Harmful effects of burning various fuels – A comparison of natural gas, wood and straw

by **Torben Kvist**

Based on publicly available figures a study has compared the harmful effects of burning natural gas, straw and wood, respectively, in district heating boilers. The results showed that green and renewable fuels are not inevitably less harmful than natural gas.

In the autumn 2011 Centre for Energy, Environment and Health (CEEH) published a report [1] concluding that the costs of transition to a fossil-free Danish energy supply will be considerably lower than anticipated by the Climate Commission:

The calculations made by the Climate Commission did not take into account health-related costs of burning fossil fuels. The Climate Commission suggested replacing fossil fuels by renewable sources like wind and biomass.

The costs related to the transition to fossil-free energy supply are to a large extent depending on how the transition is done; in particular which sources of energy are used in the transition period.

Therefore, DGC has made calculations that correlate health-related costs and costs resulting from climate effects of burning straw, wood and natural gas.

1. METHOD AND BACKGROUND DATA

This article presents an investigation of district heat producing boilers (no electricity production) with less than 50 MW heat input. Straw, wood and natural gas were chosen as they are frequently used fuels at district heating boilers.

1.1 Emission factors

The National Environmental Research Institute (NERI) complies and publishes national emission inventories of different combustion technologies with different fuels. These emission factors are stated as g emitted chemical compounds / GJ fuel used. The emission factors used for boilers are shown in **Table 1**.

Wood and straw are here regarded as CO_2 neutral, which means that the emission factor for CO_2 is set at 0 instead of the values given in **Table 1**, when the climate effect is being calculated for these fuels.

1.2 Costs related to different chemical compounds

All chemical compounds given in **Table 1** have a certain harmful effect on the surroundings. There is a big difference, however, on the harmful effect of the different matters. The harmful effect depends on the location of the emission. For example there is a difference between NO_x emission from cars in cities where many persons are directly exposed to the emission and emission from a tall chimney at a location with only moderate human exposure. In contrast to this, greenhouse gases like CO_2, nitrous oxide (N_2O) and methane (CH_4) have the same effect no matter where they are emitted.

The recently published report "CEEH's calculations of health-related costs from air pollution as given in the Climate Commission's scenarios" [1] uses data for increased health-related costs resulting from emission from e.g. combustion processes. These costs are also termed externalities or external costs. These data are taken from a background report from the same research centre [3].

Unit: g/GJ	SO_2	NO_x	NMVOC	CH_4	CO	CO_2	N_2O	$PM_{2.5}$
Wood	25.0	90	7.3	30.0	240	102,000	4.0	10.0
Straw	130.0	90	7.3	30.0	325	102,000	4.0	12.0
Natural gas	0.3	42	2.0	0.1	28	56,900	0.1	0.1

Table 1. Emission factors for district heat producing boilers with less than 50 MW heat input. Data from 2010 [2]

Euro/kg	CO	SO_2	NO_x	$PM_{2,5}$
Power plant	0.0011	12	8	19
Individual heating	0.0019	21	18	28
Industrial combustion	0.0013	15	11	20
Road transport	0.0028	91	10	44

Table 2. Socio-economic costs of emission of CO, SO_2, NO_x and $PM_{2,5}$ from different types of emission sources [3]

All prices have been calculated by the model system EVA, "Economic Valuation of Air pollution". The model system was developed at NERI and makes an integrated valuation of externalities of air pollution based on atmospheric modelling.

There are four steps of the calculation:

- atmospheric modelling of mean annual concentration contributions from emissions
- estimation of exposure based on GIS data of the location of the population – based on CPR data (Central Person Register) including age distribution.
- estimation of health effects, based on exposure-response function and associated statistical expectations to frequency of morbidity[1] and mortality[2].
- valuation based on unit values of the negative individual health effects (e.g. per life year lost, per sick day, etc.)

Decentralised combined heat and power plants are often placed on the outskirts of smaller towns and these plants have more in common with plants for industrial combustion than with large power plants when it comes to location and size [4]. Therefore, **Table 2** uses data for industrial combustion to describe the socio-economic costs of emitting different chemical compounds.

