

# Retrofitting program for Santiago buses fleet: Pilot project results.

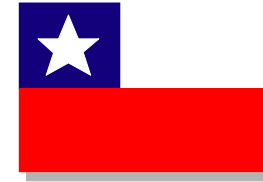


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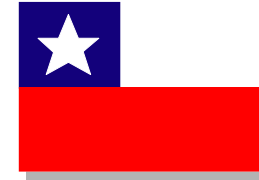
**Government of Chile**

# Chile



Chile is situated between the Andes Mountains and the Pacific Ocean in a narrow and long piece of land that does not exceed 350 kilometers of width. The maximum length of our territories reaches a 4300 kilometers.

Our country has a population of more than 15 million people. Santiago, which is the capital of the nation, represents the 32% of the total population (5 million approx.).



# Chile



In the north we have the most ardent desert in the world, with big copper mines.

In the center and the south of Chile, green and fertile valleys provide fruits, wines and grapes that are well known in the world.

Our country has a population of more than 15 million people.

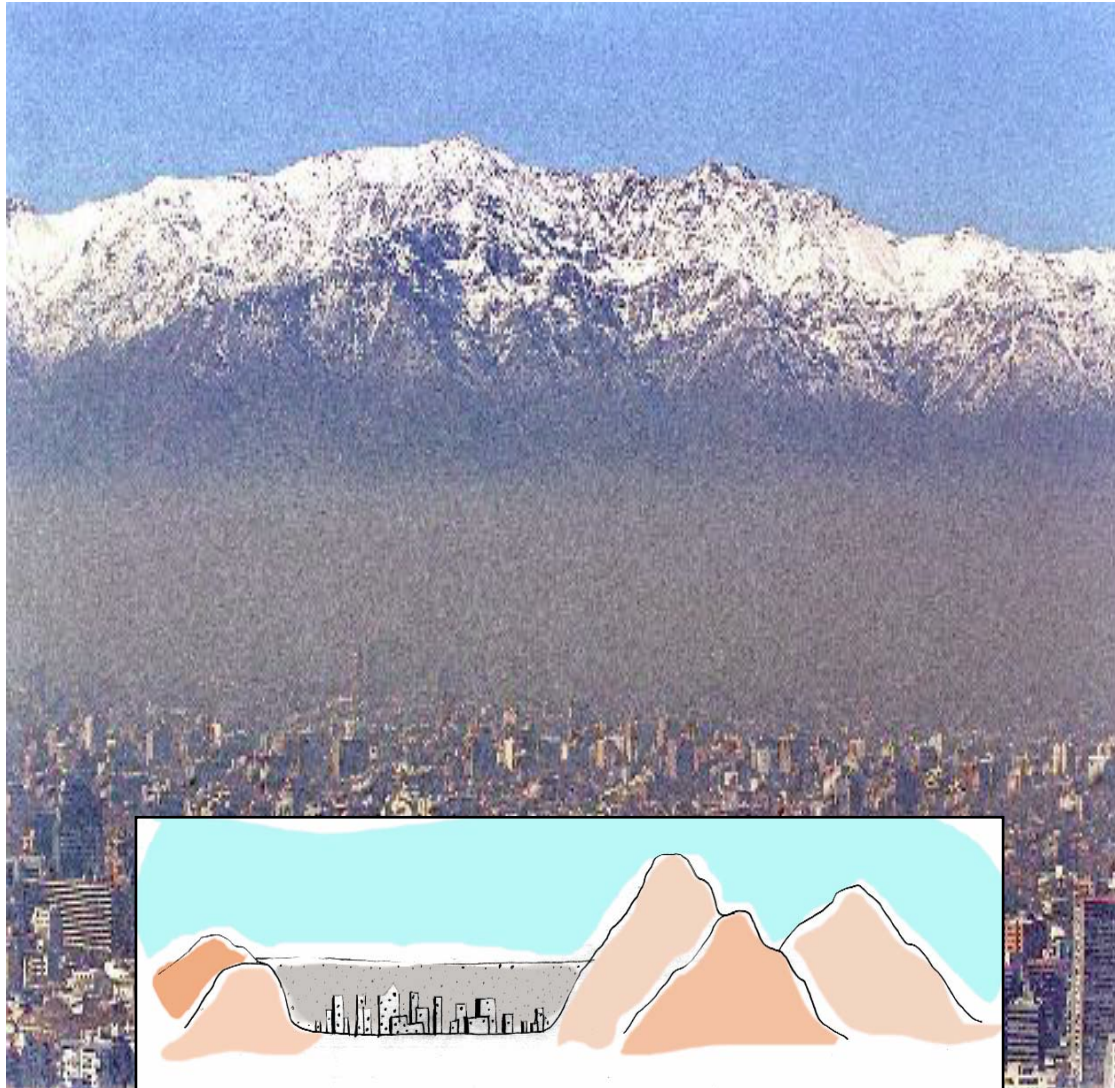
Santiago, which is the capital of the nation, represents the 32% of the total population (5 million approx.).

Chile's gross domestic product growth was 6% in 2004 and 5,6% average between 1990 – 2004

Chile is a country with political and economical stability.

Santiago

# Air Pollution Situation



The Air pollution in Santiago has one geographical origin. The city is surrounded by mountains and hills like walls and there is a thermal inversion phenomenon (the change of atmospheric temperature profile), like a roof. Then air ventilation is poor and the ascending air is stopped by a mass of warm air. Industrial and traffic emissions can saturate the air with particulate matter very quickly, mainly in winter.

