



**Mines
de Douai**

Luc BOUTARIN
Promotion 2007

S3 INTERNSHIP REPORT

AGH University of Science and Technology
Faculty of Fuels and Energy

AGH-EDF joined laboratory for environmental impact analysis

ENVIRO PROJECT



CONFIDENTIAL DOCUMENT

15th of May to 13th of August 2006
Cracow, Poland

Ecole des Mines de Douai
Option Environnement et Industrie

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- CHARACTER OF CONFIDENTIALITY -

- ✓ This document is strictly confidential, but the abstract is freely accessible.

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I would like to express my gratitude to Mr Artur Wyrwa, leader of the ENVIRO project, for giving me the opportunity to be part of it, and for supervising my training period.

Dziękuję !

- TIMETABLE -

Starting & ending point	Week	Activity
15th of May 4th of June	week 20	Discovering of work environment. Training on the RAINS model
	week 21	
	week 22	
5th of June 9th of July	week 23	Final development of RAINS Poland (EMCO SO ₂ , NO _x and PM). Assistance for ENVIRO project interim report 3 realization.
	week 24	
	week 25	
	week 26	
	week 27	
10th of July 13th of August	week 28	Development of RAINS Poland (EMCO NH ₃). Preparation of S3 report
	week 29	
	week 30	
	week 31	
	week 32	

The internship was divided in three phases which are listed below with approximate dates. A normal day of work began at 9am and finished between 4 and 7pm (with about one hour break for lunch), depending on the amount of tasks to fill.

15th of May to 4th of June (3 weeks)

- Discovering of work environment
- Readings about Polish energy sector
- Readings about the RAINS model
- Training on the RAINS model in order to became familiar with it

5th of June to 9th of July (5 weeks)

- Final development of RAINS Poland :
 - EMCO SO₂
 - EMCO NO_x
 - EMCO PM
- Assistance for ENVIRO project interim report 3 :
 - Data management
 - Figures realizations
 - Writings

10th of July to 13th of August (5 weeks)

- Development of RAINS Poland :
 - EMCO NH₃
- Preparation of S3 report

- ABSTRACT -

I held my internship as an assistant-researcher between 15th of May and 13th of August 2006 in Cracow, Poland. I worked at the Faculty of Fuels and Energy of AGH University of Science and Technology, more precisely in the AGH-EDF joined laboratory for environmental impact analysis.

I took part in the ENVIRO project. It is a project launched by EDF Polska in order to “Optimize Environment Protection Investments of EDF Polska Companies to Meet the Sustainable Development Criteria” as its full name describes it. The workpackage of the group I was integrated in was atmospheric and dispersion modelling of pollutants and integrated impact assessment. I worked on integrated impact assessment with the RAINS model.

Our aim was to develop some parts of the Poland specific version of RAINS. More specifically, the work consisted of modifications and adaptations of the European/Asian version of the emission and control module (EMCO) of the model. We had to manage with several databases, SQL programming, calculations... In the middle of my internship the EMCO module was developed for three pollutants (SO₂, NO_x, and PM) and we were able to deliver preliminary results. Those results were presented in the project interim report 3. After that we started the development of EMCO NH₃ and this work is still going on.

Remark on the reading of this document

A terminology for abbreviations is presented on page n°51.

I. INTRODUCTION

This report presents my third internship as a student from the Ecole des Mines de Douai. My placement was assistant-researcher in the AGH-EDF joined laboratory for environmental impact analysis, in Cracow, Poland. I was integrated to the workgroup of Mr Artur Wyrwa, leader of the ENVIRO project, between 15th of May and 13th of August 2006.

I chose this internship in order to gain an international experience and to learn about air pollution. It is a sector where my knowledge was limited and I wanted to improve it.

After a short presentation of the work environment I will present the main facts about the ENVIRO Project. It will lead to the exposition of the work I had to produce on the RAINS model for integrated impact assessment. This work allowed me to have some lessons and they will be presented at the end of the report.

II. WORK ENVIRONMENT

a. Akademia Górniczo-Hutnicza University of Sciences and Technology (AGH-UST)



The university was created in 1919 in order to train mining engineers, as it was a great need for Polish development, with 80 students and 6 professors. Then it was expanded to metallurgic activities in 1922.

Running over years and difficulties of Poland history (World War II), the university constantly grew up to become one of the major learning Polish institute. Nowadays studies are no longer applied only on mining and metallurgic fields but also on all other scientific and technologic activities, with 16 different faculties. But the actual university name, changed in 2003, still refers to the primary activities ("Górniczo-Hutnicza" means "Mining-Metallurgy").

Key figures (2003)

29 437 students including 18 587 in full-time and 45 foreign ones

3 962 teachers including 608 professors

16 faculties



AGH main building

b. Faculty of Fuels and Energy



Created 28 years ago as an Institute, it gained the title of Faculty in 1991. The teaching programme is related to modern technologies of processing and utilization of solid, liquid and gas fuels in relation to problems of environmental protection connected with cleaning of outgases and water, communal and industrial sewage treatment. The faculty actually teaches to 830 students with the help of 50 staff members, 14 of them professors. Three specializations are proposed :

- fuel technology
- environmental protection in power and chemical industry
- fuel and energy economy and management

This faculty is hosting the AGH-EDF joined laboratory for environmental impact analysis, in which my internship took place.



Faculty building where my internship took place

c. EDF Polska – Elektrociepłownia Kraków (ECK)



EDF Group has been present in Poland for over ten years, providing a full range of energy and environmental services. EDF Polska is currently leading 13 installations in Poland, including the head office in Warsaw.

ECK is the combined heat and power plant in Cracow. The facility was built between 1968 and 1970 and was a state-owned company until 1998 when, as a result of privatization, it gained a strategic investor : a consortium of EDF and Finelex BV.

Key figures

EDF Polska (2005)

Installed capacities : 3 215 MW_e and 4757 MW_t

Electricity production : 14,5 TW_h

Heat production : 34 600 TJ

Employment : 4 756

ECK (2005)

Installed capacities : 460 MW_e and 1 236,4 MW_t

Electricity production : 1 817 GW_h

Heat production : 8 206 TJ

Employment : 631

SO₂ emissions : 1 461,8 mg/Nm³

NO_x emissions : 569,9 mg/Nm³

Dust emissions : 124,2 mg/Nm³

N.B. : all EDF Polska installations obtained ISO 14001 certificates.



ECK chimneys



Coal stock in ECK



Power generator

III. WORK REALIZED

For the good comprehension of the report, it seems important to get a little overview of the Polish context in the energy sector and some general facts about international and European legislation on air pollution. Then I will present the ENVIRO project, in which my internship took part. This presentation will include explanations about the RAINS model and the work done on it in order to develop RAINS Poland specific version.

1) POLISH CONTEXT



Fig.1 : Map of Poland

Poland superficy is about 312 600 km², and counts a little more than 38 million people. But this number is actually decreasing. After several years of German, Austrian and Russian occupation, independence appeared in 1918, and World War II over, the country was free but under communism influence. After several years of political fights and workers strikes, Poland became a parliamentary democracy at the end of the 80s. From this moment, evolution of Polish economy is on the way, but the quite unstable political situation (several government turn-aways) is not helping.

Nowadays, even if the economical growth is above 5%, the unemployment is about 18% and more than 13% of population is living under the poverty line. Rural population is still important (38%), and the agricultural sector is employing 18,4% of active population. Industrial and services sectors are respectively employing 28,6 and 53% of active population.

Poland entered European Union the 1st of May, in 2004. Need for evolution is now crucial, in order to reach all European criterias.

a. Polish energy sector

The Polish energy sector will arrive in the next decade at a crucial turn of its history. Although the sector passed through a radical transformation since the late 1980s, following political evolution, changes are still needed in order to respond to social, economical and environmental constraints.

The adhesion to European Union is putting the country under the future applicability of most of European directives regarding energy management and environmental protection, all related to economy (Geneva Convention on Long-Range Transboundary Air Pollution, United Nations Framework Convention on Climate Change...). In nowadays estimations, Poland needs between 10 and 40 billion € of investment in the energy sector in order to reach European criterias in the future. The critical reflexion for Poland is now to think of the best investment way, which will prevent the country from a dead-end street.

Coal in Poland

The energy production is strongly coal-dependant (95% of electricity production), and Poland still got several coal mines all over the territory, employing more than 120 000 people. Total reserves are up to 30 000 million tonnes, which allows 300 years of sufficiency at current consumption ; but in fact, current and shortly operational reserves are only around 3 000 - 4 000 million tonnes, so they will be used within 30 to 40 years, unless new exploitations arise.

Use of coal is a two-edged sword : it allows a good self-sufficiency in energy for next years but it is not environmentally friendly (for example Poland is the largest SO_x emitter in Europe) and its exploitation could happen to become uncompetitive in 20 years. Poland can enjoy the feeling of fuel sufficiency but, time running out, it will be harder and harder to delay the switch to a low-carbon economy. Policy-makers should plan in next years tough decisions.

Alternatives

In Poland, more than 40% of boilers and 30% of turbines are over 30 years old, and will soon need a replacement. All technological decisions that will be made should be done carefully, as mistakes done would be hardly remediable before the mid-century.

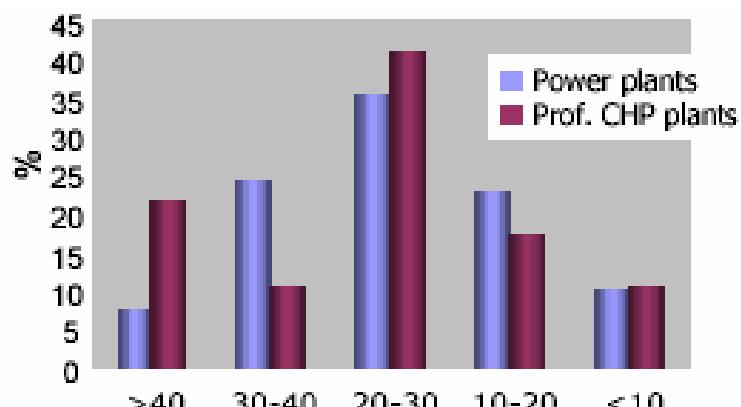


Fig.2 : Age of power plants in Poland [1]

Further development of cogeneration plants

Actually 17,6% of electricity produced in Poland is coming from co-generated heat and power (CHP) plants, leading to a 9 million tonnes coal saving. This percentage can be increased. Work can also be done in order to find a solution to the synchronization problem of CHP : power is mainly needed during day and heat during night. If a means to stock heat is developed, further coals savings could occur.

Ultra-super-critical coal-fired technology

This technology could allow reaching 50% efficiency in power plants instead of 37% actually. It would lead to a 27% coal economy.

Gas-fired plants

The advantage is an improvement in reducing emissions, but there is also the disadvantage of exterior dependence for provisioning and gas price.

Nuclear

Nuclear seems to be unavoidable in order to reach Europeans criterias. We can expect that quite a percentage of electricity production in Poland will come from that technology in the next years.

Renewable resources

With proper investments, wind farms implemented near the Baltic Sea could produce almost 10% of power needs. An other solution can be biomass : thanks to the agricultural context in Poland, its use could be a good alternative in order to save some coal.

It is possible to use renewable resources in Poland, but this sector need a start, only possible with risky investments. Maybe the government can give a hand in this area.

Poland can reach European criterias without killing its economy if a good mix of all alternatives is applied. That is why scientific and financial studies on environmental impact assessment for energy sector are strongly needed.

b. International and European legislation

Air pollution appeared in the international agenda in the seventies, when problems with acid rain and eutrophication reached the crisis point. This led to the establishment of the Convention on Long-Range Transboundary Air Pollution (CLRTAP) in 1979 in Geneva, which four years later entered into force. The Convention calls “*(...) for controlling and reducing the damage to human health and the environment caused by transboundary air pollution...*”. Up to the present the Convention has been extended to other pollutant-related issues with specific protocols.

In the late 1980s, a number of intergovernmental conferences focusing on climate change held, based on last scientific studies on the subject. To tackle this problem, the UN Framework Convention on Climate Change was signed by 154 countries in 1992 at the Earth Summit in Rio de Janeiro. The ultimate objective of the Convention is “*(...) to achieve stabilization of atmospheric concentration of greenhouse gases at levels that would prevent dangerous anthropogenic*

interference with the climate system...". In 1997 the Parties to the Convention accepted the Kyoto Protocol, in order to reduce their collective emissions of greenhouse gases.

Those international conventions have a great impact on European development. The European Commission set a strategy on air pollution : Clean Air For Europe (CAFE) program, which aim is to provide technical analysis and policy development to guarantee air quality in Europe. CAFE has compiled a set of baseline projections (mainly prepared by IIASA with RAINS model) outlining the consequences of current legislation on air quality and health. Then it explored environmental and financial benefits with different scenarios where the pollution is limited. It showed that preventing air pollution by investing in different control technologies will allow a great benefit on health care (up to 42 billion € per year), exceeding the investments. This statement, affirming that pollution control is leading to financial benefits, must now be translated in legislations and development strategies for all European countries.

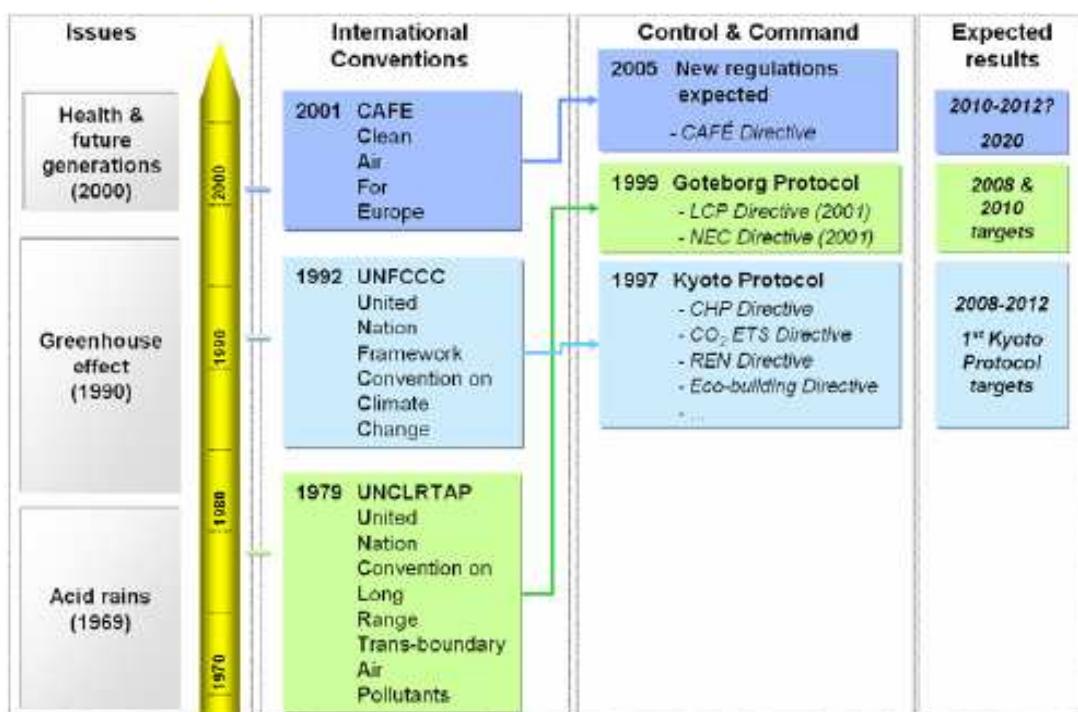


Fig.3 : International conventions for air pollution [2]

2) ENVIRO PROJECT

“Optimizing Environment Protection Investments of EDF Polska Companies to Meet the Sustainable Development Criteria”

As a company, EDF Polska is looking forward to invest more in Poland. But the actual Polish context is putting the firm into a difficult situation. Investments will have to be chosen very carefully in order to fulfil the increasing energy demand and European regulation without hurting either Polish economy or Polish people quality of life. EDF is trying to analyse the environmental social and economical impact of different scenarios of energy development to identify where and in which technology to invest. By this way good decision-making for investments will be guaranteed. In order to effectively perform such integrated impact analyses the collaboration with scientists is required.

So EDF decided to handle this by creating the ENVIRO project (full name : Optimizing Environment Protection Investments of EDF Polska Companies to Meet the Sustainable Development Criteria). The project is gathering several scientists from different polish institutes and universities (including AGH), and also setting cooperation with European institutes (IIASA, CEREA, ElfER...), that have great experience in this field. The main objective of the ENVIRO project is to provide a feedback that can help in building the EDF Polska strategy for investments into environmental protection for the next 10 to 20 years while answering the increasing need for energy demand. In the process, integrated analyses of environmental impact of EDF companies will be made using Integrated Assessment Model (IAMs) RAINS.

The kick-off meeting of the project held the 19th of May 2005 in AGH. Four work packages were set (I will next focus on the third one, as it was the one were my internship took place) :

1. Regulations and scenarios of energy development
2. Status of data base
3. Atmospheric and dispersion modelling of pollutants and integrated impact assessment
4. CBA and optimizing the EDF investments in environment protection

The aim of the work package n°3 is to perform the atmospheric dispersion of pollutants, first at national level then at regional level, and to perform an integrated impact assessment with given scenarios for future energy development. The atmospheric modelling is performed with POLYPHEMUS model and the impact assessment with RAINS model and studies on external costs (cost arising when the social or economic activities of one group of persons have an impact on another group and that impact is not fully accounted for by the first group). My work was related to the RAINS model.

