Integrated Assessment of Short-Lived Climate Pollutants for Latin America and the Caribbean: Improving air quality while mitigating climate change. Summary for decision makers

Summary
for Decision Makers

Integrated Assessment of Short-Lived Climate Pollutants in Latin America and the Caribbean

Improving air quality while contributing to climate change mitigation

UNEP

CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

Summary for Decision Makers

Integrated Assessment of Short-Lived Climate Pollutants in Latin America and the Caribbean
Improving air quality while contributing to climate change mitigation

Job No: DEW/1969/NA

ISBN: 978-92-807-3549-9

DISCLAIMERS

REPRODUCTION

SUGGESTED CITATION

UNEP and CCAC 2016. Integrated Assessment of Short-Lived Climate Pollutants for Latin America and the Caribbean: improving air quality while mitigating climate change. Summary for decision makers. United Nations Environment Programme. Nairobi, Kenya.

CREDITS

© Maps and illustrations as specified.

Copy Editor: Bart Ullstein.

Managing Editors: Graciela Raga and Paulo Artaxo.

Design and Art direction: Puntoaparte *Bookvertising*.

Summary for Decision Makers

Integrated Assessment of Short-Lived Climate Pollutants in Latin America and the Caribbean

Improving air quality while contributing to climate change mitigation

In 2011, two scientific global assessments[1] coordinated by the United Nations Environment Programme (UNEP) identified a number of win-win measures for near-term climate change and clean air benefits. Implementation of these cost-effective and readily available measures, which target reducing emissions of short-lived climate pollutants (SLCPs) in key sectors, can bring rapid and multiple benefits for human well-being and support countries achieve their development objectives, while simultaneously increasing their ambition for climate mitigation in the near term. The reduction in SLCP emissions should, however, be done in parallel with the reduction in carbon dioxide (CO_2) emissions.

While the two global assessments were very comprehensive, some specific emission characteristics and estimates of the benefits of emission reductions in different regions could not be explored in detail. This provided the motivation for more in-depth regional assessments, of which the Latin American and the Caribbean (LAC) assessment is the first.

The LAC region is one of the most urbanized in the world, with almost 80 per cent of its population living in cities, including several megacities. Urban air pollution has been a concern in the region's cities for many years, and while steps have been taken to improve it, much still remains to be done, especially in mid-size cities that are continuing to grow rapidly. As the climate changes, urban environments, which are already experiencing urban heat-island effects, face particular challenges that policy-makers need to consider, such as further increases in temperature, scarcity of water and the complexity of transport systems in cities that have grown without adequate planning. Increasing temperatures will also lead to the more widespread use of air conditioning, which is not as prevalent in LAC as in other parts of the world, in buildings and cars.

The region is also characterized by significant socio-economic inequality, both in urban and rural areas, particularly those that are difficult to access, such as in certain parts of the Andes and Amazonia. The lack of opportunities in rural areas is one of the reasons for the steady flow of people to the cities. Both outdoor and indoor air pollution strongly affect people's health.

The region has a large variety of climates due to both, its latitudinal extent and the presence of mountain ranges, the most prominent being the Andes. From the biodiversity-rich tropical areas, through the highest peaks with vulnerable tropical glaciers, to the vast continental ice fields in Patagonia, all regions are susceptible to significant change in the coming decades if climate change continues at its current rate.

Some of the glaciers in the tropical Andes have receded rapidly in the last decades, endangering the water supply at high altitudes for people and agriculture. In the sub-tropical regions of the Andes, winter precipitation builds the snowpack that supplies water for agricultural, industrial and human consumption in Chile and Argentina. Additionally, because of its many island states and the growth of coastal region development in several countries, the LAC region is particularly vulnerable to sea-level rise.

Urban pollution can be transported beyond cities, affecting agricultural areas that are vital for local food security and income generation through exports. Ozone (O_3) damage to crops can lead to substantial yield losses including maize, an important staple in many LAC countries. Rising temperatures and shifts in precipitation patterns due to climate change can also affect other important crops including coffee and sugar cane. These impacts could potentially be reduced in the near term by implementing a strategy to reduce SLCPs in the region.

The *Integrated Assessment of Short-Lived Climate Pollutants in Latin America and the Caribbean* convened more than 90 authors, under the leadership of renowned experts and institutions from the region and supported by international experts, to assess current knowledge of emissions, ambient measurements and impacts of SLCPs on the climate, and air quality in the region. A survey of national emission inventories collected the best available data and was used to develop a detailed, complete and consistent emission inventory in 13 regions within LAC[2]. Examples of mitigation measures already being considered at different levels of government in LAC have been evaluated in terms of their benefits and the barriers to their more widespread implementation. This assessment investigates the potential benefits that could be achieved if the identified measures for reducing SLCPs were to be widely implemented. It focuses on the four main SLCPs (Boxes 1 to 4): methane (CH_4), black carbon (BC), ozone (O_3), and hydrofluorocarbons (HFCs).

Through this assessment, policy makers and implementers will be able to better quantify and understand the relevant emissions in the region; identify which measures are most important for delivering near-term climate and air pollution benefits; and estimate the reductions in regional air pollutants that could be achieved by implementing these measures, with associated health and crop-yield benefits for the LAC region.

Decision makers would also find that the measures identified in this report are crucial to the regional implementation of the 2015 United Nations Framework Convention of Climate Change (UNFCC) Paris Agreement. Reductions in SLCPs could contribute significantly to an emissions pathway consistent with holding the increase in the global average temperature below 2^{0}C above pre-industrial levels, aiming at 1.5^{0}C, while also helping countries achieve the Sustainable Development Goals (SDGs) including those for human health, hunger, energy, cities and human settlements, and sustainable consumption and production. The Nationally Determined Contributions (NDCs) for several countries already include significant efforts to reduce SLCPs, focusing on BC and CH_4, and some of the measures identified in this assessment can complement them.

The results presented in the *Summary for Decision Makers* (SDM) are based upon the findings of the much more extensive *Integrated Assessment of Short-Lived Climate Pollutants in Latin America and the Caribbean*.

1. UNEP and WMO (2011) Integrated Assessment of Black Carbon and Tropospheric Ozone; and UNEP (2011) Near-term Climate Protection and Clean Air Benefits: Actions for Controlling Short-Lived Climate Forcers.
2. The regions are: Argentina, Bolivia, Brazil, The Caribbean, Central America, Chile, Colombia, Ecuador, Mexico, Paraguay, Peru, Uruguay and Venezuela. They were selected by balancing economic importance; population size; the availability of data on energy use, production, transport and contributions to total SLCP emissions in LAC; and available information on emission inventories.

Box 1

Methane

Methane (CH_4) is a powerful greenhouse gas with a lifetime in the atmosphere of approximately 12 years. Its increase in the atmosphere has caused the most significant radiative forcing of any greenhouse gas after carbon dioxide. Atmospheric CH_4 concentrations have grown as a result of human activities related to agriculture, including rice cultivation and ruminant livestock; coal mining; oil and gas production and distribution; biomass burning; and municipal waste landfilling.

Methane has a direct influence on climate, but also has a number of indirect effects including its role as an important precursor to the formation of tropospheric O_3, which in turn affects human health, crop yields and the quality and productivity of vegetation.

For some CH_4 sources, emission control measures also reduce other co-emitted substances such as the more reactive volatile organic compounds (VOCs) that contribute to the local formation of O_3, as well as air toxins such as benzene (C_6H_6), carbon tetrachloride (CCl_4) and chloroform ($CHCl_3$).

Box 2

Black Carbon

Black carbon (BC) is a potent climate-warming particle that remains in the atmosphere for a few days or weeks. It is formed by the incomplete combustion of fossils fuels, wood and other fuels. Complete combustion would turn all carbon in the fuel into carbon dioxide (CO_2), but combustion is never complete and CO_2, carbon monoxide (CO), VOCs, and organic carbon (OC) and BC particles are all formed in the process. Black carbon is always co-emitted with other particles and gases, some of which have a cooling effect on the climate. The complex mixture of particulate matter resulting from incomplete combustion is often referred to as soot.

The type and quantity of co-pollutants differs according to the source, and a high ratio of warming to cooling pollutants indicates the most promising sources to target for achieving climate benefits in the near term. Black carbon and co-emitted particles also reduce surface albedo (the ability to reflect sunlight) when deposited on snow and ice.

Black carbon and co-emitted pollutants also contribute to the formation of fine air polluting particulate matter ($PM_{2.5}$), which are strongly linked to observed short- and long-term health impacts. Specifically, $PM_{2.5}$ has been linked to a number of health impacts including premature death in adults with heart and lung disease, strokes, heart attacks, chronic respiratory disease such as bronchitis, aggravated asthma and other cardio-respiratory symptoms. It is also responsible for premature deaths of children from acute lower respiratory infections such as pneumonia. In general BC co-emitted with polycyclic aromatic hydrocarbons (PAHs) that are carcinogenic.

