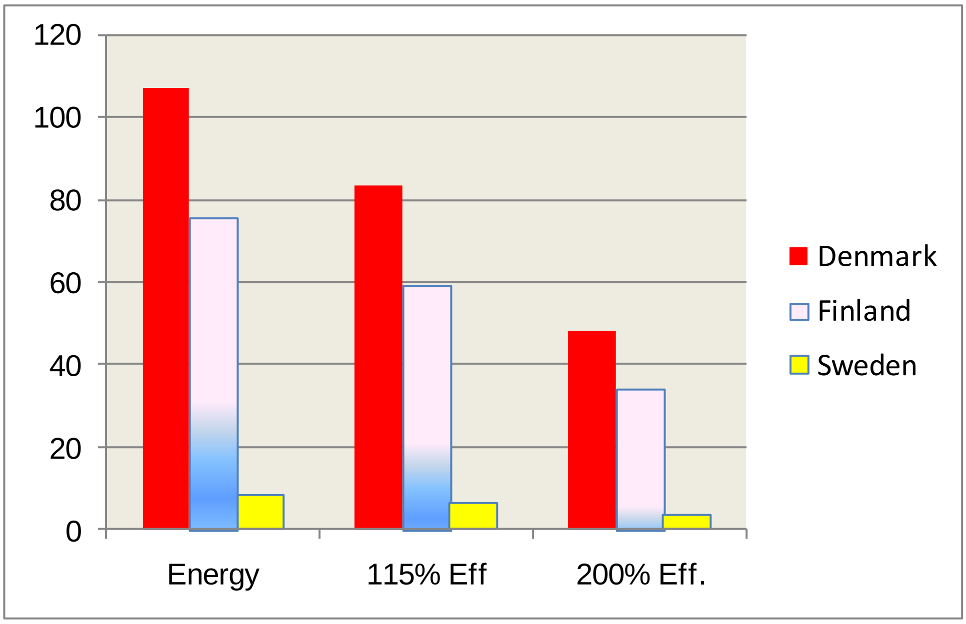

Figure 8: Comparison of specific CO_2 emission of DH in CHP systems in Denmark, Finland and Sweden with four different allocation methods (g/MJ per CHP heat).

The heat specific emissions of CO_2 have been calculated to the heat energy produced by the real CHP processes. Therefore, the values differ from those official ones calculated for the entire DH production. Another reason to deviation is the robust approach based on publically available statistics. However, the Fig.8 indicates both the differences of various allocation methods as well as the difference in using renewable sources as fuels for CHP in the three countries.