ELECTRIC ENERGY

AND

THE ENVIRONMENT

ANALYSIS OF THE EMISSION OF AIR POLLUTANTS

IN THE ARGENTINE PUBLIC UTILITIES

DANIEL CARNEVALI

CARLOS E. SUAREZ

INSTITUTO DE ECONOMIA ENERGETICA
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SUMMARY

An analysis was made of the emission of air pollutants by the Argentine public utilities, taking into account the historical evolution from 1970 to 1989.

This has shown the impact which the substitution policies implemented in the electrical sector have had on the emission of pollutants and on the "greenhouse effect". On the one hand, these policies consisted of the substitution of conventional thermal energy by hydroelectric and nuclear energy and, on the other, substitution of fuel oil, diesel oil and coal by natural gas.

Since the conventional thermal power stations require additional investments in order to avoid air pollution, the investment savings originated in this respect by the above-mentioned substitution policies have also been calculated.

Although the environmental impacts caused by hydroelectric, nuclear and natural gas production installations are also important and are located geographically in other areas, there is no doubt that the substitution policies carried out in the Argentine electrical sector signify both an ecological and an economic benefit.

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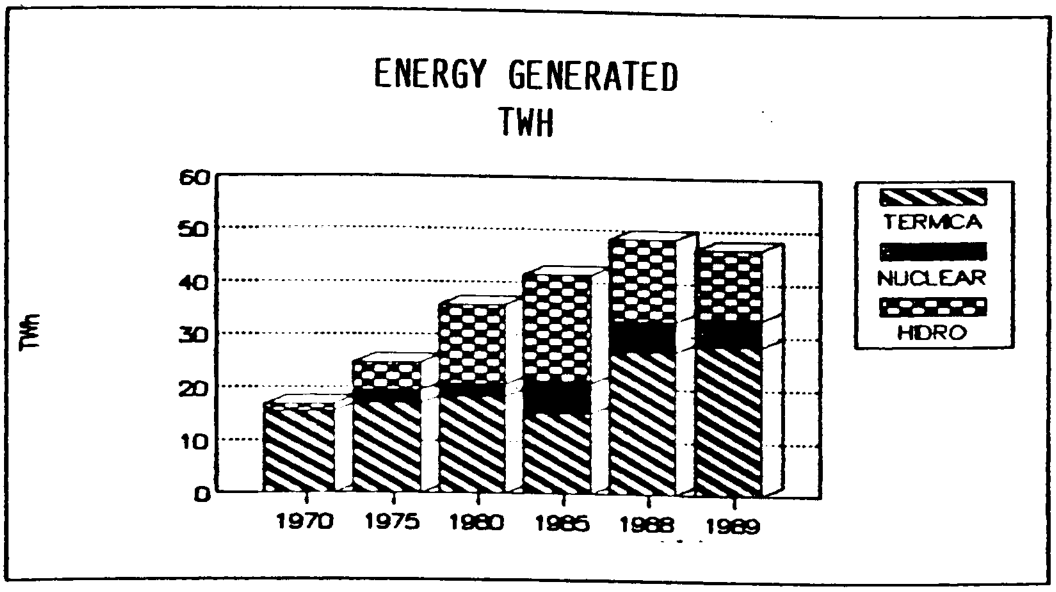
DEVELOPMENT (1)

1. Substitution of Thermal Power by Hydroelectric and Nuclear Energy

The generation of electric energy by Argentine public utilities shows the following historical evolution (Graph No. 1): a cumulative annual growth rate of 7.8% between 1970 and 1980, which dropped to 3.9% between 1980 and 1988, becoming negative in 1989 (-4.1%), with total production in 1988 almost three times greater than in 1970.

GRAPH No. 1



The successive increases in electricity generation were covered mainly by hidroelectric generation and, to a lesser extent, by nuclear and thermal generation.

