SOCIO ECONOMIC ANALYSIS OF ENVIRONMENTAL OPTIMISATION OF NATURAL GAS FIRED ENGINES

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Sisse Liv Jørgensen
Flemming Møller

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Abstract: This report analyses budget and welfare costs associated with changing settings in a gas engine. The purpose is to analyse what it will cost the plant owner and society if one would change the engine settings in order to obtain lower NOx emissions. The plant owner will loose while society will gain wealth when aiming for lower NOx emissions. The loss for the plant owner is primary caused by taxes while the gain for society is caused by less health expenses. The report also analyses if placement have any effect for society; however, since the population density does not differ very much across Denmark this does not have any mayor effect.

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Preface

This report is prepared in connection with Kvist et al. (2010): "Environmental optimisation of natural gas fired engines", which summarizes the main conclusion from the present report along with conclusions from other parts of the project. This report presents and explains the economic analysis in more detail.

Sammendrag

Denne rapport vurderer de økonomiske konsekvenser ved forskellige motorindstillinger på naturgasfyrede kraftvarmeværker (CHP, Combined Heat and Power Production) baseret på resultater i Kvist et al. (2010), hvor konklusionerne fra indeværende rapport også er at finde. Formålet med at ændre motorindstillingerne er et forsøg på at opnå et lavere niveau af NO_x-udledninger. Den økonomiske analyse består dels af en budgetøkonomisk analyse og dels af en velfærdsøkonomisk analyse af effekterne ved at ændre på indstillingerne på gasmotorer. Derudover vurderes de velfærdsøkonomiske effekter af den geografiske placering af CHP-anlæggene. I analyserne antages, at den totale elektricitet- og varmeproduktion forbliver uændret. Dvs., hvis ændringer i motorindstillingerne medfører en lavere varmeproduktion, vil tabet blive erstattet af varmeproduktion på naturgasfyrede kedler.

Den budgetøkonomiske analyse viser, at der generelt er et trade-off mellem NO_x-udledninger og omkostningerne for CHP anlægget. Når NO_x-udledningerne reduceres øges produktionsomkostningerne. Ved en enkelt motorindstilling produceres der dog mere varme end ved indstillingerne med højere udledninger, og dermed sparer man på udgifterne til produktion af varme på kedler.

Den velfærdsøkonomiske analyse tager også højde for de afledte effekter af at ændre motorindstillingerne. Dvs. der tages også højde for de ændrede motorindstillingers konsekvenser for andre luftemissioner end NO_x. Det drejer sig om stoffer, som kan have sundhedseffekter, samt om klimagasudledninger. Analysen viser, at samfundet samlet set vil vinde på lavere NO_x-udledninger - hovedsagligt pga. positive sundhedseffekter.

Endelig viser analysen vedrørende placering af anlægget, at den geografiske placering ikke har nogen særlig velfærdsøkonomisk effekt. Det skyldes, at der ikke er den store variation i befolkningstæthed på tværs af Danmark, hvorved der heller ikke er de store forskelle i sundhedseffekterne.

Summary

This report assess the economic consequences of different CHP-engine (Combined Heat and Power production) settings based on results found in Kvist et al. (2010), which also contains the conclusions of this report. The purpose of changing engine setting is to obtain lower levels of NO_x emissions. The economic analysis is divided into a budget economic analysis and a welfare economic analysis of the effects of changing the gas engine settings. Furthermore, the welfare economic effects of geographical location of the gas engine are assessed. The analysis assumes that the total electricity and heat production from engines and boilers will be unchanged. That is, if changed engine settings cause a lower heat production on engines heat production on boilers will be increased.

The budget economic analysis shows that in general there is a trade off between NO_x emissions and economic costs. Reduction of NO_x emissions leads in most cases to the higher economic cost. Only for one engine setting a decrease in NO_x emissions results in lower economic costs. This is due to the fact that in this case there will be produced more heat on engines, which means that cost of heat production on boilers can be reduced.

The welfare economic analysis also takes the derived effects of changing the engine settings into account. That is, also the value of emission changes is included in the analysis. Over and above the consequences for NO_x emissions changed engine settings also have consequences for other air emissions that might have health effects and changed engine settings also have climate gas effects. The welfare economic analysis clearly shows that society will benefit from lower NO_x emission levels mainly due to the positive health effects.