# Achievements of Decontamination Plan

SOURCE	10 YEARS AGO	NOW
<b>Buses</b>	14.000 Buses 15 years average age	7.500 Buses 5 years average age
<b>Gas oil</b>	5.000 ppm Sulfur	50 ppm Sulfur
<b>Gasoline</b>	All with Lead.	All unleaded
<b>Passenger Cars</b>	100% Non-Catalytic	20% Non-Catalytic 80% Catalytic (currently EURO III or EPA 94 is required for new cars)
<b>Industries</b>	Firewood, Coal and heavy Oils.	Natural gas and Low Sulfur Diesel (50 ppm )
<b>Electric Generation</b>	Coal	Natural gas and Low Sulfur Diesel (50 ppm)

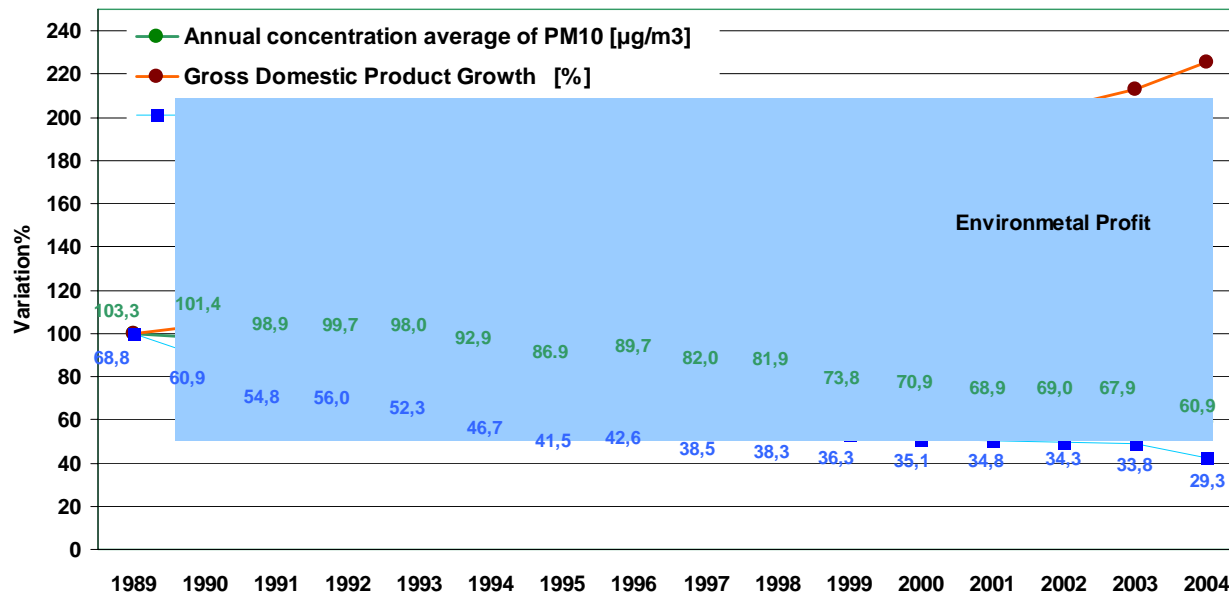
In ten years the bus fleet of public transport was reduced from 14.000 to 7.500 buses.

The Gas Oil for cars diminished the sulfur content from 5.000 to 50 ppm . Now all gasoline is unleaded.

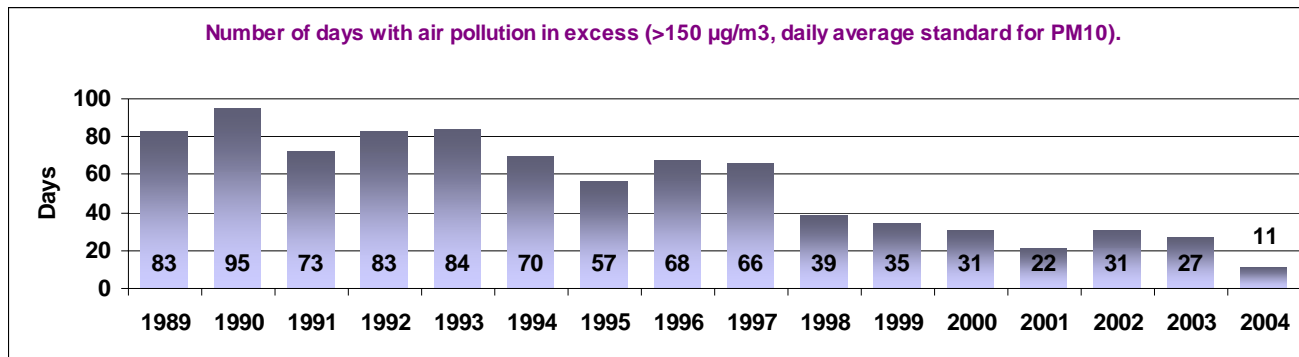
Ten years ago there were only cars without catalytic converter now 80% of cars have emission control.

Ten years ago industries used firewood, coal and heavy diesel. Today they use Natural Gas and low sulfur diesel (50 ppm).