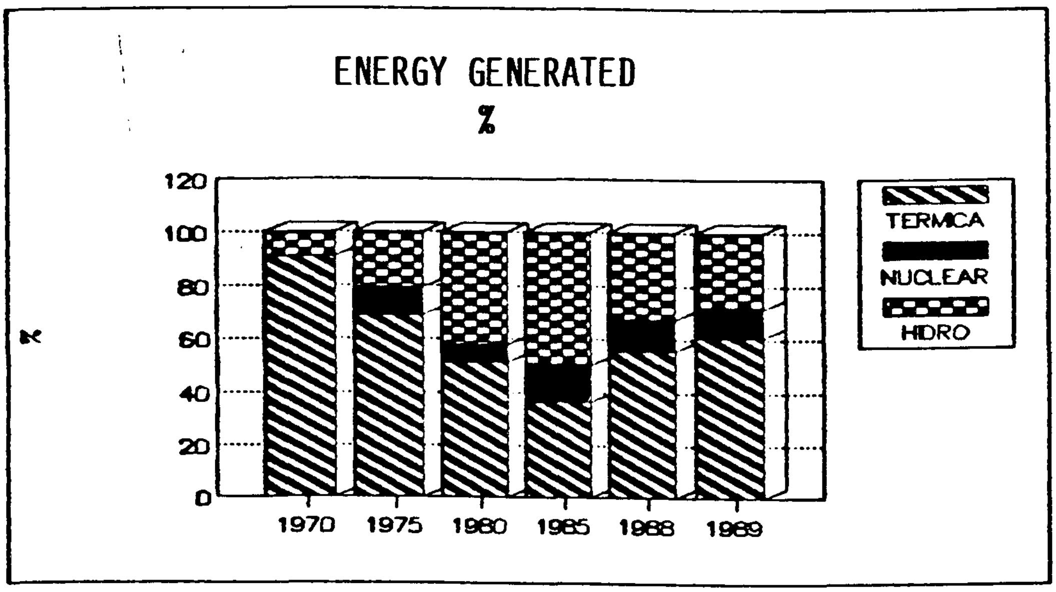
Around 1985 this tendency was intensified with even a reduction in absolute values of thermal generation. This was due to abundant availability of hydroelectric power which led to a preference for that resource oven fossil fuels.

(1) The term, 'Thermal Power' will be used in this paper to indicate 'Conventional Thermal Power'. Furthermore, the numerical data corresponding to all the graphs presented, are given in the Appendix.

Subsequently, in 1988 and 1989, low hydraulicity situations occurred in the main hydric basins, as well as some technical difficulties in the hydroelectric and nuclear installations. As a result, it was necessary to increase thermal generation again, reversing the substitution tendency recorded in previous years. The cumulated delay at that time, of the hydroelectric and nuclear proyects envisaged in the successive energy plans for ensuring continuity of the substitution strategy, forced this return to the past.

In Graph No. 2, which shows the percentage participation of the different types of power stations in generating electric energy, the substitution policies referred to can be clearly seen, with the variations mentioned around 1985, 1988 and 1989.

