



## Effects of the Reduction of Natural Gas in Particulate Matter Emissions in The Metropolitan Region, Chile

### ABSTRACT

**Palabras Claves:** Material particulado, gas natural, Santiago.

La reducción del suministro de gas natural desde Argentina ha afectado a las fuentes fijas de mayor emisión. Esto debería aumentar las emisiones y concentraciones de material particulado ya que el combustible que se utilizaría en vez del gas sería el petróleo diesel. A mayor contaminación, las enfermedades respiratorias aumentan, por lo tanto la restricción de gas implica costos productivos y en salud pública.

**Key words:** particulate matter, natural gas, Santiago.

The reduction of gas supply from Argentina has affected the most contaminating fixed sources. This should produce an increment in particulate matter emission and concentration, since, instead of gas, fuel oil is used. The rise of pollution implies a rise in respiratory diseases; therefore the reduction of gas supply means expenses in both production and public health.



# Effects of the Reduction of Natural Gas in Particulate Matter Emissions in The Metropolitan Region, Chile

---

**Andrés González**

Director del Centro de Desarrollo Medioambiental  
Universidad Central

## 1. INTRODUCTION

The Metropolitan Region, more specifically Santiago city, has endured high levels of air pollution during the last decades. As in many large cities around the world, in Santiago the increment of population and development have caused a rise of energy consumption and therefore, of emissions. During the eighties, Santiago presented a sharp rise of population and also an important economic growth, hence the air quality became harmful for people's health.

Nevertheless, in the nineties this situation changed. In Chile, and specifically in Santiago, the process of economic growth continued and in spite of that air quality improved a lot, fact which is due to several reasons.

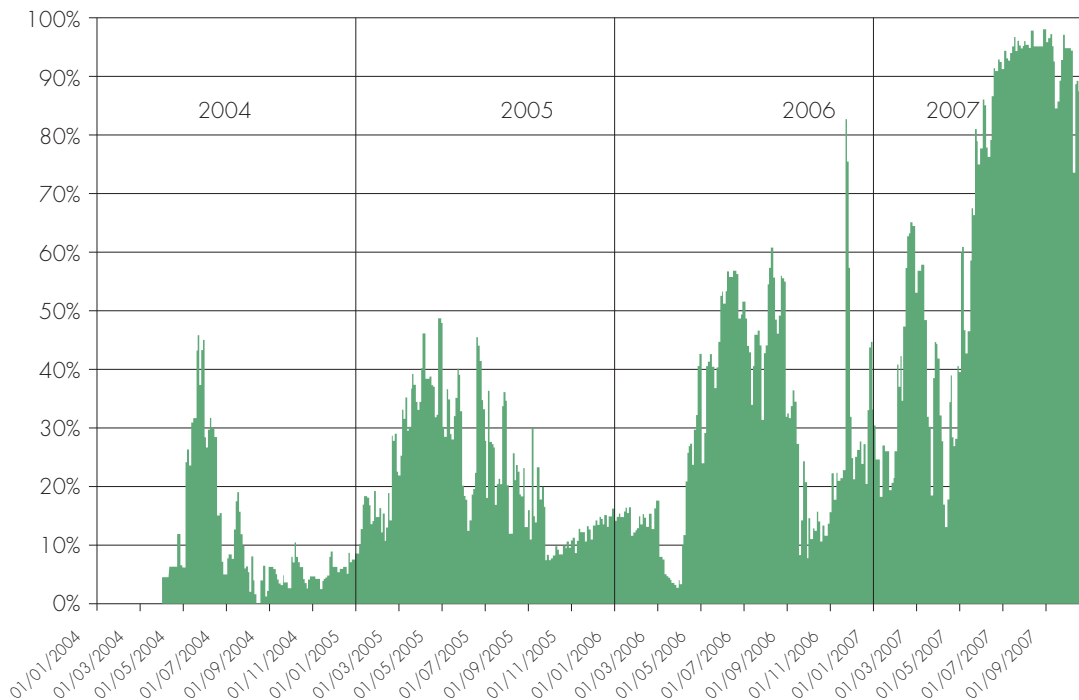
In 1996, the Metropolitan Region –where Santiago is located– was declared a saturated zone because of high levels of four air pollutants (particulate matter breathing, total of suspended particulates, carbon monoxide, and ozone), and a latent zone owing to the levels of nitrogen dioxide in the air. Based on the Supreme Decree 131, Santiago was declared both a saturated and latent zone, and therefore a decontamination plan (for a saturated zone) and a prevention plan (for a latent one) were implemented in this region.