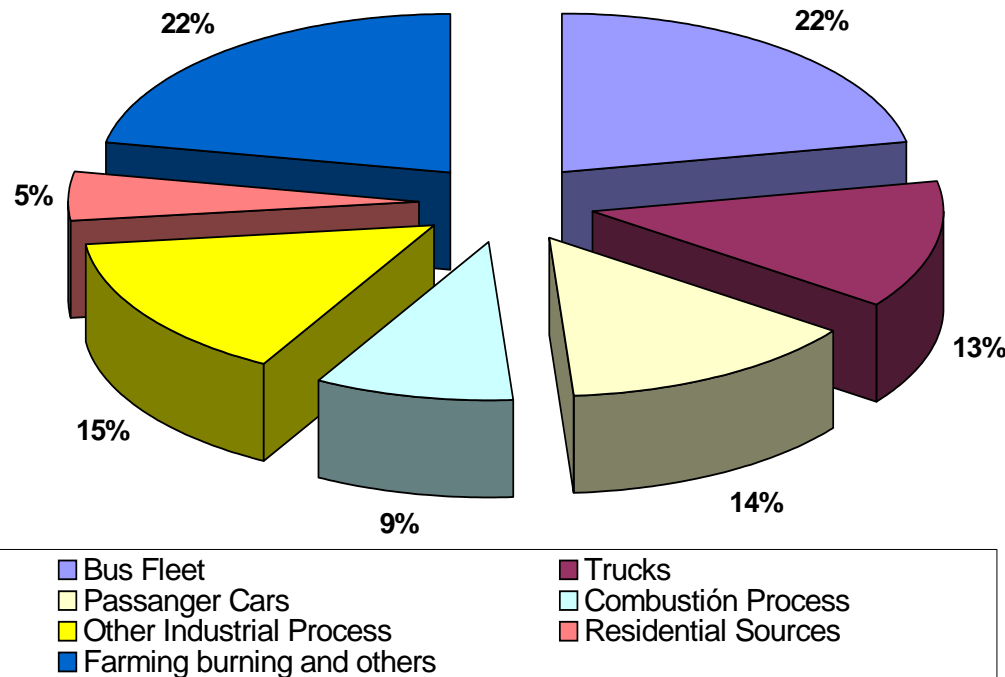
# Santiago Air Quality: Historical Evolution



In 1989 began a decontamination plan. Then the annual concentration average of PM10 was 103,3 [ $\mu\text{g}/\text{m}^3$ ]. In 2004 it was 60,9 (40% of reduction). Simultaneously the productive activities increased (the gross domestic product was doubled in this period). The target for 2010 is to comply with the national standard of 50 [ $\mu\text{g}/\text{m}^3$ ] for annual concentration average of PM10 and no day with air pollution in excess of 150 [ $\mu\text{g}/\text{m}^3$ ] (daily average standard).



# Current Shares of PM10 Inmission

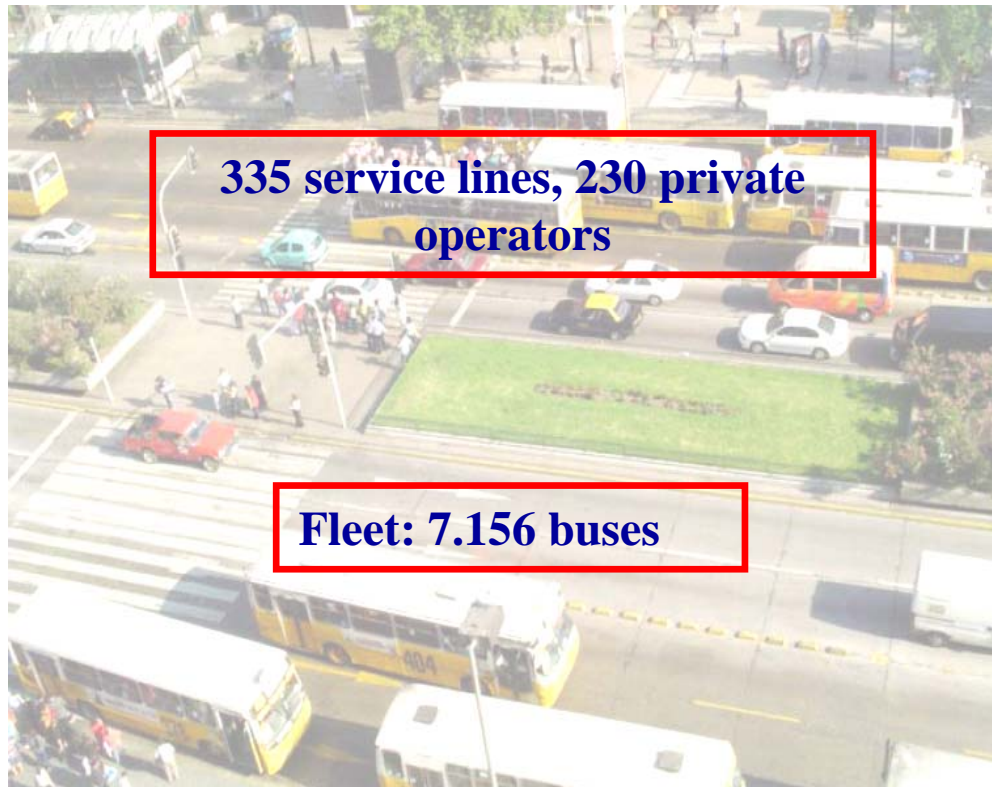


The single most relevant PM source in Santiago is the bus fleet of public transportation with a share of 22%. The new target for public transportation in the Decontamination Plan is a reduction of 75% of PM, and includes a mandatory retrofitting program for old buses (EURO I, EUROII). This target was included in the new public transportation plan for Santiago: Transantiago.