The costs mentioned above only cover health-related costs. The impact on environment and climate is not included in the data given in **Table 2**. The climate effect will be included below by using a CO_2 allowance price of 15.20 Euro/ton (for 2011) and an allowance price of 34.50 Euro/ton (for 2030). These figures are given in the publication from the Danish Energy Agency (in Danish) "Premises for socio-economic analyses in the energy sector" [5]. In addition, CH_4 and N_2O are regarded as 21 and 310 times more powerful greenhouse gases than CO_2.

2. DISTRICT HEATING BOILERS BURNING WOOD, STRAW OR NATURAL GAS

The emissions stated in **Table 1** combined with the emission-related costs shown for "Industrial combustion" in **Table 2** result in the total external costs associated with burning straw, wood and natural gas, respectively, in heating plants as shown in **Figure 1**. **Figure 1** shows that in spite of the fact that the two bio fuels are regarded as CO_2 neutral the external costs associated with using wood as fuel and natural gas, respectively, are roughly equal, while the use of straw as fuel will entail considerably higher external costs. The primary reason for this is that as a fuel straw contains considerably more sulphur than wood. When combusted, sulphur is emitted as SO_2.

A CO_2 allowance price for 2011 of 15.20 Euro/ton will result in 20% higher calculated external costs when burning wood compared to burning natural gas. A CO_2 allowance price for 2030 of 34.50 Euro/ton will result in 30% lower calculated external costs when burning wood compared to burning natural gas.

In addition, **Figure 1** shows that external costs associated with biomass are primarily caused by NO_x and SO_2

[1] Morbidity is the ratio of incidence of sickness to size of the population where the incidences occur.

[2] Mortality is the death rate of a population

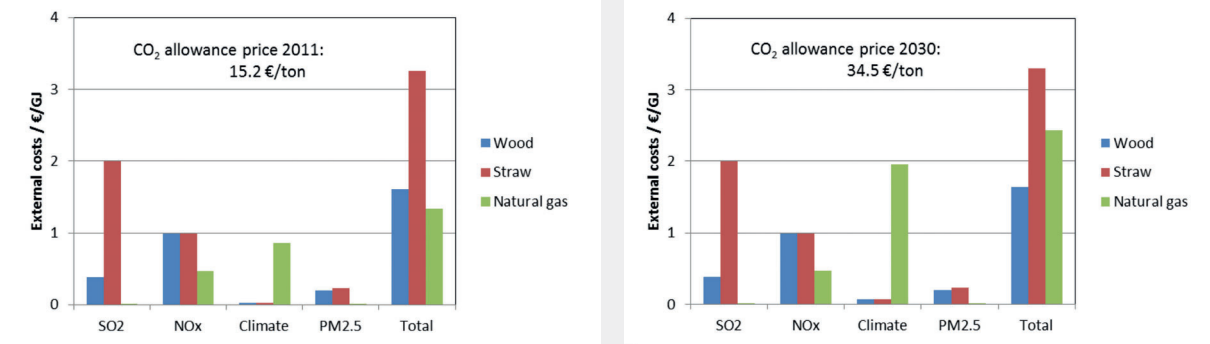

Figure 1. External cost associated with emissions from district heating boilers fired with wood, straw or natural gas. Costs for the individual chemical compounds are as stated for "industrial heat" in **Table 2.** CO_2 allowance price is for 2011 and as the Energy Agency expects the CO_2 allowance price to be in 2030.

that produce regional health effects, while natural gas will produce climate effects and only to a lesser extent result in negative health effects.

3. GOING FORWARD

3.1 Which harmful effects are least unpleasant?

As mentioned the calculations indicate that the impact of straw and wood is primarily due to emission of SO_2 and NO_x. These chemical compounds produce negative *regional* health effects. The negative impact of using natural gas primarily results in *global* climate effects.

This difference has the effect that when priorities have to be set regarding the use of biomass or natural gas, there will be an implicit prioritising between regional health effects and global climate effects.

3.2 The right fuel at the right place

It will neither be profitable nor necessary to install flue gas cleaning to reduce emission of these chemical compounds at small plants that are described in this article. On the other hand, this may be the case for large plants equipped with both NO_x and sulphur cleaning equipment and fired with biomass only. Moving the use of biomass to large plants with flue gas cleaning would result in considerably reduced emissions.

It would lead to a reduction of the overall harmful impact of the same fuel mix if biomass would primarily be used in large boilers with flue gas cleaning and natural gas would primarily be used in the small boilers instead of biomass.

REFERENCES

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