POST-2015 CONSENSUS

Post-2015 Development Agenda

Brazil Perspectives

Air Pollution

SPEAKER

Bjorn Larsen

Bjorn Larsen is an economist and consultant to international and bilateral development agencies, consulting firms, and research institutions with 25 years of professional experience from over 50 developing countries. His expertise includes quantitative health risk assessment, health risk valuation, benefit assessment of environmental protection, cost-benefit and cost effectiveness analysis of environmental health intervention. His primary fields of work are outdoor air pollution, household air pollution from solid fuels, household water supply, sanitation and hygiene, and poverty-environmental health linkages.

Table of Contents

Summary: White Paper Report by Bjorn Larsen

Air pollution kills about 49,000 Brazilians every year. About half of these deaths – 25,000 – are from the outdoor pollution that we normally worry about, particularly in cities. The other 24,000 result from household air pollution, caused by cooking with wood and other solid fuels. This affects mainly rural communities. Deaths from both outdoor and indoor air pollution represent one in every 26 deaths from all causes in Brazil, making it the ninth largest mortality risk in the country.

In both cities and countryside, the cause is the same: tiny particles in smoke which we breathe in and which can lead to chronic lung disease and acute respiratory infections, lung cancer, heart disease and strokes. This does not just affect Latin America, but is a global problem causing over 6 million deaths worldwide each year.

The most dangerous of the airborne particle are known as PM2.5 (particulates less than 2.5 thousandths of a millimeter across) which can penetrate deep into the lung. The World Health Organization (WHO) has set a limit for average outdoor ambient air pollution of 10 micrograms (millionth of a gram) of PM2.5 per cubic meter of air (10µg/m3). In urban areas, the level may be twice this, for example 22µg/m3 measured recently in Sao Paulo and 7-28µg/m3 in six major cities near busy streets. Overall, about 40% of the Brazilian population is estimated to breathe air which is more polluted than the WHO guidelines.

Generally, air quality in Brazilian cities is reasonably good, although about 7,000 lives could be saved by reducing maximum outdoor PM2.5 exposure to 15µg/m3, the World Health Organization's third interim target. But reducing indoor air pollution would be a much less expensive way to save as many lives.

19 million Brazilians – about 9.5% of the population – cook primarily with firewood, and many other households use wood as a secondary fuel. For these households, air pollution is often at least ten times higher than in towns and cities. Another 2-3% of the population use charcoal as their primary or secondary cooking fuel. This is less polluting than wood, but households still face substantial pollution.

In Latin America, the person doing the cooking in households using firewood breathes air with an average concentration of PM2.5 of 115-265µg/m3, 11 to 26 times the WHO recommended level. Replacing open fires and traditional stoves with improved, well-maintained cookstoves with chimneys that vent to the outside reduces this exposure by over half.

Doing this in Brazil should reduce average PM2.5 exposure from 180 to 80µg/m3. To make greater improvements, households need to make the transition to the more expensive propane (LPG). If all households in a community used LPG, pollution may decline to 25µg/m3 or less, but exposure would be perhaps double that if only a fraction of households changed.

Adoption of improved cookstoves would reduce PM2.5 exposure by over half and reduce the risk of disease and death by 34%. Going further and using LPG would reduce disease and death by 47-67%, depending on the rate of adoption across the community.

The market for improved cookstoves is underdeveloped in many parts of the country and little has been done to promote them in the last two decades. Countries in the region including Mexico, Peru and Guatemala have successfully marketed biomass stoves with a chimney to vent the smoke[1]. Similar stoves in Brazil, such as the Ecofagao and IDER can cost 500 Reals including installation, but they burn only about half the amount

[1] Berrueta, V., Edward, R., and Masera, O. 2008. Energy performance of wood-burning cookstoves in Michoacan, Mexico. Renewable Energy, 33(5), 859–870.

of wood used in traditional stoves, so there are savings on fuel costs. On the other hand LPG stoves can cost 500-600 Reals, and the fuel can cost a further 400 Reals a year.

For both cases, the benefits in health, fuel savings and time more than outweigh the cost. There are benefits worth about 7 Reals for each one spent on improved cookstoves and 2.8 Reals for spending one on LPG stoves (somewhat less if there is still substantial pollution from firewood). Spending to reduce household air pollution gives 2-20 times more benefit per Real than spending money on typical measures to reduce urban ambient air pollution.

Since a full transition to LPG could not happen quickly, a reasonable interim target would be to convert half the households to improved wood-burning cookstoves and the other half to LPG. This would save 7,350 lives a year and reduce the total number of deaths and cases of illness by 41%. Converting fully to LPG would save a further 5,000 lives a year.

A whopping 6-7 million people die each year globally from pollution of the air by tiny particles that we breathe. These tiny particles inflict chronic lung disease, heart disease, stroke, lung cancer, acute respiratory infections and other illnesses.[i] The most dangerous of these particles are less than 2.5 thousands of a millimeter wide and are called PM2.5 (particulate matter of less than 2.5 microns). These particles are found in both the outdoor ambient environment and in the indoor household environment.