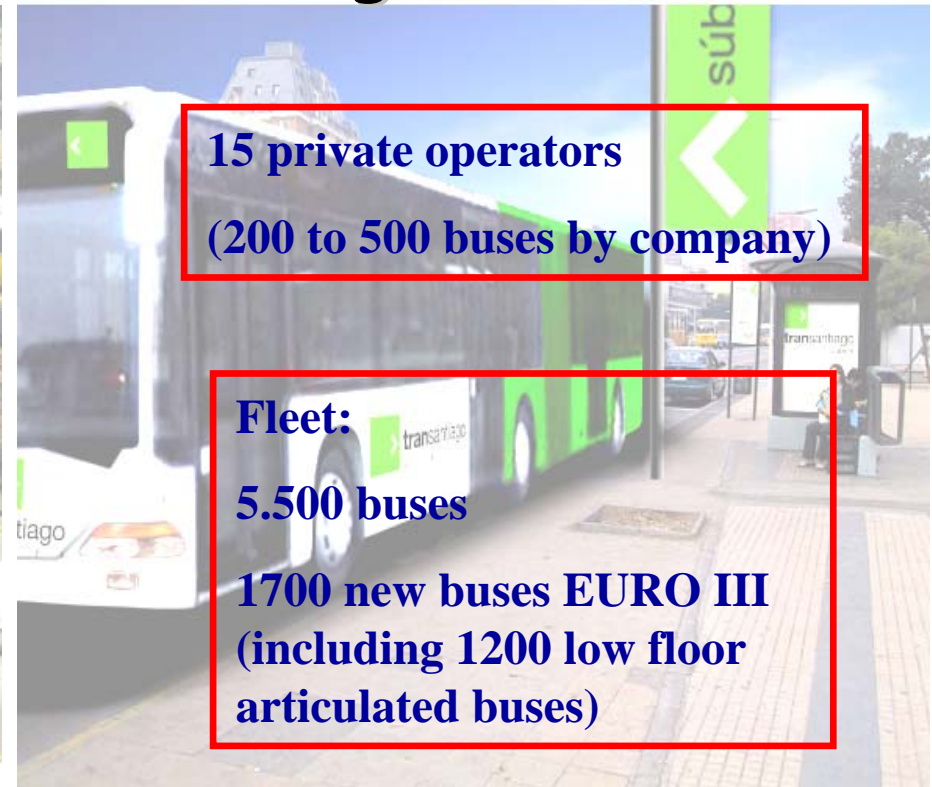
# Transantiago Plan

Transantiago is the public transportation plan of Santiago. The target is to improve it through an integrated, efficient, safe and modern system, which is environmentally and financially sustainable.

## Now



## Transantiago August 2006





# Transantiago fleet



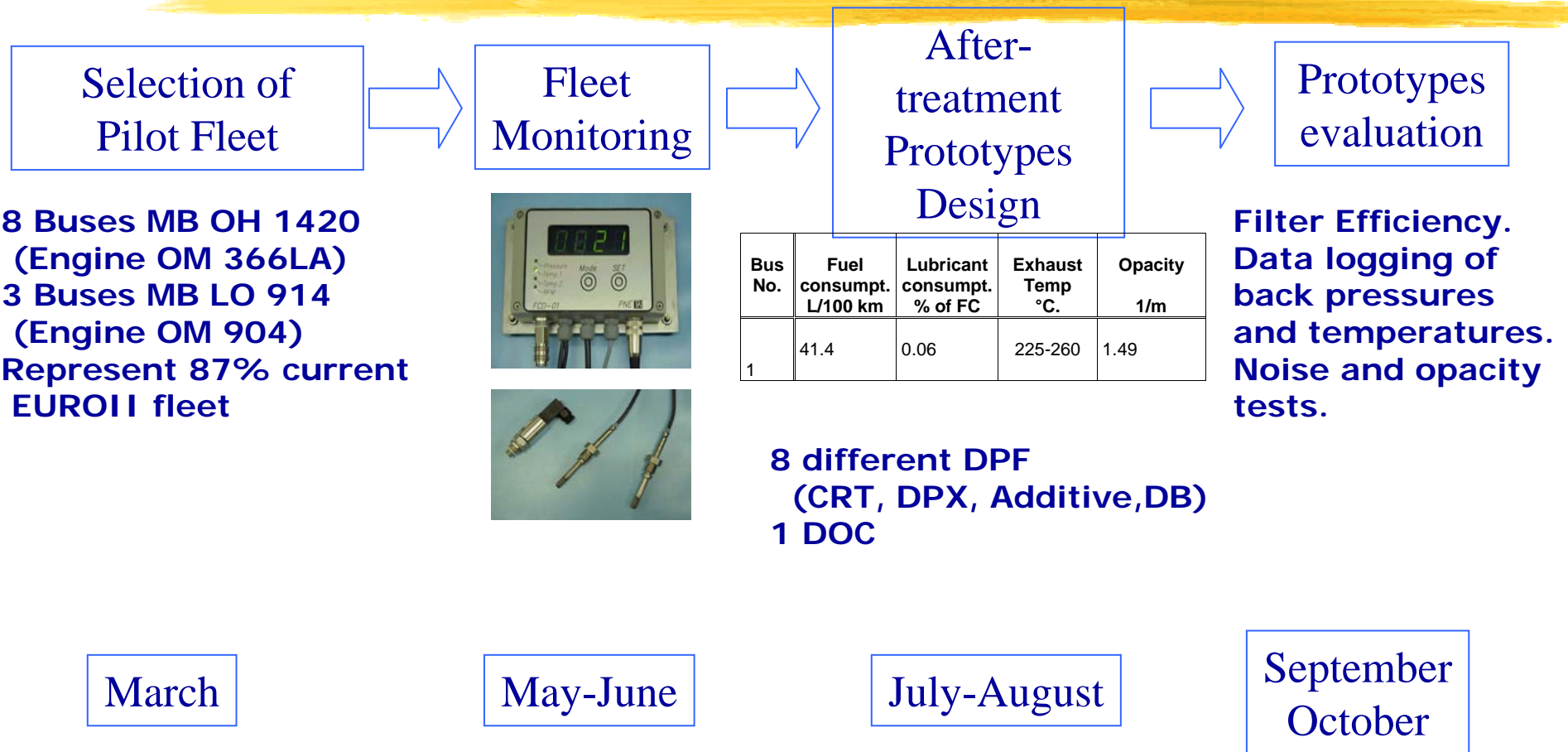
The bus fleet for Transantiago includes new and old buses.

