Support to Local and Regional Air Quality Public Policy - Results of the First - Phase of the Integrated Environmental Strategies (IES) project in São Paulo, Brazil

Flavio Cotrim Pinheiro
Subcontractor to US National Renewable Energy Laboratory
Rua Mateus Grou, 398 apt. 83, São Paulo, SP 05415-040 Brazil
Tel: (11) 3082-6254 / Mobile: (11) 8275-0197
Fax: +1 (707) 982-0659 (note that this is a US number)
e-mail: flavio@flaviopinheiro.com

Other Authors:
Luiz Tadeu Siqueira Prado, tprado@iee.usp.br
Prof. Dr. Alfésio Luís Ferreira Braga, abraga@unisa.br
Dr. Luiz Alberto Amador Pereira, luiz.aa.pereira@uol.com.br
Profa. Dra. Simone G. El Khouri Miraglia, miraglia@terra.com.br
Gleice Margarete de Souza Conceição, gleice@usp.br
Prof. Dr. Paulo Hilário Nascimento Saldiva, pepino@usp.br
Prof. Dr. György Miklós Böhm, gyorbohm@usp.br
Prof. Dr. Maria de Fátima Andrade, mftandra@model.iag.usp.br
Odon Roman Sanchez-Ccoyllo, Regina Maura de Miranda
Ramon Arigoni Ortiz, ecprao@bath.ac.uk
Dr. Ronaldo Serôa da Motta, seroa@ipea.gov.br

Abstract

The United States Environmental Protection Agency (USEPA) initiated the Integrated Environmental Strategies (IES) in 1998 to assist developing countries with evaluation and human benefits of technologies and policies for reducing greenhouse gas emissions. The overall objective of the IES project in Brazil is to establish a framework for development, analysis and implementation of integrated, environmentally sustainable policies for the São Paulo Metropolitan Region (SPMR), with particular focus on the 1 Also from the University São Marcos, Environmental Engineering Department transport system. This framework is expected to supply decision-makers with stronger policy instruments to simultaneously address local, regional and global environmental issues based on technical, economic and social criteria. The São Paulo project analyzed strategies with potential for implementation that can optimize the local-regional-global benefits.

The IES program in Brazil focuses on the São Paulo Metropolitan Region (SPMR), a conglomerate of cities with a total population of almost 17 million people (approx. 10% of the Brazilian population), a GDP of US$100 billion (approx. 20% of the National GDP), and 6 million vehicles (approx. 25% of the national fleet). The workgroup for the IES project consists of representatives from São Paulo State Environmental Agency (CETESB), the Medical School of the University of São Paulo(FM-USP), the Institute of Astronomy, Geophysics and Atmospheric Sciences of the University of São Paulo (IAG-USP), the Institute of Applied Economics Research (IPEA), and two independent energy consultants. This work summarizes the methods and results for the first phase of the project, recently completed, which:

Analyzed health impacts of the PROCONVE program in São Paulo in the 1990's; Developed a set of baseline and alternative energy/emission/air quality scenarios for São Paulo to analyze specific technologies and policy measures under consideration for implementation to mitigate local air pollution and also GHG emissions; Assessed and quantify the air pollution, environmental health and climate change benefits of each scenario; Estimated the economic benefits and costs of most relevant scenarios. The local pollutants considered were particulate matter (PM10), sulfur dioxide (SO2), carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOCs), and ozone (O3). Greenhouse gas, namely carbon dioxide (CO2) and methane (CH4), were also considered. Health effects considered included mortality and morbidity outcomes for children, elderly and adults. All health data used was local data. The PROCONVE 1990's analysis compared the changes in health effects in two different periods 1991-1994 and 1997-2000. According to this analysis, PROCONVE resulted in net benefits to public health in period 1997-2000 of over 4,500 avoided deaths and 5,500 avoided hospital admissions, which were valued in US$ 2.86 to 3.98 billion. Various alternative air quality scenarios were developed from emission projections for years 2005, 2010, 2015 and 2020. All major emission sources in RMSP were considered with special attention to mobile sources – the main source of emissions according to studies done by CETESB. For alternative scenarios that resulted in the greatest reduction of emissions, the health impacts were estimated and economically valuated. Results may already be helpful for decision-making. Nonetheless, cost of implementation of each scenario needs to be further investigated. With respect to greenhouse gas emission mitigation, due to the relatively clean Brazilian energy matrix, reductions are not as impressive as in other countries. But they are observed in some scenarios.

Keywords: Air pollution, public policy, Integrated Environmental Strategies (IES), São Paulo, Brazil.