Box 3

Ozone

Ozone (O_3) is a reactive gas that exists in two layers of the atmosphere: the stratosphere (the upper layer) and the troposphere (ground level to ~15 km). In the stratosphere, O_3 protects life on Earth from the sun's harmful ultraviolet (UV) radiation. In contrast, at ground level, it is an air pollutant, which is harmful to human and ecosystem health, and is a major component of urban smog. Tropospheric O_3 is also an important greenhouse gas. The threefold increase of O_3 concentrations in the northern hemisphere in the past 100 years has made it the third most important contributor to the human enhancement of the global greenhouse effect, after CO_2 and CH_4. Ozone has a lifetime of a few hours to days in the atmosphere.

Tropospheric O_3 is a highly reactive oxidant that harms human health and significantly reduces crop productivity as well as the uptake of atmospheric carbon by vegetation. Ozone is known as a secondary pollutant because it is not emitted directly, but is formed when precursor gases such as CH_4, CO, oxides of nitrogen (NOx) and non-methane volatile organic compounds (NMVOC) react in the presence of sunlight. Ozone is particularly dangerous for children, the elderly and people with lung or cardiovascular disease – it can worsen bronchitis, emphysema, asthma, and may permanently scar lung tissue. Recent studies have also linked both short- and long-term ozone exposure to premature death, heart attacks, strokes, heart disease, congestive heart failure, and possible reproductive and developmental harm.

Box 4

Hydrofluorocarbons

Hydrofluorocarbons (HFCs) are a group of industrial chemicals primarily produced for use in refrigeration, air-conditioning, insulating foams and aerosol propellants, with minor uses as solvents and for fire protection. HFCs were developed to replace stratospheric ozone-depleting substances (ODS) that are currently being phased out under the Montreal Protocol on Substances that Deplete the Ozone Layer. Many HFCs are very powerful greenhouse gases and a substantial number have a lifetime of between 15 and 29 years in the atmosphere.

Hydrofluorocarbons have only been commercialized since the early 1990s, and their abundance in the atmosphere is currently small. They are, however, among the fastest growing greenhouse gases, largely as a result of increasing demand for refrigeration and air-conditioning, particularly in developing countries. If left unchecked, HFC consumption is projected to double by 2020, and their emissions could contribute substantially to radiative forcing in the atmosphere by the middle of the century.

Key messages

1

Poor air quality and global warming have already affected vulnerable populations and ecosystems in LAC, resulting in premature deaths, crop yield losses and damage to ecosystems.

Premature deaths from exposure to $PM_{2.5}$ and O_3 in 2010 are estimated to be around 64 000, with a possible underestimate of deaths from exposure to $PM_{2.5}$ of an additional 20 000. Exposure to O_3 has also been responsible for an estimated 7.4 million tonnes in yield losses for soybean, maize, wheat and rice. Increased temperatures at high altitudes in the Andes are linked to glacier retreat and decreased water availability. Projected increases in temperature across the whole of LAC will have consequences for sensitive agricultural crops and ecosystems.

2

Agriculture, mobile and commercial refrigeration, and transport are the sectors that produce the largest emissions of CH_4, HFCs and BC.

Another large source of methane in several countries is the fossil fuel production sector. Consistent estimates from the reference scenario allow the identification of mitigation opportunities in relevant sectors within the 13 regions addressed in the report. Forest fires are the largest source of BC in South America, but the net impact of all emissions from this source is near-term cooling due to the high emission of OC. Therefore it is not considered part of an SLCP strategy.

3

Based on the reference scenario, without any action to reduce SLCP emissions, the influence of LAC emissions on climate, human health and agriculture will increase significantly by 2050.

Warming due to emissions of CH_4 and from incomplete combustion in LAC is projected to almost double between 2010 and 2050. At a global level, an associated temperature increase of 2.6–4.8° C by 2081–2100, compared to the mean of 1986–2005, is projected.

4

A number of SLCP measures have been identified that, by 2050, have the potential to reduce warming in LAC by up to 0.9° C, premature mortality from $PM_{2.5}$ by at least 26 per cent annually, and avoid the loss of 3–4 million tonnes of four staple crops each year.

They would deliver an additional 40 per cent reduction in premature deaths from tropospheric O_3 by 2050. If a 75 per cent reduction in forest fires were achieved by 2050, there would be a further 36 per cent reduction in premature deaths.

5

Efforts and experience on reducing some SLCPs are already in place across LAC and could be scaled up if identified barriers were overcome.

Many of the identified measures have already been implemented at national and subnational scales. Widespread reductions of SLCPs, with large near-term benefits for the region, could be achieved by strengthening current policies and improving regional cooperation.

Key message 1

Poor air quality and global warming have already affected vulnerable populations and ecosystems in LAC, resulting in premature deaths, crop yield losses and damage to ecosystems.

Almost 80 per cent of the population in the region lives in cities, including several megacities (those with a population of more than 10 million inhabitants). Significant episodes of urban air pollution are common, with urban pollution generally including high concentrations of O_3 and $PM_{2.5}$. Black carbon and co-emitted pollutants, including polycyclic aromatic hydrocarbons (PAHs), are part of and contribute to formation of $PM_{2.5}$ and have been linked to a variety of health problems and even death.

Particulate matter

Three models used as part of this assessment suggest that 64 000 premature deaths in 2010 were associated with outdoor exposure to ambient $PM_{2.5}$. This is likely, however, to be an underestimate and premature deaths could be up to about 81 000 according to the latest figures from the Global Burden of Disease (GBD) project.

Ambient $PM_{2.5}$ concentrations were calculated with emission data from GAINS (Box 5) and using the GISS and GEOS-Chem Adjoint models (Box 6); one additional estimate was based on a recent assessment of satellite data. These concentration estimates were, in turn, used in concentration-response relationships with population data and baseline mortality numbers to estimate the number of expected premature deaths from $PM_{2.5}$ each year. The average of the models and satellite data for 2010 was about 47 000 premature deaths (with a range of estimates of between 32 000 and 64,000). This is likely to be an underestimate, in part due to the coarse scale of the modelling in relation to the size of urban centres in which most people in LAC live. These numbers be compared to the WHO estimate of 58 000 deaths for lower and middle-income countries of the Americas, and to the Global Burden of Disease (GBD) project, which has estimated 81 000 premature deaths in 2010.

Ozone

Premature deaths in LAC associated with outdoor exposure to O_3 in 2010 were estimated to be about 5 000.

Deaths from exposure to ambient O_3 concentrations in LAC were calculated using the TM5-FASST model, and this estimate is the same as that from the GBD project, according to the data available through the Institute for Health Metrics and Evaluation.

Exposure to tropospheric O_3 in 2010 resulted in yield losses of approximately 7.4 million tonnes of four major crops – soybean, maize, wheat and rice.

Most of the total estimated crop yield losses in 2010 were concentrated in three countries – Argentina, Brazil and Mexico. Soybean is a large source of export revenue for several LAC countries.

Regional climate

There are a large variety of climates in LAC, due to its latitudinal extent and to the presence of the Andes and other mountain ranges. Very sensitive ecosystems are associated with specific climates and are vulnerable to the rapid climate changes experienced in recent decades.

Temperatures have been increasing globally and in LAC in recent years, particularly at high altitude, contributing to the retreat of glaciers.

Some of the glaciers in the tropical Andes have been receding at around 3 per cent a year, compared to 0.18 per cent a year from the little ice age maximum in the 17th and 18th centuries to the beginning of the 20th century[3]. Others, Chacaltaya glacier in Bolivia for example, have even disappeared due to the 0.1° C per decade temperature increase since the 1970s. The resulting diminished water availability affects people in many Andean regions. High temperatures, changes in precipitation patterns and exposure to pollutants, have already affected local agriculture and sensitive ecosystems at high altitudes.

In the sub-tropical regions of the Andes, the yearly winter precipitation builds the snowpack that is crucial for water availability for agriculture, industry and human consumption in Chile and Argentina. Significantly increasing temperature trends in the region have led to earlier snowpack melting and decreased water availability during crop development.

Increased frequency of heat waves and increasing precipitation have been detected in regions of south-eastern South America, which, enhanced by strong El Niño events, have caused extensive flooding and loss of life and crops. Increases in temperature and shifts in precipitation patterns will continue to affect LAC if no special measures are taken to curb global change.

The Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5)[4] has highlighted the impact of climate change on economically important crops in LAC. As coffee is particularly sensitive, large reductions in yield and profits have been projected under current climate scenarios; IPCC AR5 predicts an overall reduction in the area suitable for coffee production by 2050 in all countries evaluated. One study in Brazil indicated that a 3° C rise would cause a 60 per cent decline in coffee yields in the State of São Paulo. This highlights the significance of trying to limit warming in LAC over the next few decades using an SLCP strategy.

3. Rabatel et al. 2013: Current state of glaciers in the tropical Andes: A multi-century perspective on glacier evolution and climate change. *Cryosphere*, 7(1), 81–102, doi:10.5194/tc-7-81-2013.
4. IPCC AR5. 2007. Dasgupta, P., Morton, J.F., Dodman, D., Karapinar, B., Meza, F., Rivera-Ferre, M.G., Toure Sarr, A. and Vincent, K.E. 2014. Rural areas. In Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R. and White, L.L. (eds.). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.

Key message 2

Agriculture, mobile and commercial refrigeration, and transport are the sectors that produce the largest emissions of CH_4, HFCs and BC.