For new Buses, Transantiago gives incentives (extending time of concession), to operators that use cleaner buses than EURO III (for instance EURO III with filter).



Old buses must be less than 8 years old and accepted standards are EURO III, Euro II or Euro I. Euro I and Euro II buses must reduce PM emissions in at least 70% (in mass) through after-treatment devices. These devices have to be approved by the Center of Vehicle Certification and Control (3CV).

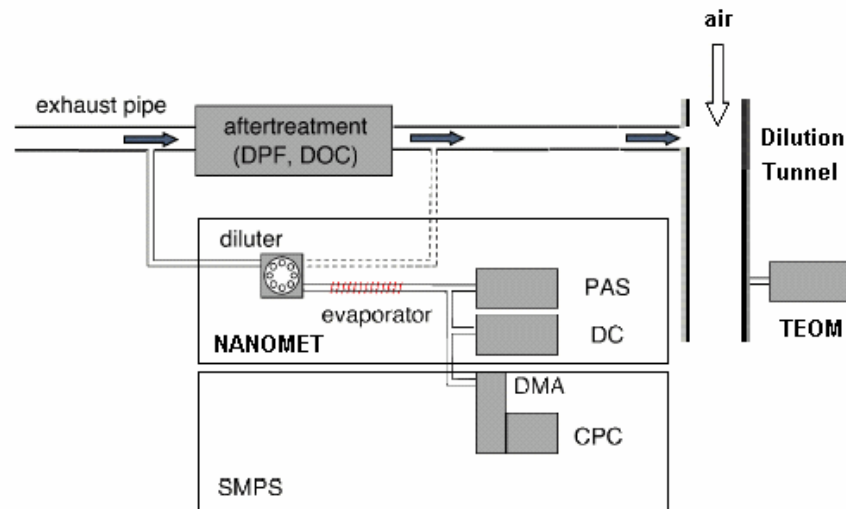
# Post treatment pilot program



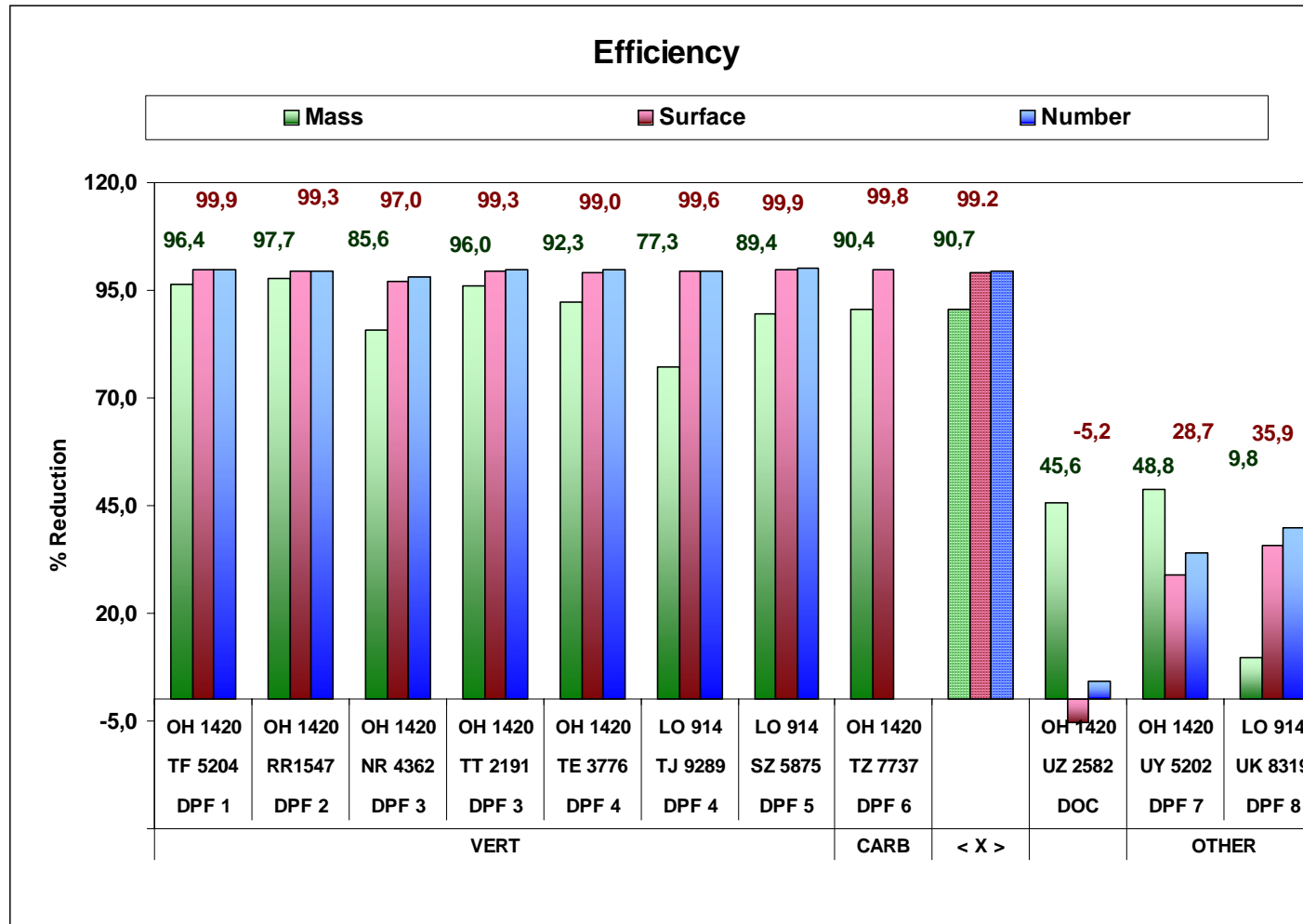
2004

# Efficiency measurement methodology

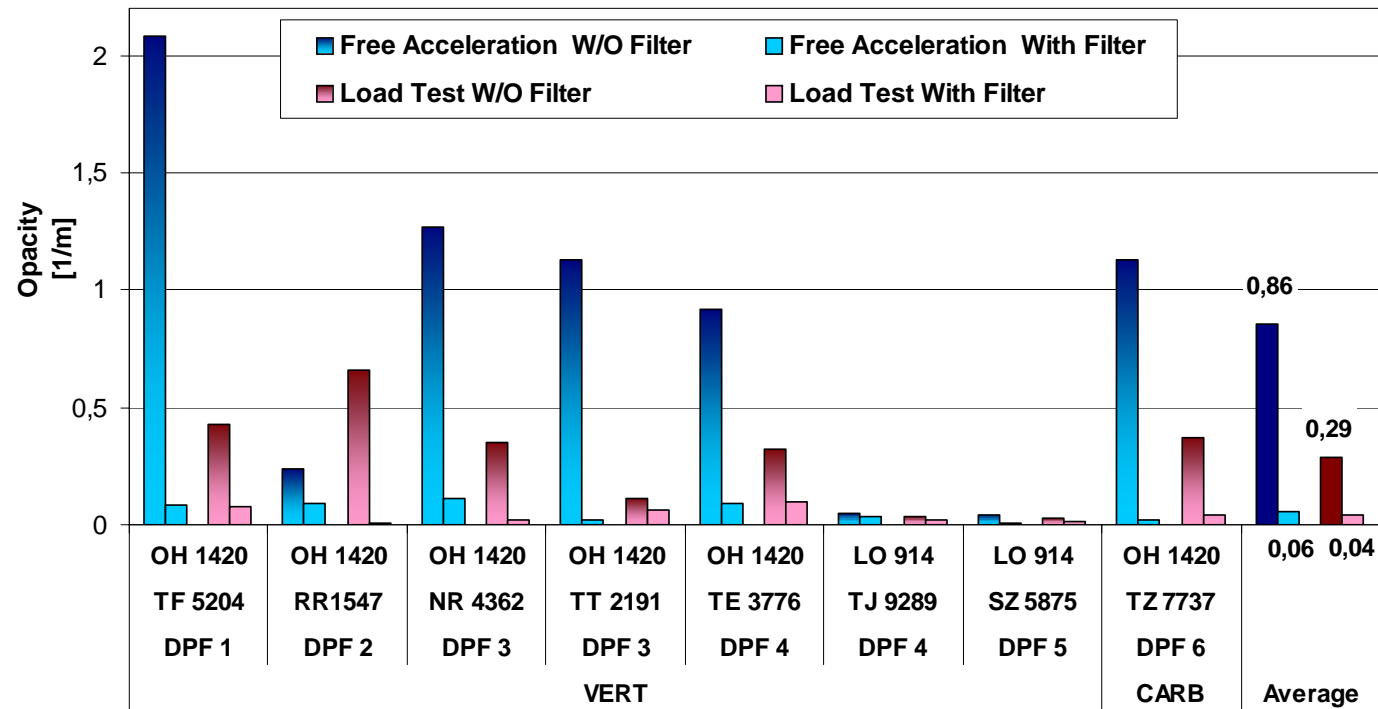
Mass with dilution tunnel and TEOM.  
Size distribution of solid particulate with SMPS.  
Solid particulate surface with Nanomet.