1. Introduction

This study covers the São Paulo Metropolitan Region (SPMR), which is located in Southeastern Brazil on a plateau 700 meters above sea level on the edge of the coastal mountain range. It consists of 39 municipalities covering an area of 8 thousand square kilometers (approximately 0.1% of the Brazilian territory) and with a total population of 17.89 million (approximately 10% of the national population). SPMR's average population density is 2,236 people per square kilometer, but there are large discrepancies in population density within it.

In 2002, SPMR had a GDP of US$100 billion, what represented about 20% of Brazil's GDP. In SPMR there is intense but decreasing industrial activity. This decrease is a result of industrial migration to the interior of São Paulo State and to other states of Brazil. On the other hand, the service sector is growing within SPMR. As a result, one could expect a reduction in the share of emissions from industrial sources. The transport sector, in contrast, has shown a sharp increase especially after the Real national economic stabilization plan in 1994 when purchasing automobiles became possible to a larger portion of the population. In SPMR there are over 6 million private cars, what represents about 50% of the State fleet or 25% of the national fleet. In addition to private cars the metropolitan area also counts with some 20 thousand buses for public transportation; a growing number of motorcycles and mini-vans; a large number of trucks and road buses that come and go or drive through the metropolitan area; and 319 kilometers of subway and surface train lines.

The São Paulo Metropolitan Region faces various social and environmental problems and air pollution is among the most important. It affects the entire population, being the poor usually more vulnerable to it.

The São Paulo State Environmental Protection Agency (CETESB) worked hard in the 80's to reduce industrial air pollution. As a consequence, sulfur dioxide (SO2) levels have been below air quality standard limits for more than a decade and industrial sources remain secondary contributors to air pollution. Lead additives have been completely removed from gasoline for about 15 years mainly due to the availability of ethanol (commercial gasoline in Brazil now contains 24% of ethanol). Carbon monoxide concentrations, a major concern in the early 90's, were considerably reduced over the years as a consequence of the national PROCONVE program, even though the fleet has increased sharply. However, air pollution remains a concern, especially when considering particulate matter (PM10) and ozone (O3).

This study also estimated future emissions of greenhouse gas were even though these emissions are quite limited already in Brazil due to its relatively clean energy matrix (e.g., electricity is produced predominantly by hydro power plants and a significant share of the fuel consumed by vehicles is ethanol produced from local sugar cane plantations). One of the goals of this study was to identify policy alternatives that could provide both local and global benefits (i.e., reduce air pollution and greenhouse gas emissions).

2. Energy and Emission Inventory and Scenarios

The energy inventory for year 2000 (base year) included parameters from various sources, including population, GDP, sector shares of GDP, pass.km, ton.km, average vehicle occupancy, mileage, and fuel economy, energy intensities for various processes and devices, and many others.4 The sectors considered for the energy/emission inventory and scenarios were Transport, Commercial, Industrial, Residential, and Power Generation (local gas-fired power plants). Emissions considered included those resulting from fuel combustion, including local pollutants regularly monitored by CETESB (São Paulo State Environmental Protection Agency) and the most relevant greenhouse gases.5 Emission factors were from various sources, including CETESB (local pollutants from light vehicles), Ministry of Science and Technology (greenhouse gases from light vehicles), EPA AP-42 database (local pollutants from most industrial, commercial and residential sources, as well as for electric generation and fugitive emissions in fueling stations), and IDEE-Argentina (local pollutants for heavy-duty vehicles). Future emission scenarios were estimates based on future emission limits of new vehicles and replacement of energy-consuming equipments and vehicles. The transport sector was studied in greater detail, as there is more reliable information on it. Also, vehicles are responsible for most of the local air pollution in São Paulo, as it has been determined by receptor-model studies carried out by CETESB. 4 CETESB's emission inventory was not used for this work since it was necessary to have an inventory based on parameters appropriate for building scenarios. Parameters were collected or estimated using information from CETESB, Metrô (São Paulo State subway company), SEADE (São Paulo State Foundation for Data Analysis), EMPLASA (São Paulo State Company for Metropolitan Planning), São Paulo State Secretaries of Energy and Metropolitan Transport, ANP (National Petroleum Agency), GEIPOT (National Study Group for Transport Policy Integration). Industry process emissions were not included for lack of information. 5 CETESB maintains a network of stations since 1981 and it also operates manual mobile stations. Automatic network system measures total suspended particles (TSP), PM10, SO2, CO, O3, non-methane hydrocarbons (HC) and NOx levels. Manual systems may measure non-methane HC, NOx, aldehydes, and PM2.5. Local Pollutants Greenhouse Gases Particulate Matter PM_{10} Carbon

Dioxide CO_2 (biogenic and non-biogenic) Sulfur Dioxide SO_2 Methane CH_4 Carbon Monoxide CO Ozone O_3 Nitrogen Oxides NOx Volatile Organic Compounds VOCs

Scenarios for period 2000-20206

The inventory and the scenarios were prepared by using LEAP (Long-Range Energy Alternatives Planning System), which is a software devised to analyze, in an integrated way, the relation between energy and the environment.