About 49,000 people die each year from this air pollution in Brazil.[ii] About 25,000 of the deaths are from outdoor ambient air pollution mainly in urban areas[iii], and 24,000 are from household air pollution caused by cooking with wood and other solid fuels. The estimate of deaths from household air pollution reflects new evidence of health effects and better methodologies to estimate these effects.[iv]

Deaths from outdoor ambient and household air pollution represent one in every 26 (3.8%) deaths from all causes in Brazil. This makes air pollution the ninth largest mortality risk factor in the country after dietary risks, high blood pressure, physical overweight, tobacco smoking, high fasting plasma glucose, alcohol and drugs, physical inactivity and low physical activity, high cholesterol, among dozens of factors assessed by the Global Burden of Disease 2010 Project.[v]

As global evidence of severe health effects of PM2.5 has been mounting, the World Health Organization (WHO) in 2005 revised its Air Quality Guideline (AQG) for annual average outdoor ambient air pollution concentrations to 10 microgram of PM2.5 per cubic meter of air (10 $\mu g/m^3$). In contrast, annual average PM2.5 concentrations were recently about 22 $\mu g/m^3$ in Sao Paulo, 7-13 $\mu g/m^3$ at ten monitoring sites in Rio de Janeiro, and 7-28 $\mu g/m^3$ in six major Brazilian cities at sites near streets with high traffic volumes.[vi] Nationally, an estimated 40% of the Brazilian population breathe air that contains more PM2.5 than WHO's annual AQG.

Although ambient air quality in many Brazilian cities is reasonably good, further improvements can be made. For instance, about 7,000 lives can be saved each year if Brazil ensures that no one is exposed to outdoor ambient PM2.5 concentrations exceeding WHO's third interim air quality target of 15 $\mu g/m^3$. But this will in all likelihood be far more expensive than achieving the same health improvements by promoting improved stoves and LPG for cooking to reduce household air pollution.

Controlling household air pollution

Nearly 20 million people, or 9.5% of the population, cook primarily with firewood in Brazil today and many other households continue to use firewood as secondary fuels. Air pollution in these households is severely health damaging, with pollution levels often 10-15 times higher than in urban areas. Approximately 2-3% of the population use charcoal as primary or secondary cooking fuel, facing substantial but less pollution than households using firewood. The population

cooking primarily with firewood declined from approximately 45% in 1975 to 10% in 1995, but very little progress has been achieved in the last two decades.[vii]

There are two broad options to control household air pollution from use of solid fuels:

i) adopt improved biomass cookstoves that reduce PM2.5 concentrations in the household environment; or
ii) speed up the transition to propane (LPG) or natural gas which is practically free from PM2.5.

A study some years ago in the state of Minas Gerais and the North East region of Brazil found that 2/3rd of households that cooked with firewood or charcoal used open or semi-closed stoves with no chimney. And among those with chimney, many were poorly maintained. Nearly 2/3rd of households cooked indoors and somewhat over 1/3rd cooked outdoors with stoves often attached to the homes.[viii] Smoke from such outdoor cooking does, however, severely affect the person cooking, often seep indoors, and pollutes neighboring houses and the community at large.

But the worst pollution is for those who cook indoors with firewood. The average 24-hours concentrations of PM2.5 in the air breathed by the person cooking (personal exposure) are in the range of 115-265 μg/m^3, according to recent studies in several countries in Latin America. This is 11-26 times higher than WHO's recommended level of 10 μg/m^3 for annual ambient air quality. The same studies found that 24-hours personal exposures declined on average by over 50% from installation of improved cookstoves with chimney that vents the smoke out of the indoor environment [ix]

Promoting and adopting improved cookstoves with chimney in Brazil among those who cook indoors may be expected to yield similar improvements in household air quality, that is a reduction in PM2.5 exposure from an average of about 180 μg/m^3 when cooking over open fire or traditional, open stove to an average of about 80 μg/m^3 after installing and properly operating and maintaining an improved stove with chimney.

The use of LPG for cooking is more expensive than the use of solid fuels, but is much cleaner and therefore more effective in reducing personal exposure to PM2.5. Personal exposures after adopting LPG will, however, depend on the level of pollution in the community from households continuing to use solid fuels as well as level of pollution from other sources. With only a fraction of households adopting LPG, personal exposures may be 50 μg/m^3. If all households adopt LPG, personal exposures may decline to 25 μg/m^3 depending on the extent of other sources of PM2.5 pollution. In very clean communities, personal exposures may be reduced to levels below WHO's annual ambient AQG of 10 μg/m^3.

Adoption of improved cookstoves with chimney reduces the risk of disease and death by around 34% compared to cooking over open fire or traditional. This is substantially less than the reduction in PM2.5 exposure of over 50%, and is due to the characteristics of the relationship between PM2.5 exposure levels and associated magnitude of risk of disease and death that are

found in scientific studies. Adoption of LPG stoves is expected to reduce disease and deaths by 47-67% depending on the level of community pollution. Reaching WHO's ambient annual AQG would reduce disease and deaths by about 91%.