Finally the analysis regarding location of CHP-plants shows that location has no substantial welfare economic effect. This is due to the fact that the population density in Denmark does not differ much across the country, and therefore there is no substantial difference in health effects.

1 Introduction

In relation to the project on environmental optimisation of natural gas fired engines (Frohn et al. 2010; Andersen, 2010) this report will go into depths with the economic consequences of different engines settings. The conclusions of this report are found in the main report "Environmental optimisation of natural gas fired engines" (hereafter referred to as main report), cf. Kvist et al. (2010).

This report has two objectives.

The first objective is to assess the budget economic and welfare economic effects respectively of a change in the gas engine settings in order to obtain reduced levels of NO_x emissions.

The second objective is to assess the welfare economic effects of placing the same engine (unit #3) at different locations and thereby having different exposure and health effects.

It is assumed that the production of electricity and heat should be unaffected by the changes in engine settings. Therefore, the budget economic effects only depends on how the changed gas engine settings affect the expenditures of the district heating plant (CHP plant) – i.e. input expenditures and tax payments. The welfare economic analysis includes both the value to society of changed resource use and emissions, but not tax payments. However, if changes in tax payments affect the net-revenue of the public sector this might cause a change in the so-called "dead weight loss" to society - which should be taken into account.

The value of the emission changes depends among other things on their health effects and therefore it is also interesting to analyse the welfare economic effect of different placing of the same engine with unchanged settings. The health effects depend on how many persons are affected by the emissions thereby the health effect is determined by population density in the area around the place where the plant is situated.

This analysis concentrates on the effects of changed operation conditions at the plants in question for one year. All prices are 2010 prices. The analysis is focusing on the impact in Denmark – not taking the effects outside the borders into account. This differs from the other analysis in this project, were the environmental and health effects are simulated for the whole affected area – including other European countries. The value of health effects in countries other than Denmark is not comparable to the costs of different engine settings and therefore these health effects are excluded from the analysis in this paper.

2 Impact statement

The changes in gas engine settings and thereby in NO_x emissions will affect the budget economic costs of CHP plants. The engines are running with different combinations of ignition timing and excess of air – these are set in order to obtain NO_x levels 500, 400, 300 and 200 mg/m^{3}n (main report, Section 4.2). In the following the case with the highest NO_x level (M4) is used as reference – this makes it easier to see how costs change when NO_x emissions fall. M1-M8 defines different settings for the engines. In order to achieve each level of NO_x there are two possible tools, one where the ignition timing (TI) is changed (M1, M2 and M4) and one where the excess of air (λ) is changed (M5, M6 and M8). M3/7 is the point of reference. See Table 1.

Table 1 Examined operation conditions (table from main report).

Unit: mg/m^3(n) @ 5% O_2	TI_1	TI_2	TI_3	TI_4
λ_1			M_5 NO_x = 200	
λ_2			M_6 NO_x = 300	
λ_3	M_1 NO_x = 200	M_2 NO_x = 300	$M_{3/7}$ NO_x = 400	M_4 NO_x = 500
λ_4			M_8 NO_x = 500	

In order to keep the experiment as simple as possible it is assumed that the electricity produced is (approximately) unchanged. This means that there will be a change in heat production on engines, which is assumed to be substituted by production on boilers. These assumptions are illustrated in the first part of Table 2. In the first row the almost unchanged electricity production, then how much heat is produced – divided out on engines and boilers, in order to keep the total production unchanged.

The next part of the table illustrates the consumption of gas for engines and boilers. For the engines the gas consumption depends on the settings of ignition timing and excess of air. For the boilers the change in gas consumption is only due to changes in heat production, which as mentioned, substitute changes in heat production from engines.

The changes in engine settings will, according to the main report (main report, Section 7.2), not have any effect on maintenance cost on the engines; however, the maintenance costs on boilers are dependent on the heat production and therefore will change due to the changes in this production. The cost is 5 DKK/MWh heat produced (main report, Section 7.3). The amount of heat, which has to be produced on boilers is dependent on whether it is the ignition time (M1, M2 & M4) or the excess of air (M5, M6 & M8) that is changed. In case M1 and M2 the engines actually produce more heat than needed - that is the engines produce excess heat compared with the point of reference. While in the cases of M5, M6 and M8 the boilers have to produce more heat.