These plans have allowed emission control and improved the air quality. In this context, many measures provided an explanation about why the emissions have been reduced and why the air quality has grown better.

1. The sources, mainly fixed, changed from fuel oil to natural gas<sup>1</sup>. As natural gas produces less emissions of particulate matter than fuel oil, air quality has improved.
2. An improvement of fuel oil reducing sulfur from 300 ppm to 50 ppm.
3. An improvement of gasoline reducing sulfur from 400 ppm to 30 ppm.
4. Implementation of a compensation system for boilers (both industrial and residential) with emission discharged through a duct with a maximum flow rate greater than or equal to 1000 m<sup>3</sup>/hour.
5. Cleaning-and-vacuuming street Programs.

Natural gas is mainly imported from Argentina (almost 100%), therefore the supply depends on the quantity this country assigns to Chile. Since 2004, Argentina has been gradually reducing the amount of natural gas. Nowadays, the supply of natural gas is only meant for residential consumption, residential boilers and commercial processes. In this context, large sources of particulate matter emission do not have access to natural gas; therefore large boilers and processes must use alternative fuels.

**Graphic N° 1**  
Natural Gas Restriction as compared to normal requirements



Source: National Energy Commission. Chile.

As exposed in graphic N° 1, restrictions of natural Argentinean gas have been increasing; therefore most fixed sources must find alternative kinds of fuels. The fuel used by large sources, instead of natural gas, is oil. The problem is that fuel oil produces double of particulate matter emissions as compared to natural gas<sup>2</sup>.

<sup>1</sup> The unitary emission using of Natural Gas of particular matter, according to the Ministry of Health, is 15 mg/m<sup>3</sup>, while the unitary emission of particular matter for using fuel oil N#2 is 30 mg/l

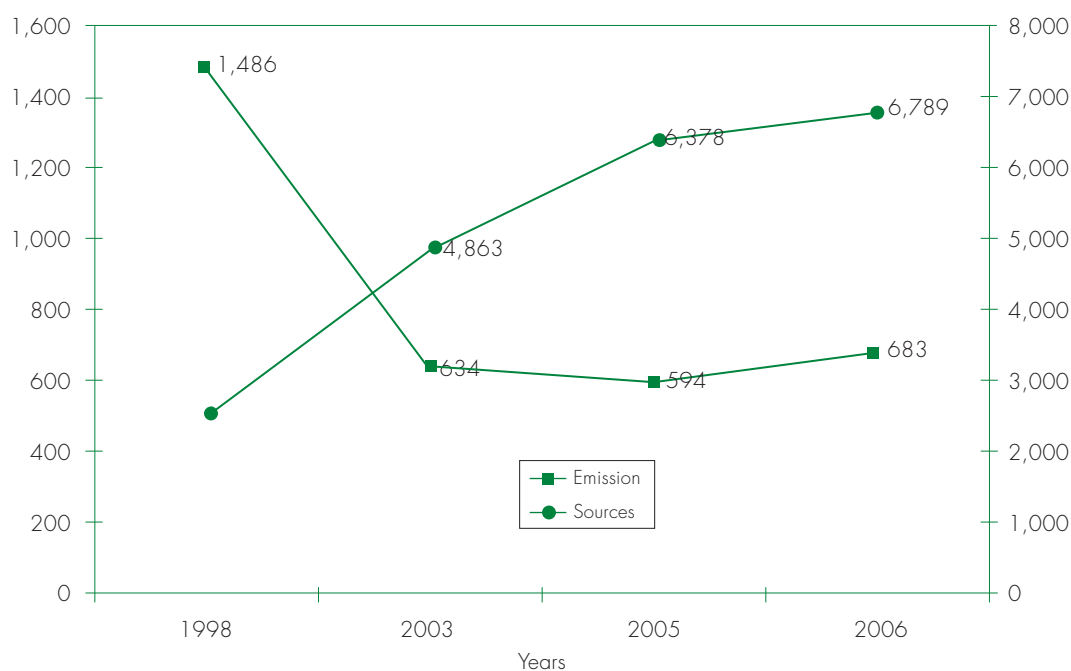
<sup>2</sup> According to the Ministry of Health, the unitary emission of particular matter using natural gas is 15 mg/m<sup>3</sup>, while the unitary emission of particular matter for using fuel oil N#2 is 30 mg/l.