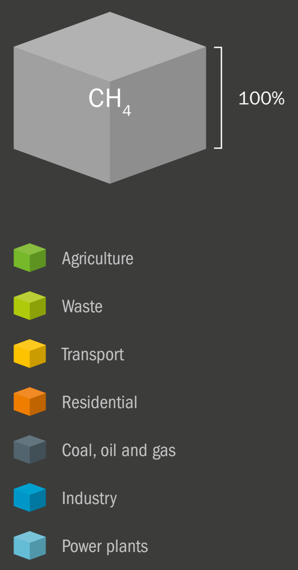
The main sources of CH_4, a precursor of tropospheric O_3, HFCs and BC in the LAC region were quantified in this assessment. The key emitting sectors of CH_4 are agriculture, coal, oil and gas production and distribution, and waste disposal. The main sources of HFCs are refrigeration and air conditioning in vehicles and buildings. The major sources of BC emissions are cooking and heating stoves, biomass burning, diesel on- and off-road vehicles, in-field burning of agricultural residues, and small industrial sources including artisanal brick kilns. Ozone is produced from NOx, and VOCs emissions from the industrial and transport sectors, as well as CH_4, and CO from the main sources of incomplete combustion.

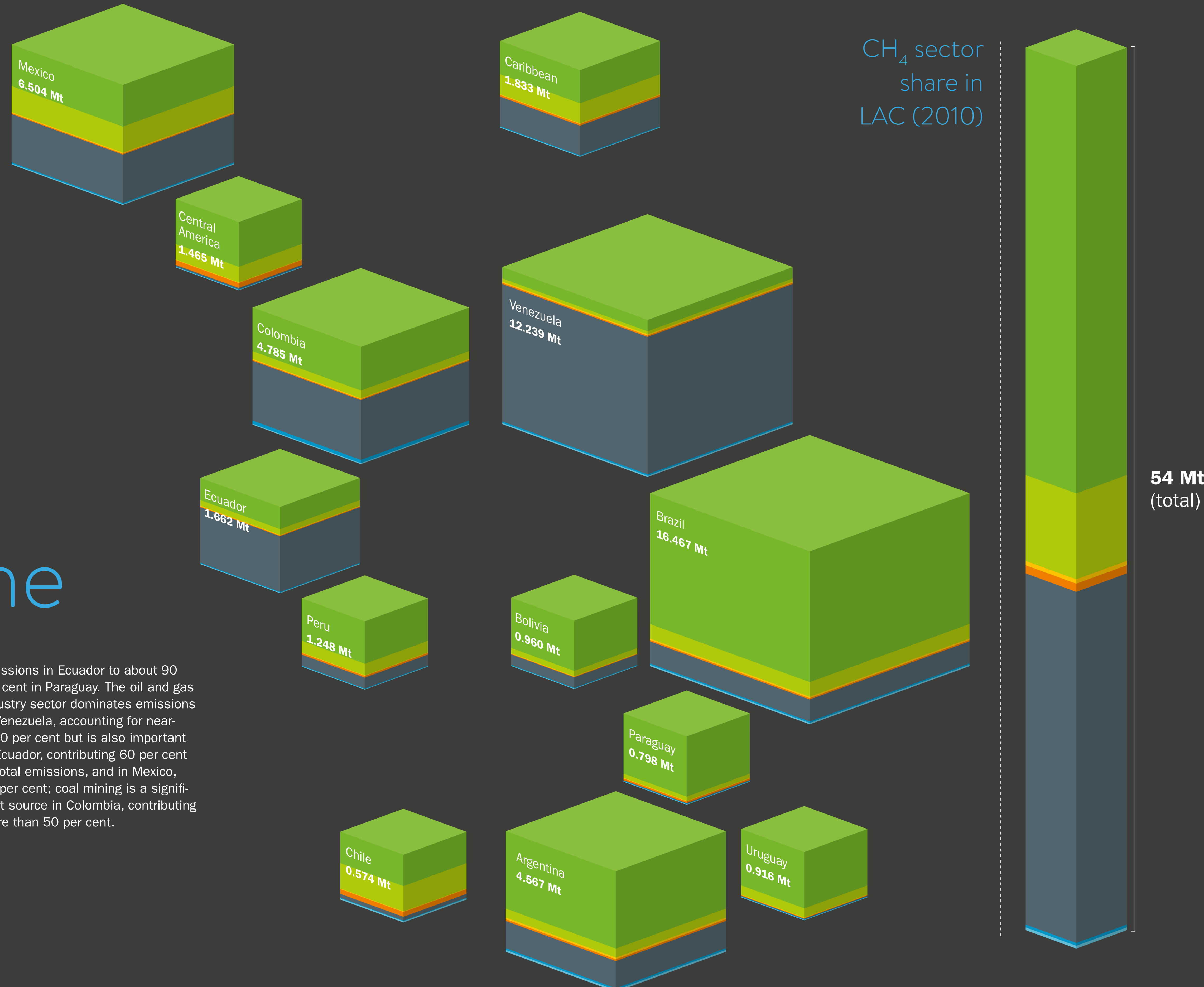
FIGURE 1

Sectoral and regional contribution to CH_4 emissions in the LAC region in 2010.

NOTE

1 teragram (Tg) = 1 million tonnes (Mt)

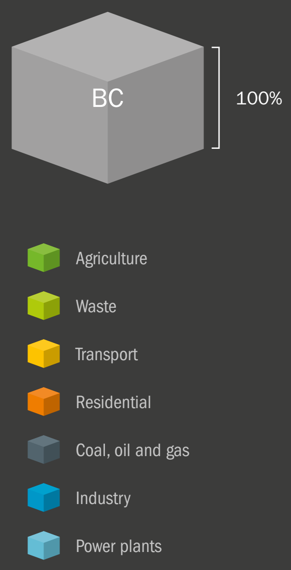


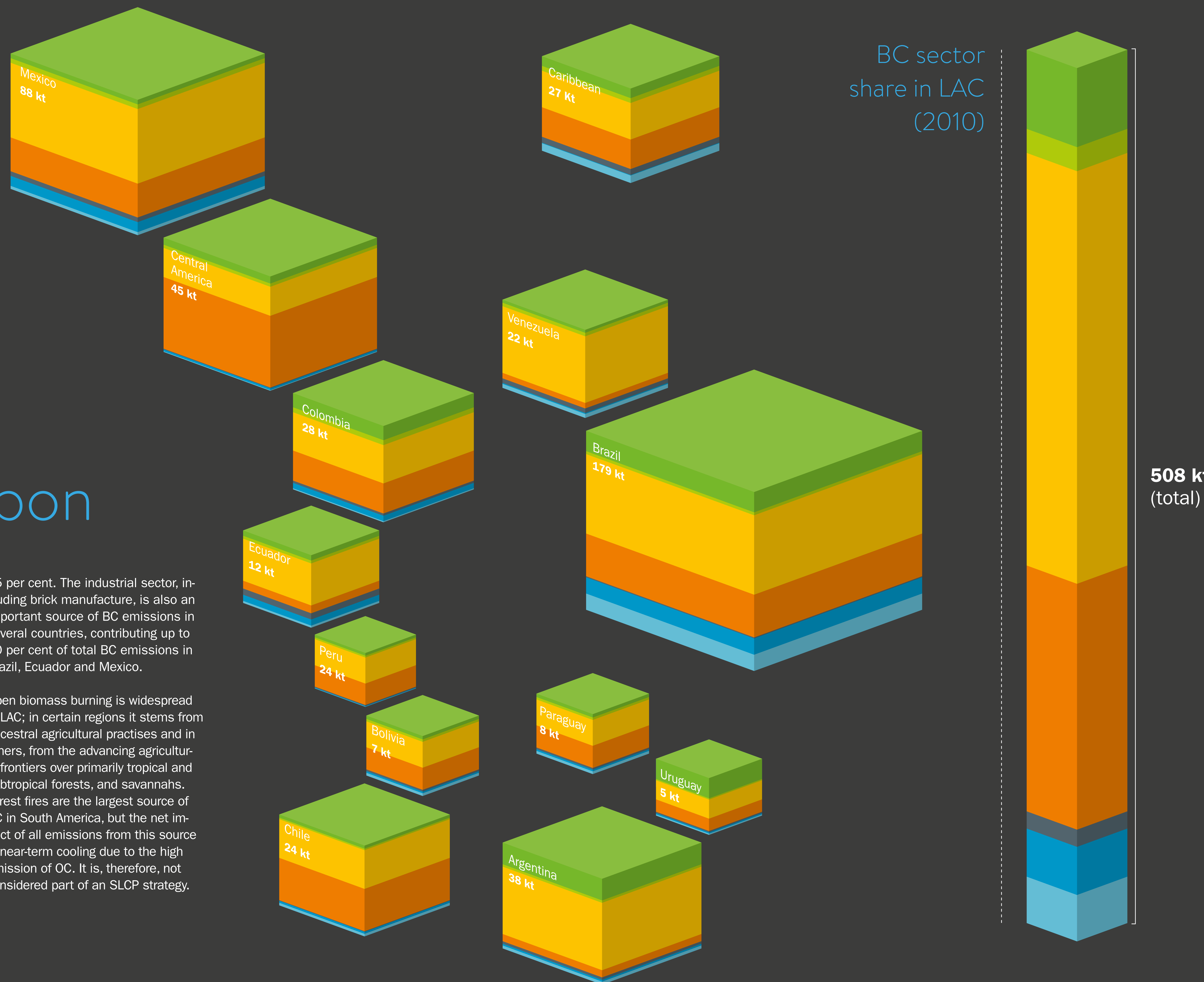


Methane

The LAC region emits about 54 teragrams (Tg) of CH_4 (baseline 2010) per year, accounting for approximately 15 per cent of total global CH_4 emissions, with just over half LAC's emissions originating in Brazil and Venezuela (Figure 1). Virtually all of these emissions in the region originate from three sectors: agriculture, approximately 50 per cent; coal, oil and gas production and distribution, approximately 40 per cent; and waste management, approximately 10 per cent. At the national level, the importance of specific sectors varies but, with exception of Venezuela, agriculture is a major source, ranging from about 30 per cent of total CH_4 emissions in Ecuador to about 90 per cent in Paraguay. The oil and gas industry sector dominates emissions in Venezuela, accounting for nearly 90 per cent but is also important in Ecuador, contributing 60 per cent of total emissions, and in Mexico, 40 per cent; coal mining is a significant source in Colombia, contributing more than 50 per cent.