Some major assumptions for all scenarios:

- SPMR's population increases up to 25 million in 2020;
- Mobility per capita increases slightly;
- SPMR's economy has a constant growth rate larger than in the previous two decades but smaller than the 1970's;
- Income distribution improves;
- Energy efficiency improves;
- Use of natural gas and renewable energy sources (i.e., ethanol fuel) increases;
- Cogeneration increases as well;
- Large amounts of hydropower are imported from other regions through long-term contracts at stable and moderate prices.

The Baseline Scenario (also referred to as Emission Factor Gradual Reduction – EFGR in this report), takes into account gradual emission factor improvement for light vehicles. It assumes that average emission factors for light passenger vehicles in SPMR will be reduced up to 2020 according to the trend in the last 5 years (1997-2002).

The Growth Only (GO) scenario assumes that there is no improvement in emission factors for any technology in any sector. Although this is not a realistic scenario, especially for the fact that light vehicles have been increasingly regulated over the past 15 years and will continue to face stricter regulations at least until 2009 (PROCONVE program). This scenario allows one to estimate the benefits of the PROCONVE program for the period 2000-2020 if one compares it with the baseline scenario (EFGR).

All other scenarios (i.e., all scenarios except Growth Only) consider reductions of average emission factors for light vehicles either equal or greater than in baseline scenario. Some scenarios include improvement in emissions from heavy vehicles as well, as it is briefly explained below.

3. Air Quality Modeling

Using emission inventory from base year (2000) and meteorological data, the IES project team calculated ambient air quality concentrations for year 2000, which were calibrated with air quality monitoring data from CETESB. Then, ambient air quality concentrations were estimated for each scenario for years 2005, 2010, 2015, and 2020. The information necessary to run the air quality model was provided by CETESB (past air quality and meteorological data for model calibration) and the emissions inventory and scenarios developed by this project. Concentrations of PM10 were estimated from NOx values. The CIT model was use to estimate air quality concentrations for all other pollutants.

4. Health Impact Analysis

To analyze the health impacts of PROCONVE, the Laboratory of Experimental Air Pollution (LPAE) of the Medical School of the University of São Paulo used:

- Air quality data (particulate matter PM_{10}, sulfur dioxide SO_2, nitrogen dioxide NO_2, carbon monoxide CO, ozone O_3), minimum temperature, and relative humidity from 1991 to 2000 provided by CETESB;

- Mortality (São Paulo municipal government database PROAIM) - fetal deaths, and elderly (older than 64 years of age) total deaths (ICD 9th revision 0-800), respiratory deaths (ICD 9th revision 460-519), and cardiovascular deaths (ICD 9^{th} revision 90-459);

- Morbidity (national government database DATA–SUS) - respiratory hospital admissions (ICD 9th revision 460-519) for children (younger than 3 years of age) and elderly (older than 64 years of age); and ? LPAE’s own epidemiological studies on the health effects of urban air pollution carried out since early 1990’s. These epidemiological studies included studies on elderly total deaths [Saldiva *et al*. 1995], elderly respiratory deaths [Miraglia *et al*.1997], children respiratory mortality [Saldiva *et al*., 1994; Conceição *et al*., 2001], fetal deaths [Pereira *et al*., 1998]; elderly respiratory emergency room visits [Martins *et al*., 2002], children respiratory emergency room visits [Lin *et al*., 1999], and children respiratory hospital admissions [Braga *et al*., 1999; Braga *et al*., 2001].