Next, main facts about the ENVIRO project are listed :

Why the project is important

- ✓ Emission reduction targets set by the international Conventions UNCLRTAP and UNFCCC, which have been ratified by Poland, as well as EU regulations concerning air quality (CAFE), strongly affect the development of the Polish energy sector
- ✓ The adoption of relevant regulations constitutes a major financial burden for the development of energy sector
- ✓ The number of studies on integrated environmental and health impact assessment of Polish energy sector (and other sectors) also which take into account the external costs, is not

sufficient (such studies hardly exist)

- ✓ It is of great importance to provide the least cost solutions to maintain the environmental, social and economical equilibrium at present and also in next decades

Genesis of the problem

- ✓ Poland is a coal-based country, which currently uses 52% of hard coal and 13% of lignite for its primary energy demand and will still remain the main energy carrier in, at least, the next 10 to 20 years
- ✓ Poland is the largest SO₂ emitter in Europe with significant emission of other pollutants like NO_x or PM.
- ✓ Most of the existing power plants will need complete replacement or overhaul over the coming 10 to 30 years
- ✓ Significant amount of bad quality coal is burnt outside the LCP sector without any emission control measures implemented (rural domestic heating for example)

Tasks

- ✓ Modelling of atmospheric dispersion of pollutants at the national and regional level (in regards to the latter in particular in regions where EDF companies are present) using POLAIR 3D and POLYPHEMUS model
- ✓ Preparation of the historical data on and modelling of the future activity levels of sectors (giving the emphasis on the energy sector)
- ✓ Integrated environmental (and health) impact assessment of Polish energy sector (EDF companies)
- ✓ Cost benefit analysis of the environment protection investments of EDF companies
- ✓ Optimization of the investments to meet relevant regulations
- ✓ Further development and improvements of methodology and tools

Main objective

- ✓ Provide the feedback for building EDF Polska strategy for the investments into environmental protection for the next 10 to 20 years while answering the increasing need for energy demand

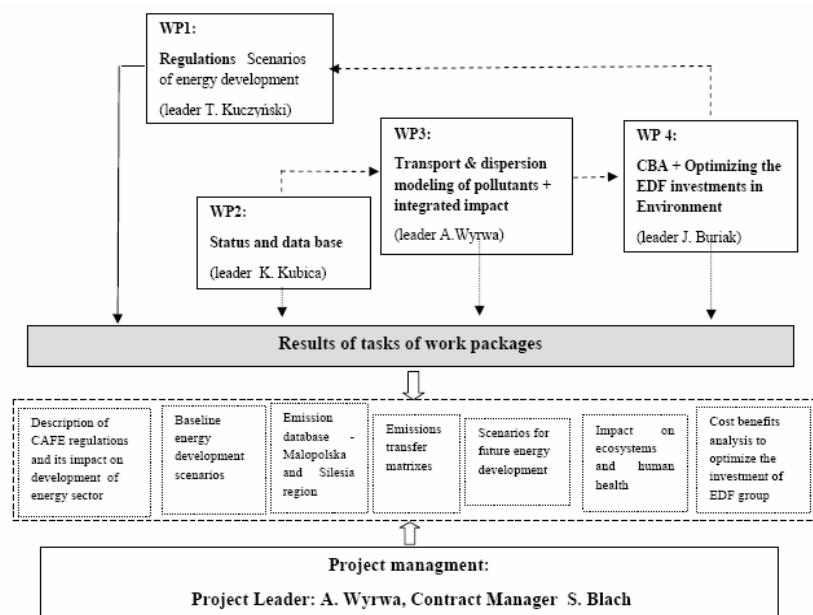


Fig.4 : Original organizational structure of the ENVIRO project [2]

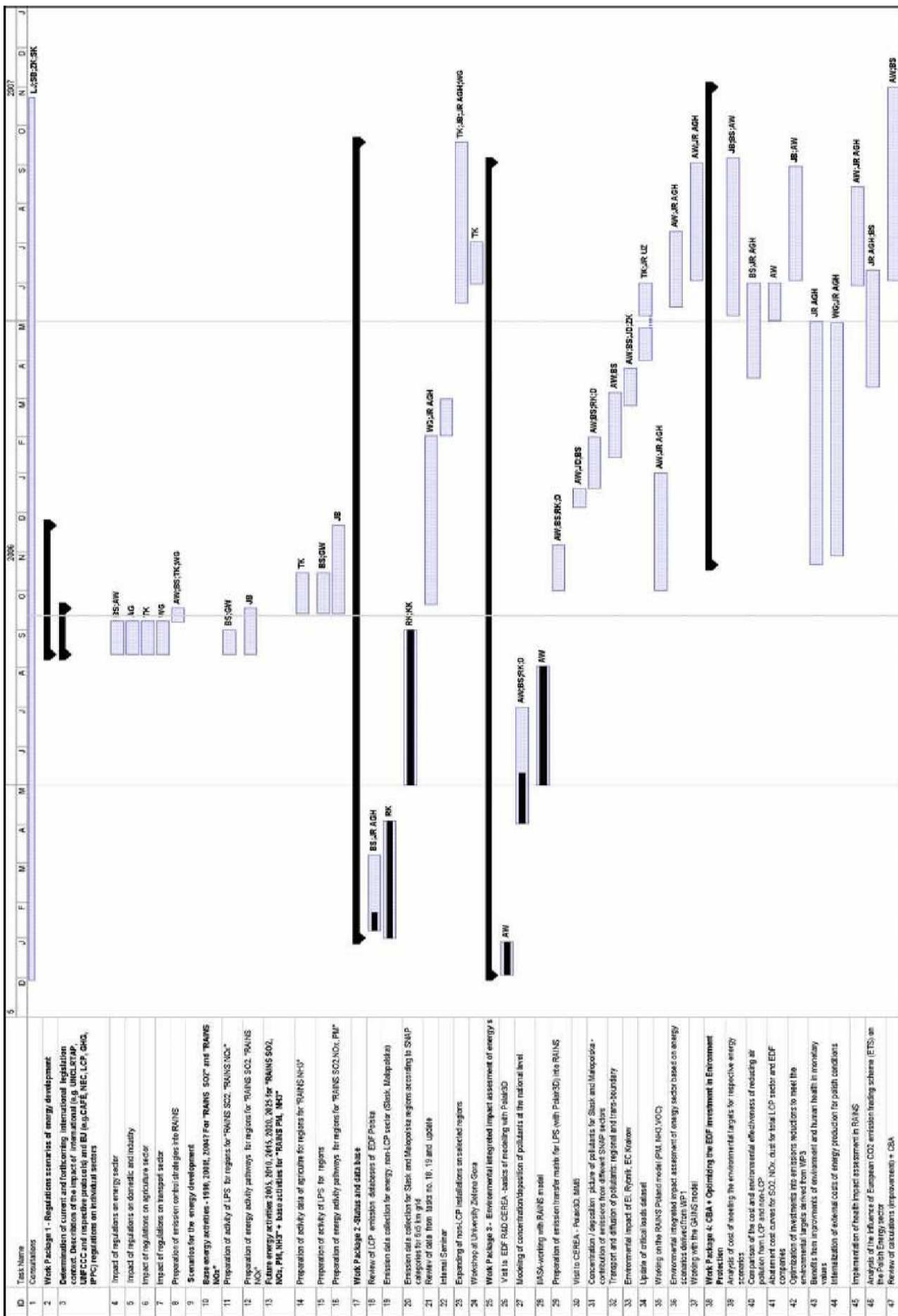


Fig.5 : ENVIRO project original timetable [2]

3) THE RAINS MODEL

a. General presentation

RAINS is an Integrated Assessment Model. Integrated assessment modelling enables to identify the emission reduction scenarios, providing the information on how to optimally allocate the emission reduction investments in order to effectively tackle the problem of an adverse impact of air pollution on environment and human health. Integrated Assessment Models are able to calculate present and future levels of pollutants emissions. They can also calculate the atmospheric dispersion of air pollutants, even at transboundary distances and then related ground level concentration and/or deposition at the ground. The latter can be confronted with the threshold values for the protection of ecosystems (e.g. critical load for acidification) or health dose-response functions (i.e. functions showing an interrelation between air pollution and for example premature deaths) and reveal the level of harmful exceedances (if exist). Finally, if decision is made to mitigate the adverse effects, IAMs “look through” all regions, sectors, abatement technologies for the least cost option for emission reduction (taking into account all constraints and the emission transport characteristics) to reach the predetermined deposition/concentration levels.

The Regional Air Pollution Information and Simulation (RAINS) model has been developed by the International Institute for Applied System Analysis (IIASA) in Austria, from the beginning of last 90s. It combines information on economic and energy development, emissions control potentials and costs, atmospheric dispersion characteristics and environmental sensitivities towards air pollution.

The model is divided in 3 modules :

- EMCO : emissions and control costs
- DEP : dispersion and deposition
- OPT : optimization

Mainly, it allows studying of 3 major pollutants : SO₂, NO_x, Particulate Matter (PM fine, coarse and total suspended), but it is also possible to get data on CO₂, VOC, NH₃ and N₂O. Modules can be either used separately or in inter-dependence. It is possible to run modelling from year 1990 to year 2030.

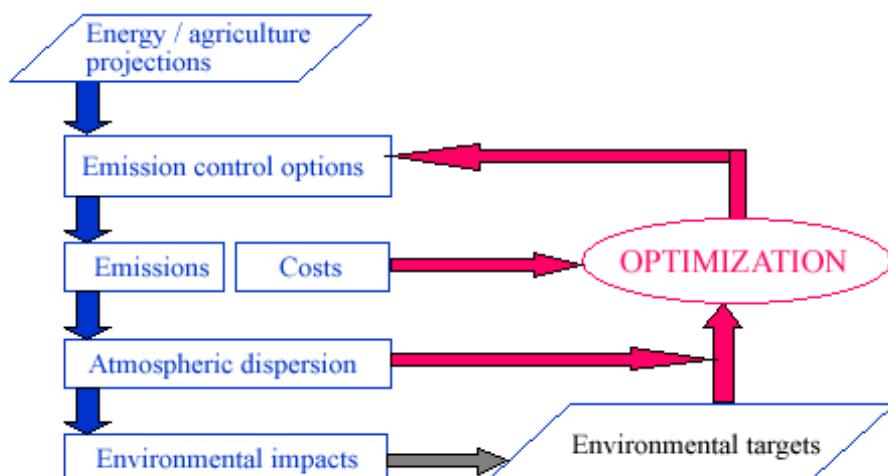


Fig.6 : RAINS model structure [5]

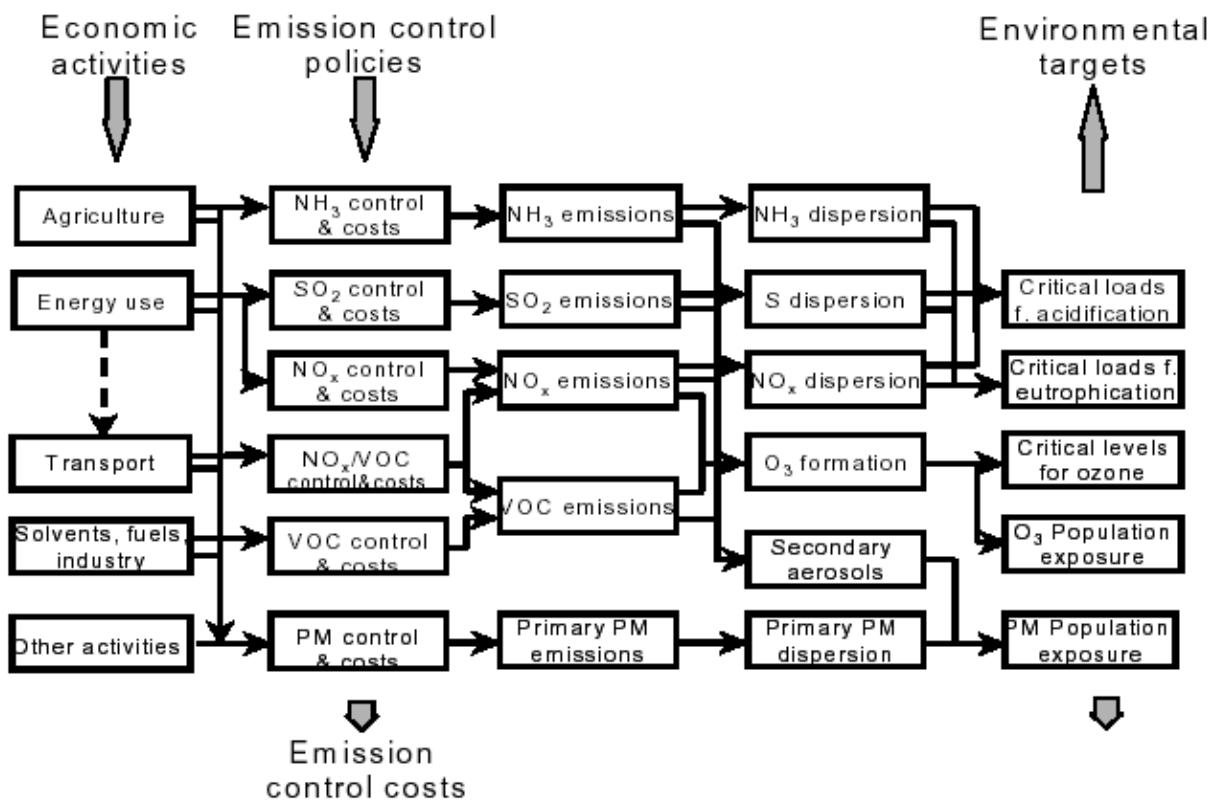


Fig.7 : Flow of information in the RAINS Model [5]

With RAINS, it is possible to analyse plenty of energy scenarios for a country or for a selected region. The optimisation module is used in order to find the cost-minimal combination of emission controls. It is also obvious that the model should not give an unique answer : some solutions are proposed, so different means to control pollution can be used. It is so because the aim of RAINS is to be a help for decision-makers : they should be able to choose a solution applicable to their own region and context, and it is not obligatorily the cost-minimal one. RAINS is totally policy-independent. It is a scientific tool for decision-making help, who provides independent and transparent scientific data on the energy sector.

Possibilities of RAINS are huge, but some system boundaries are applied because it is important to keep the model manageable and transparent. So it is not possible to integrate as many aspects of pollution control as possible, but just relevant ones.

Most important aspect of RAINS is that it is one of the reference models for European Union energetic and environmental projections. It was used for CAFE and it will certainly be used in the envisaged revision of the Goteborg protocol. That is why it is the model used for impact assessment in the ENVIRO project.

My work was only related to the EMCO module. I will next present its interface.

b. RAINS EMCO interface

Energy pathway editor

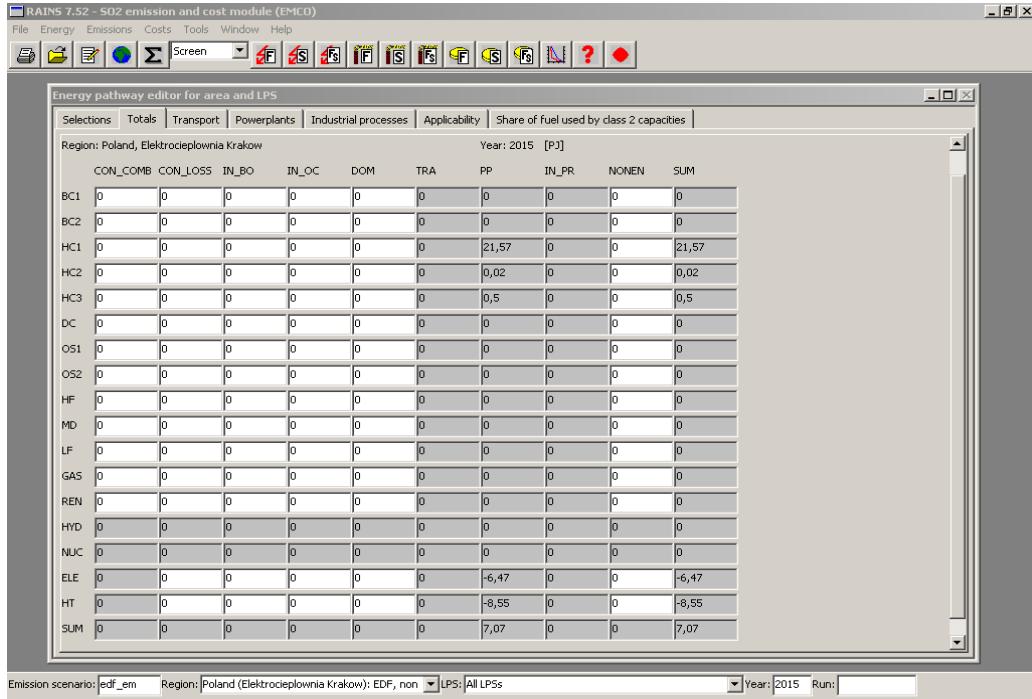


Fig.8 : Energy pathway editor

The interface is a classic software interface. There is a menu where access to everything is possible, a tool-bar for shortcuts buttons (most of them for results visualisation), and a situation bar at the bottom, indicating the actual work situation (emission scenario, region, etc...).

On the figure above, the software is displaying the energy pathway editor. It is obviously named after its function : setting input parameters for energy consumption in the area selected. Columns are representing sectors and rows fuels. Parts in gray are available by clicking on the related tab. For example to set parameters for the column "TRA" you need to click on tab "Transport". Once settled, the energy pathway can be saved under any name.

Control strategy editor

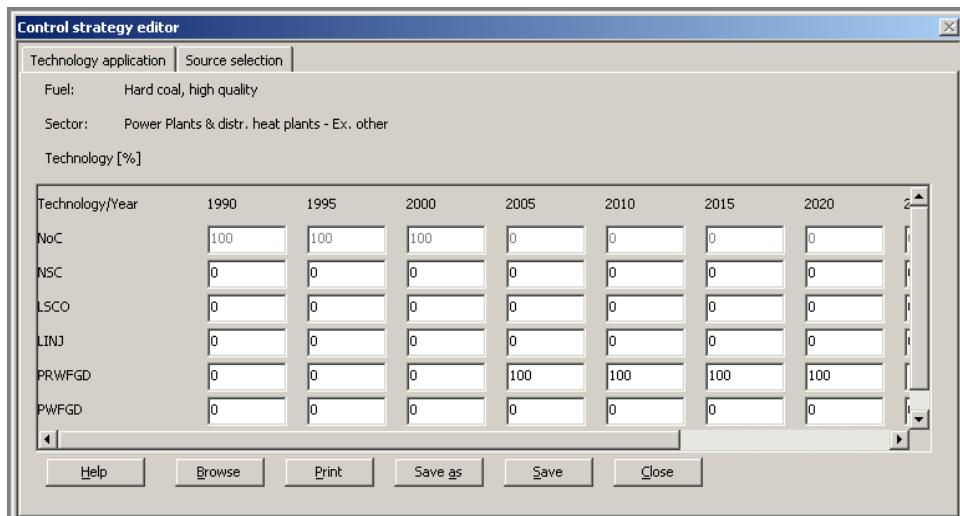


Fig.9 : Control strategy editor

In this section, it is able to input parameters for emission control technologies. Numbers inputted represents the percentage of installation capacities controlled by each technology. As energy pathway, control strategies can be saved under several names.