GRAPH No. 2

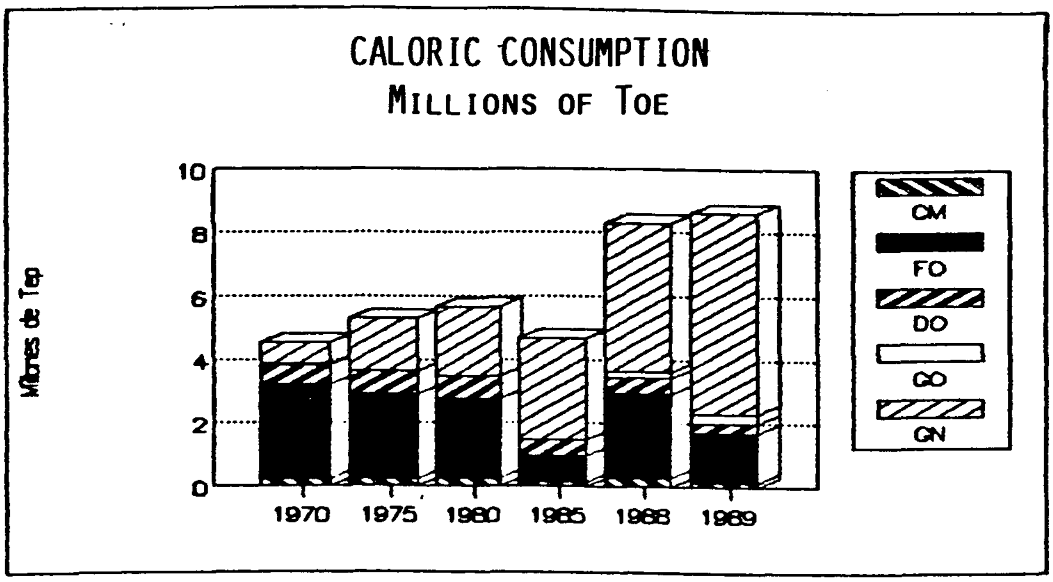


It shows that in 1985 hydro-nuclear generation reached 64% of the total compared to only 9,0% in 1970, having absorbed the whole of the increase in electricity generation of the period. The problems mentioned above meant returning in 1989 to a structure similar to that of 10 or 11 years earlier (40% hydro-nuclear and 60% thermal).

2. <u>Substitution of Fuel Oil by Natural Gas</u>

Graph No. 3 shows fuel comsumption for thermal generation. The abbreviations used correspond to: C (Coal), FO (Fuel Oil), DO (Diesel Oil), GO (Gas Oil) and NG (Natural Gas).

GRAPH No. 3



As can be observed in this Graph, a policy of fuel substitutions was added to the hydro-nuclear substitution proccess, implying that the successive increases in caloric comsumption had been covered by natural gas, gradually reducing comsumption of fuel oil.

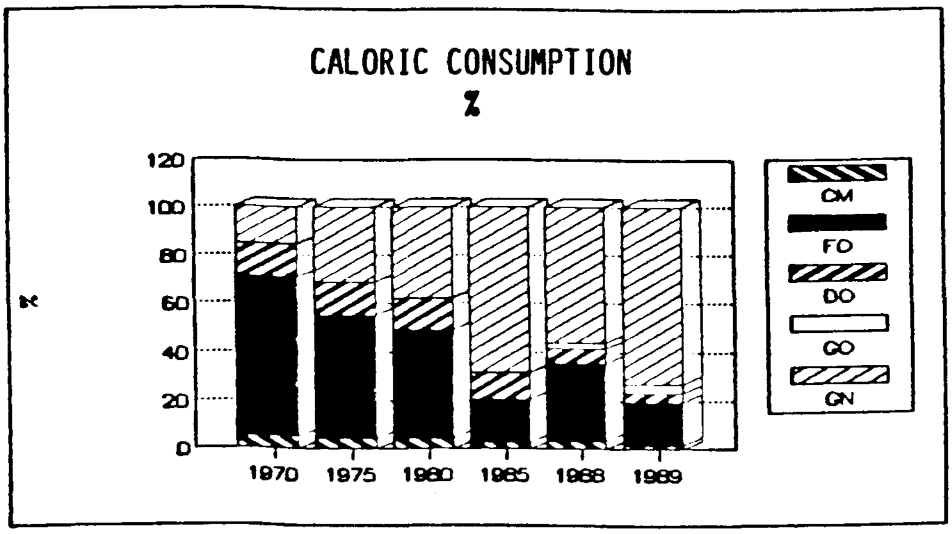
Around 1985 this tendency was strongly intensified with the start-up of the Center-West gas pipeline (in 1982) which increased the transport capacity of natural gas, thus permitting an increase in its consumption. In this way, a notable reduction of about 66% was achieved in consumption of fuel oil, diesel oil and coal. To this must be added the high hydro increase reducing fuel consumption.

The transport capacity of the above pipeline was progressively absorbed by the increases in Natural gas consumption, mainly by the Residential and Industrial sectors. For this reason, on reaching 1988 when an increase in thermal generation was required, it was not possible to maintain the percentage share for natural gas since the transport capacity of that fuel was relatively saturated. It was therefore necessary to resort to raising the participation of fuel oil and even coal temporarily, reversing the substitution tendency which was occurring. In addition, there was an increase in the use of diesel installations, which are generally not adapted to operate with natural gas, and in many cases are located in places where natural gas does not reach. This led to an increase in gas oil consumption, which until that time had been negligible.

