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AIR POLLUTION FROM FUEL COMBUSTION IN STATIONARY SOURCES

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1. Introduction

1.1. Energy consumption in 1968

The total energy consumption in Norway in 1966 was in excess of 13 mill. tons oil equivalents. This does not include consumption in connection with ships sailing overseas. The growth of the national demand has been very strong in the years following 1950. In the period 1950-1960, it was 5% p.a., 6,4% p.a. in the period 1960-1966, and 7% p.a. in the period 1966-1968. The total energy consumption in 1968 being 15,156 mill. t.o.e.

Since 1900, the type of fuels used has varied very much. Coal, coke and wood played an important role in the country's energy supply until the first years after the second World War. In 1966, however, these fuels amounted to less than 1/10 of the country's basic consumption. Hydro-electric power and oil predominate the fuels used today. Hydro-electric power provides a large amount of the country's need. However, despite the large domestic supply, Norway uses a large amount of liquid fuels, which causes the energy supply to be very dependent on imports. The consumption of energy in Norway is shown in tables I and II (6).

Table I: Total consumption of utilized energy in Norway in 1966, according to categories of consumption.

	Solid 1) fuels Tcal	Liquid 2) fuels Tcal	Hydro-elec. power Tcal	Total Tcal	Total %
Power-demanding industries	760	1 140	16 500	18 400	27
Other industries	400	12 850	6 720	19 970	29
Communications	7	4 780	362	5 149	7
Domestic and agricultural	2 200	4 130	9 950	16 280	25
Others 3)	708	4 559	3 435	8 702	12
Total Tcal	4 075	27 459	37 967	68 501	100
Total %	6	40	54	100	-

1) including gas from ovens in iron and steel plants and from coal.
2) including fluid gas.
3) uncertain (calculated residual).

Table II: Total energy consumption in Norway 1968

	Solid fuels	Liquid fuels	Hydro-electr. power	Total
Total mill. t.o.e.	1 137	5 536	8 492	15 156
Total %	7,5	36,5	56	100

1.2. Expected fuel consumption in 1980

Estimates for 1980 are based upon the following assumptions (6):

- assumed growth in gross national product 4% p.a.
- assumed average growth in industrial production 5% p.a.
- growth in total energy consumption 1966-1970 5,3% p.a.
- " " " " 1970-1990 4,5% p.a.
  (including mobile sources, which are expected to have a very strong growth in energy consumption).

There are two alternatives worked out for the proportions between oil and hydro-electric power. The first alternative gives oil a high proportion, the second gives the larger proportion to hydro-electric power (6). It is most probable that the true figure will lie somewhere in between and the arithmetic mean is used here (the latest oil price increases will perhaps now favour hydro-electric power). Oil from the North Sea is not taken into account for it is assumed that there will be no real utilization of fuel from this source until after 1980.

1.2.1 Domestic consumption

This type of oil can be divided into room heating and household requirements.
Household requirements are purposes mainly covered by hydro-electric power. The growth in hydro-electric power consumption in this sector was 5% p.a. until 1964. The total

energy requirements for room heating grew in this same period at almost 3% p.a., hydro-electric power alone increased 8% p.a. There is no reason to expect strong growth in room heating by hydro-electric power in the future (6).

It is assumed that the total energy-demand for room heating will increase at a rate of 3,5% p.a. until 1980, and gradually decrease until 1990. It is uncertain whether the use of hydro-electric power will expand at the sacrifice of liquid fuels, or vice versa. This will be determined, among other things, by the price differential between hydro-electric power and oil, and possible restrictions against use of heavy fuel oil to prevent air pollution.

On the 1st November 1970 a law was introduced in this country stating:

> "All public oil fired plants and private plants in Oslo with a yearly consumption of less than 700 metric tons, must use fuel oils having less than 0,8% by weight of sulphur, and be free from residue.
> Private plants in Oslo with a yearly consumption of more than 700 metric tons must use fuel oils having less than 2,5% by weight of sulphur".

It is possible that this law will be altered in autumn 1971. Other industrial towns in Norway may come under this law in the future, depending on the state of the air pollution which they suffer.

Based on the price differential between oil and hydro-electric power today (that is before the last increase in oil prices), hydro-electric power will probably meet 60-80% and liquid fuels 20 - 40% of the energy demand for house heating; coal, coke and wood not being taken into account.

1980	high	low
hydro-electric power	24 600 GWh	21 600 GWh
liquid fuels	940 000 tons	640 000 tons

1.2.2. Mining, pulp, paper and other industries (6)

With regard to domestic central heating, the price differential between liquid fuels and hydro-electric power will determine their proportional use in the future. Furthermore, the price and applicability if the equipment using such energy will have some influence.

Estimated common industry and mining demand in 1980

	high	low
hydro-electric power	11 400 Tcal	6 100 Tcal
liquid oils	19 300 Tcal	14 000 Tcal

Estimated pulp and paper demand in 1980

Growth in the total energy demand will be in the order of 2% p.a. In 1966, the firm consumption of hydro-electric power was 30% of the total energy consumption. In 1990 this lie somewhere between max 50%, min 25%.

	high	low
Hydro-electric power 1980	4 020 GWh (8% p.a.)	2 770 GWh

(Estimates from Pulp and Paper Council: 5 280 GWh).

1.2.3. Commercial and Service industries

Although the dominating part of the consumption is for room heating, illumination also takes an important part. The growth of demand has been 7,4% p.a. in the last few years, but this is expected to decrease to some 5% p.a.