Universidad Central, through the Environmental Development Center, has been researching the reduction of natural gas effects in Santiago's emissions. The aim of this research is to measure the effect of particulate matter emissions as a consequence of the reduction of natural gas supply.

## 2. EVOLUTION OF PARTICULATE MATTER EMISSIONS IN SANTIAGO

Particulate matter emissions have been decreasing as a result of the measures mentioned above. The fixed sources started using natural gas as fuel instead of others; therefore they lowered particulate matter emissions.

**Graphics N° 2**  
Evolution of the number of sources and particulate matter emissions



Source: Elaborated from data provided by Health Ministry of Metropolitan Region.

Graphic N° 2 shows that the number of sources has been increasing from 2,514 to 6,789. This means a rise of 93% in only eight years. On the other hand, particulate matter emissions decreased in 1998 from 1,486 tons per year to 683 in 2006. This implies an important achievement regarding the control of particulate matter emissions in Santiago.

The trend remains the same; that is, a rise in the number of sources and a reduction of emissions. However from 2005 to 2006, particulate matter emissions have increased. This situation may have happened because of four main reasons:

1. It is impossible to continue reducing particulate matter emissions because sources have had access to the best technology available.
2. Some sources may have started using fuel oil again.
3. A rise in the number of sources from 6,378 to 6,789.
4. All of the above.

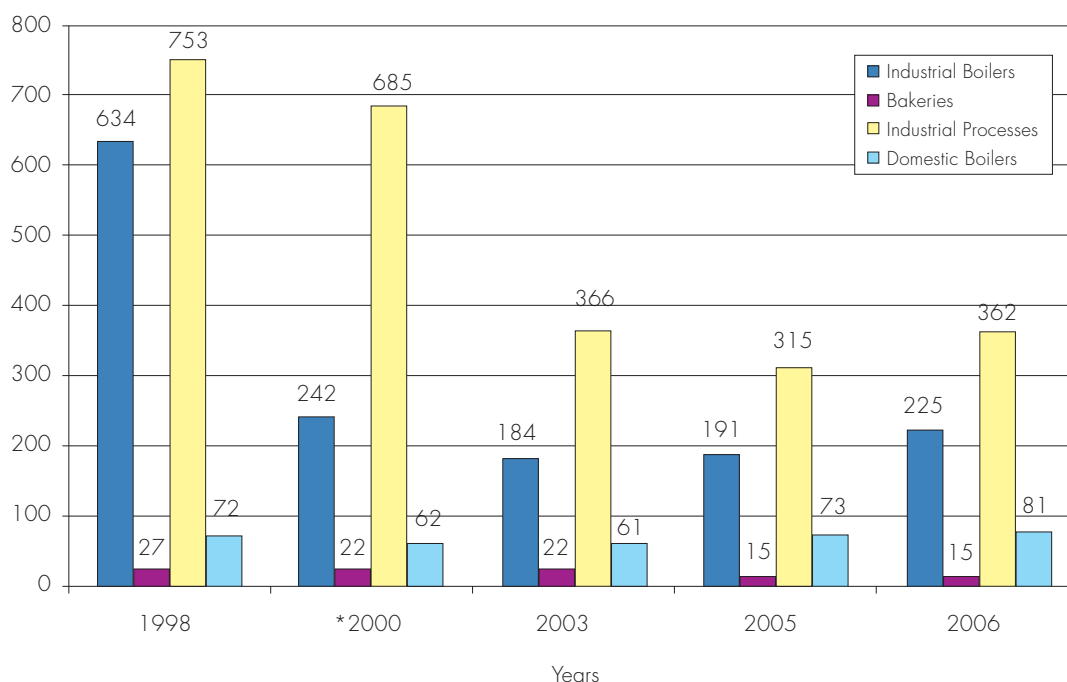
Therefore, through this information it is not possible to conclude that the rise of particulate matter emissions comes as a result of the reduction in the supply of natural gas from Argentina.