Table 1. Household cooking stoves and PM2.5 pollution exposure

	Open fire, traditional stove	Improved cookstove with chimney	LPG stove (substantial community pollution)	LPG stove (some community pollution)	WHO Ambient Annual AQG
PM2.5 exposure ($\mu g/m^3$)	180	80	50	25	10
Avoided disease and deaths (%)	-	34%	47%	67%	91%

Very little seems to have been done in Brazil in the last two decades to promote improved cookstoves among households cooking with solid fuels. And improved cookstove markets are underdeveloped in many parts of the country.[x]

Improved cookstove programs in other Latin American countries most often promote closed biomass stoves with two or three hot plates and an attached chimney that vents the smoke out of the kitchen and indoor environment, and provide fuel wood savings of 40-60% relative to cooking on open fire. Examples are the Patsari stove in Mexico, the Inkawasi stove in Peru, the Eco-Plancha stove in Guatemala, and the Ecostove in Honduras, and Nicaragua.[xi] Similar types of stoves in Brazil, such as the Ecofagao and IDER, can cost 500 Reals including local materials and installation.[xii]

The use of LPG for cooking is more expensive than the use of solid fuels. A full-size LPG stove with multiple burners can cost 500-600 Reals, and LPG fuel can cost a household 400 Reals per year.

Despite these costs, the benefits of improved cookstoves with chimney and use of LPG for cooking by far outweigh the costs. For every Real spent on improved cookstoves the benefits are in the range of 4 to 9 Real. For every Real spent on LPG stoves and fuel the benefits are in the range of 1.4 to 3.8 Reals.[xiii] These benefits are health improvements, solid fuel savings and cooking time savings. The costs include initial cost of stoves, maintenance and repair, LPG fuel, and cost of programs to promote adoption of improved stoves and LPG.

In perspective, the benefits per Real spent on household air pollution control are 2-20 times higher than benefits per Real spent on several typical measures to control ambient PM2.5 pollution in urban areas. A major reason for this difference in benefits is the benefits of fuel savings and cooking time savings from improved cookstoves and LPG.[xiv]

Table 2. Reals of benefits for every Real spent on household air pollution control

	Improved cookstove with chimney	LPG stove (substantial community pollution)	LPG stove (some community pollution)
Reals of benefits			
High (VSL)	9.4	3.0	3.8
Medium (DALY=US$ 5,000)	6.9	2.3	2.8
Low (DALY=US$1,000)	3.5	1.4	1.5

Note: High, Medium and Low benefits reflect a range in valuation of death and disease. Low: A year of life and year lost to disease is valued at US$ 1,000. Medium: A year is valued at US$ 5,000. High: A death is valued by applying a so called value of statistical life (VSL). A very conservative VSL equal to 15 times the GDP per capita in Brazil is applied, reflecting that the use of solid fuels is predominantly in the poorer areas of the country.

The message is clear:

i) Improved cookstoves with chimney should be promoted for adoption by households that currently cannot afford LPG; and

ii) LPG should be promoted as the best choice whenever households can afford it.

A reasonable ***interim*** target is to achieve adoption of improved cookstoves with chimney by 50% of the households that currently use solid fuel for cooking, and achieve adoption of LPG stoves by the other 50% of households. A ***final*** target would be to achieve that all households use LPG, or other clean cooking solutions.

Reaching the interim target would reduce the number of deaths and cases of illness by 41% and save 7,350 lives per year among the households that now cook indoors primarily with firewood. Reaching the final target would save an additional nearly 5,000 lives per year.

Table 3. Annual health benefits of reaching household air pollution control targets

	Interim target	Final target
Avoided disease and deaths (%)	41%	67%
Avoided number of deaths per year	7,350	12,200

Total annualized cost of reaching the interim target is approximately 1 billion Reals and total annual benefits are 1.7 – 4.0 billion Reals. The cost associated with half of households adopting improved cookstoves is only one-fifth of the cost associated with half of households adopting LPG stoves.

Reaching the final target of 100% adopting LPG costs 1.7 billion Reals per year, or 0.7 billion Reals more than reaching the interim target. Reaching the final target provides annual benefits of about 2.5 – 6.3 billion Reals. This is substantially more than twice the benefits of 50% of households adopting LPG stoves due to the extra benefits of avoiding community pollution when all households convert to LPG.

Table 4. Total annual costs and benefits of reaching interim and final target

TARGET	Costs per year (Million Reals)	Total Benefits per year (Million Reals)		
		VSL	DALY = US$5,000	DALY = US$1,000
50% of those using unimproved cookstoves switch to improved cookstoves	162	1,528	1,116	563
50% of those using unimproved cookstoves switch to LPG cookstoves	832	2,526	1,952	1,184
100% of those using unimproved cookstoves switch to LPG cookstoves	1,665	6,355	4,721	2,530

Making the promotion of improved cookstoves and LPG effective and sustainable

Households are more likely to adopt improved stoves or use LPG when they are well informed and understand the full health benefits to be gained, not only for the person cooking but also for the other members of the family who are also exposed to elevated levels of air pollution throughout the household environment.