1980	high	low
hydro-electric power	11 000 Tcal	7 900 Tcal
liquid fuels	7 900 Tcal	4 800 Tcal

1.2.4. Power-demanding industries

While the growth in other industries is almost independent of energy supplies, the power demanding industry is dependent

on supplies of cheap hydro-electric power. It is assumed 4% p.a. growth until 1980, and a consumption of hydro-electric power in 1977 of 39,1 TWh,firm power with regard to the electric power stations.

The average growth in the aluminium industry has been estimated to be 12% p.a. until 1973 with the exception of the planned building of two new plants. The average growth in the iron and steel industry is calculated to be 12% p.a. in the next three years, not including the planned building of a further new plant.

The production of ammonia based on hydro-electric power is expected to decrease. The production of calcium carbide will probably continue at its present figure whilst the production of silicon carbide will increase.

1.3. The relationship between oil and hydro-electric power

As mentioned, the relationship is very dependent on economics. The situation is illustrated by figure 1.

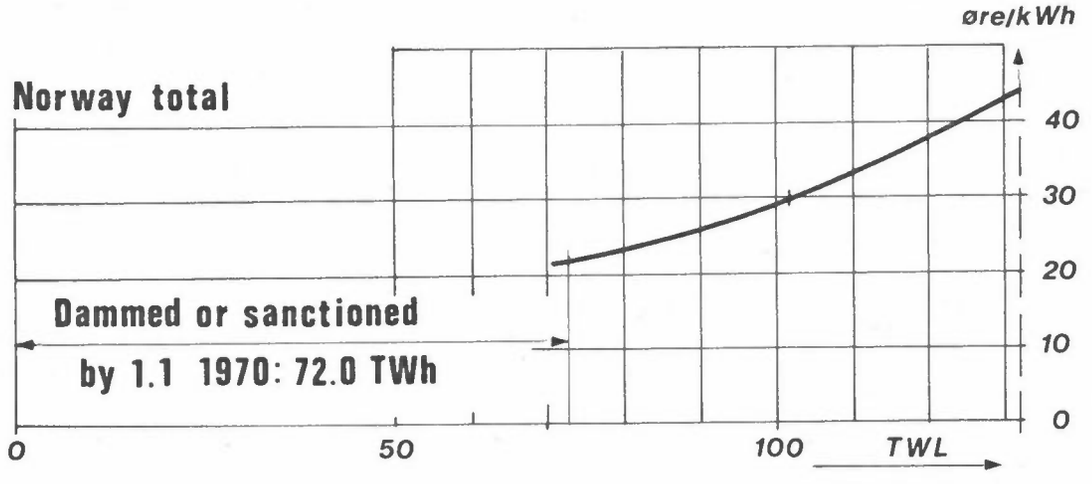

Figure 1: Remaining available hydro-electric power resources in Norway (not dammed and not sanctioned by 1/1 1970). Stipulated building costs, 1967-prices.

Norway has enough natural water resources to cover the expected energy demand in the next decades. Calculations have shown that it will be more expensive to base the whole energy demand on hydro-electric power in the future, than to combine it with oil fired electricity generating plants. Remaining hydro-electric

power resources, at the economic favourable price level (below 28,5 øre/KWh), are still so great that this will be the dominating energy resource in the next decade. In this period, the electricity production will be based mainly upon hydro-electric power. With the cost-relations existing in our country between oil fired electric plants and hydro-electric power plants, it will be necessary to produce eletricity from oil for only shorter periods. The primary function of the electricity from oil will be as a supplement in years when water supply is low. One estimate for 1980 (6) assumes that oil fired power plants will provide 1,5 TWh, while hydro-electric power provides 91,5 TWh (93 TWh total). This report is based on there being one oil fired power plant with 250 MW capacity in 1980 with an average of 1300 working hours per year. No definite decision has yet been taken regarding the building of and atomic and/or oil fired power plant in Norway, however, the first atomic power plant in Norway is planned to be in operation in 1981. At that time, electricity must be available from oil fired power plants, whether it comes from Norwegian or a Swedish source (or Danish). If this plant is built in Norway, it is assumed it will be built without abatement equipment. This plant will consume 65 tons oil/hour at 250 MW capacity. The use of oil having a sulphur content of 1% by weight is here assumed.

2. Consumption of fuels in 1968 and 1980

2.1. Coal 1968

Domestic and commercial total: 78 000 tons = 54 000 t.o.e. (10).
Industry (exclusive iron and steel plants and coke ovens):
134 000 tons = 93 800 t.o.o. (10).

Norsk Koksverk A/S (coke-ovens) does not use coal or coke for heating purposes.

Iron and steel plants: 10 tons = 7 t.o.e. (11). (this is not taken into account in the regions).

Consumption in Oslo (13): industry 3 500 tons = 2 500 t.o.e.,
domestic and commercial 4 000 tons = 2 800 t.o.e.

The rest of the coal consumed by "domestic and commercial users" is based on the regions with regard to their population.

Imported via Oslo from Poland: 17,500 tons: This provides nearly all the consumption in Oslo, Akershus, Hedmark and Oppland (13). The total sum of the consumption by "domestic and commercial users" in those regions exceeds that imported via Oslo. The difference is assumed to be covered by import via other places (Drøbak, Drammen, Trondheim).

These assumptions lead to the conclusion that there is no consumption of coal for heating purposes in the industry in these regions.