The main purpose of this study is to see how emissions change due to changes in settings on the engines. Besides these changes there will also be emission changes from the boilers because these have to substitute for changes in heat production on engines. In Table 2 emissions of emissions from engines and boilers are divided out into the different emissions.

Table 2 Impact table.

	M4 NO_x = 500	M8 NO_x = 500	M3/7 NO_x = 400	M6 NO_x = 300	M2 NO_x = 300	M5 NO_x = 200	M1 NO_x = 200
Electricity production (kwh)	7,670,546	7,653,167	7,666,440	7,652,929	7,664,638	7,673,736	7,671,790
Heat production (kwh) - total	9,694,688	9,694,688	9,694,688	9,694,688	9,694,688	9,694,687	9,694,688
-Engines	9,676,879	9,631,249	9,694,688	9,679,013	10,013,516	9,532,119	10,104,455
-Boilers	17,809	63,439	-	15,675	- 318,828	162,569	- 409,767
Gas consumption (m^3n) - total	1,683,775	1,686,261	1,689,903	1,694,588	1,678,245	1,728,222	1,695,145
-Engines	1,682,154	1,680,490	1,689,903	1,693,162	1,707,249	1,713,433	1,732,422
-Boilers	1,620	5,771	-	1,426	- 29,004	14,789	- 37,277
Maintenance costs (DKK)	89	317	-	78	- 1,594	813	- 2,049
Emissions Engines (kg per year)							
CH_4	109,777	109,588	114,097	121,603	121,193	141,597	129,077
C_2H_4	1,482	1,514	1,577	1,829	1,924	2,397	2,176
C_2H_6	10,722	10,691	10,407	11,448	11,479	13,214	12,268
C_3H_8	8,168	7,821	8,578	9,019	8,641	10,785	8,925
HCHO	3,974	4,100	4,257	4,478	4,699	5,456	5,235
NO	18,827	20,057	14,002	9,587	10,785	5,140	6,686
NO_2	8,609	6,938	8,199	6,055	7,411	6,969	8,830
CO	22,296	23,116	23,747	26,364	26,900	35,257	29,455
CO_2	13,535,069	13,520,565	13,519,051	13,530,442	13,631,478	13,630,903	13,885,312
O_2	2,302	2,271	2,365	2,460	2,397	2,681	2,365
CH_4	292,320	291,816	303,825	323,811	322,720	377,052	343,714
Emissions - boilers (g per year)							
SO_2	19	69	-	17	- 344	176	- 443
NO_x	2,692	9,591	-	2,370	- 48,203	24,578	- 61,952
NMVOC	128	457	-	113	- 2,295	1,170	- 2,950
CH_4	962	3,425	-	846	- 17,215	8,778	- 22,126
CO	1,795	6,394	-	1,580	- 32,135	16,386	- 41,301
CO_2 (kg per year)	3,639	12,964	-	3,203	- 65,154	33,222	- 83,738
Change in taxes (DKK)		12,218	17,930	34,902	- 13,153	119,671	30,481

Note: In Appendix it is possible to see all intermediate calculations.

The last thing that will change is tax payments. These payments depend on gas consumption. In this analysis carbon dioxide (CO_2) tax, nitrogen oxide (NO_x) tax, methane (CH_4) tax and energy tax are taken into account. The CO_2, NO_x and CH_4 taxes are all based on the total gas consumption. The CO_2 tax is 0.351 DKK per m^3n gas consumed. The NO_x

tax, which was introduced in 2010, is 0.028 DKK per m^3n gas consumed and the CH_4 gas, which will be introduced in 2011, is 0.066 DKK per m^3n gas consumed. The energy tax is also based on gas consumption, 2.27 DKK per m^3n gas consumed, but for engines only a fraction of the gas is subject to energy-tax, this is thoroughly explained in the main report (main report, Section 7.1). In this study the production is electrical efficient – therefore the so called E-formula is used. This means that the fraction of fuel subject to energy taxation is 1-(electrical efficiency/0.65), the electrical efficiency is for all settings calculated to be around 0.40.