The magnitude of benefits of improved biomass cookstoves and LPG for cooking depends very much on prevailing pollution levels, and the magnitude of pollution reductions achieved by adoption of new stoves and fuels. This is influenced by multiple factors, such as characteristics of dwellings, cooking location, cooking practices, and activity patterns of household members. These factors can be positively modified by stove promotion programs to enhance the benefits of improved biomass cookstoves and LPG stoves.

The sustainability of pollution reductions are also influenced by the condition of improved cookstoves. Promotion programs need therefore demonstrate and encourage proper use, maintenance and repairs of stoves.

There are advantages to making stove promotion programs community focused. The use of solid fuels by one household affects surrounding households. Smoke is vented out of one household for so to enter the houses of others and also pollute the ambient outdoor air in the community. The ultimate aim must therefore be to achieve “unimproved stove free” and eventually “solid biomass free” communities.

Notes and further readings

[i] Lim, S.S., Vos, T., Flaxman, A.D., Danaei, G., et al. 2012. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet,* 380: 2224-60, and http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/

[ii] Estimate by Bjorn Larsen for the Copenhagen Consensus Center.

[iii] This estimate is based on ground level ambient air PM2.5 monitoring data in several of the major cities and metropolitan areas in Brazil, as well as extrapolated ambient PM2.5 concentrations for secondary cities and rural areas.

[iv] Burnett, RT., Pope, CA III., Ezzati, M., Olives, C., Lim, SS., et al. 2014. An integrated risk function for estimating the global burden of disease attributable to ambient fine particulate matter exposure. *Environmental Health Perspectives,* 122: 397-403.

[v] http://www.healthdata.org/gbd

[vi] Larsen, B. and Skjelvik, JM. 2014. Environmental health in Piaui State of Brazil: An economic assessment of health effects and their costs. Prepared for the World Bank. Washington, D.C., USA.

[vii] The estimates of household use of firewood and charcoal presented here are based on analysis of the Brazil National Energy Balance 2013. https://ben.epe.gov.br/downloads/Relatorio_Final_BEN_2014.pdf

[viii] Accenture. 2011. Brazil feasibility study: sector mapping. Prepared for the Global Alliance for Clean Cookstoves. www.cleancookstoves.org

[ix] Armendariz-Arnez, C., Edwards, RD., Johnson, Rosas, IA., et al. 2010. Indoor particle size distributions in homes with open fires and improved Patsari cook stoves. *Atmospheric Environment*, 44: 2881-86.

Armendariz-Arnez, C., Edwards, RD., Johnson, M., Zuk, M., et al. 2008. Reduction in personal exposures to particulate matter and carbon monoxide as a result of the installation of a Patsari improved cook stove in Michoacan Mexico. *Indoor Air,* 18(2): 93-105.

Clark, M., Peel, J., Burch, J., Nelson, T., Robinson, M., Conway, S., Bachand, A., and Reynolds, S. 2009. Impact of improved cookstoves on indoor air pollution and adverse health effects among Honduran women. *International Journal of Environmental Health Research*, 19(5): 357-368.

Fitzgerald, C., Aguilar-Villalobos, M., Eppler,. AR., et al. 2012. Testing the effectiveness of two improved cookstove interventions in the Santiago de Chuco Province of Peru. *Sci Total Environ,* 420: 54-64.

Hartinger, SM., Commodore, AA., Hattendorf, J., Lanata, CF., et al. 2013. Chimney stoves modestly improved indoor air quality measurements compared with traditional open fire stoves: results from a small-scale intervention study in rural Peru. *Indoor Air,* 23(4): 342-52.

Masera, O., Edwards, R., Armendariz-Arnez, C., et al. 2007. Impact of Patsari improved cookstoves on indoor air quality in Michoacan, Mexico. *Energy for Sustainable Development,* 11(2): 45-56.

McCracken, JP., Smith, KR., Díaz, A., Mittleman, MA., Schwartz, J. 2007. Chimney stove intervention to reduce long-term wood smoke exposure lowers blood pressure among Guatemalan women. *Environmental Health Perspectives,* 115(7): 996-1001.

Northcross, A., Chowdhury, Z., McCracken, J., Canuz, E., and Smith, K. 2010. Estimating personal PM2.5 exposures using CO measurements in Guatemalan households cooking with wood fuel. *J Environ Monitoring,* 12: 873-78.

Pollard, S., Williams, D'A., Breysse, P., Baron, P., et al. 2014. A cross-sectional study of the determinants of indoor environmental exposures in households with and without chronic exposure to biomass fuel smoke. *Environmental Health,* 13: 21.

Winrock. 2008. Peru healthy kitchen/healthy stove pilot project. Winrock International under cooperative agreement with USAID. December 2008.