The distribution of the coal consumption in industry in these regions is uncertain. Heavy consumers for heating purposes are (11):

Food manufacturing industries	1 600 tons
Coal mining	4 000 tons
Breweries and manufacturing of malt	1 000 tons
Manufacture of structural clay products	5 000 tons
Manufacture of transport equipment	1 000 tons
Total sum (1968)	15 000 tons

That these figures do not agree very well with those first mentioned (10), is due in part to the fact that they include coal as raw materials in industries excluding iron and steel plants and coke ovens. An example is the production of electrodes in the aluminium industry. It is assumed that this amount is too small to have any influence on the total energy picture.

This group is divided on the regions according to their population.

2.2. Coal 1980

Consumption in industry, iron and steel excluded
20 000 tons = 14 000 t.o.e.

divided in

industry	11 700 tons =	8 200 tons
domestic and commercial	8 300 tons =	5 800 t.o.e.

Only one new plant is expected to use coal in 1980 (A/S Leca at Rælingen). The consumption there will be 5 000 tons = 3 500 t.o.e. The remainder is expected to be shared by the biggest ports, where the coal can be imported cheaply. These will be in the regions Østfold, Oslo, Telemark, Sør-Trøndelag, Vest-Agder, Nordland and Troms.

2.3. Coke 1968

Domestic and commercial total
208 000 tons = 139 200 t.o.e. (10)
Industry (excluding iron and steel plants and coke ovens)
171 000 tons = 114 600 t.o.e. (10)
Iron and steel industry
1 343 tons = 900 t.o.e. (11)
(this is ignored in the regions).

Consumption in Oslo (13):

Domestic and commercial	21 500 tons	=	14 400 t.o.e.
industry	1 500 tons	=	1 000 t.o.e.

Coke imported via Oslo: 30 000 tons, which is expected to cover the consumption in Oslo, Akershus, Hedmark and Oppland. As for coal this leads to a negligable coke consumption in the industry in these regions. The coke consumption by domestic and commercial and other industries is divided between the other regions according to their population.

2.4. Coke 1980

Expected total use in Norway (7):

Other industries	18 000 tons	= 12 000 t.o.e.
Domestic and commercial	40 000 tons	= 27 000 t.o.e.

These figures are based on the 1968 consumption. Coke in the iron and steel industry is assumed to equal the 1968 consumption.

2.5. Gas manufacture in 1968

At present, there are two gas-works in Norway, one in Oslo and one in Bergen. The gas is produced from light naphtha, 0,48 - 0,49 kg naphtha gives 1 Nm^3 gas (14). 1 Nm^3 gas = 0,42 t.o.e. (7).

Table III: Consumption of manufactured gas 1968

1968	tons naphtha (10)	1000 Nm^3	t.o.e.
Oslo	5 811	12 000	5 000
Bergen	8 354	17 000	7 000
Total	14 165	29 000	12 000

The gas is available for both industrial and domestic use, at an estimated usage of 50% to each group. The delivery areas are limited to Oslo and Bergen. The gas does not contain sulphur (14). Light naphtha contains <0,05% by weight S (17).

2.6. Gas manufacture in 1980

The consumption is assumed to be constant from 1968 to 1980.

2.7. L.P.G.

The total L.P.G. in Norway in 1966 (7) amounted to 13 000 t.o.e. and was used for private consumption, agriculture, ships and industry. Since this amounts to a very little part of the total fuel consumption, it is estimated:

Table IV: Consumption of L.P.G.

T.o.e.	1968	1980
Industry	6 000	7 000
Domestic and Commercial	6 000	7 000
Total	12 000	14 000

These figures are distributed throughout the regions according to their population.

3. Fuel oils

3.1 Specifications for fuel oils

Table V: Specification for fuel oils

"Light fuel oils":

Type	ρ	ρ15°C	%S	Lower calorific value (kcal/kg)	Ash content % by weight
Light petroleum	0,81	(0,78)	≤0,05[1]	[2]	≈0
Gas oil (fyr 1)	0,85		0,4	10 300	0,001
Diesel oil (fyr 2)	0,90		0,5	10 200	0,001

[3]

[1] in this report calculated as 0,04% S.
[2] smog point 26-35 mm, flash point 40°C.
[3] light naphtha also included, % S <0,05, here calculated as free of sulphur.

"Heavy fuel oils":

Type	ρ	%S	Lower calorific value (kcal/kg)	Ash content % by weight
Light fuel (fyr 3)	0,93	1,75	9 950	0,04
Heavy fuel (fyr 4-6)	0,96	2,2	10 100 - 9 780	0,04
fyr 4		2,0	10 100	0,001
fyr 4A		1,0	10 100	0,001
fyr 5		2,2	9 840	0,04
fyr 6		2,3	9 830	0,05
Bunker C		2,5	9 780	0,06

3.2. Domestic and commercial 1968

Agriculture is placed in this group. The figures for 1968 are given by (12) for each region.

3.3. Domestic and commercial 1980

Increase in the energy consumption in this sector is caused by population increase, and the decrease in the consumption

of coal and coke, may be covered by fuel oils or electricity. The proportions can be assumed in a high and a low estimate for each. The most probable proportion lies somewhere in between. The arithmetic mean has been chosen.

Growth in oil consumption for fuel combustion: 4% p.a. (5% - 2,8%) until 1980, 3,2% p.a. in the following years (7).

Table VI: Consumption of fuel oils by domestic and commercial users

Norway total t.o.e.	1968	1980
Light fuel oils	978 433	1 566 500
Heavy fuel oils	378 576	606 100
Total	1 357 009	2 172 600

It is assumed that the proportions of light to heavy fuel oils are the same. In fact, the regulations by law will tend to favour the consumption of more light fuel oils, and this is seen as a change for the good. These figures are based on the regions according to population expectation in 1980, and consumption of fuel oils in each region in 1968.