This study assessed the health benefits of the PROCONVE program comparing two periods: 1991-1994 and 1997-1999.[11]

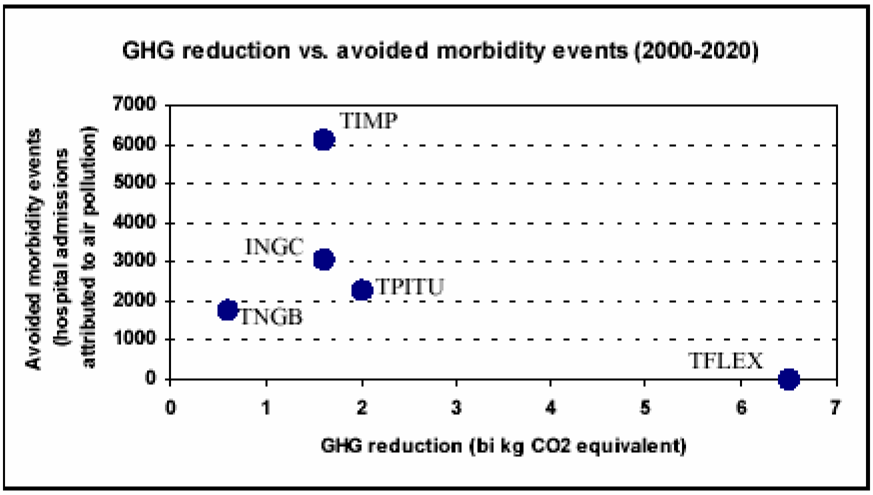
The various studies carried out by LPAE covered different time spans in the 1990s’s and used different analysis techniques. New time-series analyses were carried out to standardize the methodology, according to Schwartz [1994].

5. Economic Valuation

The monetary evaluation of health effects is an essential input to the cost-benefit analysis of air pollution reduction strategies, as health benefits are expected to be some of the major benefits of such strategies.
Valuing health benefits associated with air pollution require site-specific parameters that demand a great effort of research and data collection. As an alternative to survey methods, benefit transfer functions are considered as a methodological shortcut to apply willingness to pay (WTP) based estimates from one specific area to another study area [Brower, 1998; Seroa da Motta, Ortiz and Ferreira, 1999].
In this project, it was made estimates of transferred morbidity and mortality health benefits associated with air pollution in São Paulo. Davis *et al.* [1999] probably indicate the most recent available values used in the United States, Europe and Canada for mortality and morbidity health outcomes for policymaking.[14] The American estimates were originally reported in "The Benefits and Costs of the Clean Air Act Amendments of 1990 - USEPA", the European values were reported in ExternE, 1998, and all of them were adjusted to 1999 by the US dollar inflation between 1990 and 1999.

6. Results

Energy and Emission Inventory and 2000-2020 Scenarios for Air Quality Modeling, Health Effects Estimates and Economic Valuation were performed for each scenario with respect to the baseline (EFGR scenario). We are presenting an integrated analysis of results obtained in this investigation.
Results from this study may be presented in various forms according to the interest of decision makers. For example, if decision are interested in reducing the number of hospital admissions and, at the same time, there is an interest to reduce greenhouse gas emission reductions, the following graph may be very helpful to decision making.



TPITU – Simulates the State government PITU program (SPMR's Integrated Transport Plan) by increasing mobility per capita and the share of public transportation (buses, train, and subway).
TFLEX – Assumes that most of the light vehicles fleet will be flex-fuel vehicles by 2020 and that these vehicles will consume ethanol more frequently than gasoline.
TDHB – Assumes that hybrid diesel-electric buses will replace current conventional diesel buses over the next 20 years. In 2020 there will be some natural gas buses (10%) and most other buses will be diesel-electric buses.
TNGB – Assumes that natural gas buses will replace current conventional diesel buses completely over the next 20 years.
TIMP – Assumes that an Inspection and Maintenance Program for light vehicles is implemented in the entire SPMR in 2005 and that it will not be interrupted until 2020.
TBDT – Assumes that more efficient heavy diesel trucks (road cargo) with emission control devices will gradually replace all current diesel trucks in the next 20 years.
INGC – Assumes greater penetration of natural gas cogeneration in industrial and commercial sectors.
RCSWH – Assumes greater penetration of residential and commercial solar water heating systems. In 2020, 25% of the residences and 30% of the commercial establishments would have solar heated water.
RRSL – Assumes increase in commercial and residential lighting efficiency and introduction of photovoltaic cells for lighting in rural areas.

References

ANP (National Petroleum Agency) – http://www.anp.gov.br/

Braga ALF, Conceição GMS, Pereira LAA, Kishi HS, Pereira JCR, Andrade MF, Gonçalves FLT, Saldiva PHN, Latorre MRO. Air Pollution and Pediatric Respiratory Hospital Admissions in São Paulo, Brazil. J Environ Med 1999; 1:95–102.