Zuk, M., Rojas, L., Blanco, S., Serrano, P., et al. 2007. The impact of improved wood-burning stoves on fine particulate matter concentrations in rural Mexican homes. *J Exposure Sci and Environ Epidemiology,* 17:224-32.

[x] See viii.

[xi] Berrueta, V., Edward, R., and Masera, O. 2008. Energy performance of wood-burning cookstoves in Michoacan, Mexico. *Renewable Energy*, 33(5), 859–870.

GACC. 2014. Guatemala country action plan for clean cookstoves and fuels – annexes. Global Alliance for Clean Cookstoves. www.cleancookstoves.org

Winrock. 2008. Peru healthy kitchen/healthy stove pilot project. Winrock International under cooperative agreement with USAID. December 2008.

[xii] See viii.

[xiii] These benefits and costs are based on data for Brazil. Regional estimates are provided in Larsen, B. 2014. Benefits and costs of the air pollution targets for the Post-2015 Development Agenda. Air Pollution Assessment Paper. Copenhagen Consensus Center. http://www.copenhagenconsensus.com/post-2015-consensus/air-pollution

[xiv] See Larsen, B (2014) in xiii.

Air Pollution in Brazil

Better air?

better health?

for whom?

for how much?

05 MAY 2015

Bjorn Larsen
Consultant
Email: BL@Bjorn-Larsen.com
Website: www.bjorn-larsen.com

Questions to ask ourselves

- Does Brazil have an air pollution problem?
- How big is the problem?
- Who are most affected?
- Can we do something about it?
- Shall we do something?
- What will be the benefits?
- What are the costs?
- Are there answers to these questions?

First of all – what air pollution?

- We are talking about:
  - Very small particles – smaller than 2.5 microns in diameter
  - We call them PM2.5
  - They penetrate deep into our lungs
- They cause:
  - Heart disease; Stroke; Lung cancer; Chronic and acute lung diseases
- This is the pollutant that causes 6-7 million deaths per year in our world

So does Brazil have a PM2.5 problem?

- There has been achievements:
  - PM2.5 air quality are moderate in major urban areas
  - Liquefied petroleum gas (LPG propane) have successfully expanded in urban areas, and even in rural areas

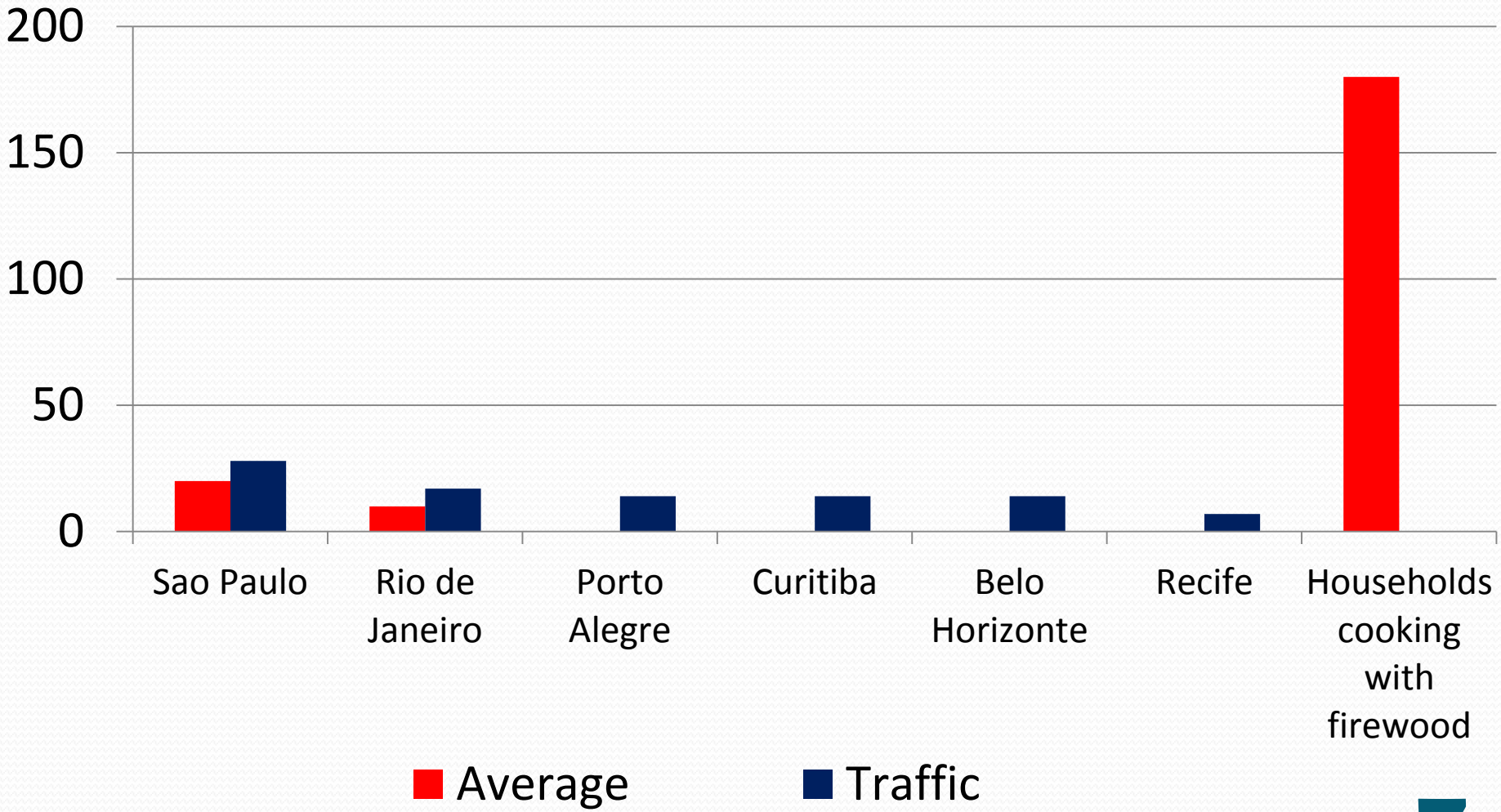
A PM2.5 problem?