According to the Ministry of Health, Metropolitan Region, the fixed sources are classified as industrial boilers, domestic boilers, industrial processes and bakeries. Industrial boilers and processes represent more than 85% of the total of particulate matter emissions<sup>3</sup>. In this context, the control of emissions from these sources (industrials boilers and industrials processes) is a very important factor to consider in order to improve air quality in Santiago.

Graphic N°3 shows particulate matter emissions by type of fixed source. As it was mentioned above, industrial boilers and processes are the most important sources of emissions. Besides, as seen in graphic N°2, the total of emissions has decreased. Industrial boilers and processes reduced particulate matter emission from 1387 tons per year in 1998 to 582 tons in 2006. However the number of industrial boilers and processes decreased from 1187 in 1998 to 1899 in 2006<sup>4</sup>.

### Graphic N° 3

Emission by type of sources Tons/year/PM



Source: Elaborated from data provided by the Ministry of Health, Metropolitan Region.

Domestic boilers and bakeries have not noticeably changed their emissions, even though there were 1327 sources in 1998 and then, in 2006, 4294 sources<sup>5</sup>.

<sup>3</sup> González Vidal, Andrés "The reduction of natural gas effects in the emissions in Santiago", Santiago, Universidad Central, November 2007.

<sup>4</sup> Ibid.

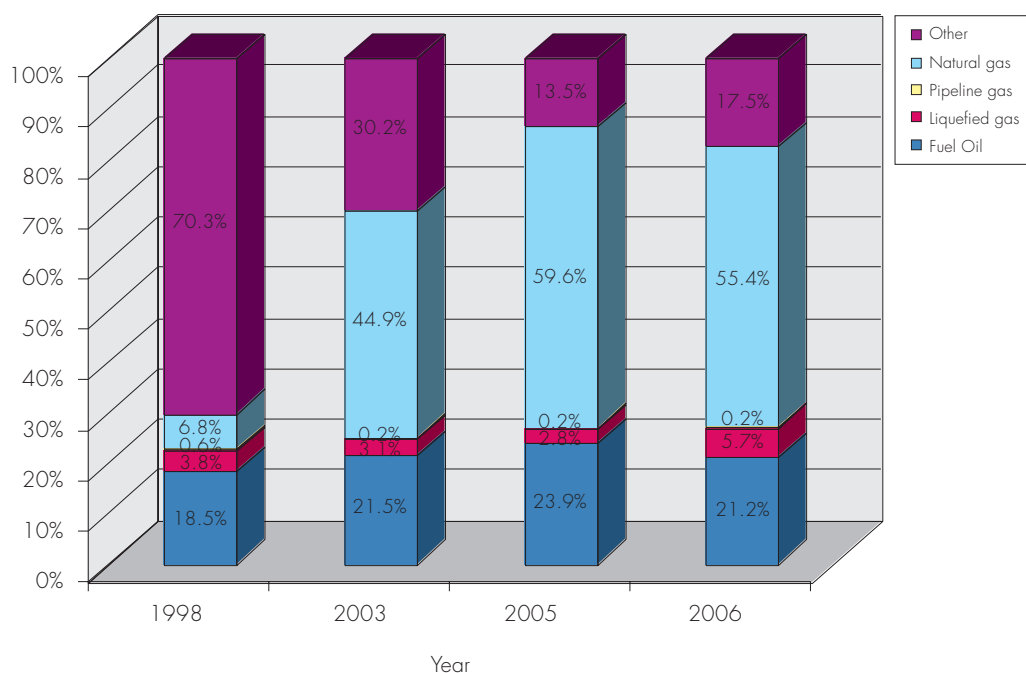
<sup>5</sup> Ibid.

In the year 2000, emissions were calculated from the emissions inventory, and this inventory has a similar trend of information than the Ministry of Health.