Emission scenario editor

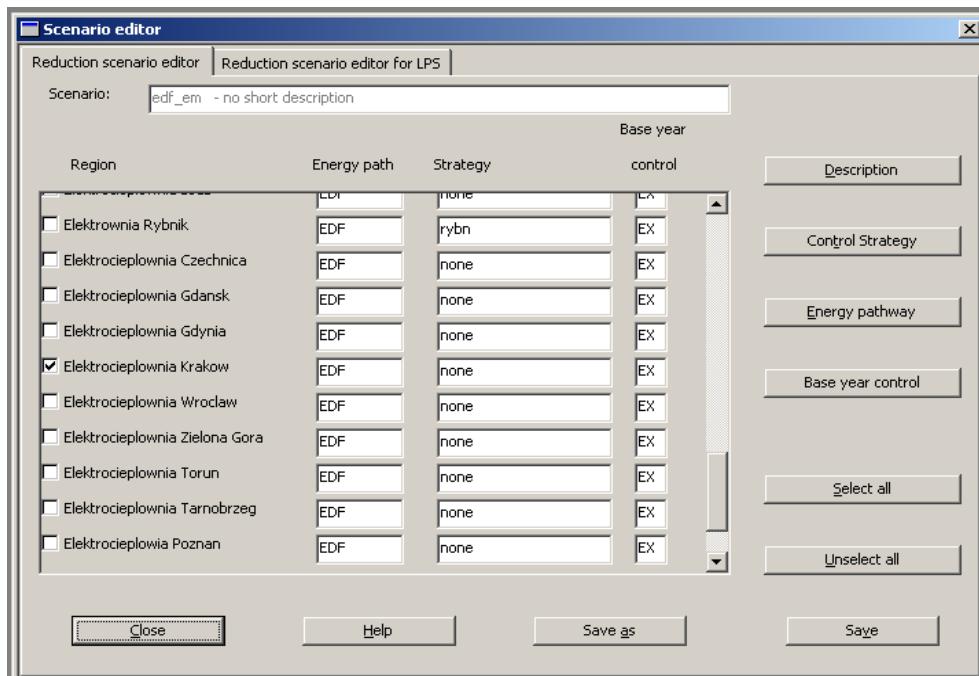


Fig.10 : Emission scenario editor

The emission scenario is the association of energy pathways and control strategies. The editor allows choosing for each area an energy pathway and an emission control strategy. So when results are needed, it is just necessary to pick an area and an emission scenario.

Results visualisation

SO2 ABATEMENT COSTS by SECTOR (region totals minus selected LPS) [M€/year] -> Poland, KRAK

sector/year	1990	1995	2000	2005	2010	2015	2020	2025	2030
CON_COMB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN_BO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN_OC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DOM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TRA_RD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TRA_OT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TRA_OTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PP_EX_WB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PP_EX_OTH	0.00	0.00	2.78	2.55	2.55	2.52	2.52	2.52	2.52

SO2 ABATEMENT COSTS by FUEL per SECTOR in the year = 2015 [M€/year] -> Poland, KRAK

fuel sect	CON_COMB	IN_BO	IN_OC	DOM	TRA_RD	TRA_OT	TRA_OTS	PP_EX_WB	PP_EX_OTH	PP_NEW	PROC	SUM
BC1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BC2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HC1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.55	4.60	0.00	7.15
HC2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HC3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Fig.11 : Costs visualisation

Here are two results examples : the up window displays costs by sector and year, and the low one costs per fuel and sector for year 2015. It is also possible to displays costs by fuel and year. The system is the same for displaying energy consumption and emissions.

RAINS allows displaying results on energetic activity, pollutant emissions and costs related to emission control. It is also possible to obtain cost curves displaying costs (total and marginal) in function of emission reduction.

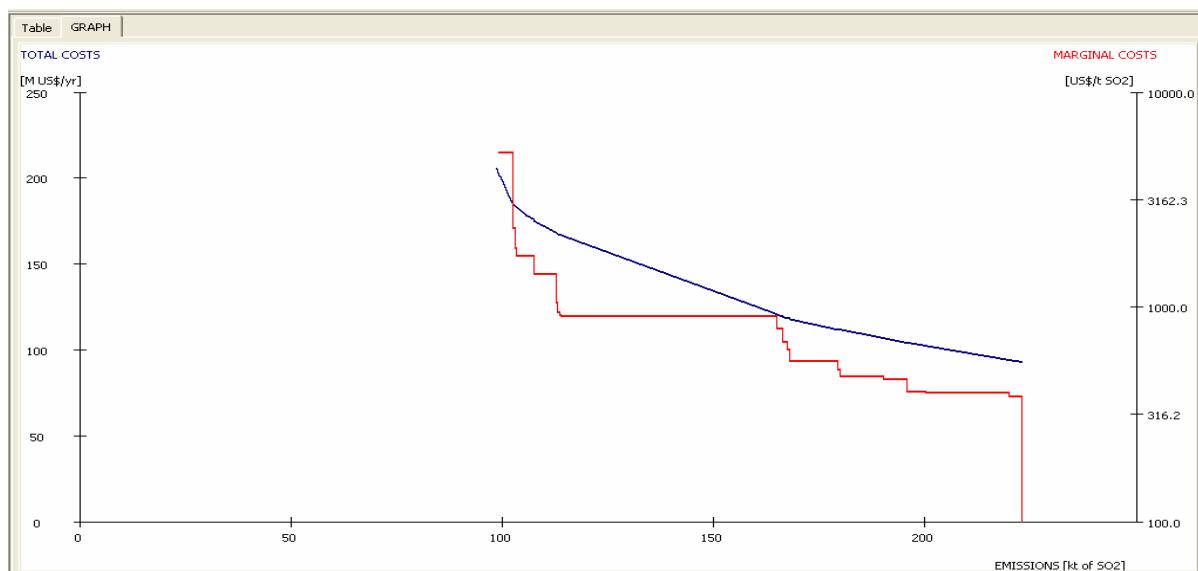


Fig.12 : Cost curve

c. RAINS Online

We were working on a computer version of RAINS but IIASA is also displaying a version of RAINS on the Internet. RAINS Europe Online was our reference model to compare our own results. We were also picking some parameters from its database. The model is freely accessible using this net adress : <http://www.iiasa.ac.at/rains/Rains-online.html?sb=8>.

The next figure represent the interface : it is possible to access plenty of information : activities, emissions, impacts...

The screenshot shows the RAINS Online interface for SO2 emissions. The top navigation bar includes links for Site map, Activities, Emissions, Control, Cost, Impacts, Others, Logout, SETTINGS, Current version (set to Nov04), Area (set to One region, POLAND), Version (set to NEC00), Scenario (set to NEC0_NAT_CLE (NEC00)), Description, Calculate, and Display a table.

The main content area displays a table titled "SO2 emissions by region". The table header includes columns for Region, Emissions (in kilotonnes), and Description. The table body lists several regions with their corresponding emissions values.

On the left side, there is a sidebar with several sections:

- EMISSIONS - SO2**: Sub-sections include Calculated emissions, Total by country, Total by region, Aggregated by activity/sector, Emissions by activity type, Details for process sector, By Corinair SNAP1, By UNECE NFR1, By UNECE NFR2, Details for emissions calculation, Implied emission factor.
- Emission related parameters**: Sub-sections include Sulfur content, Sulfur retention in ash, Heat values of fuels, Sulfur content of low sulfur fuels, SO2 fuel-sector combinations.
- Emission factors**: Sub-sections include Fuel combustion, Processes, Whole emission vector.
- Removal efficiencies**: Sub-sections include Add-on SO2 control technologies, Processes, Whole emission vector.

At the bottom of the page, there is copyright information for the International Institute for Applied Systems Analysis (IIASA) and a note about the current version.

Fig.13 : RAINS Online interface

d. Introduction to my work on RAINS

RAINS is a tool to convert input data into output data. It simply uses programmed algorithms to calculate several needed data. Algorithms are included into the software and are impossible to edit. Without having access to the RAINS code, the user can only works on input data and parameters which are made of databases. It is possible to edit it by using RAINS interface but also by working directly on datatables, using a datatable editor or SQL programmer. By this last mean, possibilities are greatly spread : instead of just changing numbers step by step, one can write programs in SQL to modify the whole structure of RAINS. Such programs can be used to convert European/Asian version of RAINS, applied on European or Asiatic countries (the Asia version can be used as it included LPS options), to a Poland specific version (applied to Polish regions and power plants). Using this methodology, step after step, the development of RAINS Poland is ongoing and is still improved. It consists mainly in database management, SQL programming, algorithms checking, in order to approach as close as possible the online reference model of IIASA.

I took part in this work. In the first phase of my internship I discovered the environment of work and the RAINS model. Mainly during this period I read about Polish energy sector, EDF facts, and mostly IIASA reports and documentation concerning RAINS. It allowed me to discover the structure and the philosophy of such a model, created for integrated impact assessment. Then I helped and assist for the improvement of the development of EMCO SO₂, NO_x and PM for Poland. When I began my training period this work was in its final step, so mainly the aim was to check for errors and to reach as much as possible the reference model of IIASA. After many calculation checking, datatables updating (by hand or using SQL programming) and so, those three EMCO modules were set for preliminary results (see appendix 1). Those preliminary results were then presented in the third interim report from the ENVIRO project. Realization of this report took the major part of our work at this time.

After the delivery of the report, a meeting with EDF and scientists associated to ENVIRO held in our building. The purpose was the setting of the next step for the project. One result of the meeting was the necessity to develop EMCO NH₃, in order to get more complete information on damages done to environment. So the third phase of my internship began with the development of RAINS NH₃. It was more difficult for me at this time as the starting point was the Europe version, unmodified. And we were also facing a lack of data about this sector, mostly for agriculture.

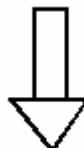
On the next page there is an example of RAINS interface modification using a datatable.

Example

RAINS Europe

PARENT_ABB	ITEM_NAME	ITEM_ABB	KEY	NAME	LNAME
ROOT	ALBANIA, WHOLE COUNTRY	ALBA	1	ALBA_WHOL_area	ALBANIA, WHOLE COUNTRY
ROOT	AUSTRIA, WHOLE COUNTRY	AUST	2	AUST_WHOL_area	AUSTRIA, WHOLE COUNTRY
ROOT	BELARUS, WHOLE COUNTRY	BELA	39	BELA_WHOL_area	BELARUS, WHOLE COUNTRY
ROOT	BELGIUM, WHOLE COUNTRY	BELG	3	BELG_WHOL_area	BELGIUM, WHOLE COUNTRY
ROOT	BOSNIA, HERZEG. WHOLE COUNTRY	BOHE	50	BOHE_WHOL_area	BOSNIA, HERZEG. WHOLE COUNTRY
ROOT	BULGARIA, WHOLE COUNTRY	BULG	4	BULG_WHOL_area	BULGARIA, WHOLE COUNTRY
ROOT	CROATIA, WHOLE COUNTRY	CROA	49	CROA_WHOL_area	CROATIA, WHOLE COUNTRY
ROOT	CYPRUS, WHOLE COUNTRY	CYPR	55	CYPR_WHOL_area	CYPRUS, WHOLE COUNTRY
ROOT	CZECH, REP. WHOLE COUNTRY	CZRE	46	CZRE_WHOL_area	CZECH, REP. WHOLE COUNTRY
ROOT	DENMARK, WHOLE COUNTRY	DENN	6	DENN_WHOL_area	DENMARK, WHOLE COUNTRY
ROOT	ESTONIA, WHOLE COUNTRY	ESTO	43	ESTO_WHOL_area	ESTONIA, WHOLE COUNTRY
ROOT	FINLAND, WHOLE COUNTRY	FINL	7	FINL_WHOL_area	FINLAND, WHOLE COUNTRY
ROOT	FRANCE, WHOLE COUNTRY	FRAN	8	FRAN_WHOL_area	FRANCE, WHOLE COUNTRY
ROOT	GERMANY, REGIONS	GERM	-99	GERM_REGI_area	GERMANY, REGIONS
GERM	GERMANY, NEW COUNTRIES	NEUL	9	GERM_NEUL_area	GERMANY, NEW COUNTRIES
GERM	GERMANY, OLD COUNTRIES	OLDL	10	GERM_OLDL_area	GERMANY, OLD COUNTRIES
ROOT	GERMANY, WHOLE COUNTRY	GERM	89	GERM_WHOL_area	GERMANY, WHOLE COUNTRY
ROOT	GREECE, WHOLE COUNTRY	GREE	11	GREE_WHOL_area	GREECE, WHOLE COUNTRY
ROOT	HUNGARY, WHOLE COUNTRY	HUNG	12	HUNG_WHOL_area	HUNGARY, WHOLE COUNTRY
ROOT	IRELAND, WHOLE COUNTRY	IREL	14	IREL_WHOL_area	IRELAND, WHOLE COUNTRY
ROOT	ITALY, WHOLE COUNTRY	ITAL	15	ITAL_WHOL_area	ITALY, WHOLE COUNTRY
ROOT	LATVIA, WHOLE COUNTRY	LATV	44	LATV_WHOL_area	LATVIA, WHOLE COUNTRY
ROOT	LITHUANIA, WHOLE COUNTRY	LITH	45	LITH_WHOL_area	LITHUANIA, WHOLE COUNTRY
ROOT	LUXEMBOURG, WHOLE COUNTRY	LUXE	16	LUXE_WHOL_area	LUXEMBOURG, WHOLE COUNTRY
ROOT	MALTA, WHOLE COUNTRY	MALT	57	MALT_WHOL_area	MALTA, WHOLE COUNTRY
ROOT	NETHERLANDS, WHOLE COUNTRY	NETH	17	NETH_WHOL_area	NETHERLANDS, WHOLE COUNTRY
ROOT	NORWAY, WHOLE COUNTRY	NORW	18	NORW_WHOL_area	NORWAY, WHOLE COUNTRY
ROOT	POLAND, WHOLE COUNTRY	POLA	19	POLA_WHOL_area	POLAND, WHOLE COUNTRY
ROOT	PORTUGAL, WHOLE COUNTRY	PORT	20	PORT_WHOL_area	PORTUGAL, WHOLE COUNTRY

Table A : Regions datatable into RAINS Europe program files



Predefined selections Countries/Regions

(1) To select a whole country, mark the box to the left of country name (right side of the window).
(2) To select a region in a country, find its name on a tree displayed on the left side of the window. Click plus sign (+) on the left to Asia, then again (+) on the left to country name and so on until region name appears. Then mark the box to the left of the region name on the right side of the window.
(3) You may also use 'Select all' buttons for multiple selections.

Predefined selections
Countries/Regions

[+]
Europe

- [-] ALBANIA, WHOLE COUNTRY
- [-] AUSTRIA, WHOLE COUNTRY
- [-] BELARUS, WHOLE COUNTRY
- [-] BELGIUM, WHOLE COUNTRY
- [-] BOSNIA, HERZEG. WHOLE COUNTRY
- [-] BULGARIA, WHOLE COUNTRY
- [-] CROATIA, WHOLE COUNTRY
- [-] CYPRUS, WHOLE COUNTRY
- [-] CZECH, REP. WHOLE COUNTRY
- [-] DENMARK, WHOLE COUNTRY
- [-] ESTONIA, WHOLE COUNTRY
- [-] FINLAND, WHOLE COUNTRY
- [-] FRANCE, WHOLE COUNTRY
- [-] GERMANY, REGIONS

Select all regions
Unselect all regions

Select all items in a region
Unselect all items in a region

Cancel
Help
OK

Fig.14 : Regions selection in RAINS Europe interface

RAINS Poland

PARENT_ABB	ITEM_NAME	ITEM_ABB	KEY	NAME	LNAME
ROOT	Poland	POLA	-99	Polska	POLAND
POLA	Wojewodztwo Dolnoslaskie	DSLA	1	POLA_DSLA_area	Dolnoslaskie
POLA	Wojewodztwo Kujawsko Pomorskie	KPOM	2	POLA_KPOM_area	Kujawsko_Pomorsk
POLA	Wojewodztwo Lubelskie	LUBE	3	POLA_LUBE_area	Lubelskie
POLA	Wojewodztwo Lubuskie	LUBU	4	POLA_LUBU_area	Lubuskie
POLA	Wojewodztwo Lodzkie	LODZ	5	POLA_LODZ_area	Lodzkie
POLA	Wojewodztwo Malopolskie	MPOL	6	POLA_MPOL_area	Malopolskie
POLA	Wojewodztwo Mazowieckie	MAZO	7	POLA_MAZO_area	Mazowieckie
POLA	Wojewodztwo Opolskie	OPOL	8	POLA_OPOL_area	Opolskie
POLA	Wojewodztwo Podkarpackie	PKAR	9	POLA_PKAR_area	Podkarpackie
POLA	Wojewodztwo Podlaskie	PLAS	10	POLA_PLAS_area	Podlaskie
POLA	Wojewodztwo Pomorskie	PMOR	11	POLA_PMOR_area	Pomorskie
POLA	Wojewodztwo Slaskie	SLAS	12	POLA_SLAS_area	Slaskie
POLA	Wojewodztwo Swietokrzyskie	SWEI	13	POLA_SWEI_area	Swietokrzyskie
POLA	Wojewodztwo Warminsko Mazurskie	WARM	14	POLA_WARM_area	Warminsko_Mazurs
POLA	Wojewodztwo Wielkopolskie	WPOL	15	POLA_WPOL_area	Wielkopolskie
POLA	Wojewodztwo Zachodniopomorskie	ZPOM	16	POLA_ZPOM_area	Zachodniopomorsk
POLA	Elektrownia Turow	TURO	21	POLA_TURO_area	Turow
POLA	Elektrownia Belchatow	BELC	19	POLA_BELC_area	Belchatow
POLA	Elektrownia Kozienice	KOZI	22	POLA_KOZI_area	Kozienice
POLA	Elektrownia Ostroleka	OSTR	32	POLA_OSTR_area	Ostroleka
POLA	Elektrownia Siekierki	SIEK	29	POLA_SIEK_area	Siekierki
POLA	Elektrownia Zeran	ZERA	28	POLA_ZERA_area	Zeran
POLA	Elektrownia Skawina	SKAW	33	POLA_SKAW_area	Skawina
POLA	Elektrownia Jaworzno I_II_III	JAWO	26	POLA_JAWO_area	Jaworzno
POLA	Elektrownia Lagisza	LAGI	30	POLA_LAGI_area	Lagisza
POLA	Elektrownia Laziska	LAZI	27	POLA_LAIZ_area	Laziska
POLA	Elektrownia Siersza	SIER	31	POLA_SIER_area	Siersza
POLA	Elektrownia Polaniec	POLC	24	POLA_POLC_area	Polaniec

Table B : Regions datatable into RAINS Poland program files

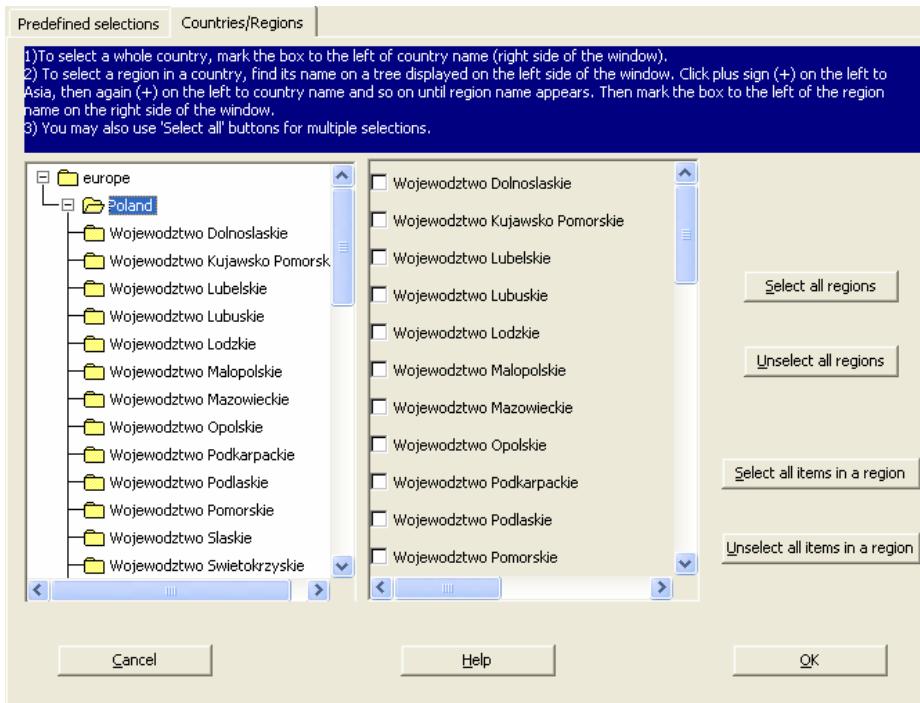
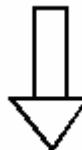


Fig.15 : Regions selection in RAINS Poland interface

In this example the datatable was edited by using a simple database file editor. But due to the amount of files and data in each one, most of them are edited using SQL programming.

e. SQL programming

I will next present a work I have done about the transport sector in EMCO NO_x using a software including SQL tools. The problem was the setting of unit costs for emission abatement in the database. To set those costs, you need to set input parameters in related datatables and then run a costs initialization in EMCO interface. The initialization will, as it is named, initialize the database with new parameters.