- So what is the problem?
  - 40% of the population in Brazil is exposed to outdoor PM2.5 above WHO's annual guideline of 10 microgram per cubic meter of air ($\mu g/m^3$)
  - Nearly 10% of the population still relies on highly polluting fuels for cooking and heating (mainly fuel wood), and mostly cook over open fire and open, traditional stoves – very little progress in the last 20 years

We may ask: So what?

- 49,000 die each year from this pollution
  - ✓ 25,000 from outdoor ambient PM2.5
  - ✓ 24,000 from household PM2.5 due to dirty cooking fuels

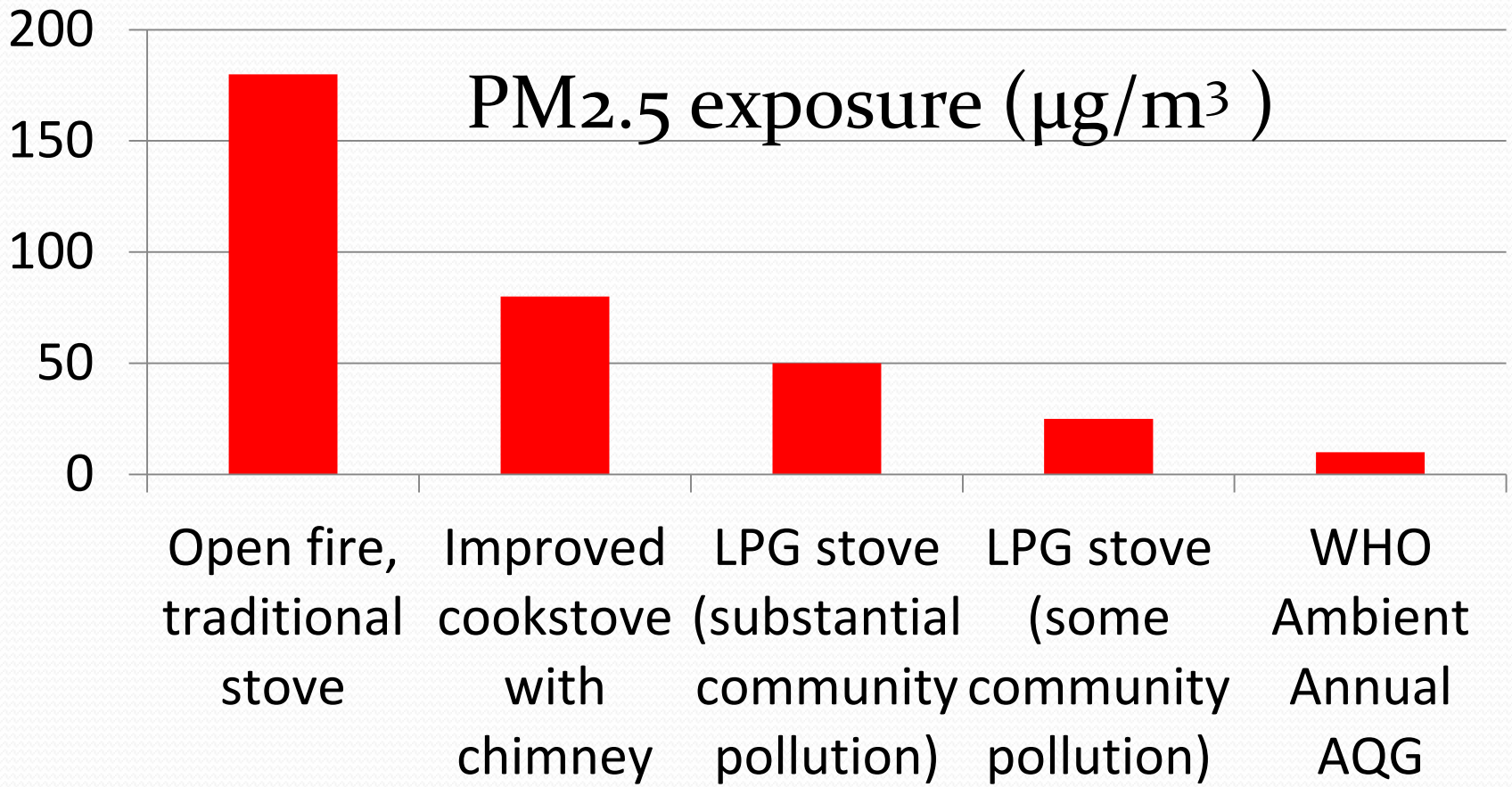
Annual average PM2.5 (μ/m³)



So who are most affected?