Graphic N° 4 displays particulate matter emissions by type of fuel.

Natural gas is the most important fuel concerning particulate matter emissions in 2006. This is because the sources have been using this kind of fuel since 1998. This fact does not mean that natural gas produces more particulate matter emissions by kilograms of fuel used.

**Graphic N° 4**  
Percentage of particulate matter emissions by type of Fuel



Source: Elaborated from data provided by the Ministry of Health, Metropolitan Region.

The evolution of fuel use shows that in 1998, natural gas was 6.8% of the total emissions, while other fuels<sup>6</sup> were 70.3%. Fuel oil and liquefied gas have kept their percentage stable in the total emissions. For example, fuel oil was 18.5% of the total emissions in 1998 and in 2006 it became to 21.2%.

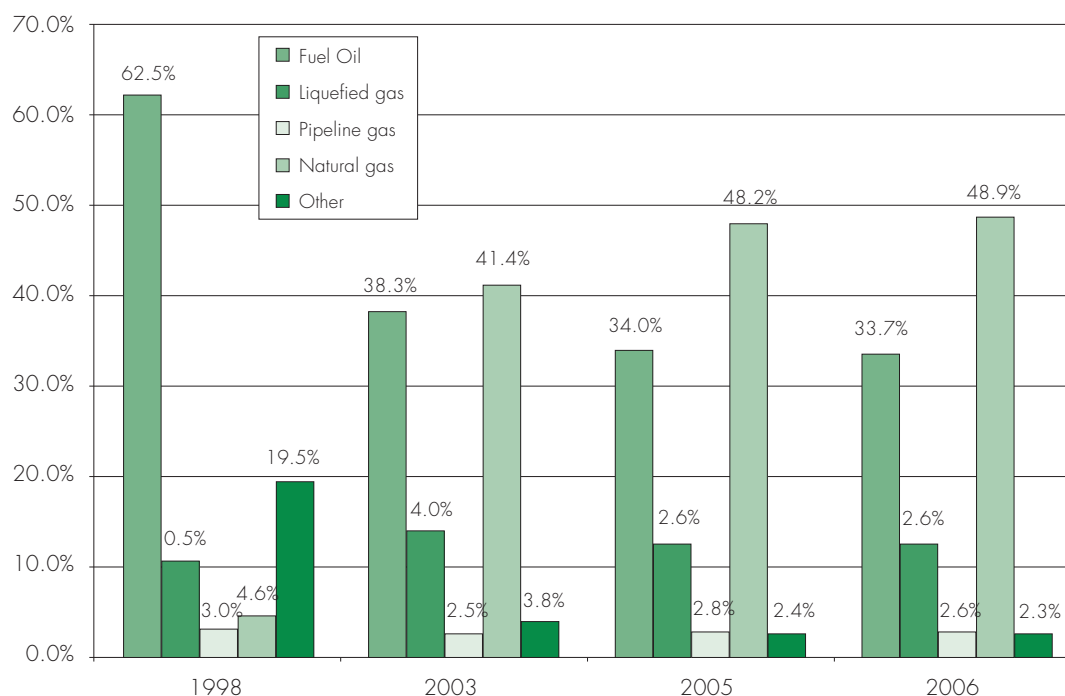
If the emissions, shown in the graphics N° 2 and N° 3, have been decreasing and those of natural gas have been increasing, it may be that other<sup>7</sup> fuels produce more pollution per kilograms of fuel used than natural gas. Therefore, despite the fact that the number of sources rose, emissions have reduced.

<sup>6</sup> Other Fuels: All fuels that are not natural gas, pipe gas, liquefied gas and fuel oil.

<sup>7</sup> Ibid.

In graphic N° 5, it is possible to see that, in 1998, the fuel that was used the most was oil, with 62,5% of the all sources. However, in 2003, this trend changed, and natural gas was used by 41,4% of sources while fuel oil use diminished to 38,3%.

**Graphic N° 5**  
Percentage of Sources by Type of Fuel



Source: Elaborated from data of the Ministry of Health, Metropolitan Region.