The consumption of fuels by "domestic and commercial users" is given by (5), based on monetary values:

Wood	1 300:	10 000 NKr
Peat	20:	"
Coal and Coke	400:	"
Fuel oils	1 800:	"
Gas	15:	"
Hydroelectric power	8 500:	"

These numbers shows that there is a large consumption of wood in Norway. This is not taken into account in this report.

3.4. Refineries

Vestfold (20)

Refinery fuel (fyr 6), 2,2 % S

1968: 27 000 t.o.e. → 1 188 tons SO_2

1980: 35 800 t.o.e. → 1 575 tons SO_2

All H_2S produced is burnt for heating purposes. The emission of SO_2 by burning of H_2S in 1970 (12) at Slagentangen was of 1 692,8 tons with a refinery capacity of 4,2 mill. tons crude oil pr. year. The refinery capacity in 1968 was of 2,9 mill. tons crude oil pr. year, which gives a relative SO_2-emission of 1 168,8 tons. It is assumed that Valløy has the same sulphur content in the gas burnt there. These calculations give a SO_2-emission of 65,2 tons in 1968. The SO_2-emissions in 1980 are calculated in the same manner, assuming the same % S in the gas and no abatement equipment.

Rogaland (10)

1968

Refinery fuel, 2,5 %S, 0,02 % ash

35 800 t.o.e. ⟶ 1 790,0 tons SO_2

Refinery gas, 0,6% S, 11 500 Tcal/ton

46 400 t.o.e. ⟶ 556,8 tons SO_2

1980

Refinery fuel, 1,7% S, 0,02% ash

48 000 t.o.e. ⟶ 1 632,0 tons SO_2

Refinery gas, $<$ 0,01 %S (= 0,01 %S)

228 000 t.o.e. ⟶ 45,6 tons SO_2

The refinery has a Claus-equipment for sulphur.

Hordaland (19)

The refinery at Mongstad will start up in 1975. It is planned with sulphur recovering installation for the gas, with 90% efficiency.

1980

Refinery fuel, 1 %S

40 000 t.o.e. ⟶ 800 tons SO_2

Refinery gas

180 000 t.o.e. ⟶ 500 tons SO_2

The rest of the Mongstad complex is included in the 4 % annual increase in oil consumption in industry.

Table VII: Total consumption by refineries

1980: Case 1

	1968	1980	1968	1980	1968	1980	1968	1980
Refinery gas	101,4	508,3	383,3	1921,4	1790,8	2800,0	32,4	162,7
Refinery fuel	62,8	123,8	540,1	1064,7	2978,0	4007,0	179,6	354,1

Refinery fuel oil is treated as heavy fuel oil with average sulphur content 2,2%.

3.5. Iron and steel plants

This group includes basic iron and steel industry (11): manufacture of ferro-alloys, iron and steel works and rolling mills, iron and steel foundries. Smelting and refining of metals are included in"other industries". The smelting industry is proportionally large in Norway.

Most of the steel production takes place at three large plants:

Norsk Jernverk A/S, Nordland (6 ovens)
Christiania Spigerverk A/S, Oslo
Bremanger Smelteverk A/S, Sogn & Fjordane (1 oven).

The melting ovens producing crude iron are all electrically heated. The gas from the crude iron is used for heating purposes at Norsk Jernverk A/S. Bremanger utilizes 20 % of their gas, the rest is burnt in free air. The gas utilized at Bremanger is comparatively small, and therefore neglected here. The consumption in this group is taken from (11). Due to the small amounts of fossile fuels utilized for heating purposes, these figures are included in "other industries" in the regions (excluding Norsk Jernverk A/S).

The consumption of gas in this group is represented by the consumption at Norsk Jernverk A/S (22) which is as follows:

1968:
Gas: 32 mg S/Nm^3

235 000 000 Nm^3 = 98 700 t.o.e. $\longrightarrow$ 15,04 tons SO_2

Heavy fuel oil: 2 %S: 9 900 t.o.e.

1980
Gas: 32 mg S/Nm^3

380 000 000 Nm^3 = 159 600 t.o.e. $\longrightarrow$ 24,32 tons SO_2

Heavy fuel oil: 2 %S: 9 900 t.o.e.

3.6. Coke ovens

The only coke oven plant in Norway is situated in Nordland. Its consumption is (17):

1968:

Heavy fuel "Bunker C", 2,5% S: 9 000 t.o.e.
Light naphtha (0,05% S ≃ 0% S) 10 000 t.o.e.
Coke oven gas (S removed), 4 500 kcal/Nm^3
7.10^7 Nm^3 = 31 500 t.o.e.

1980:

Fuel oils will probably be replaced by gas or hydro-electric power in the future. It is here assumed that gas is used. Coke oven gas: 50 500 t.o.e.

3.7. Other industries. 1968

This group includes smelting and refining of metals. All smelting ovens are heated by hydro-electric power.
In the production of siliconmanganese and ferromanganese in closed ovens, the gas produced may be utilized for heating purposes (the gas from production of ferrosilicon may not).

Plants using their gas are:

Sauda, Rogaland
Tinfos, Telemark
Porsgrunn Elektrometal, Telemark

The plant last mentioned burns the main part of the gas produced in free air, some is sold to Norsk Hydro A/S, Telemark, which has also a closed oven for production of carbide. The amounts utilized are relatively small, and very difficult to estimate and in this report they are not taken into account.