FIGURE 2
Sectoral and regional contribution to BC emissions in the LAC region in 2010.
NOTE
1 gigagram (Gg) = 1 000 tonnes (kt)





Black carbon

The LAC region emits about 508 Gg of BC (baseline 2010) per year, and is responsible for less than 10 per cent of total global anthropogenic emissions of BC, excluding those from forest and savannah fires. More than 60 per cent of the region's emissions originate in Brazil and Mexico. Two major source sectors emit about three quarters of BC emissions in LAC: transport and the residential combustion of solid fuels (Figure 2). Nationally, the transport sector makes up the largest portion of BC emissions in most countries, other than in Chile, Paraguay and the countries of Central America where residential combustion contributes a higher proportion. The agricultural sector is a significant source in a number of countries including Uruguay, approximately 35 per cent; Argentina, approximately 20 per cent; and Colombia, approximately 15 per cent. The industrial sector, including brick manufacture, is also an important source of BC emissions in several countries, contributing up to 10 per cent of total BC emissions in Brazil, Ecuador and Mexico.

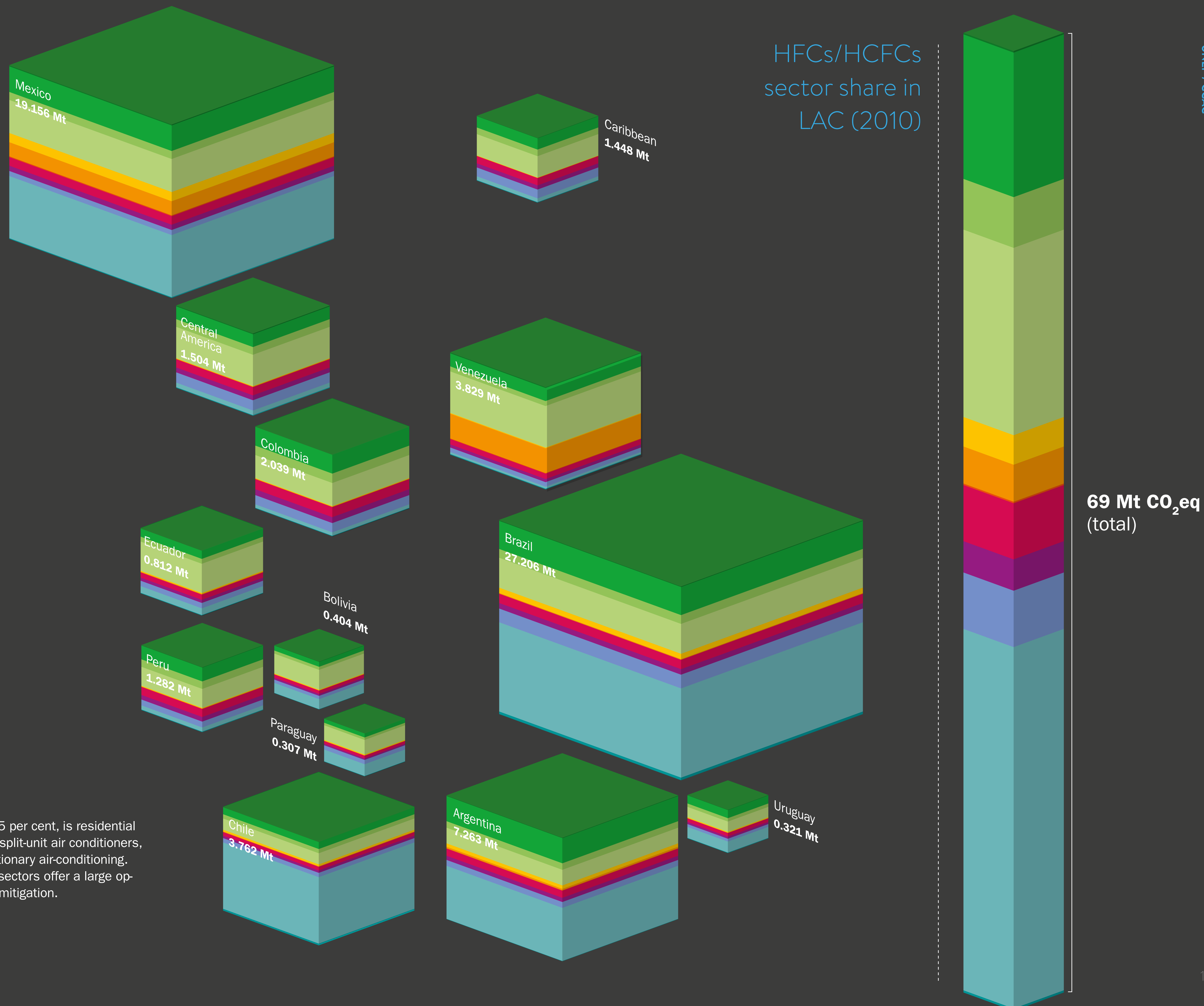
Open biomass burning is widespread in LAC; in certain regions it stems from ancestral agricultural practises and in others, from the advancing agricultural frontiers over primarily tropical and subtropical forests, and savannahs. Forest fires are the largest source of BC in South America, but the net impact of all emissions from this source is near-term cooling due to the high emission of OC. It is, therefore, not considered part of an SLCP strategy.

FIGURE 3

Sectoral and regional contribution to HFCs emissions in the LAC region in 2010.

NOTE

1 teragram (Tg) = 1 million tonnes (Mt); CO_2eq = carbon dioxide equivalent



Hydrofluoro-carbons

In 2010, the LAC region was responsible for only 8 per cent of total global HFC emissions, with 77 per cent originating in Argentina, Brazil and Mexico (Figure 3). The majority of the HFC emissions come from two sectors, mobile air conditioning, about 20 per cent, and commercial refrigeration, around 38 per cent. The third largest source of emissions, contributing around 15 per cent, is residential window- and split-unit air conditioners, listed as stationary air-conditioning. These three sectors offer a large opportunity for mitigation.

Box 5
The GAINS model and scenarios developed for the LAC assessment

The best available emission data in the LAC region was collected from national emissions inventories. This regional information and inputs from LAC researchers was used in the GAINS model to develop a detailed, complete and consistent emission inventory and the scenarios used in the assessment. This is a ***significant step forward*** as no country in the region had a complete and up to date emissions inventory and there are substantial gaps in knowledge in many countries.

The GAINS model (Greenhouse gas – Air pollution Interactions and Synergies; http://gains.iiasa.ac.at) was developed by the International Institute for Applied Systems Analysis (IIASA) and estimates emissions of greenhouse gases and air pollutants in a consistent framework. GAINS holds essential information about key sources of emissions, environmental policies and further mitigation opportunities for nearly 170 countries/regions[a] at a global level. The emission calculation in *GAINS* draws on the available literature and has been reviewed by experts from academia, governments and industry. It applies emission factors that reflect country-specific conditions, including fuel quality, combustion technologies, fleet composition and application of control technologies.

Taking into consideration economic development, population size and the availability of data on energy use and production, transport, contribution to total SLCP emissions in LAC and available national emission inventories, the assessment distinguishes 13 regions/countries (p.3) for which reference and mitigation scenarios were developed. Emissions for key air pollutants, including black carbon, CH_4, CO_2 and HFCs were estimated for 1990–2010 using a consistent approach for the 13 LAC regions.

Reference scenario: describes emissions that could result from current trends with no further action than is already planned. This scenario is very similar to the IPCC RCP8.5 used in other assessments.

Climate scenario: describes a CO_2 emission scenario designed to constrain the global temperature increase by 2100 to 2° C.

SLCP scenario: projects emissions that would result from implementing a set of measures that are identified in relation to the LAC sources of emission.