The increment of the use of natural gas from 1998 to 2003 concurred with the increase of sources number and reduction of the emissions of particulate matter. It is important to explain that the change in the percentage of fuel by types of sources does not mean that number of sources by types of fuel have been decreasing, as it was explained above, the number of sources have been increasing, and therefore some types of fuels are, in percentage, less used now than before. However, the number of sources may have remained stable or risen.

Particulate matter emissions in Santiago have decreased for many reasons, and one of them is the use of natural gas instead of fuel oil and others. Besides, the most important sources of emissions are industrial boilers and processes, so if they start to use fuel oil again, emissions would increase.

The information from the Ministry of Health does not reveal that the sources have been changed from natural gas to any other kind of fuel. Nevertheless, graphic N°1 shows that the Metropolitan Region has endured great reductions of supply of natural gas, so sources cannot use this fuel. The restrictions of supplies of natural gas affect both industrial boilers and processes (the most contaminating sources). However, bakeries and domestic boilers are still using natural gas.

The Environmental Development Center has been researching this situation, and this research is measuring the effect of natural gas reduction of particulate matter emission from industrial boilers. The effect was measured only in these types of sources because, as it was mentioned above, both bakeries and domestic boilers have not endured reduction in natural gas supply. Besides, industrial processes are very heterogeneous, so it is impossible to implement an emission factor. Apart from that, with the data provided by the Ministry of Health, it is not possible to determine which kind of processes these are.

Graphic N° 6 displays particulate matter emissions of industrial boilers in two forms. The emissions from scenario 1 were calculated from data from the Ministry of Health, while emissions from scenario 2 were calculated assuming that there is no supply of natural gas for industrial boilers.

The formula to calculate new emissions for industrial boilers, according to the RES-2063 of Health Ministry, is:

#### Volume of exhaust dry real gases

$$GRS^8 = GES^9 + Ae^{10} * EA^{11} / 100$$

$$GRS \text{ Fuel oil} = 11.41 + 12.22 * 0,2 = 13,9$$

#### Conversion Fuel

$$\text{Natural gas consumption (kg/h)} * 1.1^{12} = \text{fuel oil consumption (kg/H)}$$

#### New Flow

$$\text{New flow} = GRS * \text{new fuel consumption of fuel oil.}$$

#### New Emission

$$\text{New flow} * 20, 57 \text{ mg/m}^3 \text{ (emission factor of fuel oil)}^{13} * \text{hours} * \text{days.}$$

As it can be seen in graphic N°6, the scenario 1 showing natural gas emissions has 250 tons of particulate matter emission while the same sources, without natural gas, have 440 tons. The emissions would increase in 76%, and that is important because every ton emitted in populated areas, as Santiago is, leads to higher exposures and greater health consequences than emission sources that are further removed from population centers<sup>14</sup>.

The first conclusion of this result is that the Ministry of Health does not have updated information, therefore some strategies and plans implemented may not be adequate.

Besides, from this analysis, it is possible to perceive that the reduction of natural gas supply from Argentina has affected both people and public health. So, the reduction of natural gas does not only mean detriment in production but also in health.

<sup>8</sup> Volume of exhaust dry real gases

<sup>9</sup> Volume of exhaust gases estioichimetry

<sup>10</sup> Volume of air estioichimetry, calculated from the elemental composition of the fuel.