# Efficiency measurements results

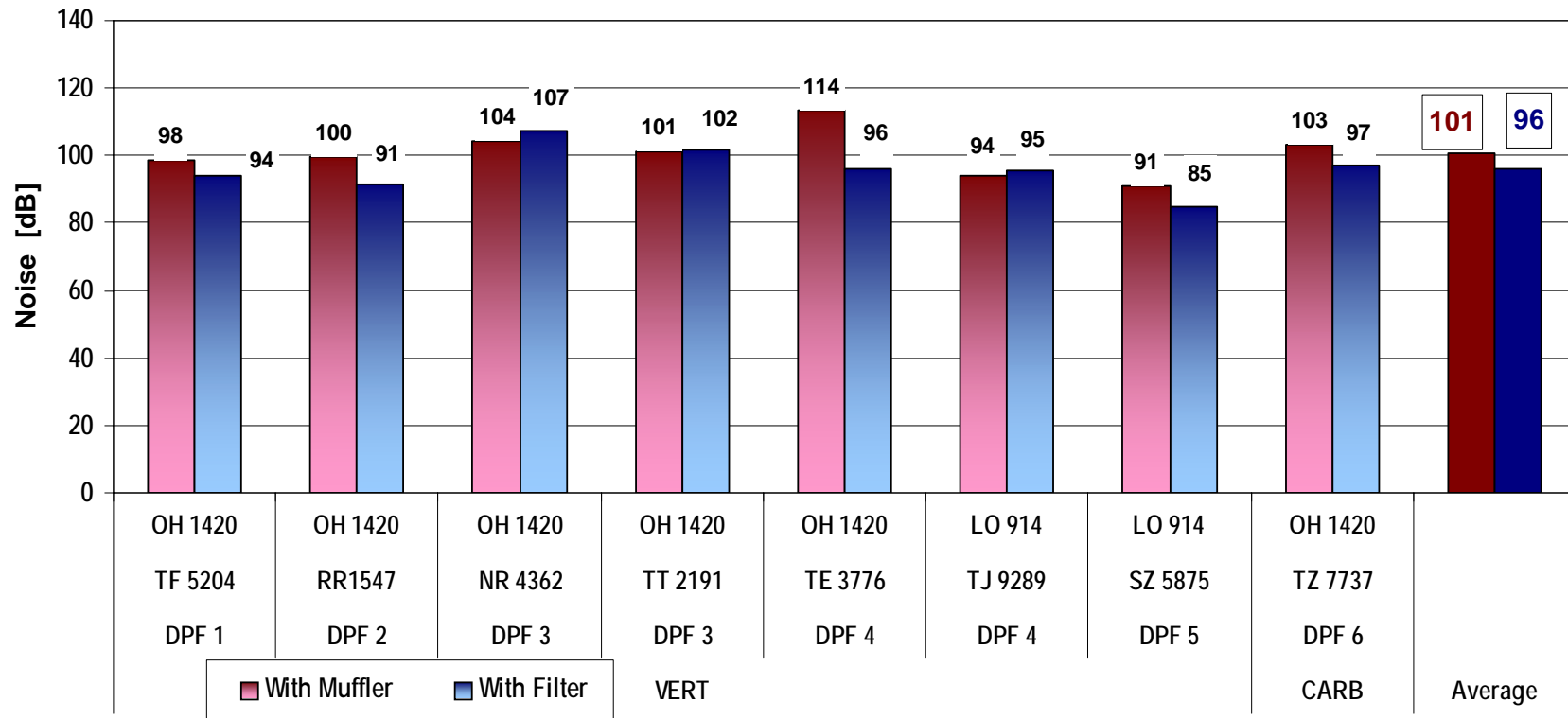


# Opacity results



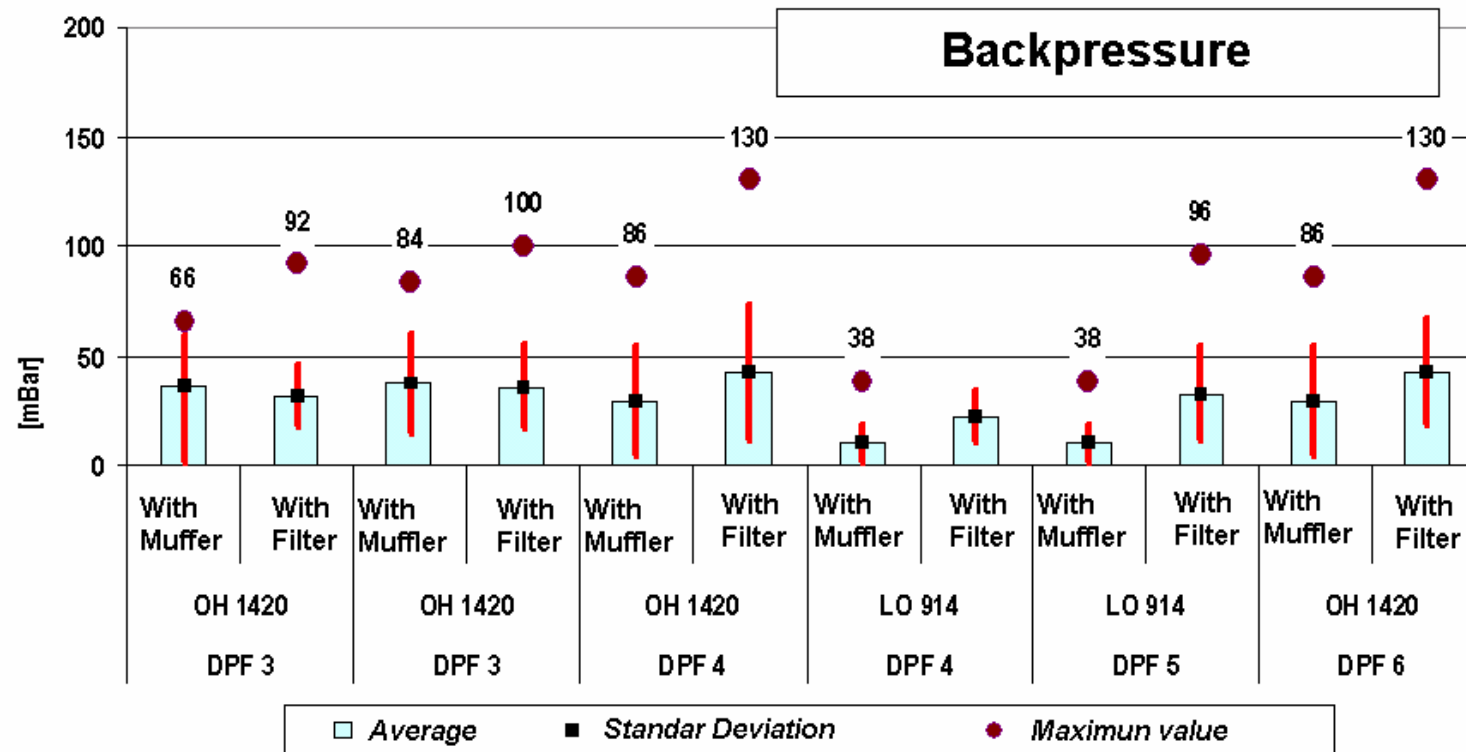
The program continued with only the 6 good efficiency DPF.  
For opacity we used partial flow opacimeter.

# Noise results



**Noise was measured during free acceleration conform to the Chilean regulation.  
Important reductions, in general (except for DPF 3 and DPF 4 on a LO 914 bus model).**

# Backpressure results



- Backpressures was measured immediately before original Muffler and tested DPF with a datalogger.
- Values below 200 [mBar] were required for DPF.  
DPF 1 and DPF 2 with additive couldn't comply, mainly due to deficiencies in the electrical system of the buses.