With the start-up of the Neuba II gas pipeline in the second half of 1988, transport capacity of natural gas was risen again. Consequently, another increase in the participation of natural gas was observed, along with a drop in fuel oil and coal consumption to similar levels than those of 1985 (i.e. a return to the afore-mentioned substitution policy). This, however, was not the case for gas oil, which substituted diesel oil in a technically unjustifiable process, since the available DO did not cover the required technical specifications.

All this can be clearly appreciated in Graph No. 4 which shows the percentage participation of the different fuels in thermal generation.

GRAPH No. 4



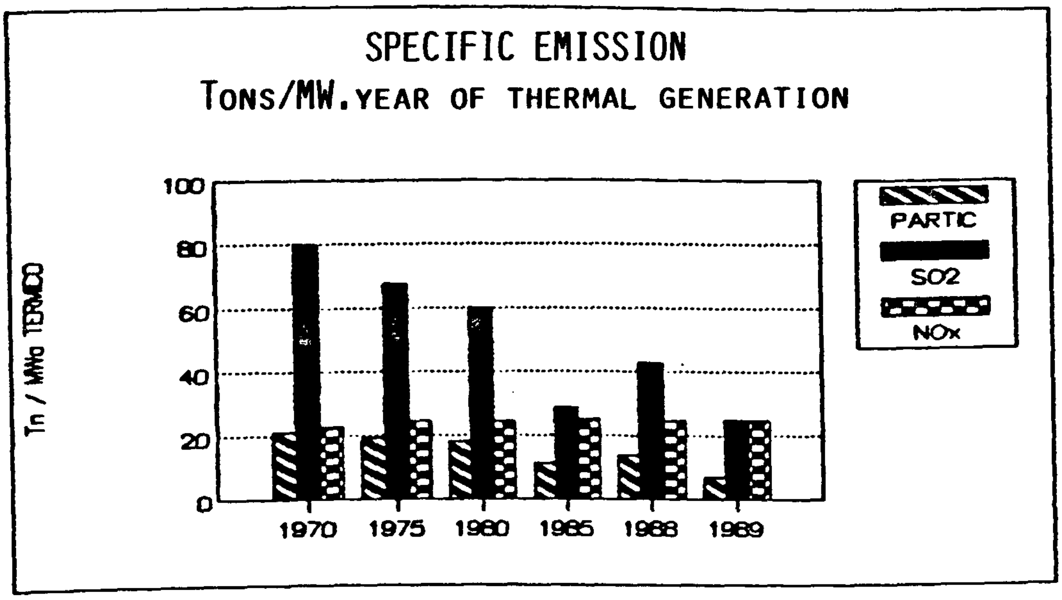
It can be observed that in 19 years, the participation of natural gas goes from 15% to 73%, causing that of coal to drop from 5 to 2% and oil products from 80% to only 25%.

Both substitution processes analyzed, which are the pivots of the electrical development strategies forecast by the energy plans drawn up in the 60's and 70's, have had a significantly, positive impact as regards the emission of air pollutants connected with the greenhouse effect, acid rain and deterioration of the ozone layer. Ind the following points, the evolution of emission of atmospheric pollutants by the Argentine electrical sector from 1970-1989 is detailed.