The consumption of fuel oils in each region is given by (12) and the figures are used directly. In the regions the consumption by iron and steel industry is included in "other industries". The consumption at the refineries is not included.

3.7.1. Consumption of gas

Table VIII: The consumption of gas in Norway 1966 (7).

National consumption.		246 mill m^3
Utilized for secondary energy production		65 "
Total		311 mill m^3
		≈ 1 306 tcal
Utilized in industry:	790 tcal =	79 000 t.o.e.
Utilized domestic & commercial	175 tcal =	17 500 t.o.e.
Utilized total	965 tcal =	96 500 t.o.e.

Refineries	1968:	101 400 t.o.e.
Coke ovens	1968:	31 500 t.o.e.
Iron & steel	1968:	98 700 t.o.e.

These figures show that there may be small amounts of gas left for other installations.

3.8. Other industries 1980

The annual growth in the total energy-demand in industry is expected to be 5% (6). The power-demanding industry is expected

to have a higher annual growth, but as this growth will be met by hydro-electric power, it is of no consequence in this case.

It is assumed that fuel oils will meet the falling consumption of coal and coke.

The highest estimate for oil consumption for heating purposes gives 5 % annual growth, the lowest 2,8 % p.a.. The average, 4% p.a., is chosen without changing the proportion between light and heavy fuel oils, or the relative amounts consumed in each region relating to 1968.

In 1970 taxes were introduced on fuel oils relating to their sulphur content, but these taxes were to small to make light fuel oils economically competitive with heavy fuel oils.

4. Categories for Installations and Fuels

Table IX: Categories for installations and fuels in Norway.

Power Stations	Refineries	Coke ovens	Iron and steel	Other industries	Domestic and Commercial
-	-	manufac-tured gas	manufac-tured gas	manufactu-red gas	manufactured gas
Heavy fuel oil (1980)	heavy fuel oil	heavy fuel oil	heavy fuel oil	heavy fuel oil	heavy fuel oil
-	-	light fuel oil	-	light fuel oil	light fuel oil
-	refinery gas	-	-	-	-
-	-	-	(hard coal)¥	hard coal	hard coal
-	-	-	(coke)¥	coke	coke
-	-	-	-	L.P.G.	L.P.G.
-	-	(wood)¥	(wood)¥	(wood)¥	(wood)¥

¥ neglected

5. Fuel consumption in Norway

The total fuel consumption in Norway in 1968 and estimated total for 1980 is given in table X (page 19).

6. Emission loads

In calculating the emission loads, the figures from Appendix II in (1) is used:

Oxides of nitrogen: United States
Oxides of sulphur : Canada
Particulates : United States

In this report coke is dealt with as coal. When heavy fuel oils for residential purposes are replaced by low sulphur light oils as in case II-V, the light oils are assumed to contain 0,5% S.

The average sulphur content in coal and coke exceeds 1%: Coal and coke with a lower sulphur content are mainly consumed as raw materials in the processes.

The 1% oil used in cases II-V for industrial purposes is assumed to be desulphuretted heavy fuel oil, having the same qualities as common heavy fuel oil in calculating nitrogen and particulate emissions.

For each of the cases that have been examined the total emission load is summarized below:

Table XI: Total emission loads in 1968 and estimated emission loads for 1980 (Case I - V)

	1968	Case I	Case II	Case III A	Case III B	Case IV	Case V A	Case V B
Sulphur oxides	104,0	161,8	91,3	91,3	91,2	69,8	69,9	69,5
Particulates	19,9	12,5	11,6	11,6	12,4	8,2	8,2	8,2
Nitrogen oxides	23,7	34,2	34,1	34,1	34,2	34,1	34,1	34,2

The emission loads for each consumption group and each region are given in Appendix I and II.

Table X: Fuel consumption in Norway based on categories of installations and types of fuels.

Fylke : Folketall 1968: 3 835 486

Region: Total Population 1980: 4 265 139

SECTORS	TYPE OF FUEL	t.o.e. 1968	t.o.e. 1980	Notes
Power Stations	Heavy fuel	-	84 500	
Refineries	Refinery gas	101 400	508 300	
	Refinery fuel	62 800	123 800	
Coke Ovens	Coke oven gas	31 500	50 500	
	Light fuel	10 000	-	Light naphtha
	Heavy fuel	9 000	-	
Iron and Steel	Light fuel	-	-	Wood: 239m^3 (11)
	Heavy fuel	32 000*	51 200*	Hydroelectric power:6 600 000KW
	Coal	(7)	-	*Included in "Other Industry" in the regions, except Nordland region.
	Coke	(900)	(1 000)	
	Gas	98 700	159 600	
Other Industries	Manufac. gas	6 000	6 000	
	Light fuel	234 200	374 700	
	Heavy fuel	1 591 900	2 561 400	
	Coal	93 800	8 200	
	Coke	114 600	12 000	
	L.P.G.	6 000	7 000	
Domestic and Commercial	Manufac. gas	6 000	6 000	
	Light fuel	978 400	1 566 500	
	Heavy fuel	378 600	606 100	
	Coal	54 600	5 800	
	Coke	139 200	27 000	
	L.P.G.	6 000	7 000	
SUM TOTAL		3 954 700	6 165 600	

7. Operating costs

7.1. Domestic and commercial users

A reduction of pollutant emissions can only be obtained by fuel substitution in new installations. With declining consumption of coal for these uses in Norway, and the effect of price differential between the different types of fuel, it is assumed that no increase in capital or operating costs in this sector is apparent.