Due to limitations of our RAINS version (version 7.52) in emission control combinations, we were not able to represent all combinations present in our reference model (RAINS Online version 8.0) on our EMCO NO_x. We had to choose some of them and the criteria was the fuel consumption. As we can see on the table “EDF_encl” from RAINS 8.0, representing the fuel consumption in the transport sector, higher fuel consumptions (and so NO_x emissions) occur for those three Sector / Fuel / related Control Technology combinations :

1. TRA_RD_LD4 / GSL / LFEU1, LFEU2, LFEU3, LFEUI4
(Transport_Road_LightDuty4strokes / Gasoline / LightDutyEuro)
2. TRA_RD_HD / MD / HDEU1, HDEU2, HDEU3, HDEU4
(Transport_Road_HeavyDuty / MediumDistilates / HeavyDutyEuro)
3. TRA_OT_AGR / MD / CAGEU1, CAGEU2, CAGEU3, CAGEU4
(Transport_Other_Agriculture / MediumDistilates / AgricultureEuro)

N.B. : “Euro” is a package of control techniques which enable to meet European emission standards.

We need to transpose the parameters of those combinations into three combinations of EMCO 7.52.

COU_ABB	REG_ABB	YEAR	FUEL_ABB	TRA_RD_LD2	TRA_RD_M4	TRA_RD_LD4	TRA_RD_HD	TRA_OT_LD2	TRA_OT_CNS	TRA_OT_AGR	TRA_C
POLA	DLSA	1990	BC1								
POLA	DLSA	1990	BC2								
POLA	DLSA	1990	DC								
POLA	DLSA	1990	ELE								
POLA	DLSA	1990	ETH								
POLA	DLSA	1990	GAS								
POLA	DLSA	1990	GSL	1.153	0.047	9.077	0.431				
POLA	DLSA	1990	H2								
POLA	DLSA	1990	HC1								
POLA	DLSA	1990	HC2								
POLA	DLSA	1990	HC3								
POLA	DLSA	1990	HF								
POLA	DLSA	1990	HT								
POLA	DLSA	1990	HYD								
POLA	DLSA	1990	LPG								
POLA	DLSA	1990	MD		0.743	8.557		0.566		4.466	
POLA	DLSA	1990	MTH								
POLA	DLSA	1990	NOF								
POLA	DLSA	1990	NUC								
POLA	DLSA	1990	OS1								
POLA	DLSA	1990	OS2								
POLA	DLSA	1990	REN								

Table C : EDF_encl in RAINS 8.0

Structure of transport sector control strategies in EMCO 7.52

Choose of three combinations

Combinations available in EMCO 7.52 (Sector / Fuel / Control technology) :

- TRA_RD_LD4 / MD / MDLDCM,MDLDAM,MDLDEC,MDLDNX
/ LF / LFCC1,LFCC2,LFCC3, LFCC4
/ GAS / GLDCC
- TRA_RD_HD / MD / EUR1,EUR2,EUR3,EUR4
/ LF / LFHDCC
/ GAS / GHDCC
- TRA_OT_LB / HF / DHFCM
/ MD / EUR1,EUR2,EUR3,EUR4
/ LF / LFCC1,LFCC2,LFCC3,LFCC4
- TRA_OT_SSM / MD / STMCM
- TRA_OT_SSL / HF / STLCM,STLSCR
/ MD / STLCM,STLSCR

We can see that the sector “TRA_OT_AGR” does not exist in EMCO 7.52. We will choose “TRA_OT_LB” to replace it because sectors “TRA_OT_SSM” and “TRA_OT_SSL” represent ship transport. We can also see that the fuel “GSL” does not exist in EMCO 7.52. We will choose “LF” to replace it because there is four control technologies associated, and because we will use the fuel “MD” for other combinations. For other sectors and fuels, there are equivalents between RAINS Online and EMCO.

So we chose those three combinations :

- TRA_RD_LD4 / MD / MDLDCM,MDLDAM,MDLDEC,MDLDNX
/ LF / LFCC1,LFCC2,LFCC3,LFCC4
/ GAS / GLDCC
(Transport_Road_LightDuty4Strokes/LightFractions/CatalyticConverter)
- TRA_RD_HD / MD / EUR1,EUR2,EUR3,EUR4
/ LF / LFHDCC
/ GAS / GHDCC
(Transport_Road_HeavyDuty/MediumDistillates/Euro)
- TRA_OT_LB / HF / DHFCM
/ MD / EUR1,EUR2,EUR3,EUR4
/ LF / LFCC1,LFCC2,LFCC3,LFCC4
(Transport_Other_LandBased/MediumDistillates/Euro)
- TRA_OT_SSM / MD / STMCM
- TRA_OT_SSL / HF / STLCM,STLSCR
/ MD / STLCM,STLSCR

Transposition of parameters from RAINS Online to EMCO 7.52

To resume what is said above, we need those input parameters transpositions (Online → EMCO) :

1. TRA_RD_LD4 / GSL / LFEUI, LFEUII, LFEUIII, LFEUIV
→ TRA_RD_LD4 / LF / LFC1, LFC2, LFC3, LFC4
2. TRA_OT_AGR / MD / CAGEUI, CAGEUII, CAGEUIII, CAGEUIV
→ TRA_OT_LB / MD / EUR1, EUR2, EUR3, EUR4
3. TRA_RD_HD / MD / HDEUI, HDEUII, HDEUIII, HDEUIV
→ TRA_RD_HD / MD / EUR1, EUR2, EUR3, EUR4

N.B. : Colours red, green and blue are related to coloured squares on tables I will present after.

As “EUR” control technology is used in both transportations 2 and 3, we will have to run initialization of costs coefficients in EMCO in two steps :

- 1st initialization : transposition 1 + transposition 2
- 2nd initialization : transposition 3

It is so because it is not possible to set two different range of parameters for “EUR”, but fortunately, the table for unit costs (unit costs are stored into table “EDF_tr_uc”) is rank by Sector/Fuel/Control technologies, so there can be there two different range of results related to “EUR” technology, as this technology appears in more than one combination.

By running two initializations we will obtain two different results files for unit costs (the first one need to be saved under an other name first in order to prevent overwriting during second initialization). The input of parameters for 1st initialization, saving of the first result table, then input of second range of parameters for 2nd initialization, saving of the second result table, will be done with the help of a SQL program. This program will also combine the two results files into one final table “EDF_tr_uc”.

SQL program

Methodology for cost coefficient initialization

This program allows to perform two cost initializations in EMCO NO_x with two different kinds of input parameters for transport sector, and to combine the two results into one final file "EDF_tr_uc.dbf". Parameters are set through two datatables : “cotecnox” (NO_x and VOC removal efficiencies) and “noxtcom2” (investment coefficient, operation and maintenance cost, additional fuel demand), for which I prepared two versions, one for 1st initialization and one for 2nd initialization, by taking values from RAINS Online.

	TECH_ABB	CORINAIR	EFF_CONST	VOCEFF
	LFCC1	210	71.0	74.7
	LFCC2	210	87.0	87.3
	LFCC3	210	92.0	93.3
	LFCC4	210	96.0	96.8
	MDLDCM	210	31.4	31.4
	MDLDAM	210	50.0	50.0
	MDLDEC	210	59.8	59.8
	MDLDNX	210	80.4	80.4
	GHDCC	210	85.0	85.0
	LFHDCC	210	85.0	85.0
	EUR1	210	34.0	36.0
	EUR2	210	50.0	47.0
	EUR3	210	70.0	66.0
	EUR4	210	70.1	92.7

Table D : cotechnox (1st initialization)

	TECH_ABB	INV_C	FO_M	FUELDEM
	LFCC1	222	0.0636	
	LFCC2	229	0.0456	
	LFCC3	301	0.0509	
	LFCC4	342	0.0308	
	MDLDCM	165	0.1020	
	MDLDAM	303	0.0647	
	MDLDEC	858	0.0358	
	MDLDNX	1199	0.0313	
	GHDCC	2293	0.0300	
	LFHDCC	3025	0.0376	
	EUR1	185	0.0250	
	EUR2	1520	0.0250	
	EUR3	2450	0.0250	
	EUR4	6950	0.0250	

Table E : noxtcom2 (1st initialization)

	TECH_ABB	CORINAIR	EFF_CONST	VOCEFF
	LFCC1	210	71.0	74.7
	LFCC2	210	87.0	87.3
	LFCC3	210	92.0	93.3
	LFCC4	210	96.0	96.8
	MDLDCM	210	31.4	31.4
	MDLDAM	210	50.0	50.0
	MDLDEC	210	59.8	59.8
	MDLDNX	210	80.4	80.4
	GHDCC	210	85.0	85.0
	LFHDCC	210	85.0	85.0
	EUR1	210	34.0	36.0
	EUR2	210	26.0	47.0
	EUR3	210	39.0	66.0
	EUR4	210	66.0	92.7

Table F : cotechnox (2nd initialization)

	TECH_ABB	INV_C	FO_M	FUELDEM
	LFCC1	222	0.0636	
	LFCC2	229	0.0456	
	LFCC3	301	0.0509	
	LFCC4	342	0.0308	
	MDLDCM	165	0.1020	
	MDLDAM	303	0.0647	
	MDLDEC	858	0.0358	
	MDLDNX	1199	0.0313	
	GHDCC	2293	0.0300	
	LFHDCC	3025	0.0376	
	EUR1	1484	0.0160	
	EUR2	2795	0.0534	0.020
	EUR3	4126	0.0535	0.057
	EUR4	7590	0.0576	0.060

Table G : noxtcom2 (2nd initialization)

Methodology :

- 1) Run program "Step1" (input parameters for 1st initialization)
- 2) Run a cost initialization in EMCO NO_x
- 3) Run program "Step3" (saves the 1st result file and set input parameters for 2nd initialization)
- 4) Run a cost initialization in EMCO NO_x
- 5) Run program "Step5" (combine the two result files)

Transpositions of input parameters will be :

*** 1st initialization

RAINS_Online	RAINS_EMCO
TRA_RD_LD4-GSL (LFEUI, LFEUII, LFEUIII, LFEUIV)	---> TRA_RD_LD4-LF (LFC1, LFC2, LFC3, LFC4)
TRA_OT_AGR-MD (CAGEUI, CAGEUII, CAGEUIII, CAGEUIV)	---> TRA_OT_LB-MD (EUR1, EUR2, EUR3, EUR4)

*** 2nd initialization

RAINS_Online	RAINS_EMCO
TRA_RD_HD-MD (HDEUI, HDEUII, HDEUIII, HDEUIV)	---> TRA_RD_HD-MD (EUR1, EUR2, EUR3, EUR4)

You can visualize the SQL program in appendix 6 on page 74.

Results

COU_ABB	REG_ABB	FUEL_ABB	SEC_ABB	TECH_ABB	UC_1995	UC_2000	UC_2005
POLA	DSLA	MD	TRA_OT_LB	EUR1	142.8439	148.0790	156.2602
POLA	DSLA	MD	TRA_OT_LB	EUR2	904.2774	937.4184	989.2095
POLA	DSLA	MD	TRA_OT_LB	EUR3	1040.7606	1078.9037	1138.5116
POLA	DSLA	MD	TRA_OT_LB	EUR4	2096.8080	2173.6543	2293.7457
POLA	DSLA	HF	TRAOTS_L	STLCM	77.8477	79.0392	80.6858
POLA	DSLA	HF	TRAOTS_L	STLSCR	109.8426	111.5239	113.8473
POLA	DSLA	MD	TRAOTS_L	STLCM	77.8477	79.0392	80.6858
POLA	DSLA	MD	TRAOTS_L	STLSCR	109.8426	111.5239	113.8473
POLA	DSLA	MD	TRAOTS_M	STMCM	1155.2857	1172.9686	1197.4054
POLA	DSLA	GAS	TRA_RD_HD	GHdcc	1590.1302	1648.4072	1739.4795
POLA	DSLA	LF	TRA_RD_HD	LFHDCC	1799.2850	1865.2274	1968.2786
POLA	DSLA	MD	TRA_RD_HD	EUR1	170.1282	176.3633	186.1071
POLA	DSLA	MD	TRA_RD_HD	EUR2	1077.0013	1116.4725	1178.1561
POLA	DSLA	MD	TRA_RD_HD	EUR3	1239.5539	1284.9825	1355.9760
POLA	DSLA	MD	TRA_RD_HD	EUR4	2497.3143	2588.8390	2731.8687
POLA	DSLA	GAS	TRA_RD_LD4	GLDCC	2841.2114	2993.9647	3256.5932
POLA	DSLA	LF	TRA_RD_LD4	LFCC1	2263.1271	2384.8006	2593.9937
POLA	DSLA	LF	TRA_RD_LD4	LFCC2	1786.2345	1882.2686	2047.3799
POLA	DSLA	LF	TRA_RD_LD4	LFCC3	2273.3829	2395.6078	2605.7488
POLA	DSLA	LF	TRA_RD_LD4	LFCC4	2171.8277	2288.5926	2489.3463

Table H : EDF_tr_uc after 1st initialization

COU_ABB	REG_ABB	FUEL_ABB	SEC_ABB	TECH_ABB	UC_1995	UC_2000	UC_2005
POLA	DSLA	MD	TRA_OT_LB	EUR1	1056.1195	1094.8255	1155.3131
POLA	DSLA	MD	TRA_OT_LB	EUR2	2376.4836	2452.4812	2571.2462
POLA	DSLA	MD	TRA_OT_LB	EUR3	2803.5980	2883.7615	3009.0368
POLA	DSLA	MD	TRA_OT_LB	EUR4	3400.0892	3507.8146	3676.1620
POLA	DSLA	HF	TRAOTS_L	STLCM	77.8477	79.0392	80.6858
POLA	DSLA	HF	TRAOTS_L	STLSCR	109.8426	111.5239	113.8473
POLA	DSLA	MD	TRAOTS_L	STLCM	77.8477	79.0392	80.6858
POLA	DSLA	MD	TRAOTS_L	STLSCR	109.8426	111.5239	113.8473
POLA	DSLA	MD	TRAOTS_M	STMCM	1155.2857	1172.9686	1197.4054
POLA	DSLA	GAS	TRA_RD_HD	GHdcc	1590.1302	1648.4072	1739.4795
POLA	DSLA	LF	TRA_RD_HD	LFHDCC	1799.2850	1865.2274	1968.2786
POLA	DSLA	MD	TRA_RD_HD	EUR1	1271.3394	1317.9329	1390.7469
POLA	DSLA	MD	TRA_RD_HD	EUR2	2695.8860	2784.1353	2922.0466
POLA	DSLA	MD	TRA_RD_HD	EUR3	3125.7262	3218.8062	3364.2668
POLA	DSLA	MD	TRA_RD_HD	EUR4	3841.1990	3965.9212	4160.8302
POLA	DSLA	GAS	TRA_RD_LD4	GLDCC	2841.2114	2993.9647	3256.5932
POLA	DSLA	LF	TRA_RD_LD4	LFCC1	2263.1271	2384.8006	2593.9937
POLA	DSLA	LF	TRA_RD_LD4	LFCC2	1786.2345	1882.2686	2047.3799
POLA	DSLA	LF	TRA_RD_LD4	LFCC3	2273.3829	2395.6078	2605.7488
POLA	DSLA	LF	TRA_RD_LD4	LFCC4	2171.8277	2288.5926	2489.3463

Table I : EDF_tr_uc after 2nd initialization

COU_ABB	REG_ABB	FUEL_ABB	SEC_ABB	TECH_ABB	UC_1995	UC_2000	UC_2005
POLA	DSLA	LF	TRA_RD_LD4	LFCC1	2263.1271	2384.8006	2593.9937
POLA	DSLA	LF	TRA_RD_LD4	LFCC2	1786.2345	1882.2686	2047.3799
POLA	DSLA	LF	TRA_RD_LD4	LFCC3	2273.3829	2395.6078	2605.7488
POLA	DSLA	LF	TRA_RD_LD4	LFCC4	2171.8277	2288.5926	2489.3463
POLA	DSLA	MD	TRA_OT_LB	EUR1	142.8439	148.0790	156.2602
POLA	DSLA	MD	TRA_OT_LB	EUR2	904.2774	937.4184	989.2095
POLA	DSLA	MD	TRA_OT_LB	EUR3	1040.7606	1078.9037	1138.5116
POLA	DSLA	MD	TRA_OT_LB	EUR4	2096.8080	2173.6543	2293.7457
POLA	DSLA	MD	TRA_RD_HD	EUR1	1271.3394	1317.9329	1390.7469
POLA	DSLA	MD	TRA_RD_HD	EUR2	2695.8860	2784.1353	2922.0466
POLA	DSLA	MD	TRA_RD_HD	EUR3	3125.7262	3218.8062	3364.2668
POLA	DSLA	MD	TRA_RD_HD	EUR4	3841.1990	3965.9212	4160.8302

Table J : EDF_tr_uc after combining by the program

We can see on table H and I that results are only changing for the “EUR” technology. It is totally normal as it is the only technology whose parameters had been changed between the two initializations. The table J is presenting the final file “EDF_tr_uc”, combination of table H and I. This is this final file used to display costs results for EMCO 7.52.