The emissions and scenarios developed in the GAINS model were provided to three global atmospheric transport models, which were then used to estimate pollutant concentrations and climate impacts and are described in Box 6.

a. As data is not available from every country, aggregated regional information is sometimes used.

Box 6
Climate modelling and impacts for the LAC assessment

GISS

The GISS model for Physical Understanding of Composition-Climate Interactions and Impacts (GISS-PUCCINI) is a global climate model that incorporates gas-phase and aerosol chemistry. It examines the behaviour of both the physical climate and atmospheric composition. All runs analyzed were performed at 2°x2.5° horizontal resolution and 40 vertical layers. The full climate response simulations were performed with the coupled atmosphere-ocean model.

GEOS-CHEM

GEOS-Chem is a global 3-D model of atmospheric composition driven by assimilated meteorological observations from the Goddard Earth Observing System (GEOS) of the NASA Global Modeling Assimilation Office. GEOS-Chem is a freely accessible community model, developed and used by research groups worldwide as a versatile tool for a wide range of atmospheric composition studies.

GEOS-CHEM ADJOINT COEFFICIENTS USED IN THE INTEGRATED BENEFITS CALCULATOR

The *adjoint* of the chemical transport model GEOS-Chem computes the individual contribution of each source (each emitted species, in each grid cell) to response metrics such as the population-weighted $PM_{2.5}$ concentrations in a particular country, or radiative forcing in a particular latitude band. This tool is applied to evaluate the influence of emissions from grids across LAC, and the rest of the world, on each of the larger countries of LAC and groups of the smaller countries. The coefficients include satellite downscaling by allocating the calculated average $PM_{2.5}$ concentrations for a grid according to the current distribution of $PM_{2.5}$ estimated from satellites; the analysis is done at the 10x10 kilometre resolution. The emissions and coefficients are multiplied together within the Integrated Benefits Calculator, being developed by Stockholm Environment Institute (SEI) and US Environmental Protection Agency (EPA) for Climate and Clean Air Coalition (CCAC) initiatives, to calculate the average population-weighted $PM_{2.5}$ concentrations used to estimate health impacts.

TM5-FASST

The global Air Quality Source-Receptor Model (TM5-FASST), developed at the European Union Joint Research Centre (JRC), links emissions of pollutants in a given source region to impacts at the downwind receptor region, using coefficients describing the relation between each precursor and each end product for each source and receptor region. The developed linear functions can be used to calculate the concentration in a receptor region from a given emission, without having to run the whole chemical transport model (TM5) each time. The model has been validated against surface, airborne and satellite observations in several exercises. TM5-FASST produces global gridded pollutant concentration fields at a 1°x1° resolution. The tool is used to determine impacts of air pollution on human health, vegetation and radiative forcing.

Key message 3

Based on the reference scenario, without any action to reduce SLCP emissions, the influence of LAC emissions on climate, human health and agriculture will increase significantly by 2050.

The GAINS model was used to define a reference scenario for LAC emissions with projections to 2050 (Box 5). In this, the warming by emissions from CH_4 and incomplete combustion in LAC is projected to almost double between 2010 and 2050. The majority of this growth is associated with a projected increase in emissions from the oil and gas production and distribution sector and from livestock production. These sectors, together with waste management, offer the greatest mitigation potential. The influence of this rise in CH_4 emissions on global temperature increase, however, is small. Emissions of BC are projected to decrease in the coming decades given the planned strategies to abate urban air pollution, particularly from the transport sector. Nevertheless, projections increase again as the planned mitigation measures would not be enough to continue to decrease emissions, unless new measures are introduced. The residential heating and cooking sector offers the second largest mitigation potential for BC.

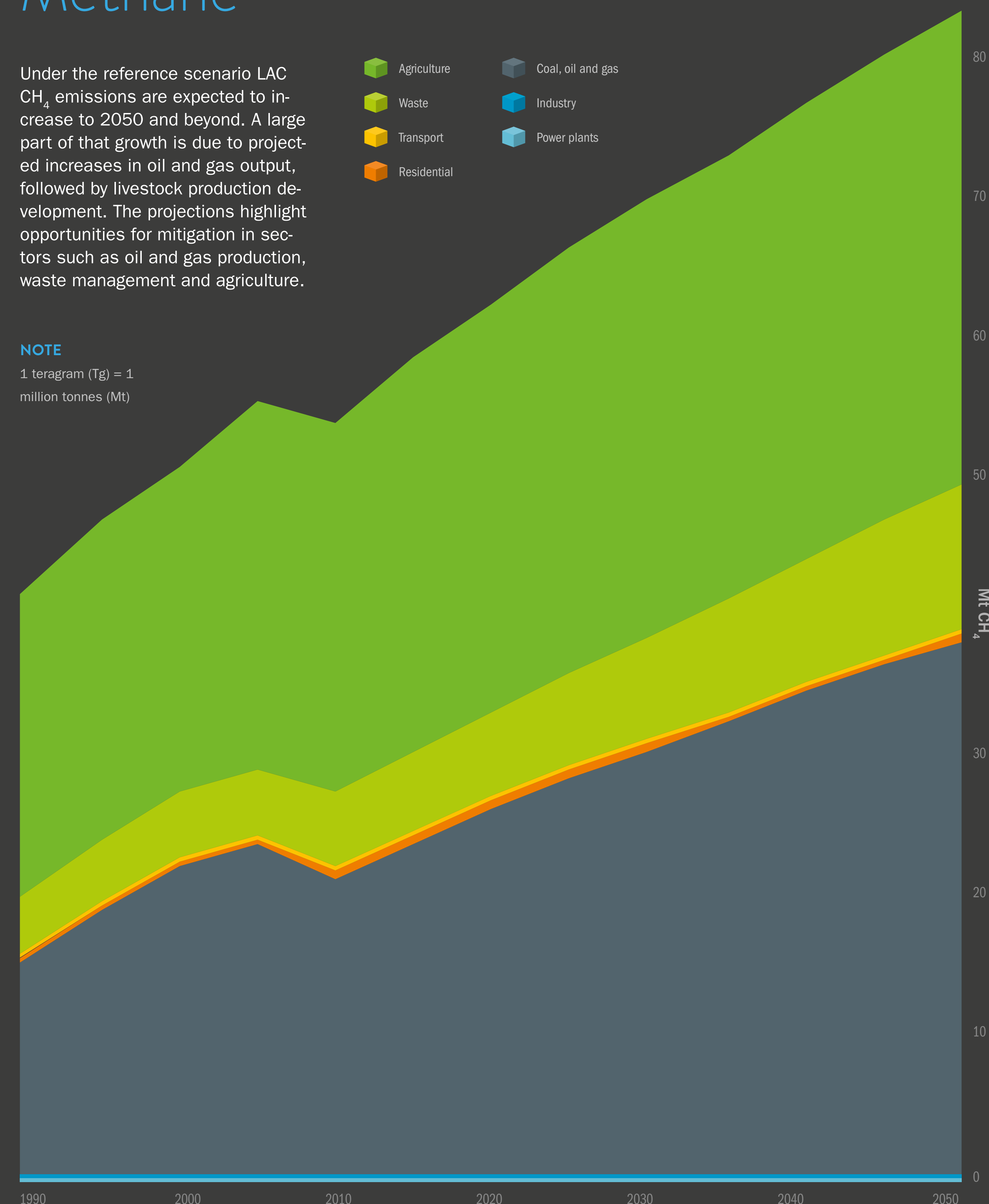
Emissions of HFCs are projected to increase from about 70 million tonnes of carbon dioxide equivalent (Mt CO_2eq) in 2010 to more than 250 Mt CO_2eq in 2050. This large increase is associated with commercial refrigeration, stationary and mobile air-conditioning and foam production, which together represent more than 90 per cent of total emissions. While every sector is expected to experience growth, the largest increase is estimated for stationary and mobile air-conditioning and represents a significant mitigation opportunity.

Box 7
Methane

Under the reference scenario LAC CH_4 emissions are expected to increase to 2050 and beyond. A large part of that growth is due to projected increases in oil and gas output, followed by livestock production development. The projections highlight opportunities for mitigation in sectors such as oil and gas production, waste management and agriculture.