7.2. Oil fired power plants, refineries and industrial plants.

Case II-V

SO_2 removed by use of 1 % S oil:

63 760,2 tons SO_2 = 31 880,1 tons S

Operating costs: \$ 180 x 31 880,1 = \$ 5 738 418

Case IV - V

SO_2 removed by stack scrubbing:

21 377,2 tons SO_2 = 10 688,6 tons S

Operating costs: \$ 60 x 10 688,6 = \$ 641 316

7.3. Coal and coke fired industrial plants

The prices for coal and coke will increase as consumption decrease (distribution, sale, transport). There is assumed to be no difference in operating costs whether coal and coke are used or replaced by 1% S oil.

Case III B

Electrostatic precipitations at new plants:

Operating costs: \$ 0,9 x 3 500 = \$ 3 150

Case IV

Sulphur oxide stack scrubbing at new plants SO_2 removed:

54 tons SO_2 = 27 tons S

Operating costs: \$ 60 x 27 = \$ 1 620

Case V B

Sulphur oxide stack scrubbing at all plants SO_2 removed:

327,4 tons SO_2 = 163,7 tons S

Operating costs: $ 60 x 163,7 = $ 9 822

7.4. Total operating costs

Table XII: Operating costs in Norway

$ 1 000	Case II	Case III A	Case III B	Case IV	Case V A	Case V B
Use of 1 % S oil in industrial plants	5738,4	5738,4	5738,4	5738,4	5738,4	5738,4
Stack scrubbing in all new oil fired plants	-	-	-	641,3	641,3	641,3
Abatement equipment in coal and coke fired industrial plants	-	-	3,2	1,6	-	9,8
TOTAL	5738,4	5738,4	5741,6	6381,3	6379,7	6389,5

8 Investment costs

8.1. Domestic and commercial users

No additive investment costs.

8.2. Oil fired power plants, refineries and industrial plants

The major investments will be at the refineries, and appear in the price for low sulphur oil.

Case IV - V

Stack scrubbing at all new plants.

Power plants: assumed capacity 250 MW (18).

Investment costs: $ 15×250×1000 = $ 3 750 000

Refineries and industrial plants: 1 181 200
additional t.o.e. in 1980
Investment costs: $7 × 1 181 200 = $ 8 268 400

8.3. Coal and coke fired industrial plants

Conversion to 1% S oil use: $1.75 pr kW.
1 o.e. = 10 000 kcal 1 KWh = 860 kcal (7)
Efficiency in industry: Coal and coke: 0,83
Hydroelectric power: 1,0 (7)

Coal and coke 1980: (8 200 + 12 000) t.o.e. = 20 200 t.o.e.

The calculation is based upon continual firing during the year:

$$20\ 200 \text{ t.o.e./year} = \frac{20200 \times 1000 \times 10\ 000}{365 \times 24} \text{ kcal/h}$$

$$= \frac{20\ 200 \times 1000 \times 10\ 000 \times 0{,}83}{365 \times 24 \times 860 \times 1{,}0} \text{ KW} = 22\ 255 \text{ KW}$$

Case II, III A, V A
Investment costs: $ 1.75×22 255 = $ 38 946

Case IV
Conversion to 1% S oil at all old plants:
16 700 t.o.e. = 18 398 KW
Investment costs: $ 1.75×18 398 = $ 32 197

Case III B
Electrostatic precipitators at new plants:
Investment costs: $ 2.0×3 500 = $ 7 000

Case IV
Stack scrubbing at new plants:
Investment costs: $ 7.0×3 500 = $ 24 500

Case V B
Stack scrubbing at all plants:
Investment costs: $ 7.0×20 200 = $ 141 400

Refineries and industrial plants: 1 181 200
additional t.o.e. in 1980
Investment costs: $7 × 1 181 200 = $ 8 268 400

8.3. Coal and coke fired industrial plants

Conversion to 1% S oil use: $1.75 pr kW.
1 o.e. = 10 000 kcal 1 KWh = 860 kcal (7)
Efficiency in industry: Coal and coke: 0,83
Hydroelectric power: 1,0 (7)

Coal and coke 1980: (8 200 + 12 000) t.o.e. = 20 200 t.o.e.

The calculation is based upon continual firing during the year:

$$20\ 200 \text{ t.o.e./year} = \frac{20200 \times 1000 \times 10\ 000}{365 \times 24} \text{ kcal/h}$$

$$= \frac{20\ 200 \times 1000 \times 10\ 000 \times 0{,}83}{365 \times 24 \times 860 \times 1{,}0} \text{ KW} = 22\ 255 \text{ KW}$$

Case II, III A, V A
Investment costs: $ 1.75×22 255 = $ 38 946

Case IV
Conversion to 1% S oil at all old plants:
16 700 t.o.e. = 18 398 KW
Investment costs: $ 1.75×18 398 = $ 32 197

Case III B
Electrostatic precipitators at new plants:
Investment costs: $ 2.0×3 500 = $ 7 000

Case IV
Stack scrubbing at new plants:
Investment costs: $ 7.0×3 500 = $ 24 500

Case V B
Stack scrubbing at all plants:
Investment costs: $ 7.0×20 200 = $ 141 400