Table 3 displays the change in tax payments due to change in production. As written earlier the different engines settings are compared to the setting, which has the highest NO_x emission - setting M4. As the taxes are based on total gas consumption (engines + boilers), and as M2 is the only case that demands less gas than in case M4 – this is also the only case were you have to pay less taxes. In the other cases the extra tax payment is between 12,000 and 120,000 DKK. What is noticeable is that in general, the less NO_x you emit (from engines) the higher taxes you will have to pay – except from the case M2 and M1.

Table 3 Taxes (DKK).

	M8	M3/7	M6	M2	M5	M1
	NO_x = 500	NO_x = 400	NO_x = 300	NO_x = 300	NO_x = 200	NO_x = 200
CO_2 tax	873	2,151	3,796	- 1,941	15,601	3,991
NO_x tax (2010)	70	172	303	- 155	1,245	318
CH_4 (2011)	164	404	714	- 365	2,934	750
Energy tax (engines)	1,689	18,880	30,531	58,824	69,999	113,716
Energy tax (boilers)	9,423	- 3,678	- 441	- 69,516	29,893	- 88,296
Total change in tax expenditures	12,218	17,930	34,902	- 13,153	119,671	30,481

3 Budget economic analysis

Table 4 displays the budget economic impacts. The table follows the impact table above. As the total electricity and heat production is unchanged there are no income changes for the CHP. In contrast the change in engine settings and heat production changes gas consumption and expenditure. The expenditure changes for gas are in each case calculated, and compared to the M4 case. The price of gas is 39.6 DKK in 2008-prices per GJ (40.87 DKK in 2010-prices per GJ) stated by the Danish Energy Agency. The gas expenditure increases as the NO_x emissions falls, the exception being M2. Maintenance costs are as described above. The taxes (CO_2 taxes, NO_x taxes, CH_4 taxes and energy taxes) are all dependent on the consumption of gas, and described above. It is seen that it is less expensive to change the ignition timing (M1, M2 and M4) compared with the change in excess air (M5, M6 and M8) in order to reach the same NO_x levels. It is also seen that it is less expensive for the plant to aim for a NO_x level 300 than to a NO_x level at 500 if ignition timing is changed.

Table 4 Budget economic impact table (DKK).

	M8	M3/7	M6	M2	M5	M1
	NO_x = 500	NO_x = 400	NO_x = 300	NO_x = 300	NO_x = 200	NO_x = 200
Change in gas expenditures	4,021.05	9,911.69	17,490.15	- 8,943.11	71,889.04	18,391.13
Change in maintenance costs	228.15	- 89.04	- 10.67	- 1,683.18	723.80	- 2,137.88
Change taxes	12,217.73	17,929.82	34,902.34	- 13,153.39	119,671.48	30,480.71
Total change in costs	16,466.93	27,752.46	52,381.81	- 23,779.68	192,284.32	46,733.97

4 Welfare economic analysis

One thing is how the private budget economy of the CHP plants is affected by the changed operation conditions; another is how society's welfare is affected by this. The private economy of the CHP plants takes all the economic costs of the changed operation conditions into account; that is changes in income, input costs and tax payments. A cost benefit analysis (CBA) is a statement of how the changed operation affects society's welfare; in other words, not only does it take welfare effects of changes in production and resource use into account but also welfare effects connected with environmental impact changes. In this project it primarily means that the welfare economic value of emission changes. This project assumes that the electricity output of the CHP plant is fixed, while heat production varies. The changed heat production will be substituted by production of heat on boilers. So, for society there is no change in the amount of electricity or heat provided by the plants. However, as described in the impact assessment in Table 2 there is a change in the consumption of natural gas and in maintenance costs. The changed gas consumption will also affect the emissions from the plants and thereby among other things human health.

When calculating the welfare economic value of the change in gas consumption and maintenance expenditures – the expenditures measured in factor prices have to be multiplied with the standard conversion factor (SCF) 1.17 – cf. the Ministry of Environment (2010) (in Danish context this is called net excise factor). This is done in order to take the value of the alternative production measured in consumer prices into account – that is the value of what could be produced with the gas if it was not used to produce electricity and heat this way.