Braga ALF, Saldiva PHN, Pereira LAA, Menezes JJC, Conceição GMS, Lin CA,

Brouwer, R. (1998). "Future Research Priorities for Valid and Reliable Environmental Value Transfer". CSERGE Working Paper GEC 98-28: London.

CETESB (São Paulo State Enviromental Agency) - http://www.cetesb.sp.gov.br/

CETESB (2002a). Relatório de Qualidade do Ar 2001 [In Portuguese].

Conceição GMS, Miraglia SGEK, Kishi HS, Saldiva PHN, Singer JM. Air Pollution and Child Mortality: A Time-Series Study in São Paulo, Brazil. Environ Health Perspect 2001; 109(3):347–350.

DATA-SUS (2000). Autorizações de internações hospitalares. Base agregada CD [In Portuguese].

Emplasa (São Paulo State Company for Metropolitan Planning) - http://www.emplasa.sp.gov.br/

ExternE (1998). Externalities of Fuel Cycles: Economic Valuation. - An Impact Valuation Approach. http://externe.jrc.es/publications.

GEIPOT (National Study Group for Transport Policy Integration) – http://www.geipot.gov.br/

IBGE (2000). Censo Demográfico.

IPEA (1999). Boletim Mercado de Trabalho, Rio de Janeiro.

Lin CA, Martins MA, Farhat SCL, Pope III CA, Conceição GMS, AnastácioVM, Hatanaka M, Andrade WC, Hamave WR, Böhm GM, Saldiva PHN. Air Pollution and Respiratory Illness of Children in São Paulo, Brazil. Paed Perinatal Epidemiol 1999; 13(4):475–488.

Lin, C.A., Pereira, L.A.A., Conceição, G.M.S., Kishi, H.S., Milani J.R.R., Braga, A.L.I., Saldiva, P.H.N. Association Between Air Pollution and Ischemic Cardiovascular Emergency Room Visits. Environ Res 2003, 92:57-63.

Martins LC, Latorre MRDO, Saldiva PHN, Braga ALF. Air pollution and emergency room visits due to chronic lower respiratory diseases in the elderly: an ecological time-series study in São Paulo, Brazil. J Occup Environ Med 2002; 44:622-627.

Metrô (São Paulo State Subway Company) - http://www.metro.sp.gov.br/

Miraglia SGEK, Conceição GMS, Saldiva PHN, Strambi O. Analysis of the impact of fuel consumption on mortality rates in São Paulo. In: Urban Transport and the Environment for the 21st Century III. Sucharov L, Bidine G (eds.). Computational Mechanics Publication, Southampton, UK, 435-444, 1997.

Pereira LAA, Loomis D, Conceição GMS, Braga ALF, Arcas RM, Kishi HS, Singer JM, Böhm GM, Saldiva PHN. Association Between Air Pollution and Intrauterine Mortality in São Paulo, Brazil. Environ Health Perspec 1998; 106(6):325–329.

Saldiva, P.H.N., Lichtenfels, A.J.F.C., Paiva, P.S.O., Barone, I.A., Martins, M.A., Massad, E., Pereira, J.C.R., Xavier, V.P., Singer, J.M., Böhm, G.M. Association Between Air Pollution And Mortality Due to Respiratory Diseases in Children in São Paulo, Brasil: A Preliminary Report. Environ Res 1994; 65:218-225.

Saldiva, P.H.N., Pope II, C.A., Schwartz, J., Dockery, D.W., Lichtenfels, A.J.F.C., Salge, J.M., Barone, I., Böhm, G.M. Air Pollution and Mortality in Elderly People: A Time Series Study in São Paulo, Brazil. Arch Environ Health 1995; 50(2):159-163.

Serôa da Motta, R., Ortiz, R. and Ferreira, S.F. (1999). "Health and Economic Values for Mortality and Morbidity Cases Associated with Air Pollution in Brazil", draft paper for presentation at The Expert Workshop on the Ancillary Benefits and Costs of GHG Mitigation Strategies, Resources for the Future, Washington, DC, March 27th-29th 2000.

SEADE. Demografia. Informações dos Municípios Paulistas 2002; [Online] [In Portuguese]. Acessed in December 10 2002. Available at: www.seade.gov.br
Secretaria Estadual de Energia (São Paulo State Energy Secretary)
Secretaria Estadual de Transportes Metropolitanos (São Paulo State Metropolitan Transport Secretary)

Schwartz, J. Generalized Additive Models in Epidemiology. In: International Biometric Society, Invited Papers. 17th International Biometric Conference, August 8-12, Hamilton, Ontario, Canada. Washington, DC: International Biometric Society, 1994, p 55-80.