The program is running correctly and we obtained a well-working version of EMCO NO_x. We just need to remember that combinations names are not anymore related to their real signification, but to the one from RAINS Online. For example if you are running a cost calculation for TRA_OT_LB (Transport_Others_LandBased) in fact the results are corresponding to TRA_OT_AGR (Transport_Others_Agriculture). For values results there is still improvement to do in order to reach the model from IIASA but the average costs result in the transport sector is quite good (see table O on page 45).

This work had to be done because of limitations of RAINS 7.52 compared to RAINS 8.0 in the transport sector, and it allows a good approximation of costs. Anyway, ENVIRO is more focalised on the power plant sector. But ENVIRO is looking forward to get for itself a computer version of RAINS 8.0 from IIASA, in order to improve again and again accuracy of results, and moreover to suppress actual limitations.

f. RAINS EMCO SO₂ calculations [4]

To present how RAINS can calculates, I will expose calculation of emissions and control costs in EMCO SO₂. In a first time I will set input parameters, expose formulas and then finally results.

Parameter	Symbol	Unit	Value
Activity level of sector	act	PJ/year	50
Sulphur content	sc	%/100	0,0139
Heat value	hv	GJ/t _{SO₂}	11,3
Sulphur retention in ash	sr	%/100	0,22
Application factor of control technology	af	%/100	0,7
Removal efficiency of control technology	η	%/100	0,95
Intercept of the investment function	c _i ^f	€/kW _t	36
Slope of the investment function	c _i ^v	k€	10 000
Boiler size	bs	MW _t	550
Flue gas volume (relative to hard coal)	v	%/100	1,2
Retrofit cost factor	r	%/100	0,3
Interest rate	q	%/100	0,04
Lifetime of equipment	lt	years	20
Maintenance costs and overhead	f	%/100	0,04
Specific demand for labour	λ ^l	man-year/GW _t	10,8
Labour cost	c ^l	€/man-year	10 000
Plant capacity utilization	pf	hours/year	5 200
Specific demand for electricity	λ ^e	GW _h /PJ _t	1
Electricity price	c ^e	€/kW _h	0,04
Specific demand for sorbents	λ ^s	t/t _{SO₂}	1,56
Sorbent cost	c ^s	€/ton	18
Specific demand for byproducts/waste disposal	λ ^d	t/t _{SO₂}	2,6
Byproducts/waste disposal cost	c ^d	€/ton	0

Table K : Input parameters

Formulas

- Uncontrolled emissions

$$E^{unc} \text{SO}_2 = act * ef$$

$$ef = 2 * \frac{sc}{hv} * (1 - sr) * 10^6$$

ef = unabated emission factor [t_{SO₂}/PJ]

- Controlled emissions

$$E^{contr} \text{SO}_2 = act * ef * af * (1 - \eta)$$

- Investments

$$I = \left(ci^f + \frac{ci^v}{bs} \right) * v * (1 + r)$$

- Annualized investments

$$I^{an} = I * \frac{(1 + q)^{lt} * q}{(1 + q)^{lt} - 1}$$

- Fixed operating costs

$$OM^{fix} = I * f$$

- Variable operating costs

$$OM^{var} = \frac{\lambda^l * c^l}{pf * 3600 * 10^{-6}} + \lambda^e * c^e * 10^6 + ef * \eta * (\lambda^s * c^s + \lambda^d * c^d)$$

- **Unit reduction cost per PJ**

$$c_{PJ} = \frac{I^{an} + OM^{fix}}{pf * 3600 * 10^{-12}} + OM^{var}$$

- **Unit reduction cost per ton of SO₂ removed**

$$c_{SO_2} = \frac{c_{PJ}}{ef * \eta}$$

- **Reduction costs per year**

$$c_{year} = (E^{unc}_{SO_2} - E^{contr}_{SO_2}) * c_{SO_2}$$

Results

Parameter	Symbol	Unit	Value
Unabated emission factor	ef	t _{SO₂} /PJ	1 918,94
SO ₂ uncontrolled emissions per year	E ^{unc} _{SO₂}	t _{SO₂} /year	95 946,90
SO ₂ controlled emissions per year	E ^{contr} _{SO₂}	t _{SO₂} /year	3 358,14
Investments	I	€/kWt	84,52
Annualized investments	I ^{an}	€/kWt	6,22
Fixed operating costs	OM ^{fix}	€/kWt	3,38
Variable operating costs	OM ^{var}	€/PJ	96 958,82
Unit reduction cost per PJ	c _{PJ}	€/PJ	609 797,63
Unit reduction cost per ton of SO ₂ removed	c _{SO₂}	€/t _{SO₂}	334,50
Unit reduction cost per year	c _{year}	€/year	30 971 300,90

Table L : Results

4) CURRENT STATUS OF THE PROJECT

Some preliminary results of RAINS Poland can be seen in the appendix 1 on page 57. They were calculated for the emission scenario NEC0_NAT_CLE. It is the reference emission scenario for the project as it was the scenario sent by the Polish government to the European commission. Year of calculation is 2005.

Those preliminary results obtained with EMCO SO₂, NO_x and PM are carriers of hope for the future of the project. We can see on next tables, displaying results for whole Poland, that the difference with IIASA reference online model is not huge, especially for total results.

Sector	SO₂ [kt/yr]			NO_x [kt/yr]		
	model	IIASA	difference	model	IIASA	difference
Energy conversion	55,930	55,958	0,00%	10,760	10,76	0,00%
Industry - boilers	55,660	53,4	+ 4,23%	23,380	24,783	- 5,66%
Industry - Other combustion	16,570	11,399	+ 45,36%	24,440	22,78	+ 7,29%
Domestic	190,80	184,273	+ 3,54%	60,250	60,252	0,00%
Road transport	13,350	11,606	+ 15,03%	177,470	175,526	+ 1,11%
Other transport	2,090	1,484	+ 40,84%	68,280	73,312	- 6,86%
Sea transport	3,380	0,964	+ 250,62%	2,7	2,7	0,00%
Power plants	885,710	824,965	+ 7,36%	258	315,727	- 18,28%
Processes	91,920	90,812	+ 1,22%	54,050	45,313	+ 19,28%
Sum	1 315,410	1 246,107	+ 5,56%	679,300	744,905	- 8,81%

Table M : Comparison of SO₂ and NO_x controlled emissions from model and IIASA [3]

More or less, our model is quite overestimating SO₂ emissions and underestimating NO_x emissions. The transport sector for SO₂ should be reconsidered as it is incorrect (250% error). Anyway ENVIRO is more focused on the power plants sector. Results are good in this sector for SO₂ (less than 8% difference), but not so much for NO_x (over 18% difference). But general results are good, so the methodology is validated (except in transport for SO₂) ; now improvement in accuracy should be done by working on input parameters (fuel consumption, removal efficiencies...).

Concerning PM emissions (total suspended), results are good. The biggest difference is only 10% and for total it is less than 1%. Methodology is validated. As for SO₂ and NO_x, improvement in accuracy for some sectors can be made by working on input parameters.

PM _{TSP} [kt/yr]			
SNAP codes	Model	IIASA	difference
1:Combustion in energy industries	43,420	39,236	+ 10,66%
2:Non-industrial combustion plants	189,920	189,897	+ 0,01%
3:Combustion in manufacturing industry	18,940	18,71	+ 1,23%
4:Production processes	29,900	34,525	- 13,40%
5:Extraction and distribution	30,720	31,079	- 1,16%
7:Road transport	25,290	25,288	+ 0,01%
8:Other mobile sources and machinery	8,960	9,985	- 10,27%
9:Waste treatment and disposal	7,670	8,374	- 8,41%
10:Agriculture	65,830	63,521	+ 3,64%
Sum	420,650	420,615	+ 0,01%

Table N : Comparison of PM_{TSP} controlled emissions from model and IIASA by SNAP codes [3]

Sector	SO ₂ costs [M€/year]			NO _x costs [M€/year]		
	model	IIASA	difference	model	IIASA	difference
Energy conversion	1,520	1,524	- 0,26%	1,940	1,948	- 0,41%
Industry - boilers	3,610	3,623	- 0,36%	0,510	0,512	- 0,39%
Industry - Other combustion	12,210	12,201	+ 0,07%	0,370	0,353	+ 4,82%
Domestic	28,810	28,812	- 0,01%	0	0	0,00%
Road transport	177,390	121,28	+ 46,26%	442,730	474,409	- 6,68%
Other transport	65,230	44,598	+ 46,26%	7,260	7,502	- 3,23%
Sea transport	0	0	0,00%	0	0	0,00%
Power plants	475,670	535,72	- 11,21%	32,180	26,764	+ 20,24%
Processes	16,940	15,802	+ 7,20%	0	4,707	- 100,00%
Sum	781,370	815,956	- 4,24%	484,960	522,706	- 7,22%

Table O : Comparison of SO₂ and NO_x emission control costs from model and IIASA [3]

Regarding emission control costs, once again it seems that the transport sector for SO₂ is not working properly. But the correlation for total result is good (less than 5 and 8%). For NO_x improvement should be done in the power plant sector and especially in processes where calculation is not working. Concerning PM costs, we did not prepare a table because our computer version of RAINS is not allowing us to display costs ranked by SNAP codes, as it is displayed on IIASA online reference model.

To resume, almost all sectors are good in the calculation methodology. There are still errors to erase in some fields (especially transport sector for SO₂), but the global model is working properly, as the total correlation is around 5-8%. More accurate input parameters are expected to reduce more and more this difference percentage. Moreover, if ENVIRO can get a computer version of RAINS 8.0, a lot of improvements will be done. But our actual version of RAINS Poland can allow some preliminary energy scenarios analysis.

Now the ENVIRO project is entering in its next phase and new developments began : for example EMCO NH₃. When my internship ended, this work was in a good way and it should be finalize soon. It aims to get more data related to damage done on the environment. Those data could allow further analysis of external costs.

Concerning the work done with POLYPHEMUS on atmospheric modelling, it is on a good way. There is though a problem with calculation time. Each simulation is taking several days before end of calculations, so modelling is only possible for short periods (about one month maximum). The team is looking forward to use a super-computer from the computer department of AGH, but there is for the moment a compatibility problem between POLYPHEMUS and the super-computer.

Until the end of 2006, each member of the team is going for training in order to improve their knowledge and skills on their specialities:

- Artur Wyrwa is going to IIASA to work on RAINS
- Janusz Zyśk is going to CEREA to work on POLYPHEMUS
- Anna Stęzały is going to ElfER to work on external costs
- Marcin Pluta is going to ElfER to work on energy scenarios
- Beata Śliż is currently in ElfER to work on Geographic Information Systems

Those training periods will be very beneficial for the project, as it will gather the different lessons done in those famous European institutions.

The end of the project has been re-scheduled for the end of year 2008. At this time, the combination of works done on RAINS, POLYPHEMUS and external costs will allow accurate analysis of different energy pathways and emission control scenarios, in order to highlight relevant orientations for the future of the Polish energy sector.

IV. PERSONNAL IMPRESSIONS

I chose this internship mainly because it held in a foreign country and because I wanted and needed an international experience. I did not choose Poland especially but I chose the subject of the ENVIRO project. I was attracted because I had no experience in the field of air pollution, nor energy sector, and it seemed to me a good opportunity to develop my knowledge in those domains.

My working language was English so I improved myself communicating in this language. Of course it would have been better to have a period in an English-spoken country but as all my readings and writings were in English I did learn a lot. I was also always speaking in English to my colleagues and to Polish people so I gained more spontaneity in my talking.

Being in a foreign country increased my adaptation skills, especially because I was not always able to communicate in English. I had to adapt myself to the hosting country and it was a good teaching.

My scientific knowledge is clearly improved after this training period. My placement was assistant-researcher so I discovered about scientific research. In fact it was my first experience in this domain. I had the chance to be part of a great scientific project related to industry, whose subject was including as well environmental and financial aspect. The energy sector is influencing a lot of other ones and it is related to quality of life. That is why it is very interesting : it includes a lot of different parameters ruling life in our society.

With this internship, I discovered how a research group can work, what is made in order to reach the objectives. It is a very step-by-step way to work. All those steps are ending by building something bigger, and that is exposed from time to time into articles or interim reports. Those last reports are very important are they are the representation of the work done. It is with the analysis of those transcriptions that it could be said if the research project is well running or if it has to be stopped or re-oriented. I learned about inter-relations between sciences and industry or policy (through relation between European Union and IIASA for example). The work done with RAINS is having an impact on European policy.

I was expecting to learn more about air pollution but in fact I learned much about energy and informatic model for environmental impact assessment. Working on the RAINS model allowed me to train on such a model, and now I can see more precisely how is built and structured such a scientific tool. As it is related to the energy sector, I had some lessons about it. The most interesting was the visit of the co-generation power plant of EDF in Cracow.

Difficulties in my work were coming from informatics. Working on RAINS needs computer and programming skills and my knowledge about it is very limited. It led to some problems for me but after three months of training I can say I improved in this field.

As my internship was held as an assistant-researcher and not as an assistant-engineer, I found myself in lack of lessons about industry or management for example. But it was balanced by the knowledge I listed above and I hope I will be able to train more about engineering skills on next

year during my last training period. Anyway, I gained during those three months in Cracow useful knowledge for my scientific and professional course. I am not seeing myself working in the research field in the future but I am glad I had the opportunity to discover some work related to the air pollution and the energy sector. It will be an experience I will remind to myself during my future career.

I will finish my impressions by giving some comments about the hosting country. World of work in Poland is not drastically different from France, as it remains a European country. But some differences are noticeable from time to time. Political history of Poland is responsible for some but, time running out, it evolved.

I really enjoyed my time in Poland. I had the chance to be in Cracow which is a city full of Polish history and culture, but it is also one of the best European places for entertainment. It is a very beautiful town, as it was not destroyed during the war. Cracow is a great teaching city in Poland so the student life is very active, and I think it is one of the best places to crash for an European student.

The greatest chance of my period in Poland was to be part of a very good working team. I was really well welcomed by Mr. Wyrwa and his group and I will not forget the good working atmosphere. I will remember Polish people as friendly.

V. CONCLUSION

The ENVIRO project is still going on until the end of 2008, at present schedule. At this time, if everything is going well, results obtained with RAINS will allow accurate analysis of different energy and emission control scenarios. Combined with studies made with POLYPHEMUS for atmospheric dispersion, and also studies regarding external costs, EDF Polska will have a relevant scientific tool for help in decision-making regarding future investments. They will be able to optimize as much as possible their investments in Poland in order to insure energy distribution as well as environmental legislation.

The thirteen weeks I had in Poland were beneficial for me. I gained scientific knowledge concerning environmental issues related to the energy sector and the legislation associated. I also trained on an integrated model for impact assessment, and I learned a lot as it was the first experience for me in this field. I had the opportunity to be part of a great project and I discovered in more details the world of research. I will remember this experience for the end of my studies and for my future career.

I was very glad to train in a foreign country to improve my English language skills but moreover to gain an international experience, as I think that an engineering-student needs it in its formation in order to become a good engineer.

- TERMINOLOGY -

CAFE : Clean Air For Europe

CBA : Cost Benefits Analysis

CEREA : Centre d'Enseignement et de Recherche en Environnement Atmosphérique

CHP : Cogenerated Heat and Power

CO₂ : Carbon Dioxide

EDF : Electricité De France

EIfER : European Institute for Energy Research

EMCO : EMission and COst module

ETS : Emission Trading Scheme

IAMs : Integrated Assessment Models

IIASA : International Institute for Applied System Analysis

LCP : Large Combustion Plants

LPS : Large Point Sources (power plants for example)

N₂O : Nitrous Oxide

NEC : National Emissions Ceilings

NH₃ : Ammonia

NO_x : Nitrogen Oxides

O₃ : Ozone

PM : Particulate Matter

RAINS : Regional Air pollution Information and Simulation

SNAP : Selected Nomenclature for Air Pollution

SO₂ : Sulphur Dioxides

SO_x : Sulphur Oxides

SQL : Structured Query Language

UNCLRTAP : United Nations Convention on Long-Range Transboundary Air Pollution

UNFCCC : United Nations Framework Convention on Climate Change

VOC : Volatile Organic Compounds

WP : Work Package

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[4] COFALA J., SYRI S. – Sulphur emissions, abatement technologies and related costs for Europe in the RAINS model database – IIASA, 1998

Web sites

[5] <http://www.iiasa.ac.at/rains> : RAINS Online and related documentation

- APPENDIX -

Appendix 1 : Some preliminary results from EMCO SO₂, NO_x and PM, using emission scenario NEC0_NAT_CLE for year 2005 [3]

N.B. : A voivodship is a Polish region

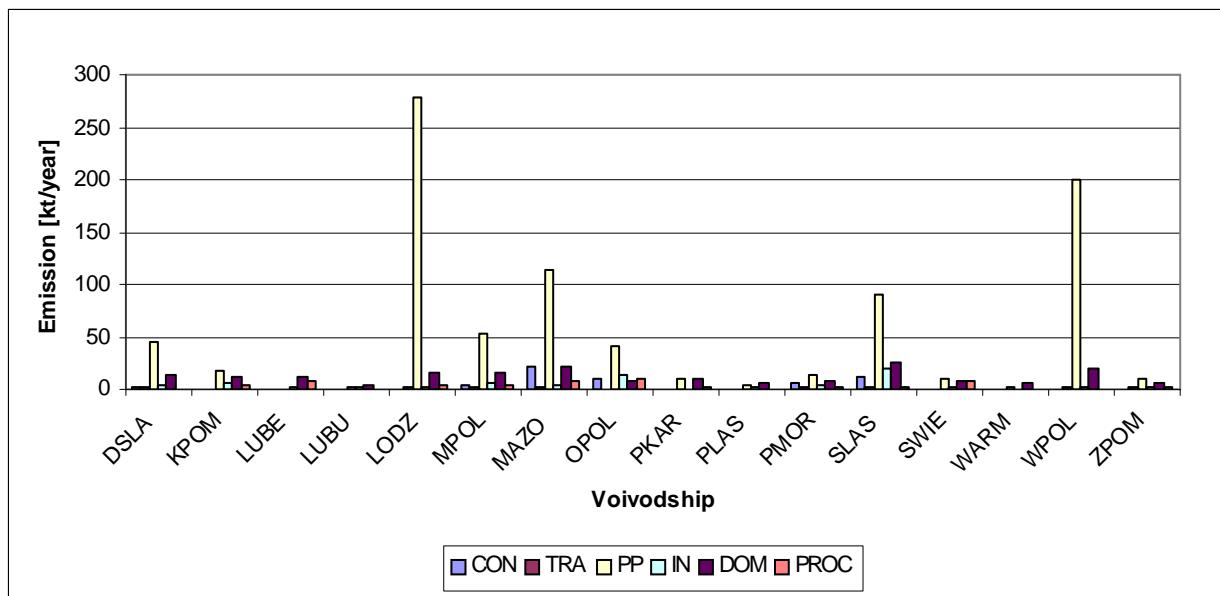


Fig.16 : SO₂ emissions by sector and voivodship [3]