# Summary and Conclusions



- 9 systems were tested in this pilot program (8 DPF and 1 DOC).
- 6 DPF systems VERT or CARB certified showed high efficiency of PM reduction in mass (90% average) and in solid ultra fines particulates (99% average).
- 4 of them showed low backpressure and good general performance in field test (local fleet under local conditions).
- The other 2 (FBC systems) had regeneration problems with the additive supply system, due to deficiencies in the electrical system of the buses.
- DOC showed poor efficiency in mass and no efficiency in solid ultra fines particulates.
- As a result of the pilot program, Chilean authorities decided to issue a new regulation for after-treatment systems certification (DS 65/2004), including:
  - a) International certification requirement (VERT or CARB, level 1),
  - b) Efficiency test in mass to be held in Chile,
  - c) Four weeks, on field compatibility test of the system mounted on a local bus.



# Summary and Conclusions




- Using the pilot test results 6 systems have been approved for Transantiago retrofitting program (Engelhard, HJS, HUSS).
- The next steps:
  - Massive installation in Transantiago EURO I and EURO II fleet (2.000 to 3.000 buses approximately), have to be retrofitted finish until July 2006.
  - Improvement of regulation for the local certification of the after-treatment systems (DS 65/2004), including an efficiency parameter for solid particulate surface.
  - A control program for installations.

# Final Note



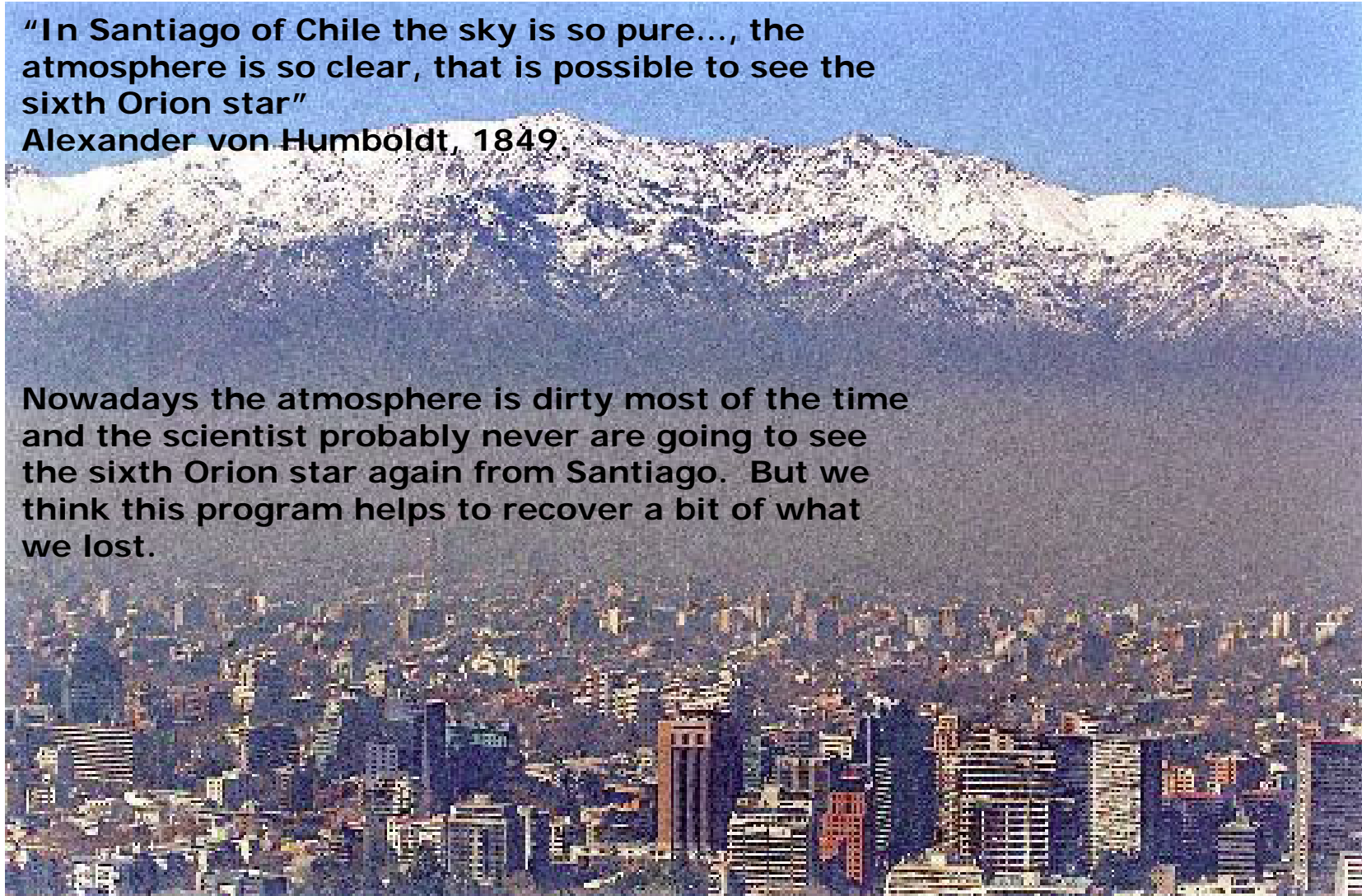
**Diesel retrofit programs can be implemented in emerging and development countries if they are accompanied by technical cooperation and know how transfer.**



**"In Santiago of Chile the sky is so pure..., the atmosphere is so clear, that is possible to see the sixth Orion star"**

**Alexander von Humboldt, 1849.**

**Nowadays the atmosphere is dirty most of the time and the scientist probably never are going to see the sixth Orion star again from Santiago. But we think this program helps to recover a bit of what we lost.**



# Acknowledgment



- **Swiss Part**
  - Swiss Agency for Development and Cooperation (COSUDE)
  - TTM Mayer
  - Matter Engineering.
- **Chilean Part**
  - National Petroleum Company (ENAP).
  - National Environment Agency.