- Nearly 20 million people – mainly in rural areas – use solid, dirty fuels as primary fuels for cooking
- They suffer severe health effects:
  - 17% of all deaths among these people are due to use of solid, dirty fuels
  - This is far more than previously understood
  - We are able to make this estimate now that we have more scientific evidence, better methodologies, and better data on exposure to PM2.5

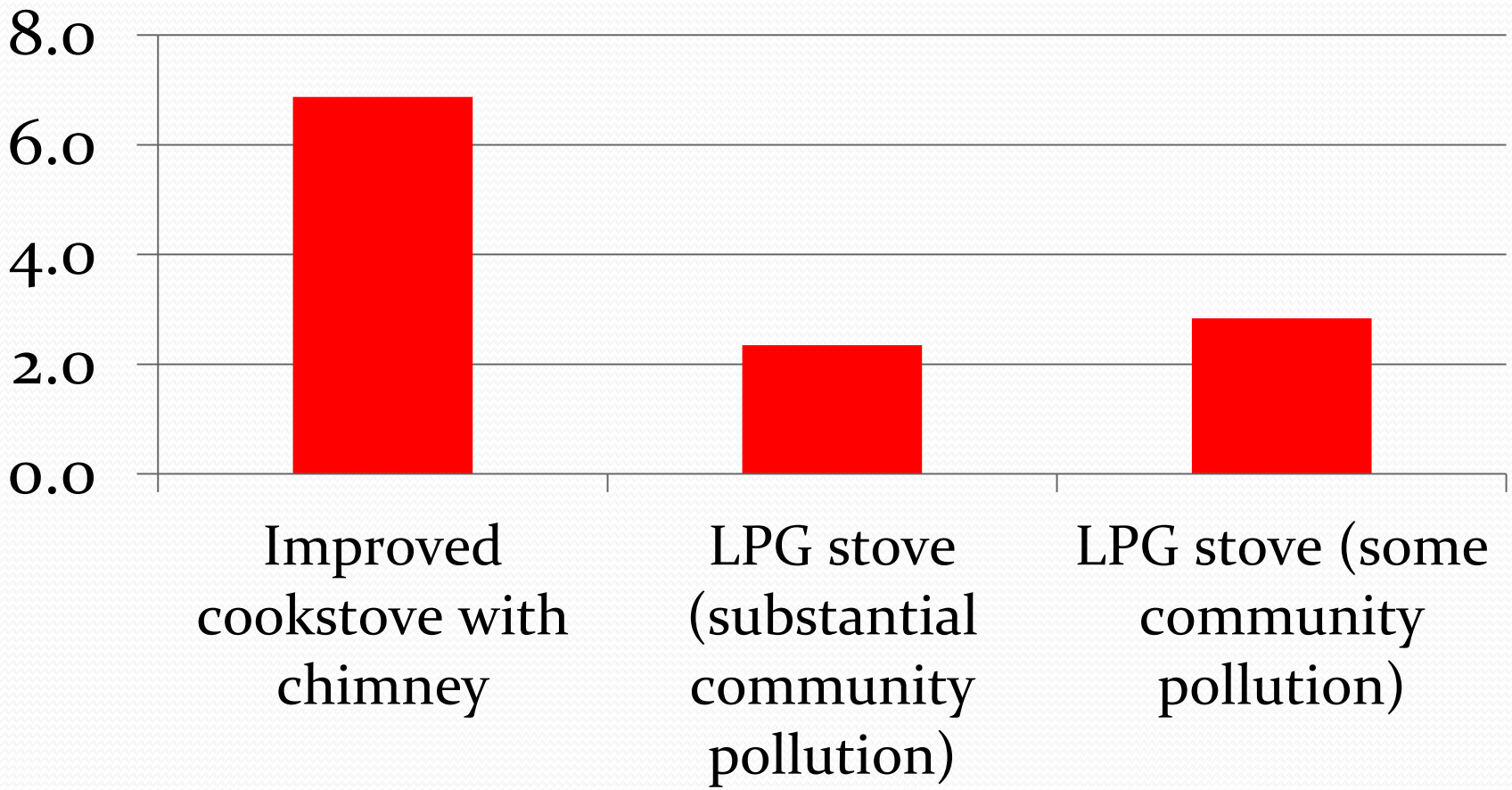
So what can we do about it?



So shall we do something about it?