NOTE

1 teragram (Tg) = 1 million tonnes (Mt)

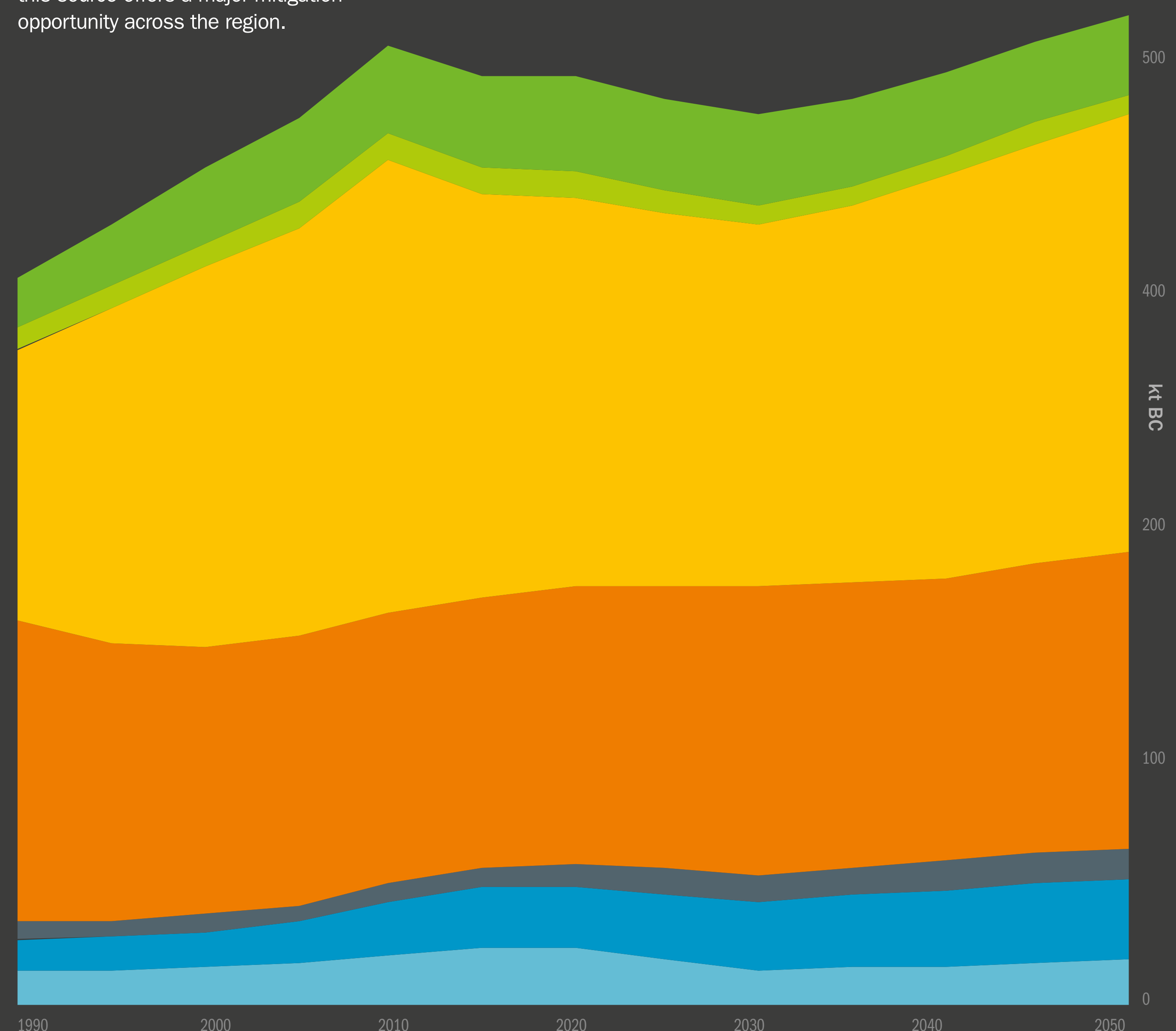


Box 8
Black Carbon

Black carbon emissions in LAC are expected to decrease in coming decades due to the introduction of ever more stringent transport legislation in several regions to reduce urban air pollution. In the longer term, however, the current legislation will not be sufficient to constrain emissions growth, highlighting a current mitigation opportunity. While emissions from the residential sector are not projected to grow in the future, this source offers a major mitigation opportunity across the region.

NOTE

1 gigagram (Gg) = 1 000 tonnes (kt)

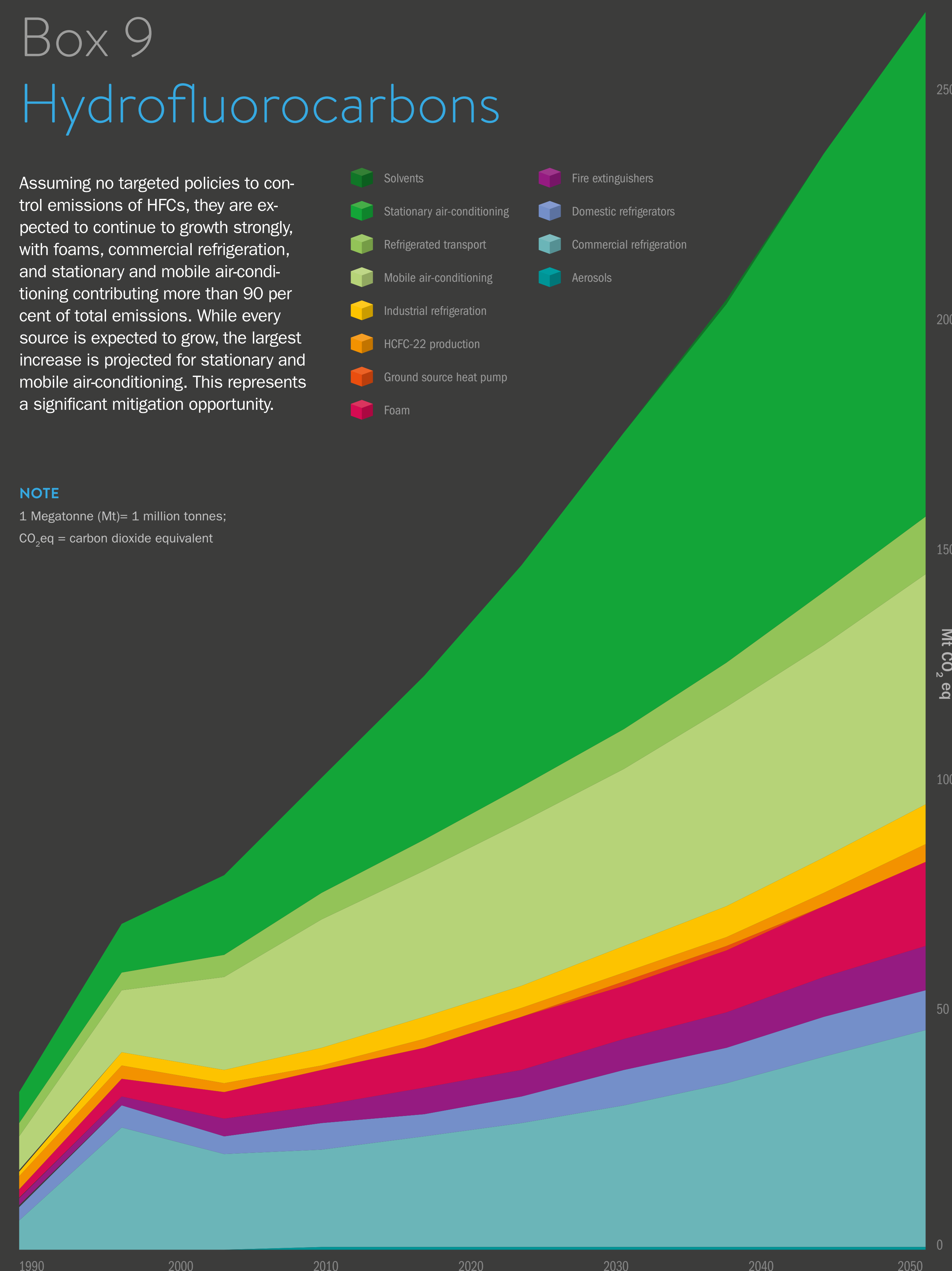


Box 9
Hydrofluorocarbons

Assuming no targeted policies to control emissions of HFCs, they are expected to continue to growth strongly, with foams, commercial refrigeration, and stationary and mobile air-conditioning contributing more than 90 per cent of total emissions. While every source is expected to grow, the largest increase is projected for stationary and mobile air-conditioning. This represents a significant mitigation opportunity.

NOTE

1 Megatonne (Mt)= 1 million tonnes;
CO_2eq = carbon dioxide equivalent



$PM_{2.5}$

Premature mortality from exposure to $PM_{2.5}$ pollution is expected to almost double by 2050, compared to 2010, under the reference scenario.

Ambient $PM_{2.5}$ concentrations were calculated from the results of two different models (GISS and GEOS-Chem Adjoint) following the reference scenario to 2050. The projected premature mortality from exposure to $PM_{2.5}$ pollution for the reference scenario indicates an increase from 47 000 in 2010 to 62 000 in 2030 (range of 27 000–95 000) and 82 000 in 2050 (range of 34 000–131 000). The increase in premature mortality is due to a combination of the changes in $PM_{2.5}$ concentrations and demographic changes – an increasing and aging population, which leads to higher vulnerability. The values calculated using different approaches provide similar estimates for the number of people dying prematurely in the LAC region.

Ozone

Premature mortality from exposure to ambient O_3 doubles between 2010 and 2050 under the reference scenario.

Premature mortality due to O_3 exposure calculated by one of the models is similar to estimates from the GBD project. The estimated 5 000 premature deaths in 2010 increase to 7 000 by 2030 and 10 000 by 2050; this corresponds to about 12 per cent of the number of premature deaths from $PM_{2.5}$ exposure. The increase in deaths from O_3 pollution is not only affected by the increase in the total population and the fact that it is aging, but also by the increase in ozone concentrations projected by the atmospheric models by 2050.

For four major crops – soybean, wheat, maize and rice – exposure to tropospheric O_3 in 2010 resulted in crop losses of approximately 7.4 million tonnes. Losses could rise to about 9 million tonnes by 2050.