8.4. Total investment costs

Table XIII: Investment costs in Norway

$ 1000	Case II	Case III A	Case III B	Case IV	Case V A	Case V B
Stack scrubbing in power plants	-	-	-	3750,0	3750,0	3750,0
Stack scrubbing in oil fired industrial plants	-	-	-	8268,4	8268,4	8268,4
Conversion from coal and coke to 1% S oil	38,9	38,9	-	32,2	38,9	-
Electrostatic precipitators in coal plants	-	-	7,0	-	-	-
Stack scrubbing in coal and coke plants	-	-	-	24,5	-	141,4
Total	38,9	38,9	7,0	12075,1	12057,3	12159,8

9. Discussion

9.1. Power plants

The prediction for 1980 is uncertain. Oil prices and oil from the North Sea are important factors here. Oil fired power plants will be in operation probably for a period of ten years, until atomic power plants have been built. The oil fired power plant at Slagentangen is planned for 500 MW capacity; the first building step giving a capacity of 250 MW (which is considered in this report). Therefore, it is possible that the capacity in 1980 will be 500 MW. However, a further plant may come into operation by that time.

9.2. Oil from the North Sea

Oil from the North Sea has a very low sulphur content. If this oil is used in Norway, it may lead to a quite different SO_2-emission, and the operating and investment costs will decrease. The first oil from the North Sea source is being brought to Norway at the present time (May 1971).

9.3. Oil prices

The increase in oil prices on the international market will favour the use of hydro-electric power resources in Norway. However, oil from the North Sea may probably reverse this, if this oil is cheaper than hydro-electric power. The consumption and the proportional use of oil and hydro-electric power are therefore very dependent on prices.

10. Conclusion

The consumption of fossile fuels in Norway and the pollution from these is very small compared to other countries. This is mainly caused by the large use of hydro-electric power. Whether hydro-electric power will remain the chief power source in the future, is dependent on oil prices. Environmental factors will also have an influence. These problems are being closely looked at and the final solution is difficult to ascertain

World oil prices are increasing, this favouring the use of hydro-electric power. Nevertheless oil from the North Sea can have an opposite effect. As long as the price of such oil is unknown, the question will be open.

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APPENDIX I

Table XIV: Total emission loads for each consumption group and each case in Norway.

EMISSION OF POLLUTANTS - AREA - TOTAL 1980 - Case I

Fuels	Purpose	Quantity 1000 t.o.e.		tons NO_2		tons SO_2		tons particulates		%S
		1968	1980	1968	1980	1968	1980	1968	1980	1.2
Coal	Dom & Com.	54,6	5,8	311,2	33,1	546,0	58,0	780,8	82,9	1.2
	Industrial	93,8	8,2	1332,0	116,4	1609,6	140,7	4690,0	410,0	1.2
Oil										
„Lyspetroleum"	Dom. & Com.	242,9	415,0			194,4	332,0			0,04
„Gasolje"		357,0	551,0			2856,0	4408,0			0,4
„Dieselolje"		378,5	600,5	1967,7	3150,3	3785,0	6005,0	1357,0	2172,6	0,5
„Light fuel"		189,0	291,3			6615,0	10195,6			1,75
„Heavy fuel"		189,6	314,8			8342,4	13851,2			2,2
„Lettbensin"	Industrial	10,0	–		–		–		–	<0,05
„Lyspetroleum"		7,8	12,7			6,2	10,2			≤0.05
„Gasolje"		92,2	148,0			737,6	1184,0	459,1	704,4	0,4
„Dieselolje"		134,2	214,0			1342,0	2140,0			0,5
„Light fuel"		114,5	212,6	16683,1	26755,5	4007,5	7441,0			1,75
„Heavy fuel"		1581,2	2523,8			69572,8	111047,2	4849,7	7826,1	2,2
„Heavy fuel"	Power plants	–	84,5	–	1056,3	–	1690,0	–	104,8	1
Coke	Dom. & Com.	139,2	27,0	793,4	153,9	1392,0	270,0	1990,6	386,1	1,3
	Industrial	114,6	12,0	1627,3	170,4	2130,4	223,1	5730,0	600,0	
Gas	Dom. & Com.	12,0	13,0	24,6	26,7	–	–	3,0	3,3	
	Industrial	142,2	223,1	537,5	843,3	15,0	24,3	45,5	71,4	
	Refineries	101,4	508,3	383,3	1921,4	1790,8	2800,0	32,4	162,7	
TOTAL	ALL	3954,7	6165,6	23 660,1	34227,3	104942,7	161820,3	19938,1	12524,3	