Collecting taxes create a distortion in the economy. In this case the tax rate is not changed – but due to change in gas consumption the sum of tax collected will change, see Table 3. If more taxes are collected from one area a welfare gain is obtained because other taxes can be reduced without affecting the amount of public expenditures. Contrary to this, if less tax is collected in one area society will suffer a welfare loss because an increase in other tax rates is necessary to keep the level of public expenditures unaffected. A tax reduction means a reduced distortion of the economy and therefore a welfare gain and vice versa for a tax increase. The value of distortion change is calculated at the change in taxes collected multiplied by the deadweight factor 1.2 cf. the Ministry of Environment (2010). Any consequences for the public sector's net-revenue might also have welfare economic value because of the "dead weight loss" of tax payments.

Table 5 Welfare economic impact table (DKK).

	M8	M3/7	M6	M2	M5	M1
	NO_x = 500	NO_x = 400	NO_x = 300	NO_x = 300	NO_x = 200	NO_x = 200
Total change of gas expenditures for society	4,704.63	11,596.67	20,463.47	-10,463.44	84,110.18	21,517.63
Change in maintenance costs for society	266.94	-104.18	-12.48	-1,969.32	846.84	-2,501.32
Change in deadweight loss+taxes	-14,661.28	-21,515.78	-41,882.80	15,784.07	-143,605.78	-36,576.85
Change in healt costs	-41,263.72	-162,607.74	-369,418.72	-278,954.27	-442,331.90	-327,734.79
Change in climate costs	-1,147.54	9,006.94	30,848.37	33,805.16	100,676.12	84,603.58
Change in emission costs	-42,411.26	-153,600.80	-338,570.35	-245,149.11	-341,655.78	-243,131.22
Total costs for society	-52,139.75	-163,608.95	-360,000.35	-241,511.67	-400,427.58	-260,328.33

One of the main qualifications of a cost benefit analysis is that it also takes the value of non-marketed goods into account – e.g. the value of a changed supply of environmental goods. In this case the change in emissions from engines and boilers is valued. The emission effects and among these the health effects of changed emissions are valuated and added to the resource costs. For the engines the welfare economic value of health effects due to the emissions has been calculated in other parts of this project (Frohn et al. 2010; Andersen, 2010). For boilers it has not been possible to have an explicit valuation of the emission changes and it has not been possible to put a price on all substances of the emissions. For NO_x and CO data for engines have been used and converted into costs on boilers based on emission factors for boilers, which are found in NERI (2009). For SO_2 the value for emissions in cities stated by the Danish Energy Agency is used. For both engines and boilers CO_2 and CH_4 the CO_2 quota-price increased with the SCF (=1.17) are used – this means that for these emissions it is the marginal social costs' of fulfilling the CO_2 reduction target that is used as accounting price. CH_4 is converted into CO_2 equivalents by multiplying by 21.

Table 5 displays the welfare economic impact table of changing production conditions on the CHP plants. The table follows the previous impact tables, adding on the standard conversion factor and the deadweight loss as well as the health and environmental values of the different engine settings. It is seen that an overall change in the settings will generate a total gain to society – as a result of negative costs. The benefits are mainly driven by the positive health effects of reducing the NO_x emissions.

5 Exposure

Another issue dealt with in this project is the welfare economic effects of locating the heating plant in different places. How different are the consequences for human health if the CHP plant is placed in an area with high population density compared with a low or medium density? This is analysed by looking at one engine, locating it - theoretically – in three different places and then calculate the exposure and health costs in the different scenarios. The experiment is done with the standard settings on the engine (M3/7 on the Wärtsilä V25SG). The only thing that will change when comparing the welfare economic consequences of the three different locations is the emission costs. The change in emission costs for the three different locations is seen in Table 6. Surprisingly enough there is a very little difference between medium and high exposure, and the medium exposure location even involve higher costs than the high exposure location. In general there are no larger differences in the costs due to placement. This conclusion may be obtained due to very small variation in population densities in Denmark.