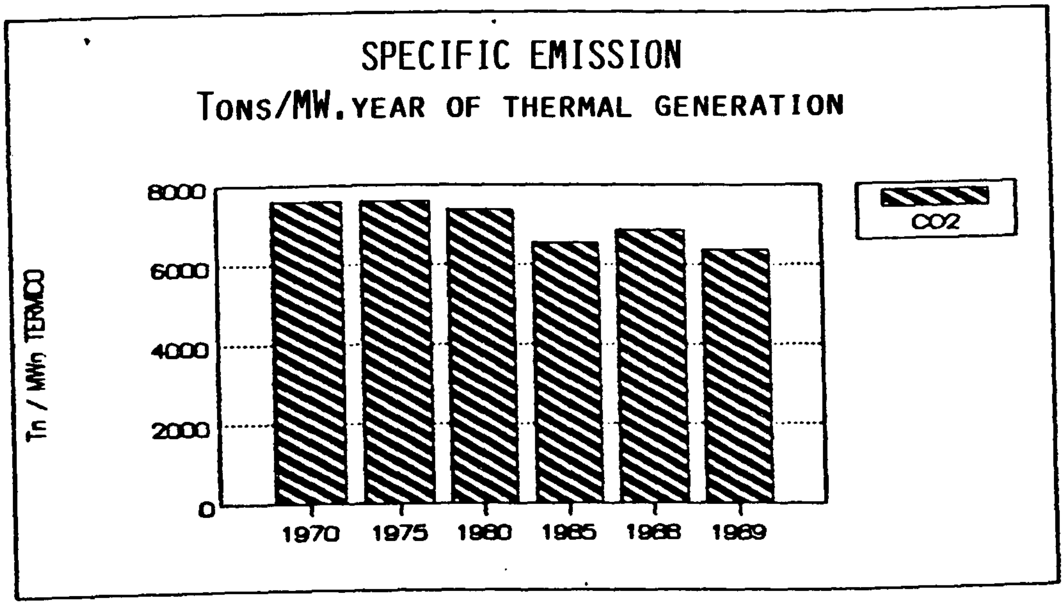
3. Emission of Pollutants

On analyzing in the first place the Specific Emission of Pollutants per MW.year of thermal generation, the following is observed:

GRAPH No. 5



GRAPH No.6



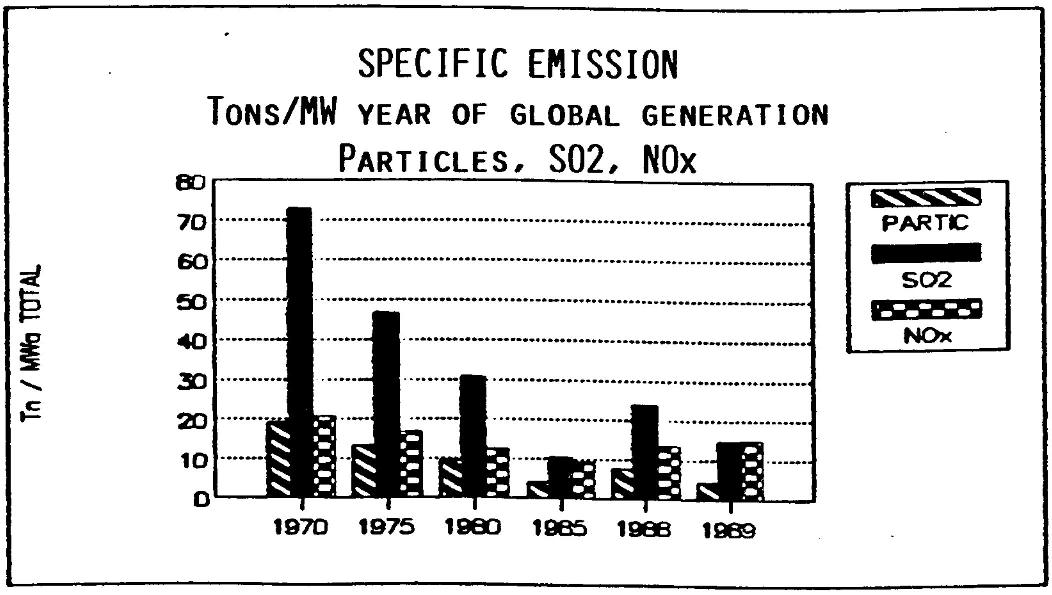
The impact of the policy of substitution by Natural gas is obvious, with the afore-mentioned variations in 1985, 1988 and 1989.