Losses in three countries, Argentina, Brazil and Mexico, make up a very large proportion of the total estimated losses in LAC in 2010 and those projected in the future. The estimated 9 million tonnes of crop losses caused by O_3 damage by 2050 represents about 3 per cent of the current yield for these four crops. Soybean, a major commodity for several LAC countries, shows the largest losses in LAC and its projected loss of about 6.5 million tonnes by 2050 represents about 5 per cent of the current yield in LAC. All the models project increases in O_3 concentrations in the region by 2050, with a corresponding increase in yield losses.

Regional climate

Temperatures have increased both globally and in LAC in recent years. Emissions under the reference scenario suggest a rapid increase in global temperature, which would also be felt in LAC.

The GISS model has estimated a warming of 1.5–3.0° C over most of Central America and tropical South America in the 2070s relative to 2010, under the RCP8.5 scenario used in the IPCC AR5. Extra-tropical regions of South America are projected to warm by 0.5–1.5° C in 2070s, relative to 2010 (Figure 4). The reference scenario designed for this assessment is similar to the IPCC AR5 RCP8.5 scenario, and equates to a global average temperature increase of between 2.6–4.8° C by 2081–2100, compared with the mean temperature in 1986–2005.

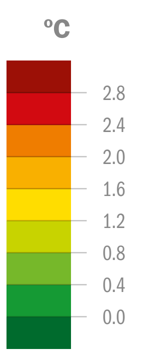
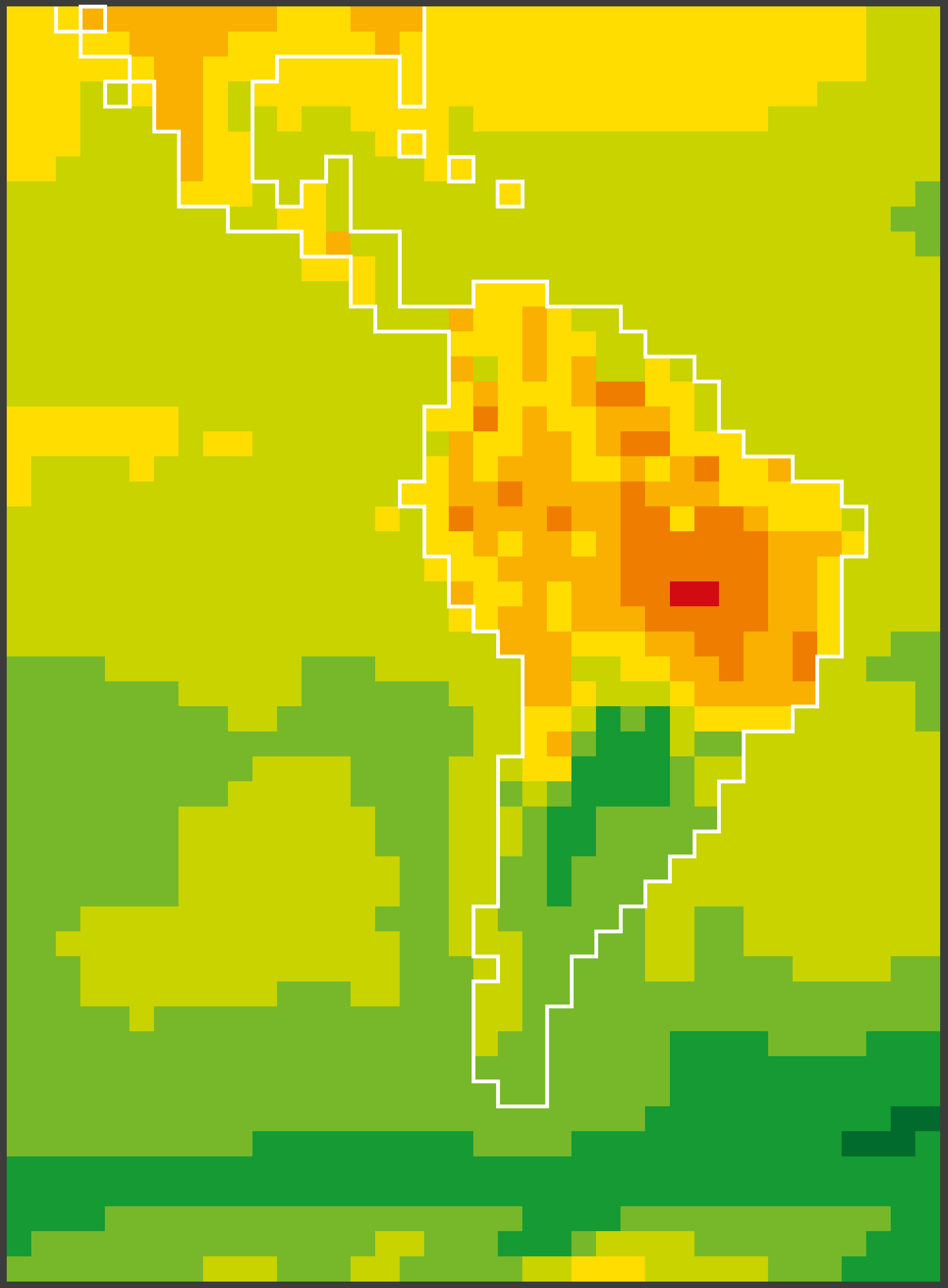


FIGURE 4

Increase in temperature over LAC region projected by GISS model using the RCP8.5 emissions. The map shows the temperature in the 2070s relative to 2010 (RCP8.5 is very similar to the reference scenario used in this assessment).



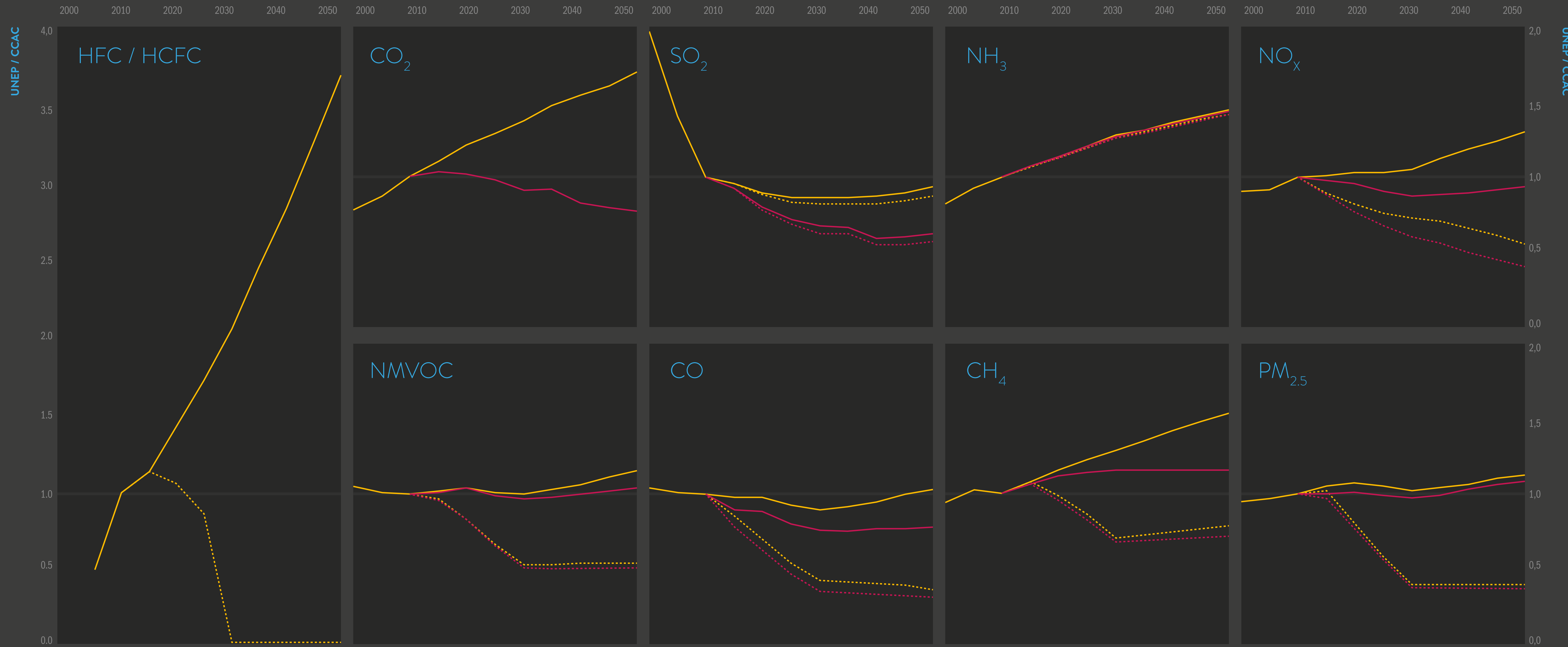
Key message 4

A number of SLCP measures have been identified that, by 2050, have the potential to reduce warming in LAC by up to 0.9° C, premature mortality from $PM_{2.5}$ by at least 26 per cent annually, and avoid the loss of 3-4 million tonnes of four staple crops each year

The SLCP strategy entails the implementation of measures that will provide major benefits for the reduction of near-term warming in the LAC region, as well as significant development benefits through reducing the impacts of air pollution on health, crops and ecosystems. Six measures have been identified that are relevant to the LAC region, and address mitigation of CH_4 emissions in the oil and gas production and distribution, waste management, coal mining and agriculture sectors. An additional eight measures address emissions from incomplete combustion in residential cooking and heating, diesel vehicles, industry, agriculture and flaring in the oil and gas industry for the mitigation of BC and other co-emitted substances. Finally, seven measures are identified to address emissions of HFCs by refrigerants in transport, industry and services.