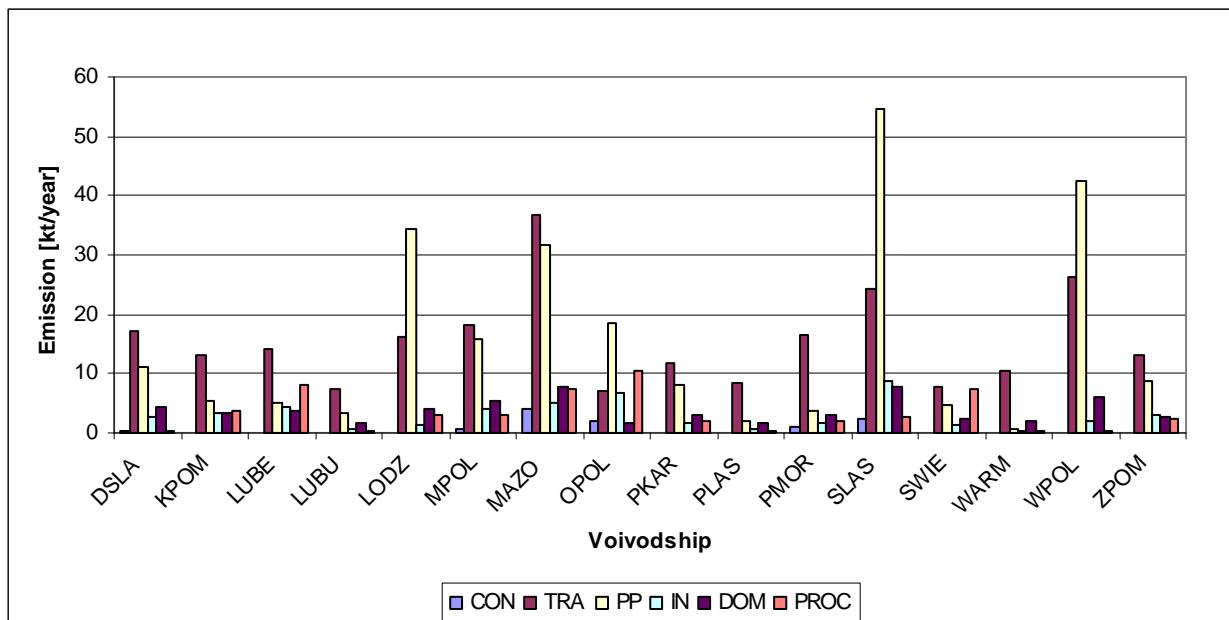


Fig.17 : NO_x emissions by sector and voivodship [3]

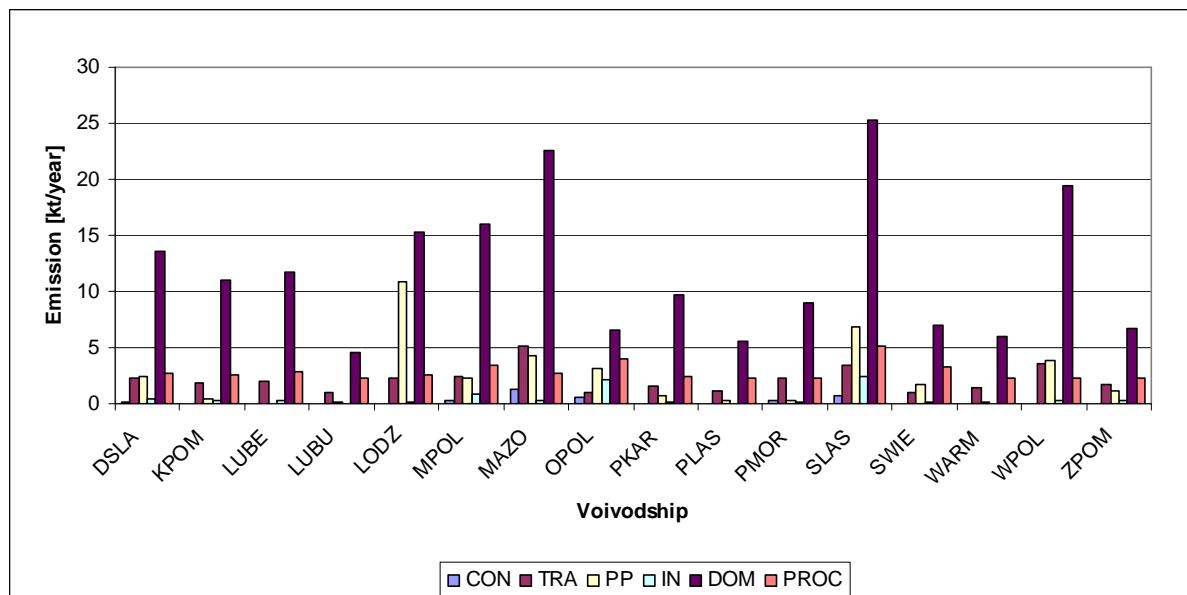


Fig.18 : PM_{TSP} emissions by sector and voivodship [3]

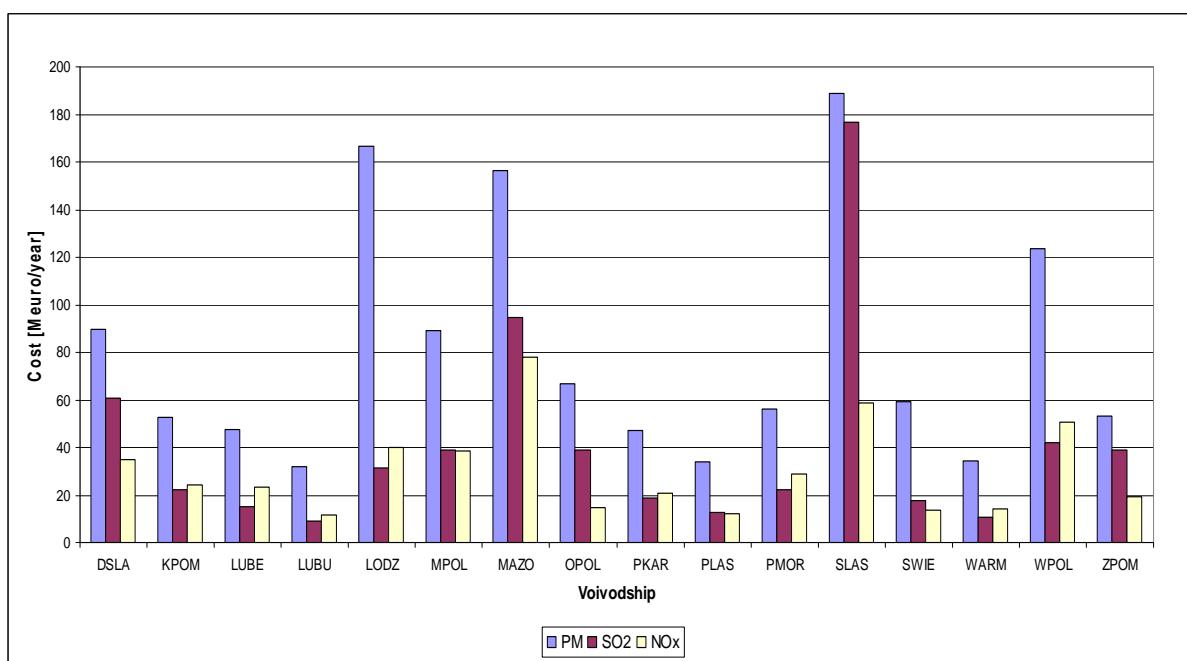


Fig.19 : Control costs per voivodship and pollutant [3]

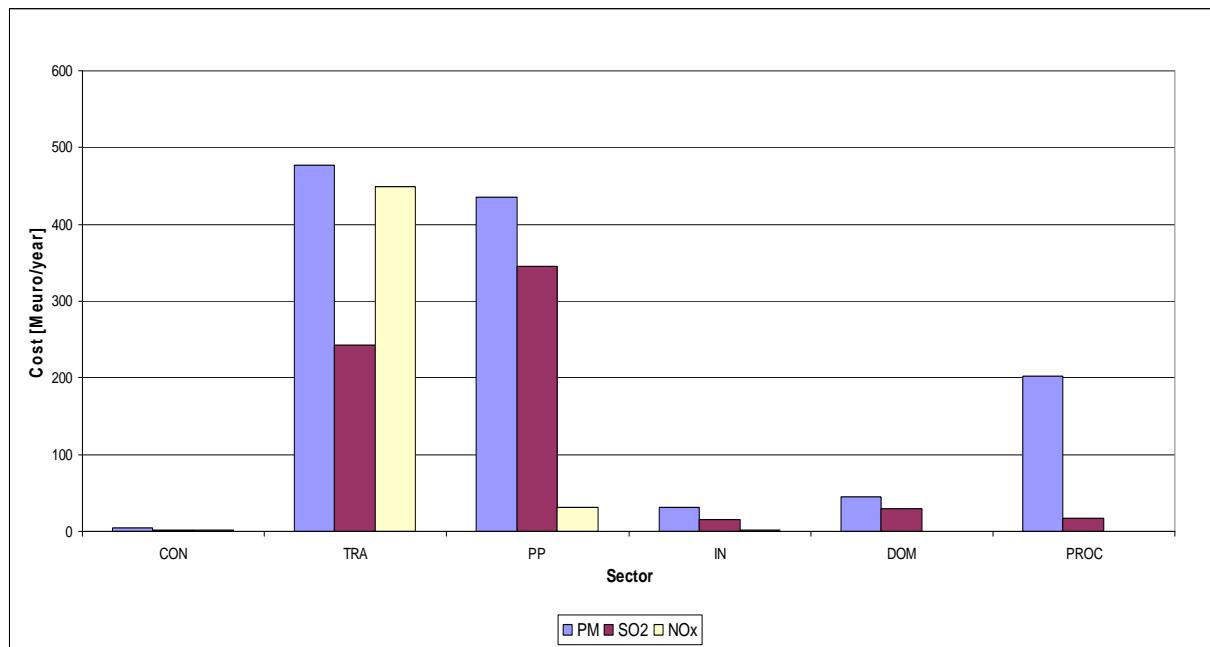


Fig.20 : Control costs per sector and pollutant [3]

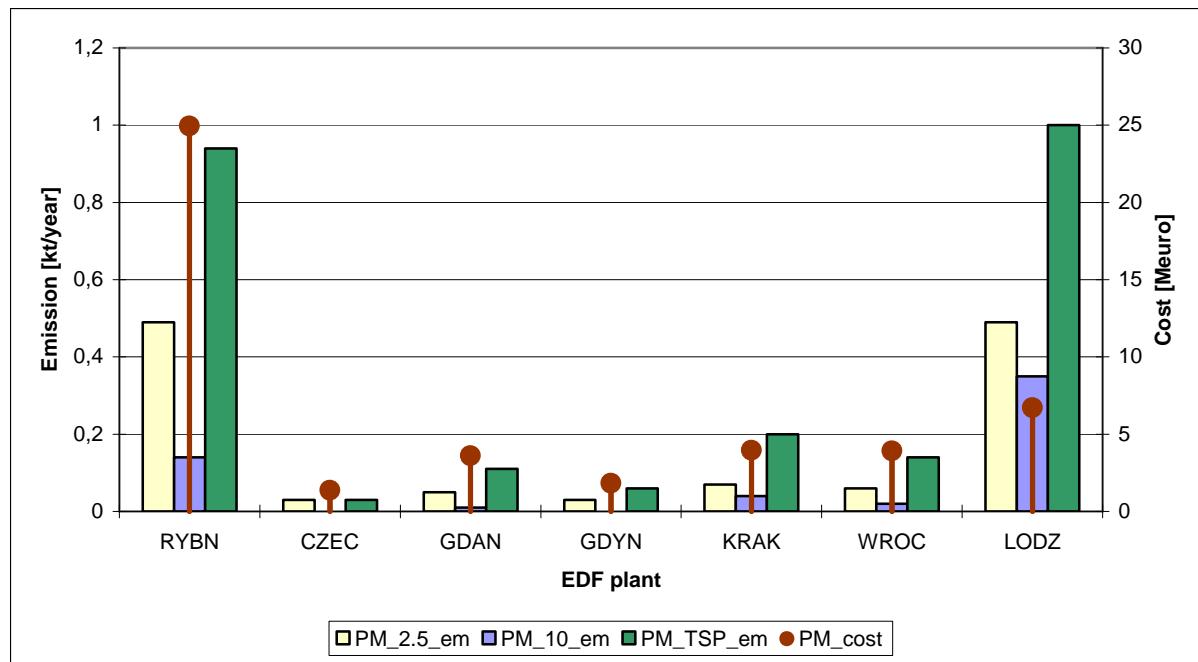


Fig.21 : Emissions of PM_{2,5}, PM_{coarse}, PM_{TSP} and control costs for EDF plants [3]

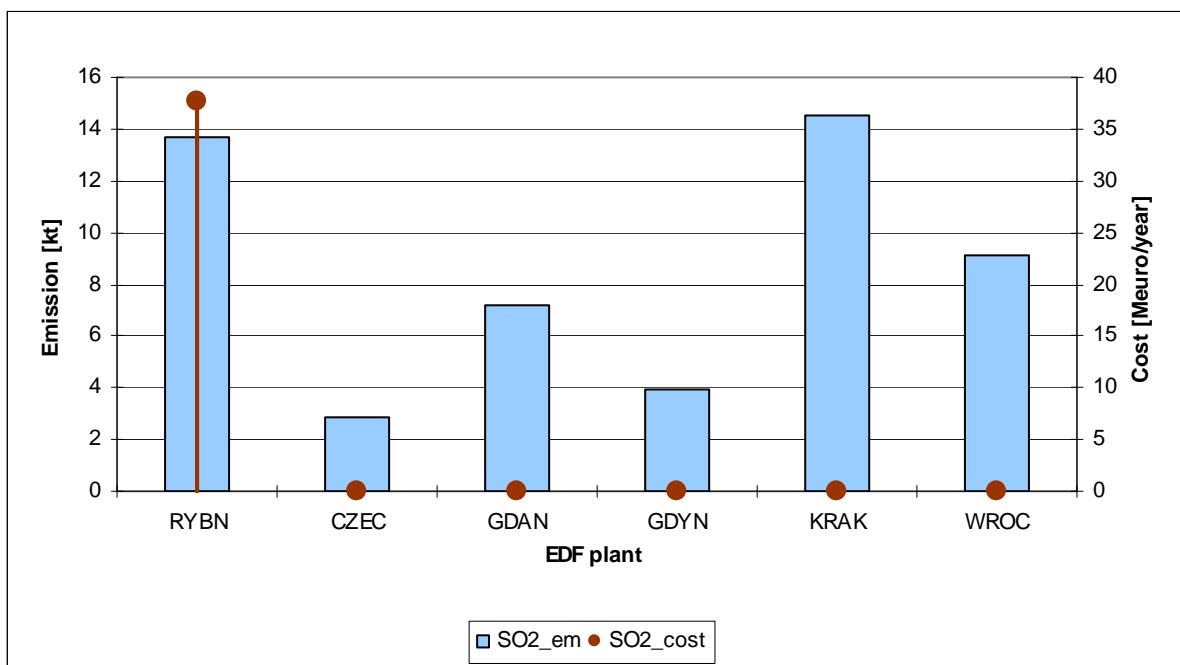


Fig.22 : Emissions of SO_2 and control costs for EDF plants [3]

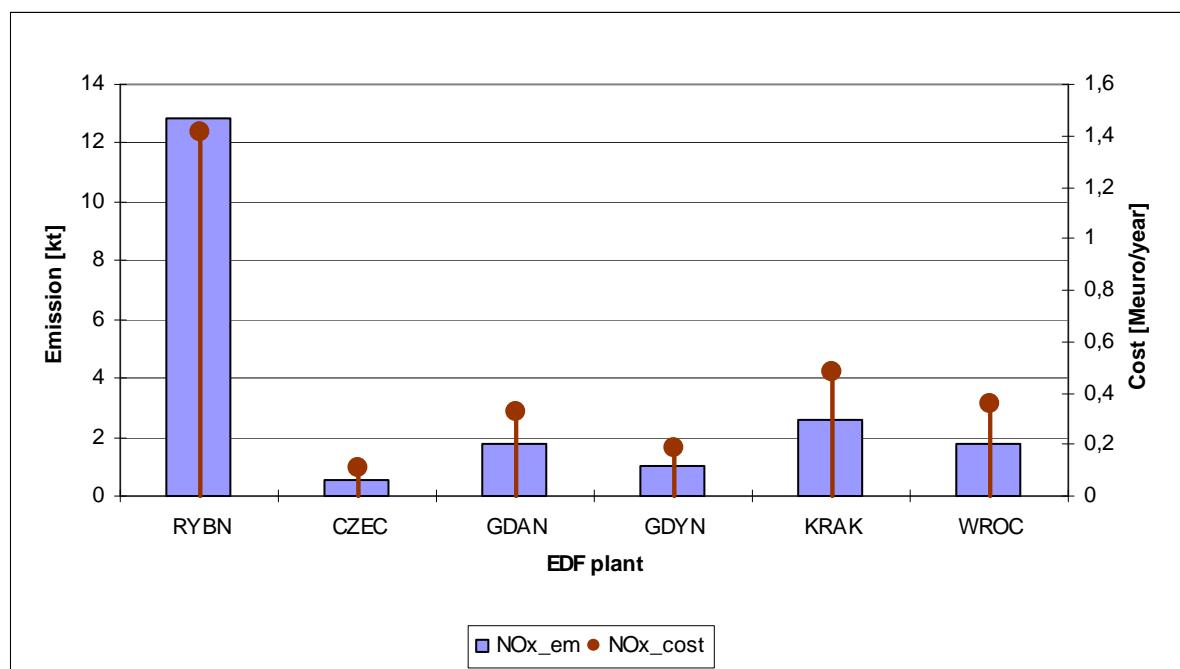


Fig.23 : Emissions of NO_x and control costs for EDF plants [3]

Appendix 2 : Country specific parameters [3]

Wages, interest rate, electricity and sorbent cost				
Country_region	Wages Euro/m-yr	Interest_rate %/100	Electricity_cost Euro/kWh	Sorbent_cost (NOx only) Euro/t
POLA_WHOL	4436	0,04	0,05	303

Country specific costs for abatement technologies		
Unit: [Euro/t]		
Technology	Sorbent	Byproduct disposal
LINJ	22	43
PRWFGD	22	0
PWFGD	22	0
RFGD	152	-218.00

Technology/country specific cost for control options	
Unit: [Euro/t]	
Technology	Byproduct disposal
CYC	23
ESP1	23
ESP2	23
ESP3P	23
FF	23
GHIND	0
WSCRB	23

Appendix 3 : Technology specific parameters for SO₂, NO_x and PM respectively [3]

Abbreviations : UCAP = unit capacity ; RETRO = retrofit factor ; INV_C & IN_V = investment coefficients ; LABOR = labour demand ; ELEDEM = electricity demand ; SORBDEM = sorbent demand ; BY_PROD = by-product disposal.