- One way of answering this question is to find answers to:
  - What are the benefits of solving this problem?
  - What are the costs?

Here we have it:
Reals of benefits per Real spent

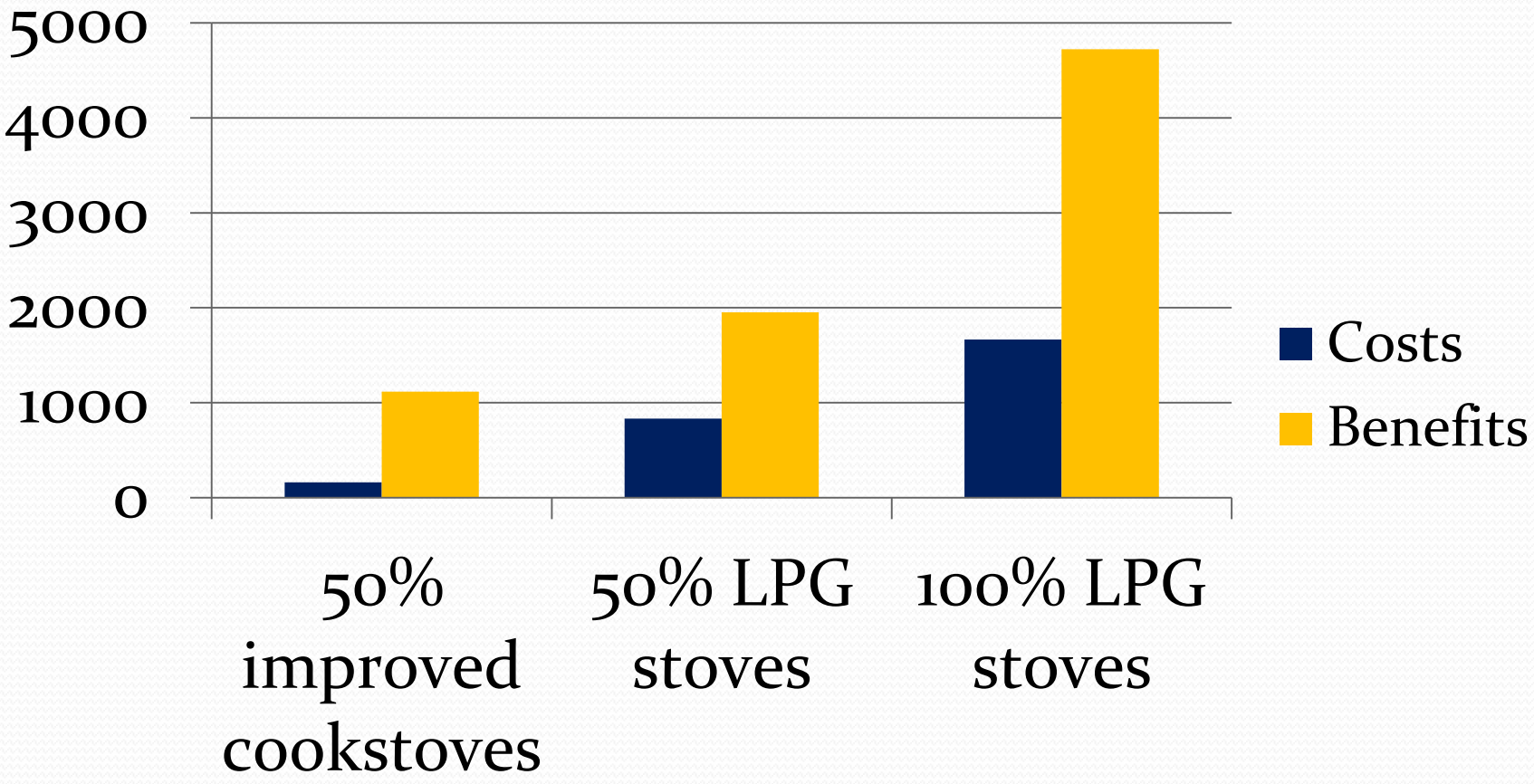


Note: 1 year of life saved is valued at US$ 5,000

What might be some achievable targets?

- Interim target:
  - 50% adoption of improved cookstoves and 50% adoption of LPG
  - Saves 7,350 lives per year
- Final target:
  - 100% adoption of LPG
  - Saves 12,200 lives per year

Achieving the targets: Benefits and costs (million Reals per year)



Note: 1 year of life saved is valued at US$ 5,000

What can we conclude?

- The benefits per Real spent on control of household air pollution is greater than on outdoor ambient air pollution.
- High benefit-cost ratios for improved cookstoves.
- But need clean fuels (e.g. LPG) for larger improvements in health.
- Households should be well informed of the enormous health risks of pollution from the use of solid fuels on open fires and traditional cookstoves.
- Programs to promote adoption of improved cookstoves must emphasize proper operation, maintenance and repair of stoves and chimneys.
- There are benefits of making promotion programs community focused with the aim of “unimproved stove free” communities and eventually “solid fuel free” communities.

Thank you for your attention!!