It can be said that evolution in the Specific Emission of SO_2 and CO_2 essentially follows, with different intensities, the evolution in percentage participation of fuel oil (see Graph No. 4). In addition, evolution in Specific Emission of particles essentially follows evolution in the percentage participation of coal and, to a lesser extent, of fuel oil. This latter is because coal, although used in small quantities, emits a much greater amount of particles than fuel oil (see "Emission Factors" in Appendix).

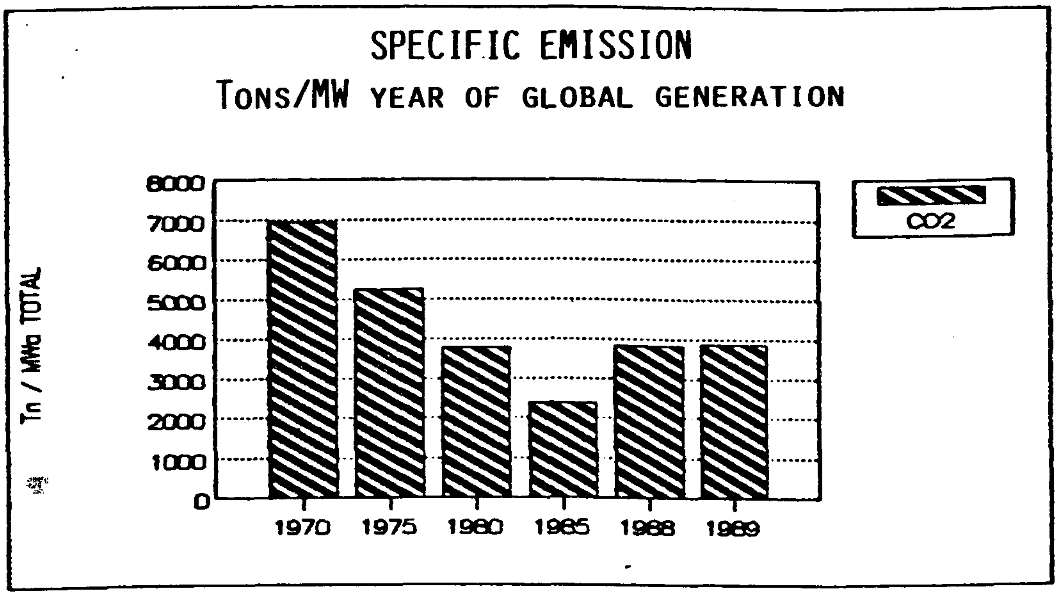
Finally, the emission of NOx does not show much difference between the various fuels since basically it is formed from the nitrogen present in the air. Therefore, it is rather a result of the combustion process, relatively independent of the type of fuel used. For this reason, the Specific Emission per MW.year of thermal generation for this contaminant is practically constant.

Turning to an analysis of the Specific Emission per MW.year of global generation (hydroelectric + nuclear + thermal), the result of the policy for substitution of thermal energy by hydroelectric and nuclear energy (Graph No.2) can be clearly seen. In other words, on reducing the percentage participation of thermal generation in global generation, the result is a reduction in the Specific Emission for every MW.year of global generation.

GRAPH No. 7



GRAPH No. 8



Thanks to the above-mentioned substitution policies, it can be seen that specific global emission was reduced substantially between 1970 and 1985, reaching the following values in this latter year as regards the base year, taken as 100:

S02	14
PARTICLES	21
CO2	35
NOX	43

Unfortunately these achievements were partially weakened in 1988 and 1989, as a result of the crisis of the electrical sector in those years and of the delay in the hydro-nuclear projects caused by financial difficulties. The problem was at its height in 1988, when the global specific emission levels rose sharply as compared to 1985 in the following percentages:

S02	140 %
PARTICLES	100 %
CO2	60 %
NOX	56 %

due to the above-mentioned restrictions in the natural gas transport capacity.