Technology specific common data on control technologies									
Technology	UCAP_FROM	UCAP_TO	RETRO	INV_C	INV_V	FO_M	LABOR	ELEDEM	SORBDEM
	MW thermal input	MW thermal input	%/100 thermal input	ECL/kW	kECL	%/yr	m ³ /yr/thermal input	GWh/PJ	t/t SO2
LINJ	0	20	0,3	57,6	0	4	3,33	0,5	4,68
LINJ	20	300	0,3	28,8	574,2	4	3,33	0,5	4,68
LINJ	300	9999	0,3	19,8	3267	4	3,33	0,3	4,68
PRWFGD	0	20	0,3	87,3	0	4	3,33	1,6	1,56
PRWFGD	20	300	0,3	74,7	264,6	4	3,33	1,6	1,56
PRWFGD	300	9999	0,3	39,6	10890,9	4	3,33	1,6	1,56
PWFGD	0	20	0,3	87,3	0	4	3,33	1,6	1,56
PWFGD	20	300	0,3	74,7	264,6	4	3,33	1,6	1,56
PWFGD	300	9999	0,3	39,6	10890,9	4	3,33	1,6	1,56
RFGD	0	20	0,3	335,7	0	4	25,2	2,2	0,01
RFGD	20	300	0,3	163,8	3440,7	4	25,2	2,2	0,01
RFGD	300	9999	0,3	101,7	21671,1	4	25,2	2,2	0,01

Technology specific data for stationary sources

Technology	UCAP_FROM	UCAP_TO	RETRO	INV_CI	INV_VI	INV_C2	INV_V2	FO_M	ELDEM	SORBDEM	CATCOST	CATLT
	MW thermal input	MW thermal input	%	Euro/kW thermal input	kEuro	Euro/kW thermal input	kEuro	%/yr	GWh/PJ thermal input	t/t NOx	Euro/m^3	hours
PBCCM	0	20	0	0	0	12,34	0	0	0	0	-1	-1
PBCCM	20	300	0	0	0	10,02	46,46	0	0	0	-1	-1
PBCCM	300	9999	0	0	0	6,4	1128,93	0	0	0	-1	-1
PHCCM	0	20	0	0	0	7,62	0	0	0	0	-1	-1
PHCCM	20	300	0	0	0	6,27	27,23	0	0	0	-1	-1
PHCCM	300	9999	0	0	0	2,82	1060,57	0	0	0	-1	-1
POGCM	0	20	0	0	0	4,63	0	0	0	0	-1	-1
POGCM	20	300	0	0	0	3,75	17,42	0	0	0	-1	-1
POGCM	300	9999	0	0	0	2,41	967,58	0	0	0	-1	-1
PBCSCR	0	20	0	0	0	32,73	0	4	0,36	0,39	6000	56000
PBCSCR	20	300	0	0	0	24,38	170,32	4	0,36	0,39	6000	56000
PBCSCR	300	9999	0	0	0	8,51	4925,91	4	0,36	0,39	6000	56000
PBCCSC	0	20	40	12,34	0	32,73	0	4	0,36	0,12	6000	56000
PBCCSC	20	300	40	10,02	46,46	24,38	170,32	4	0,36	0,12	6000	56000
PBCCSC	300	9999	40	6,4	1128,93	8,51	4925,91	4	0,36	0,12	6000	56000
PHCSCR	0	20	40	0	0	27,28	0	4	0,36	0,39	6000	56000
PHCSCR	20	300	40	0	0	20,32	141,93	4	0,36	0,39	6000	56000
PHCSCR	300	9999	40	0	0	7,1	4104,93	4	0,36	0,39	6000	56000
PHCCSC	0	20	40	7,62	0	27,28	0	4	0,36	0,17	6000	56000
PHCCSC	20	300	40	6,27	27,23	20,32	141,93	4	0,36	0,17	6000	56000
PHCCSC	300	9999	40	2,82	1060,57	7,1	4104,93	4	0,36	0,17	6000	56000
POGSCR	0	20	40	0	0	20,36	0	4	0,3	0,39	23000	80000
POGSCR	20	300	40	0	0	15,66	95,81	4	0,3	0,39	23000	80000
POGSCR	300	9999	40	0	0	6,38	2770,83	4	0,3	0,39	23000	80000
POGCSC	0	20	40	4,63	0	20,36	0	4	0,3	0,12	23000	80000
POGCSC	20	300	40	3,73	17,42	15,66	95,81	4	0,3	0,12	23000	80000
POGCSC	300	9999	40	2,41	967,58	6,58	2770,83	4	0,3	0,12	23000	80000

Technology specific data for stationary sources (combustion)

Technology	UCAP_FROM MW <th>k</th> <th>UCAP_TO MW<th>k</th><th>RETRO %</th><th>INV_C Euro/kW<th>k</th><th>INV_V kEuro</th><th>FO_M %/year</th><th>LABOR m·yr/GWh</th><th>ELDEM GWk/PJ<th>k</th><th>BY_PROD t/t TSP</th></th></th></th>	k	UCAP_TO MW <th>k</th> <th>RETRO %</th> <th>INV_C Euro/kW<th>k</th><th>INV_V kEuro</th><th>FO_M %/year</th><th>LABOR m·yr/GWh</th><th>ELDEM GWk/PJ<th>k</th><th>BY_PROD t/t TSP</th></th></th>	k	RETRO %	INV_C Euro/kW <th>k</th> <th>INV_V kEuro</th> <th>FO_M %/year</th> <th>LABOR m·yr/GWh</th> <th>ELDEM GWk/PJ<th>k</th><th>BY_PROD t/t TSP</th></th>	k	INV_V kEuro	FO_M %/year	LABOR m·yr/GWh	ELDEM GWk/PJ <th>k</th> <th>BY_PROD t/t TSP</th>	k	BY_PROD t/t TSP
ESP1	0	5	0	42,9	0	4	1,0	0,11	0,11	1			
ESP1	5	50	0	11,39	158,24	4	1,0	0,11	0,11	1			
ESP1	50	9999	0	6,11	420,09	4	1,0	0,11	0,11	1			
ESP2	0	5	0	53,63	0	4	1,0	0,13	0,13	1			
ESP2	5	50	0	14,19	197,84	4	1,0	0,13	0,13	1			
ESP2	50	9999	0	7,59	525,03	4	1,0	0,13	0,13	1			
ESP3P	0	5	0	58,41	0	4	1,0	0,15	0,15	1			
ESP3P	5	50	0	16,83	208,56	4	1,0	0,15	0,15	1			
ESP3P	50	9999	0	9,24	583,44	4	1,0	0,15	0,15	1			
CYC	0	5	0	17,16	0	4	0,8	0,15	0,15	1			
CYC	5	50	0	4,46	63,36	4	0,8	0,15	0,15	1			
CYC	50	9999	0	2,48	167,97	4	0,8	0,15	0,15	1			
FF	0	5	0	35,48	0	4,5	1,0	0,2	0,2	1			
FF	5	50	0	18,15	86,3	4,5	1,0	0,2	0,2	1			
FF	50	9999	0	13,04	349,97	4,5	1,0	0,2	0,2	1			
GHIND	0	5	0	2,2	0	4	0	0	0	0			
GHIND	5	50	0	2,2	0	4	0	0	0	0			
GHIND	50	9999	0	2,2	0	4	0	0	0	0			
WSCRB	0	5	0	52,64	0	4,5	1,0	1,3	1,3	1			
WSCRB	5	50	0	15,02	187,77	4,5	1,0	1,5	1,5	1			
WSCRB	50	9999	0	8,23	525,03	4,5	1,0	1,5	1,5	1			

2025	H2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2025	REN	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2025	HYD	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2025	NUC	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2025	ELE	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2025	HT	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2025 Sum		0,00											
2030	BC1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	BC2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	HC1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	HC2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	HC3	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	DC	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	OS1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	OS2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	HF	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	MD	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	ETH	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	GSL	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	LPG	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	MTH	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030 Gas		0,00											
2030	H2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	REN	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	HYD	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	NUC	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	ELE	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030	HT	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2030 Sum		0,00											

Appendix 5 : Example of control strategy in emission scenario NEC0_NAT_CLE [5]

Control strategy - SO2

Unit : % of total activity controlled

Activity	Sector	Technology	Y1990	Y1995	Y2000	Y2005	Y2010	Y2015	Y2020	Y2025	Y2030
BC1	CON_COMB	NSC_SO2	0	0	0	0	0	0	0	0	0
BC1	CON_COMB	LINJ	0	0	0	0	0	0	0	0	0
BC1	CON_COMB	IWFGD	0	0	0	0	0	0	0	0	0
BC1	DOM	NSC_SO2	0	0	0	0	0	0	0	0	0
BC1	IN_BO	NSC_SO2	0	0	0	0	0	0	0	0	0
BC1	IN_BO	LINJ	0	0	0	0	0	0	0	0	0
BC1	IN_BO	IWFGD	0	0	0	0	0	0	0	0	0
BC1	IN_OC	NSC_SO2	0	0	0	0	0	0	0	0	0
BC1	IN_OC	LINJ	0	0	0	0	0	0	0	0	0
BC1	IN_OC	IWFGD	0	0	0	0	0	0	0	0	0
BC1	PP_EX_OTH	NSC_SO2	0	0	0	0	0	0	0	0	0
BC1	PP_EX_OTH	LINJ	0	0	0	0	0	0	0	0	0
BC1	PP_EX_OTH	PRWFBD	0	10	40	45	50	50	60	70	80
BC1	PP_EX_OTH	PWFBD	0	0	0	0	0	0	0	0	0
BC1	PP_NEW	NSC_SO2	0	0	0	0	0	0	0	0	0
BC1	PP_NEW	LINJ	0	0	0	0	0	0	0	0	0
BC1	PP_NEW	PWFBD	0	100	100	100	100	100	100	100	100
BC1	PP_NEW	RFGD	0	0	0	0	0	0	0	0	0
BC2	CON_COMB	NSC_SO2	0	0	0	0	0	0	0	0	0
BC2	CON_COMB	LINJ	0	0	0	0	0	0	0	0	0
BC2	CON_COMB	IWFGD	0	0	0	0	0	0	0	0	0
BC2	DOM	NSC_SO2	0	0	0	0	0	0	0	0	0
BC2	IN_BO	NSC_SO2	0	0	0	0	0	0	0	0	0
BC2	IN_BO	LINJ	0	0	0	0	0	0	0	0	0
BC2	IN_BO	IWFGD	0	0	0	0	0	0	0	0	0
BC2	IN_OC	NSC_SO2	0	0	0	0	0	0	0	0	0
BC2	IN_OC	LINJ	0	0	0	0	0	0	0	0	0
BC2	IN_OC	IWFGD	0	0	0	0	0	0	0	0	0
BC2	PP_EX_OTH	NSC_SO2	0	0	0	0	0	0	0	0	0
BC2	PP_EX_OTH	LINJ	0	0	0	0	0	0	0	0	0
BC2	PP_EX_OTH	PRWFBD	0	0	0	0	0	0	0	0	0
BC2	PP_EX_OTH	PWFBD	0	0	0	0	0	0	0	0	0
BC2	PP_NEW	NSC_SO2	0	0	0	0	0	0	0	0	0
BC2	PP_NEW	LINJ	0	0	0	0	0	0	0	0	0
BC2	PP_NEW	PWFBD	0	0	100	100	100	100	100	100	100
BC2	PP_NEW	RFGD	0	0	0	0	0	0	0	0	0
DC	CON_COMB	NSC_SO2	0	0	0	0	0	0	0	0	0
DC	DOM	NSC_SO2	0	0	0	0	0	0	0	0	0
DC	DOM	LSCK	0	0	0	0	0	0	0	0	0
DC	IN_BO	NSC_SO2	0	0	0	0	0	0	0	0	0
DC	IN_OC	NSC_SO2	0	0	0	0	0	0	0	0	0
DC	PP_EX_OTH	NSC_SO2	0	0	0	0	0	0	0	0	0
DC	PP_NEW	NSC_SO2	0	0	0	0	0	0	0	0	0
DC	PP_NEW	LSCK	0	0	0	0	0	0	0	0	0
GSL	TRA_OT	LSGSL	0	0	0	0	100	100	100	100	100
GSL	TRA_RD	LSGSL	0	0	0	0	100	100	100	100	100
HC1	CON_COMB	NSC_SO2	0	0	0	0	0	0	0	0	0
HC1	CON_COMB	LSCO	0	0	0	0	0	0	0	0	0

HC1	CON_COMB	LINJ	0	0	0	0	0	0	0	0	0
HC1	CON_COMB	IWFGD	0	0	0	0	0	0	0	0	0
HC1	DOM	NSC_SO2	0	0	0	0	0	0	0	0	0
HC1	DOM	LSCO	0	0	0	0	0	0	0	0	0
HC1	IN_BO	NSC_SO2	0	0	0	0	0	0	0	0	0
HC1	IN_BO	LSCO	0	0	0	0	0	0	0	0	0
HC1	IN_BO	LINJ	0	0	0	0	0	0	0	0	0
HC1	IN_BO	IWFGD	0	0	0	0	0	0	0	0	0
HC1	IN_OC	NSC_SO2	0	0	0	0	0	0	0	0	0
HC1	IN_OC	LSCO	0	0	0	0	0	0	0	0	0
HC1	IN_OC	LINJ	0	0	0	0	0	0	0	0	0
HC1	IN_OC	IWFGD	0	0	0	0	0	0	0	0	0
HC1	PP_EX_OTH	NSC_SO2	0	0	0	0	0	0	0	0	0
HC1	PP_EX_OTH	LSCO	0	35	43,5	50	50	50	45	30	0
HC1	PP_EX_OTH	LINJ	0	10	20	20	20	20	20	20	20
HC1	PP_EX_OTH	PRWFGD	0	0	20	20	25	30	35	50	80
HC1	PP_EX_OTH	PWFGD	0	0	0	0	0	0	0	0	0
HC1	PP_EX_WB	NSC_SO2	0	0	0	0	0	0	0	0	0
HC1	PP_EX_WB	LSCO	0	0	0	0	0	0	0	0	0
HC1	PP_EX_WB	LINJ	0	0	0	0	0	0	0	0	0
HC1	PP_EX_WB	PRWFGD	0	0	0	0	0	0	0	0	0
HC1	PP_EX_WB	PWFGD	0	0	0	0	0	0	0	0	0
HC1	PP_NEW	NSC_SO2	0	0	0	0	0	0	0	0	0
HC1	PP_NEW	LSCO	0	0	0	0	0	0	0	0	0
HC1	PP_NEW	LINJ	0	0	0	0	0	0	0	0	0
HC1	PP_NEW	PWFGD	0	0	100	100	100	100	100	100	100
HC1	PP_NEW	RFGD	0	0	0	0	0	0	0	0	0
HC1	TRA_OT	LSCO	0	0	70	70	70	70	70	70	70
HC2	CON_COMB	NSC_SO2	0	0	0	0	0	0	0	0	0
HC2	CON_COMB	LSCO	0	0	0	0	0	0	0	0	0
HC2	CON_COMB	LINJ	0	0	0	0	0	0	0	0	0
HC2	CON_COMB	IWFGD	0	0	0	0	0	0	0	0	0
HC2	DOM	NSC_SO2	0	0	0	0	0	0	0	0	0
HC2	DOM	LSCO	0	0	0	0	0	0	0	0	0
HC2	IN_BO	NSC_SO2	0	0	0	0	0	0	0	0	0
HC2	IN_BO	LSCO	0	0	0	0	0	0	0	0	0
HC2	IN_BO	LINJ	0	0	0	0	0	0	0	0	0
HC2	IN_BO	IWFGD	0	0	0	0	0	0	0	0	0
HC2	IN_OC	NSC_SO2	0	0	0	0	0	0	0	0	0
HC2	IN_OC	LSCO	0	0	0	0	0	0	0	0	0
HC2	IN_OC	LINJ	0	0	0	0	0	0	0	0	0
HC2	IN_OC	IWFGD	0	0	0	0	0	0	0	0	0
HC2	PP_EX_OTH	NSC_SO2	0	0	0	0	0	0	0	0	0
HC2	PP_EX_OTH	LSCO	0	0	0	0	0	0	0	0	0
HC2	PP_EX_OTH	LINJ	0	0	0	0	0	0	0	0	0
HC2	PP_EX_OTH	PRWFGD	0	0	0	0	0	0	0	0	0
HC2	PP_EX_OTH	PWFGD	0	0	0	0	0	0	0	0	0
HC2	PP_EX_WB	NSC_SO2	0	0	0	0	0	0	0	0	0
HC2	PP_EX_WB	LSCO	0	0	0	0	0	0	0	0	0
HC2	PP_EX_WB	LINJ	0	0	0	0	0	0	0	0	0
HC2	PP_EX_WB	PRWFGD	0	0	0	0	0	0	0	0	0
HC2	PP_EX_WB	PWFGD	0	0	0	0	0	0	0	0	0
HC2	PP_NEW	NSC_SO2	0	0	0	0	0	0	0	0	0
HC2	PP_NEW	LSCO	0	0	0	0	0	0	0	0	0
HC2	PP_NEW	LINJ	0	0	0	0	0	0	0	0	0
HC2	PP_NEW	PWFGD	0	0	100	100	100	100	100	100	100
HC2	PP_NEW	RFGD	0	0	0	0	0	0	0	0	0