<sup>11</sup> Air excess determined by the method CH-3

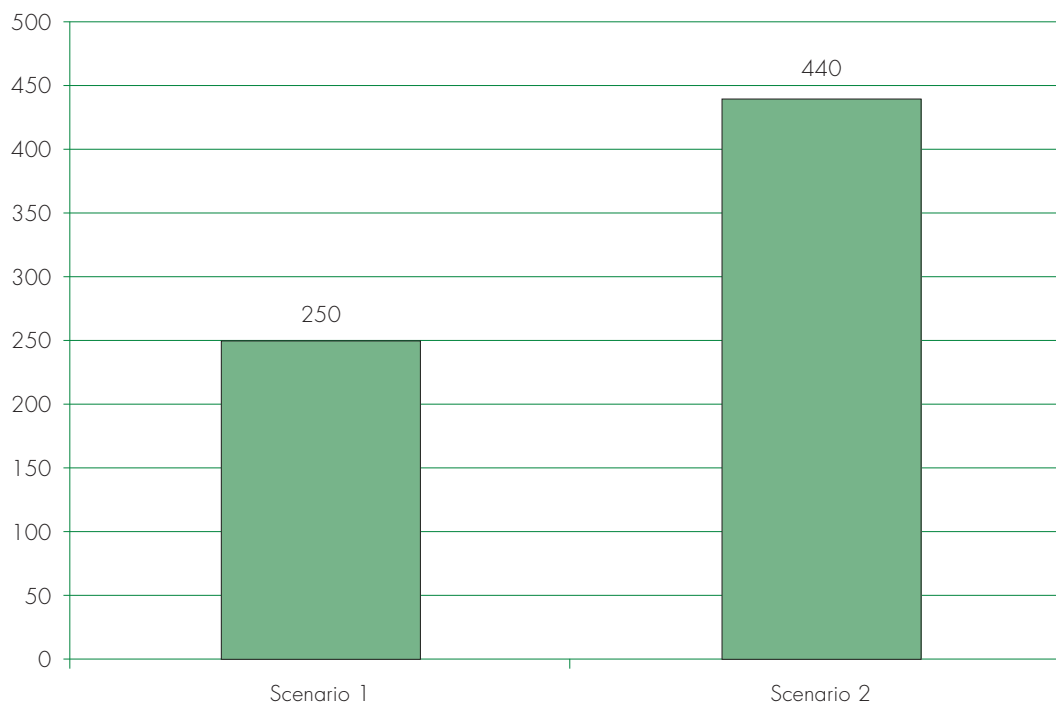
<sup>12</sup> Fuel conversion US Energy Department

<sup>13</sup> U.S. Environmental Protection Agency. AP 42, Fifth Edition, Volume I Chapter 1: External Combustion Sources

<sup>14</sup> California Environmental Protection Agency, "Health Effects of Diesel Exhaust Particulate Matter", California, March 2006.

### Graphic N° 6

Scenarios of particulate matter emission by industrial boilers



Source: Elaborated from data of the Ministry of Health, Metropolitan Region.

It is important to say that emission is not same as concentration. It is very important to clarify this point, because Santiago has thermal inversion in winter and its geography does not allow a good dispersion of pollutants.

### Table N° 1

Evolution of Critical Air Pollution Episodes Metropolitan Region 1997-2007

Episodes	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Alert recorded	38	43	23	27	6	17	19	9	4	14	22
Pre-emergency recorded	37	23	12	10	14	7	4	2	2	3	6
Emergency recorded	4	1	1	0	0	0	0	0	0	0	0
Total	79	67	36	37	20	24	23	11	6	17	28

Source: National Environmental Commission (Conama).

Table N° 1 shows that the negative episodes in the Metropolitan Region (Santiago) have been decreasing, and this is concordant with the information shown in graphics N°1 and N°2. However, it can be perceived that negative episodes have increased in 2007, maybe due to the change of fuel (from natural gas to fuel oil), but it is important to mention that in this year, Santiago had more thermal inversion because temperatures in winter lowered considerably compared to previous years. In this context, it is not easy to determinate to what extent whether the increase of emissions or thermal inversions resulted in more negatives episodes. Nevertheless, it is evident that a larger amount of emissions affected air quality in Santiago.

## ACKNOWLEDGMENTS

Carlos González, Ministry of Health  
Raúl O'ryan Universidad de Chile

## BIBLIOGRAPHY

- Fernández, Marcelo (2003). Evolución de la Calidad del Aire en Santiago. Conama.
- Corvalán, Roberto (2005). Inventarios de Emisiones Atmosféricas. Universidad de Chile. Facultad de Ciencias Físicas y Matemáticas.
- Banedier, Pablo (2003). Evolución de la Calidad del Aire en Santiago. Conama.
- U.S. Environmental Protection Agency. AP 42, Fifth Edition, Volume I Chapter 1: External Combustion Sources
- Coria Jessica (2006). Transactions in The Chilean Pollution Market: ¿Why did sources lost their emissions rights? Universidad Católica de Chile.