Table 6 Same engine – in different locations.

	Low exposure	Medium exposure	High exposure
CO_2 (kg/year)	13,560,480	13,519,051	13,560,480
Costs CO_2 (DKK)	1,719,507	1,714,254	1,719,507
CH_4(kg/year)	114,097	114,097	114,097
Costs CH_4 (DKK)	303,825	303,825	303,825
Health costs (DKK)	648,846	812,175	790,672
Total costs	2,672,178	2,830,254	2,814,004

6 Conclusions

The budget economic analysis shows that for most settings the plants will have higher costs when aiming for lower NO_x emissions. Only in the case of M2 (NO_x = 300) the plants will actually gain from changing settings compared to the M4 (NO_x = 500). This is due to a lower consumption of gas, since this setting will actually produce more heat than required on the engines – and therefore have a smaller heat production on boilers than in the basis scenario.

The welfare economic analyses take the derived effects on society into account – including non-economic effects, health effects and climate effects. In other parts of this project (Frohn et al. 2010; Andersen, 2010) the health effects are valuated and discussed. The climate effects are valuated by the price of CO_2 quotas. The analysis clearly shows that the lower emissions the more society will benefit. This is due to the value of health effects.

When changing the location of the engines – to obtain different exposure rates – the population density and thereby the health effects change. Great differences for low, medium and high exposure are not seen in this project; this is probably due to the fact that the population density in Denmark in general does not differ very much.

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Appendix

	M4 NO_x = 500	M8 NO_x = 500	M3/7 NO_x = 400	M6 NO_x = 300	M2 NO_x = 300	M5 NO_x = 200	M1 NO_x = 200
Electricity production (kwh)	7,670,546	7,653,167	7,666,440	7,652,929	7,664,638	7,673,736	7,671,790
Heat production (kwh) - total	9,694,688	9,694,688	9,694,688	9,694,688	9,694,688	9,694,688	9,694,688
-Engines	9,676,879	9,631,249	9,694,688	9,679,013	10,013,516	9,532,119	10,104,455
-Boilers	17,809	63,439	0	15,675	-318,828	162,569	-409,767
Gas consumption (m^3n) - total	1,683,775	1,686,261	1,689,903	1,694,588	1,678,245	1,728,222	1,695,145
-Engines	1,682,154	1,680,490	1,689,903	1,693,162	1,707,249	1,713,433	1,732,422
-Boilers	1,620	5,771	0	1,426	-29,004	14,789	-37,277
Change in gas consumption (m^3n)		2,486	6,128	10,814	-5,529	44,448	11,371
Maintenance costs (DKK)	89	317	0	78	-1,594	813	-2,049
Change in maintenance costs (DKK)		228	-89	-11	-1,683	724	-2,138
Emissions Engines (kg per year)							
CH_4	109,777	109,588	114,097	121,603	121,193	141,597	129,077
C_2H_4	1,482	1,514	1,577	1,829	1,924	2,397	2,176
C_2H_6	10,722	10,691	10,407	11,448	11,479	13,214	12,268
C_3H_8	8,168	7,821	8,578	9,019	8,641	10,785	8,925
C_4H_{10}	0	0	0	0	0	0	0
HCHO	3,974	4,100	4,257	4,478	4,699	5,456	5,235
NO	18,827	20,057	14,002	9,587	10,785	5,140	6,686
NO_2	8,609	6,938	8,199	6,055	7,411	6,969	8,830
CO	22,296	23,116	23,747	26,364	26,900	35,257	29,455
CO_2	13,535,069	13,520,565	13,519,051	13,530,442	13,631,478	13,630,903	13,885,312
O_2	2,302	2,271	2,365	2,460	2,397	2,681	2,365
Emissions Engines - costs							
Health costs total (DKK)	974,303	931,830	812,175	604,920	704,895	527,325	659,745
Climate costs							
CO_2 (DKK)	1,716,285	1,714,446	1,714,254	1,715,698	1,728,510	1,728,437	1,760,697
CH_4 (DKK)	292,320	291,816	303,825	323,811	322,720	377,052	343,714
Total costs (DKK)	2,982,908	2,938,092	2,830,254	2,644,430	2,756,125	2,632,814	2,764,156