In 1989, with the start-up of the Neuba II gas pipeline, the problem of natural gas provision was solved, allowing the emission of particles to be completely controlled. This however does not occur with the other contaminants, whose emissions were still higher than the 1985 values in the following percentages:

NOx	67 %
CO2	61 %
SO2	50 %

This situation is not solely circumstantial in nature, since the delay in Yacyretá, Piedra del Aguila and Atucha II will mean that the above-mentioned increase will be intensified, at least until the mid-90's, as was partially foreseen in the National Energy Plan 1986-2000.

This aspect, which until now had not been contemplatd explicitly in the national energy plans, shows unmistakebly how a proper consideration of the environmental impacts of thermal generation, particularly with coal and fuel oil, may lead to re-examining policies developed recently, based on purely economicist criteria.

4. Investment Savings arising from the Substitution Policies

Another important aspect to be considered on comparing electric energy generation alternatives, is the additional investment which must be made in thermal power stations if it is desired to reduce the emission of particles, SO2 and NOx.

To make these calculations, the average known values of "Investments for Controlling Emission of Pollutants in Electric Power Stations" (see Appendix) are used. These investments are proportional to the installed power which it is desired to control.

The calculations were made on the basis of the following criteria:

a) Hydroelectric and Nuclear Energy: Starting out from the energy generated in each year, and using an average load factor of 40% for hydroelectric power Stations and 70% for nuclear, the "theoretical" installed power corresponding to that equipment was calculated. It was then assumed, that this power was replaced by thermal equipment, and the necessary investment for controlling the emission of particles, SO2 and NOx were applied.

b) Natural Gas: Starting from the consumed natural gas value in each year and assuming thermal efficiency of 25%, the electric energy generated with natural gas was calculated. Next, taking into account an average load factor of 40%, the "theoretical" installed power which uses natural gas was calculated. It was then assumed that this power was supplied with fuel oil and diesel oil and the investments necessary for controlling particles and SO2 emission were applied. In this case the investments for controlling NOx emission were not considered since this pollutant is relatively independent of the type of fuel used, and consequently it is emitted at the present time with natural gas.

The following are the results obtained:

INVESTMENT SAVINGS (Millions of u$s):

Year	Hydro	Nuclear	Natural Gas	Total
1970	99	0	0.1	99
1975	339	95	0.2	435
1980	997	89	0.3	1086
1985	1361	218	0.5	1580

The calculation was not made for 1988 and 1989 since the hydro-nuclear generation to substitute was less than that of 1985.

As can be seen the amounts saved are not negligible (1,580 million dollars) and with them the completion on time of Atucha II and/or Piedra del Aguila could certainly have been financed.

In addition, an estimate must be made of the savings in Operation and Maintenance of the pollution control installations, and it should be remembered that the control is not absolute and therefore the emissions would have been in any case greater than those in fact observed.

As regards CO2 an equivalent calculation has not been made, since to date technological means are not available at power station level which would allow it to be eliminated. Perhaps it would be necessary to calculate the equivalent investment in afforestation which would allow the absorption of a quantity of CO2 equal to that not emitted by hydro-nuclear generation and the use of natural gas.

CONCLUSIONS

It can be clearly seen that the substitution policies carried out in the electrical sector (2) originate an important benefit as regards emission of pollutants. This benefit is evident, on the one hand, through a substantial reduction in pollutants emitted and, on the other, through an important saving in investments for controlling pollution. Both benefits are additional to those originally foreseen, since they were not taken into account when the above-mentioned strategies and policies were defined.

Of course, the strategy chosen produces, in turn, other environmental impacts of a local nature, associated with the hydroelectric, nuclear and natural gas production installations. All these impacts will have an ecological and economic component which will have to be compared correctly with the benefits already mentioned.

From this viewpont, it can be stated that the substitution policies produce an inter-regional transfer of the ecological and economic impacts: as regards the economic part, through the regional investments in hydroelectric, nuclear fuel cycle and natural gas production and transport installations, and as regards the environmental aspect, transfer occurs between the large urban centers (whose environment becomes less polluted) and the different regions of the country where the installations mentioned above are located.