EMISSION OF POLLUTANTS - AREA - TOTAL

1980

Fuels	Purpose	Quantity 1000 t.o.e.		tons NO_2		tons SO_2		tons particulates		%S
		Case II+ III A	Case IIIB	Case II+ III A	Case III B	Case II+ III A	Case IIIB	Case II+ III A	Case III B	
Coal	Dom. & Com.	5,8	5,8	33,1	33,1	58,0	58,0	82,9	82,9	1.2
	Industrial	(oil) 8,2	new 3,5 old 4,7	70,5	116,4	164,0	140,7	23,5	new 0,9 old 235,0	1.2
Oil										
„Lyspetroleum"	Dom. & Com.	415,0	415,0			332,0	332,0			0,04
„Gasolje"		551,0	551,0			4408,0	4408,0			0,4
„Dieselolje"		828,0	828,0	3150,3	3150,3	8280,0	8280,0	2172,6	2172,6	0,5
„Light fuel"		189,0	189,0			6615,0	6615,0			1,75
„Heavy fuel"		189,6	189,6			8342,4	8342,4			2,2
„Lyspetroleum"	Industrial	12,7	12,7			10,2	10,2			≈0,05
„Gasolje"		148,0	148,0			1184,0	1184,0	704,4	704,4	0,4
„Dieselolje"		214,0	214,0	26755,5	26755,5	2140,0	2140,0			0,5
„Light fuel"		(oil)212,6	(oil) 212,6			4252,0	4252,0			1(1.75)
„Heavy fuel"		(oil)2523,8	(oil)2523,8			50476,0	50476,0	7826,1	7826,1	1(2.2)
„Heavy fuel"	Power Plant	84,5	84,5	1056,3	1056,3	1690,0	1690,0	104,8	104,8	1
Coke	Dom. & Com.	27,0	27,0	153,9	153,9	270,0	270,0	386,1	386,1	1,3
	Industrial	(oil)12,0	12,0	103,2	170,4	240,0	223,1	34,3	600,0	
Gas	Dom. & Com.	13,0	13,0	26,7	26,7	-	-	3,3	3,3	
	Industrial	223,1	223,1	843,3	843,3	24,3	24,3	71,4	71,4	
	Refineries	508,3	508,3	1921,4	1921,4	2800,0	2800,0	162,7	162,7	
TOTAL	ALL	6165,6	6165,6	34114,2	34227,3	91285,9	91245,7	11572,1	12350,2	

1980	Tons NO_2					Tons SO_2					Tons particulates				
Fylke	Case II + III A	Case III B	Case IV	Case V A	Case V B	Case II + III A	Case III B	Case IV	Case V A	Case V B	Case II + III A	Case III B	Case IV	Case V A	Case V B
Østfold	4780,1	4789,7	4780,1	4780,1	4789,7	11557,3	11553,7	8112,1	8112,1	8081,1	1647,1	1727,2	1094,1	1094,1	1089,6
Akershus	1077,0	1096,6	1096,6	1077,0	1096,6	4007,1	3997,1	3500,1	3564,1	3500,1	465,7	456,6	378,8	387,9	378,8
Oslo	2828,0	2834,7	2828,0	2828,0	2834,7	11899,9	11897,9	10365,6	10365,6	10343,8	1132,1	1188,6	877,8	877,8	874,7
Hedmark	639,5	639,5	639,5	639,5	639,5	2029,0	2029,0	1704,2	1704,2	1704,2	267,1	267,1	213,0	213,0	213,0
Oppland	770,3	770,3	770,3	770,3	770,3	2226,8	2226,8	1787,2	1787,2	1787,2	300,3	300,3	227,3	227,3	227,3
Buskerud	4447,8	4455,1	4447,8	4447,8	4455,1	11033,4	11030,9	7781,8	7781,8	7758,2	1542,9	1604,2	1023,5	1023,5	1020,1
Vestfold	2581,7	2585,6	2581,7	2581,7	2585,6	7427,4	7426,4	5286,7	5286,7	5274,0	569,9	602,9	364,1	364,1	362,3
Telemark	6025,5	6031,6	6025,5	6025,5	6031,6	13894,0	13891,7	9452,9	9452,9	9432,9	2005,1	2056,9	1293,0	1293,0	1290,0
Aust-Agder	192,1	193,7	192,1	192,1	193,7	632,6	632,2	556,5	556,2	551,1	83,9	98,1	70,3	70,3	69,6
Vest-Agder	614,8	620,4	614,8	614,8	620,4	1708,9	1706,8	1344,0	1344,0	1325,8	243,5	290,7	183,3	183,3	180,7
Rogaland	2895,2	2900,8	2895,2	2895,2	2900,8	5580,2	5578,8	4410,7	4410,7	4392,6	807,1	854,2	612,6	612,6	610,0
Hordaland	1962,0	1967,6	1962,0	1962,0	1967,6	4114,0	4112,6	2833,1	2833,1	2815,0	556,8	603,9	352,0	352,0	349,3
Bergen	658,2	661,0	658,2	658,2	661,0	2134,4	2133,7	1754,7	1754,7	1745,6	245,8	269,4	182,9	182,9	181,6
Sogn & Fjordane	397,0	399,3	397,0	397,0	399,3	1265,0	1264,4	1020,6	1020,6	1013,3	156,5	175,4	116,8	116,8	115,8
Møre & Romsdal	716,5	721,6	716,5	716,5	721,6	2240,0	2238,7	1825,4	1825,4	1809,1	298,0	340,4	230,8	230,8	228,4
Sør-Trøndelag	643,4	652,4	643,4	643,4	652,4	2478,6	2475,5	2192,7	2192,7	2163,6	293,1	368,5	244,5	244,5	240,4
Nord-Trøndelag	350,2	353,0	350,2	350,2	353,0	1093,6	1092,9	918,2	918,2	909,1	146,1	169,7	116,3	116,3	115,0
Nordland	1721,4	1732,6	1721,4	1721,4	1732,6	3154,9	3150,7	2620,1	2620,1	2583,7	461,6	555,8	375,2	375,2	370,0
Troms	373,5	380,1	373,5	373,5	380,1	1492,0	1489,5	1314,9	1314,9	1293,0	177,8	234,4	148,5	148,5	145,3
Finnmark	440,0	441,7	440,0	440,0	441,7	1316,8	1316,4	1063,2	1063,2	1057,7	171,7	185,9	129,5	129,5	128,8
Total	34114,2	34227,3	34133,8	34114,2	34227,3	91285,9	91245,7	69844,7	69908,7	69541,1	11572,1	12350,2	8234,3	8243,4	8190,7

Figure 2. Map of Norway showing densely populated areas and industrial areas.

The markers indicate the centers of large emission areas.