Continued							
Change in costs (DKK)		-44,815	-152,654	-338,478	-226,783	-350,094	-218,752
Emissions - boilers (g per year)							
SO_2	19	69	0	17	-344	176	-443
NO_x	2,692	9,591	0	2,370	-48,203	24,578	-61,952
NMVOC	128	457	0	113	-2,295	1,170	-2,950
CH_4	962	3,425	0	846	-17,215	8,778	-22,126
CO	1,795	6,394	0	1,580	-32,135	16,386	-41,301
CO_2 (kg/year)	3,639	12,964	0	3,203	-65,154	33,222	-83,738
Emissions Boilers - costs							
SO_2 (DKK)	3	9	0	2	-45	23	-58
NO_x (DKK)	480	1,689	0	444	-9,066	5,126	-12,697
NMVOC (DKK)							not valuated
CH_4 (DKK)	3	9	0	2	-46	23	-59
CO (DKK)	0	0	0	0	0	0	0
CO_2 (DKK)	461	1,644	0	406	-8,262	4,213	-10,618
TOTAL	947	3,351	0	855	-17,419	9,385	-23,432
Change in emissions - boilers		2,404	-947	-92	-18,366	8,438	-24,379
CO_2 tax (DKK)	591,005	591,878	593,156	594,801	589,064	606,606	594,996
NO_x tax (2010) (DKK)	47,146	47,215	47,317	47,448	46,991	48,390	47,464
CH_4 (2011) (DKK)	111,129	111,293	111,534	111,843	110,764	114,063	111,880
Energy tax (engines) (DKK)	1,405,166	1,406,854	1,424,046	1,435,696	1,463,989	1,475,165	1,518,882
Energy tax (boilers) (DKK)	3,678	13,100		3,237	-65,839	33,571	-84,618
Total taxes	2,158,123	2,170,341	2,176,053	2,193,025	2,144,970	2,277,794	2,188,604
Change in taxes							
CO_2 tax (DKK)		873	589,182	590,827	585,091	602,632	591,023
NO_x tax (2010) (DKK)		70	172	303	-155	1,245	318
CH_4 (2011) (DKK)		164	404	714	-365	2,934	750
Energy tax (engines) (DKK)		1,689	18,880	30,531	58,824	69,999	113,716
Energy tax (boilers) (DKK)		9,423	-3,678	-441	-69,516	29,893	-88,296
Total change in tax expenditures (DKK)		12,218	17,930	34,902	-13,153	119,671	30,481

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Danmarks Miljøundersøgelser
Frederiksborgvej 399
Postboks 358
4000 Roskilde
Tlf.: 4630 1200
Fax: 4630 1114

Administration
Afdeling for Arktisk Miljø
Afdeling for Atmosfærisk Miljø
Afdeling for Marin Økologi (hovedadresse)
Afdeling for Miljøkemi og Mikrobiologi
Afdeling for Systemanalyse (hovedadresse)

Danmarks Miljøundersøgelser
Vejlsøvej 25
Postboks 314
8600 Silkeborg
Tlf.: 8920 1400
Fax: 8920 1414

Afdeling for Ferskvandsøkologi
Afdeling for Marin Økologi
Afdeling for Terrestrisk Økologi

Danmarks Miljøundersøgelser
Grenåvej 14, Kalø
8410 Rønde
Tlf.: 8920 1700
Fax: 8920 1514

Afdeling for Systemanalyse
Afdeling for Vildtbiologi og Biodiversitet

[Tom side]

SOCIO ECONOMIC ANALYSIS OF ENVIRONMENTAL OPTIMISATION OF NATURAL GAS FIRED ENGINES

This report analyses budget and welfare costs associated with changing settings in a gas engine. The purpose is to analyse what it will cost the plant owner and society if one would change the engine settings in order to obtain lower NO_x emissions. The plant owner will loose while society will gain wealth when aiming for lower NO_x emissions. The loss for the plant owner is primary caused by taxes while the gain for society is caused by less health expenses. The report also analyses if placement have any effect for society; however, since the population density does not differ very much across Denmark this does not have any mayor effect.

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