Doubtless it would be most important for the country that the Environmental and Social Evaluation Area, which reports to the National Energy Under-Secretariat, receive all the necessary support, both economic and institutional, in order to be able to carry out a periodic, systematic follow-up of all the environmental problems associated with the generation of electric energy and with the energy system in general.

The systematic publication and difusion of the indexes calculated in this paper (Specific Global Emission), can contribute to enhance the necessary awareness for introducing, from the start, the environmental aspects into the national energy planning process.

(2) On the basis of a strategy explicit in the national energy plans, priority is given to the most abundant, renewable natural resources, together with the technological development implicit in the nuclear option.

APPENDIX

ELECTRICAL GENERATION: In GWh (ref. 2)

Year	Termal	Nuclear	Hydro	Total
1970	15315	0	1492	16807
1975	16929	2517	5122	24568
1980	18274	2340	15057	35671
1985	15170	5766	20560	41496
1988	26985	5798	15682	48465
1989	28186	5039	13264	46489

ELECTRICAL GENERATION: In %

Year	Termal	Nuclear	Hydro	Total
1970	91	0	9	100
1975	69	10	21	100
1980	51	7	42	100
1985	37	14	50	100
1988	56	12	32	100
1989	61	11	29	100

FUEL CONSUMPTION: In Thousands of Toe (ref.2)

Year	CM	FO	DO	GO	GN	Total
1970	229	2974	632	8	678	4521
1975	242	2665	724	3	1638	5272
1980	253	2503	739	8	2141	5644
1985	138	831	501	9	3184	4663
1988	280	2661	501	188	4662	8292
1989	144	1542	324	310	6299	8619

FUEL CONSUMPTION: In %

Year	CM	FO	DO	GO	GN	Total
1970	5	66	14	0	15	100
1975	5	51	14	0	31	100
1980	4	44	13	0	38	100
1985	3	18	11	0	68	100
1988	3	32	6	2	56	100
1989	2	18	4	4	73	100

EMISSION FACTORS: In Kg/Toe (ref. 1)

Type	Coal	Fuel Oil	Diesel Oil	Natural Gas
Part	120.97	2.90	0.64	0.05
SO2	62.90	38.30	17.84	0.01
Part	16.94	8.07	8.64	9.46
Part	3836	3050	2969	2121

INVESTMENTS FOR CONTROL OF POLLUTANTS EMISSION IN ELECTRIC POWER STATIONS: IN u$s/MW (ref. 1)

Type	Average Investment
Part	54000
SO2	128000
NOx	50000

SPECIFIC THERMAL EMISSION

YEAR	PART Tn/MWa	SO2 Tn/MWa	NOx Tn/MWa	CO2 Tn/MWa
1970	21	80	23	7599
1975	19	67	25	7603
1980	18	60	25	7364
1985	11	29	25	6545
1988	14	43	25	6858
1989	7	25	25	6371

GLOBAL SPECIFIC THERMAL EMISSION:

	PART		SO2		NOx		CO2	
YEAR	%	Tn/MWa	%	Tn/MWa	%	Tn/MWa	%	Tn/MWa
1970	100	19	100	73	100	21	100	6925
1975	68	13	63	46	81	17	76	5239
1980	47	9	42	31	62	13	54	3772
1985	21	4	14	10	43	9	35	2393
1988	42	8	33	24	67	14	55	3818
1989	21	4	21	15	71	15	56	3863

REFERENCES

(1) "Publications, Work Reports and Personal Communications". Area of Environmental and Social Evaluation, National Energy Under-Secretariat.

(2) "Publications, Work Reports and Personal Communications" Energy Evaluation Division, National Energy Under-Secretariat.

ELECTRIC ENERGY AND THE ENVIRO NMENT

ANALYSIS OF THE EMISSION OF AIR POLLUTANTS IN THE ARGENTINE PUBLIC UTILITIES

a) Resumen → la Introducción

b) Palabras claves

- Air pollution
- Thermal Power
- Nuclear Power
- Hydroelectricity
- Oil substitution
- Power planning
- Argentina
- 1970-1989

c) To be published in Proyecto Energético, Argentina, Spanish and Natural Resources Forum, UN, New York