HC2	TRA_OT	LSCO	0	0	0	0	0	0	0	0	0
HC3	CON_COMB	NSC_SO2	0	0	0	0	0	0	0	0	0
HC3	CON_COMB	LSCO	0	0	0	0	0	0	0	0	0
HC3	CON_COMB	LINJ	0	0	0	0	0	0	0	0	0
HC3	CON_COMB	IWFGD	0	0	0	0	0	0	0	0	0
HC3	DOM	NSC_SO2	0	0	0	0	0	0	0	0	0
HC3	DOM	LSCO	0	0	0	0	0	0	0	0	0
HC3	IN_BO	NSC_SO2	0	0	0	0	0	0	0	0	0
HC3	IN_BO	LSCO	0	0	0	0	0	0	0	0	0
HC3	IN_BO	LINJ	0	0	0	0	0	0	0	0	0
HC3	IN_BO	IWFGD	0	0	0	0	0	0	0	0	0
HC3	IN_OC	NSC_SO2	0	0	0	0	0	0	0	0	0
HC3	IN_OC	LSCO	0	0	0	0	0	0	0	0	0
HC3	IN_OC	LINJ	0	0	0	0	0	0	0	0	0
HC3	IN_OC	IWFGD	0	0	0	0	0	0	0	0	0
HC3	PP_EX_OTH	NSC_SO2	0	0	0	0	0	0	0	0	0
HC3	PP_EX_OTH	LSCO	0	0	0	0	0	0	0	0	0
HC3	PP_EX_OTH	LINJ	0	0	0	0	0	0	0	0	0
HC3	PP_EX_OTH	PRWFGD	0	0	0	0	0	0	0	0	0
HC3	PP_EX_OTH	PWFGD	0	0	0	0	0	0	0	0	0
HC3	PP_EX_WB	NSC_SO2	0	0	0	0	0	0	0	0	0
HC3	PP_EX_WB	LSCO	0	0	0	0	0	0	0	0	0
HC3	PP_EX_WB	LINJ	0	0	0	0	0	0	0	0	0
HC3	PP_EX_WB	PRWFGD	0	0	0	0	0	0	0	0	0
HC3	PP_EX_WB	PWFGD	0	0	0	0	0	0	0	0	0
HC3	PP_NEW	NSC_SO2	0	0	0	0	0	0	0	0	0
HC3	PP_NEW	LSCO	0	0	0	0	0	0	0	0	0
HC3	PP_NEW	LINJ	0	0	0	0	0	0	0	0	0
HC3	PP_NEW	PWFGD	0	0	100	100	100	100	100	100	100
HC3	PP_NEW	RFGD	0	0	0	0	0	0	0	0	0
HC3	TRA_OT	LSCO	0	0	0	0	0	0	0	0	0
HF	CON_COMB	NSC_SO2	0	0	0	0	0	0	0	0	0
HF	CON_COMB	LSHF	0	0	0	0	0	0	0	0	0
HF	CON_COMB	IWFGD	0	0	0	0	0	0	0	0	0
HF	CON_COMB	RFGD	0	0	0	0	0	0	0	0	0
HF	DOM	NSC_SO2	0	0	0	0	0	0	0	0	0
HF	DOM	LSHF	0	0	0	0	0	0	0	0	0
HF	IN_BO	NSC_SO2	0	0	0	0	0	0	0	0	0
HF	IN_BO	LSHF	0	0	0	80	80	80	80	80	80
HF	IN_BO	IWFGD	0	0	0	0	0	0	0	0	0
HF	IN_OC	NSC_SO2	0	0	0	0	0	0	0	0	0
HF	IN_OC	LSHF	0	0	0	80	80	80	80	80	80
HF	IN_OC	IWFGD	0	0	0	0	0	0	0	0	0
HF	PP_EX_OTH	NSC_SO2	0	0	0	0	0	0	0	0	0
HF	PP_EX_OTH	LSHF	0	0	0	80	80	80	80	80	80
HF	PP_EX_OTH	PRWFGD	0	0	0	0	0	0	0	0	0
HF	PP_EX_OTH	PWFGD	0	0	0	0	0	0	0	0	0
HF	PP_NEW	NSC_SO2	0	0	0	0	0	0	0	0	0
HF	PP_NEW	LSHF	0	0	80	80	80	0	0	0	0
HF	PP_NEW	PWFGD	0	0	0	0	0	100	100	100	100
HF	PP_NEW	RFGD	0	0	0	0	0	0	0	0	0
HF	TRA_OT	NSC_SO2	0	0	0	0	0	0	0	0	0
HF	TRA_OT	LSHF	0	0	0	80	80	80	80	80	80
HF	TRAOTS	NSC_SO2	0	0	0	0	0	0	0	0	0
HF	TRAOTS	LSHF	0	0	0	0	0	0	0	0	0
MD	CON_COMB	NSC_SO2	0	0	0	0	0	0	0	0	0
MD	CON_COMB	LSMD1	0	0	75	100	35	35	35	35	35

MD	CON_COMB	LSMD2	0	0	0	0	65	65	65	65	65
MD	DOM	NSC_SO2	0	0	0	0	0	0	0	0	0
MD	DOM	LSMD1	0	0	75	100	35	35	35	35	35
MD	DOM	LSMD2	0	0	0	0	65	65	65	65	65
MD	IN_BO	NSC_SO2	0	0	0	0	0	0	0	0	0
MD	IN_BO	LSMD1	0	0	75	100	35	35	35	35	35
MD	IN_BO	LSMD2	0	0	0	0	65	65	65	65	65
MD	IN_OC	NSC_SO2	0	0	0	0	0	0	0	0	0
MD	IN_OC	LSMD1	0	0	75	100	35	35	35	35	35
MD	IN_OC	LSMD2	0	0	0	0	65	65	65	65	65
MD	PP_EX_OTH	NSC_SO2	0	0	0	0	0	0	0	0	0
MD	PP_EX_OTH	LSMD1	0	0	75	100	35	35	35	35	35
MD	PP_EX_OTH	LSMD2	0	0	0	0	65	65	65	65	65
MD	PP_NEW	NSC_SO2	0	0	0	0	0	0	0	0	0
MD	PP_NEW	LSMD1	0	0	75	100	35	35	35	35	35
MD	PP_NEW	LSMD2	0	0	0	0	65	65	65	65	65
MD	TRA_OT	NSC_SO2	0	0	0	0	0	0	0	0	0
MD	TRA_OT	LSMD1	0	0	75	0	0	0	0	0	0
MD	TRA_OT	LSMD2	0	0	0	100	0	0	0	0	0
MD	TRA_OT	LSMD3	0	0	0	0	100	100	100	100	100
MD	TRA_OTS	NSC_SO2	0	0	0	0	0	0	0	0	0
MD	TRA_OTS	LSMD1	0	0	0	0	0	0	0	0	0
MD	TRA_OTS	LSMD2	0	0	0	0	0	0	0	0	0
MD	TRA_RD	NSC_SO2	0	0	0	0	0	0	0	0	0
MD	TRA_RD	LSMD1	0	0	75	0	0	0	0	0	0
MD	TRA_RD	LSMD2	0	0	0	100	0	0	0	0	0
MD	TRA_RD	LSMD3	0	0	0	0	100	100	100	100	100
NOF	PR_CEM	NSC_SO2	0	0	0	0	0	0	0	0	0
NOF	PR_CEM	SO2PR1	0	0	0	0	0	0	0	0	0
NOF	PR_CEM	SO2PR2	0	0	0	0	0	0	0	0	0
NOF	PR_CEM	SO2PR3	0	0	0	0	0	0	0	0	0
NOF	PR_COKE	NSC_SO2	0	0	0	0	0	0	0	0	0
NOF	PR_COKE	SO2PR1	0	0	0	0	0	0	0	0	0
NOF	PR_COKE	SO2PR2	0	0	0	0	0	0	0	0	0
NOF	PR_COKE	SO2PR3	0	0	0	0	0	0	0	0	0
NOF	PR_LIME	NSC_SO2	0	0	0	0	0	0	0	0	0
NOF	PR_LIME	SO2PR1	0	0	0	0	0	0	0	0	0
NOF	PR_LIME	SO2PR2	0	0	0	0	0	0	0	0	0
NOF	PR_LIME	SO2PR3	0	0	0	0	0	0	0	0	0
NOF	PR_NIAC	NSC_SO2	0	0	0	0	0	0	0	0	0
NOF	PR_NIAC	SO2PR1	0	0	0	0	0	0	0	0	0
NOF	PR_NIAC	SO2PR2	0	0	0	0	0	0	0	0	0
NOF	PR_NIAC	SO2PR3	0	0	0	0	0	0	0	0	0
NOF	PR_OT_NFME	NSC_SO2	0	0	0	0	0	0	0	0	0
NOF	PR_OT_NFME	SO2PR1	0	75	75	75	75	75	75	75	75
NOF	PR_OT_NFME	SO2PR2	0	25	25	25	25	25	25	25	25
NOF	PR_OT_NFME	SO2PR3	0	0	0	0	0	0	0	0	0
NOF	PR_PIGI	NSC_SO2	0	0	0	0	0	0	0	0	0
NOF	PR_PIGI	SO2PR1	0	0	0	0	0	0	0	0	0
NOF	PR_PIGI	SO2PR2	0	0	0	0	0	0	0	0	0
NOF	PR_PIGI	SO2PR3	0	0	0	0	0	0	0	0	0
NOF	PR_PULP	NSC_SO2	0	0	0	0	0	0	0	0	0
NOF	PR_PULP	SO2PR1	0	0	0	0	0	0	0	0	0
NOF	PR_PULP	SO2PR2	0	0	0	0	0	0	0	0	0
NOF	PR_PULP	SO2PR3	0	0	0	0	0	0	0	0	0
NOF	PR_REF	NSC_SO2	0	0	0	0	0	0	0	0	0
NOF	PR_REF	SO2PR1	0	0	0	50	50	50	50	50	50

NOF	PR_REF	SO2PR2	0	0	0	0	25	25	25	25	25
NOF	PR_REF	SO2PR3	0	0	0	0	0	0	0	0	0
NOF	PR_SINT	NSC_SO2	0	0	0	0	0	0	0	0	0
NOF	PR_SINT	SO2PR1	0	0	0	0	0	0	0	0	0
NOF	PR_SINT	SO2PR2	0	0	0	0	0	0	0	0	0
NOF	PR_SINT	SO2PR3	0	0	0	0	0	0	0	0	0
NOF	PR_SUAC	NSC_SO2	0	0	0	0	0	0	0	0	0
NOF	PR_SUAC	SO2PR1	0	0	0	50	50	50	50	50	50
NOF	PR_SUAC	SO2PR2	0	0	0	0	25	25	25	25	25
NOF	PR_SUAC	SO2PR3	0	0	0	0	0	0	0	0	0
OS1	CON_COMB	NSC_SO2	0	0	0	0	0	0	0	0	0
OS1	DOM	NSC_SO2	0	0	0	0	0	0	0	0	0
OS1	IN_BO	NSC_SO2	0	0	0	0	0	0	0	0	0
OS1	IN_OC	NSC_SO2	0	0	0	0	0	0	0	0	0
OS1	PP_EX_OTH	NSC_SO2	0	0	0	0	0	0	0	0	0
OS1	PP_NEW	NSC_SO2	0	0	0	0	0	0	0	0	0
OS2	CON_COMB	NSC_SO2	0	0	0	0	0	0	0	0	0
OS2	CON_COMB	LINJ	0	0	0	0	0	0	0	0	0
OS2	CON_COMB	IWFGD	0	0	0	0	0	0	0	0	0
OS2	DOM	NSC_SO2	0	0	0	0	0	0	0	0	0
OS2	IN_BO	NSC_SO2	0	0	0	0	0	0	0	0	0
OS2	IN_BO	LINJ	0	0	0	0	0	0	0	0	0
OS2	IN_BO	IWFGD	0	0	0	0	0	0	0	0	0
OS2	IN_OC	NSC_SO2	0	0	0	0	0	0	0	0	0
OS2	IN_OC	LINJ	0	0	0	0	0	0	0	0	0
OS2	IN_OC	IWFGD	0	0	0	0	0	0	0	0	0
OS2	PP_EX_OTH	NSC_SO2	0	0	0	0	0	0	0	0	0
OS2	PP_EX_OTH	LINJ	0	0	0	0	0	0	0	0	0
OS2	PP_EX_OTH	PRWFGD	0	0	0	0	0	0	0	0	0
OS2	PP_EX_OTH	PWFCD	0	0	0	0	0	0	0	0	0
OS2	PP_NEW	NSC_SO2	0	0	0	0	0	0	0	0	0
OS2	PP_NEW	LINJ	0	0	0	0	0	0	0	0	0
OS2	PP_NEW	PWFCD	0	0	70	70	70	70	70	70	70

Appendix 6 : SQL program

Step1.prg

```
path_polska='D:\AGH\polska'  
path_costdat='D:\AGH\polska\costdat'  
  
DELETE FILE &path_polska\EDF_tr_uc.dbf  
COPY FILE &path_polska\EDF_tr_uc_copy.dbf TO &path_polska\EDF_tr_uc.dbf  
DELETE FILE &path_polska\EDF_tr_uc_copy.dbf  
  
COPY FILE &path_polska\cotecnox.dbf TO &path_polska\cotecnox_copy.dbf  
DELETE FILE &path_polska\cotecnox.dbf  
COPY FILE &path_polska\cotecnox_(1st_initialization).dbf TO  
&path_polska\cotecnox.dbf  
  
COPY FILE &path_costdat\noxtcom2.dbf TO &path_costdat\noxtcom2_copy.dbf  
DELETE FILE &path_costdat\noxtcom2.dbf  
COPY FILE &path_costdat\noxtcom2_(1st_initialization).dbf TO  
&path_costdat\noxtcom2.dbf  
  
COPY FILE &path_polska\EDF_tr_uc.dbf TO &path_polska\EDF_tr_uc_copy.dbf
```

Step3.prg

```
path_polska='D:\AGH\polska'  
path_costdat='D:\AGH\polska\costdat'  
  
COPY FILE &path_polska\EDF_tr_uc.dbf TO  
&path_polska\EDF_tr_uc_(1st_initialization).dbf  
DELETE FILE &path_polska\EDF_tr_uc.dbf  
COPY FILE &path_polska\EDF_tr_uc_copy.dbf TO &path_polska\EDF_tr_uc.dbf  
  
DELETE FILE &path_polska\cotecnox.dbf  
COPY FILE &path_polska\cotecnox_(2nd_initialization).dbf TO  
&path_polska\cotecnox.dbf  
  
DELETE FILE &path_costdat\noxtcom2.dbf  
COPY FILE &path_costdat\noxtcom2_(2nd_initialization).dbf TO  
&path_costdat\noxtcom2.dbf
```

Step5.prg

```
path_polska='D:\AGH\polska'  
path_costdat='D:\AGH\polska\costdat'
```

```

COPY FILE &path_polska\EDF_tr_uc.dbf TO
&path_polska\EDF_tr_uc_(2nd_initialization).dbf
DELETE FILE &path_polska\EDF_tr_uc.dbf
COPY FILE &path_polska\EDF_tr_uc_copy.dbf TO &path_polska\EDF_tr_uc.dbf

COPY FILE &path_polska\EDF_tr_uc_(1st_initialization).dbf TO
&path_polska\EDF_tr_uc1.dbf
COPY FILE &path_polska\EDF_tr_uc_(2nd_initialization).dbf TO
&path_polska\EDF_tr_uc2.dbf

DELETE FROM &path_polska\EDF_tr_uc.dbf WHERE FUEL_ABB='LF' AND
SEC_ABB='TRA_RD_LD4'
DELETE FROM &path_polska\EDF_tr_uc.dbf WHERE FUEL_ABB='MD' AND
SEC_ABB='TRA_OT_LB'
DELETE FROM &path_polska\EDF_tr_uc.dbf WHERE FUEL_ABB='MD' AND
SEC_ABB='TRA_RD_HD'
PACK

INSERT INTO &path_polska\EDF_tr_uc.dbf (COU_ABB, REG_ABB, FUEL_ABB, SEC_ABB,
TECH_ABB, UC_1995, UC_2000, UC_2005, UC_2010, UC_2015, UC_2020, UC_2025,
UC_2030) ;
SELECT COU_ABB, REG_ABB, FUEL_ABB, SEC_ABB, TECH_ABB, UC_1995, UC_2000, UC_2005,
UC_2010, UC_2015, UC_2020, UC_2025, UC_2030 FROM &path_polska\EDF_tr_uc1.dbf ;
WHERE FUEL_ABB='LF' AND SEC_ABB='TRA_RD_LD4'

INSERT INTO &path_polska\EDF_tr_uc.dbf (COU_ABB, REG_ABB, FUEL_ABB, SEC_ABB,
TECH_ABB, UC_1995, UC_2000, UC_2005, UC_2010, UC_2015, UC_2020, UC_2025,
UC_2030) ;
SELECT COU_ABB, REG_ABB, FUEL_ABB, SEC_ABB, TECH_ABB, UC_1995, UC_2000, UC_2005,
UC_2010, UC_2015, UC_2020, UC_2025, UC_2030 FROM &path_polska\EDF_tr_uc1.dbf ;
WHERE FUEL_ABB='MD' AND SEC_ABB='TRA_OT_LB'

INSERT INTO &path_polska\EDF_tr_uc.dbf (COU_ABB, REG_ABB, FUEL_ABB, SEC_ABB,
TECH_ABB, UC_1995, UC_2000, UC_2005, UC_2010, UC_2015, UC_2020, UC_2025,
UC_2030) ;
SELECT COU_ABB, REG_ABB, FUEL_ABB, SEC_ABB, TECH_ABB, UC_1995, UC_2000, UC_2005,
UC_2010, UC_2015, UC_2020, UC_2025, UC_2030 FROM &path_polska\EDF_tr_uc2.dbf ;
WHERE FUEL_ABB='MD' AND SEC_ABB='TRA_RD_HD'

USE &path_polska\EDF_tr_uc.dbf
SORT TO &path_polska\EDF_tr_uc00.dbf ON REG_ABB
CLOSE ALL

DELETE FILE &path_polska\EDF_tr_uc.dbf

COPY FILE &path_polska\EDF_tr_uc00.dbf TO &path_polska\EDF_tr_uc.dbf

DELETE FILE &path_polska\EDF_tr_uc00.dbf

DELETE FILE &path_polska\EDF_tr_uc1.dbf
DELETE FILE &path_polska\EDF_tr_uc2.dbf

DELETE FILE &path_polska\cotecnox.dbf

```

```
COPY FILE &path_polska\cotecnox_copy.dbf TO &path_polska\cotecnox.dbf
DELETE FILE &path_polska\cotecnox_copy.dbf

DELETE FILE &path_costdat\noxtcom2.dbf
COPY FILE &path_costdat\noxtcom2_copy.dbf TO &path_costdat\noxtcom2.dbf
DELETE FILE &path_costdat\noxtcom2_copy.dbf

DELETE FILE &path_polska\EDF_tr_uc_(1st_initialization).dbf
DELETE FILE &path_polska\EDF_tr_uc_(2nd_initialization).dbf
```