TABLE 1
Measures identified from the modelling.

Methane measures	
Oil and gas production and distribution	• Recovery and use of vented gas in oil and gas production • Reduction of gas leakage during distribution
Waste management	• Separation and treatment of biodegradable municipal solid waste (MSW) • Food industry solid and liquid waste treated in anaerobic digesters, with biogas recovery
Coal mining	• Pre-mine degasification and recovery of CH_4 during mining
Agriculture	• Anaerobic digestion – biogas from livestock manures
Measures addressing incomplete combustion (affecting BC and co-emitted species)	
Households	• Clean cooking and heating stoves
Transport	• Euro VI standards on new vehicles, including diesel particle filters (DPF) • Eliminating high emitting vehicles
Industry	• Modernized coke ovens • Modernized brick kilns • High efficiency particulate matter controls in industrial biomass and waste combustion
Agriculture	• Enforced ban of open-field agricultural burning
Oil and gas production	• Reduced gas flaring
HFCs measures	
All sectors	• Switch to low global warming potential (GWP) HFC alternatives



Implementing these measures fully will substantially reduce emissions of substances that lead to near-term warming. Methane emissions would be reduced by 45 per cent in 2030 and 48 per cent in 2050 and black carbon emissions by 69 per cent in 2030 and 88 per cent in 2050, both in comparison to the reference scenario, while HFC emissions would reduced by 98 per cent by 2030 by a very aggressive strategy (Figure 5).

The implementation of the SLCP scenario would also result in a 58 per cent reduction in NO_x emissions, 54 per cent reduction in NMVOC emissions, 65 per cent reduction in primary $PM_{2.5}$ (which includes BC and OC) and CO; 79 per cent reduction of OC, and 6 per cent reduction of sulphur dioxide (SO_2) emissions. Thus, all of the emissions that lead to the formation of $PM_{2.5}$, apart from ammonia (NH_3) from agriculture, are significantly reduced in the SLCP scenario.

FIGURE 5

Emission reductions for BC, OC, primary $PM_{2.5}$ (which includes BC and OC), CH_4, SO_2, NO_x, CO, NMVOC, NH_3, HFCs, and CO_2 relative to the reference and climate scenarios from the full implementation of measures (SLCP mitigation scenario). This shows the changes in emissions relative to 2010 emissions.

Reference
SLCP Reference
Climate
SLCP Climate

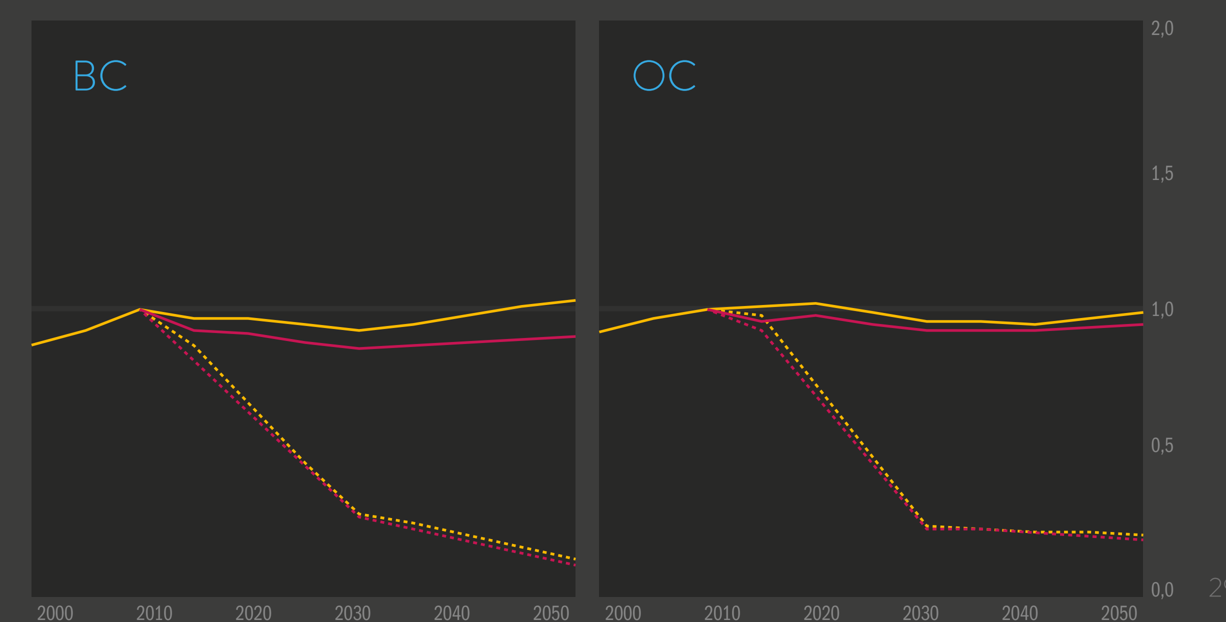
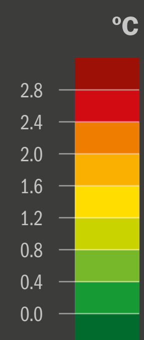
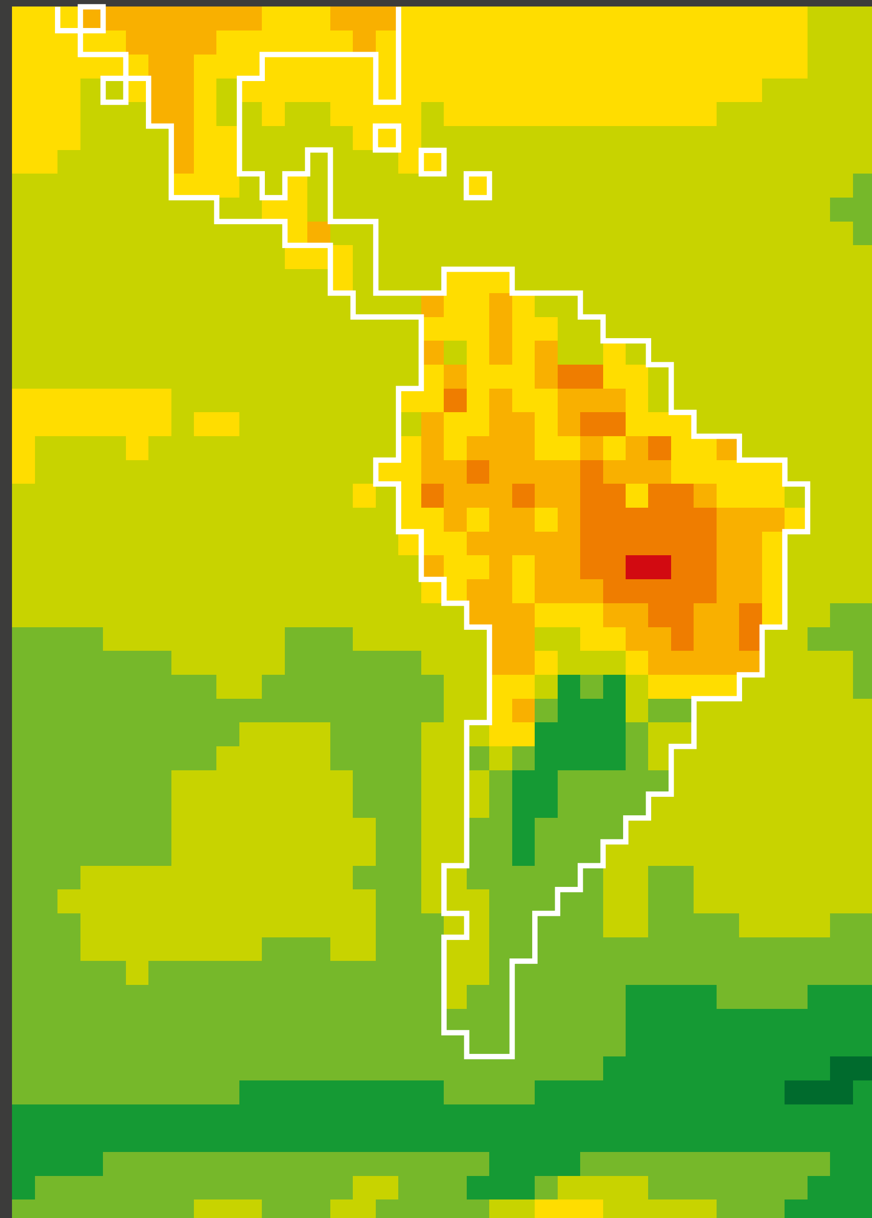
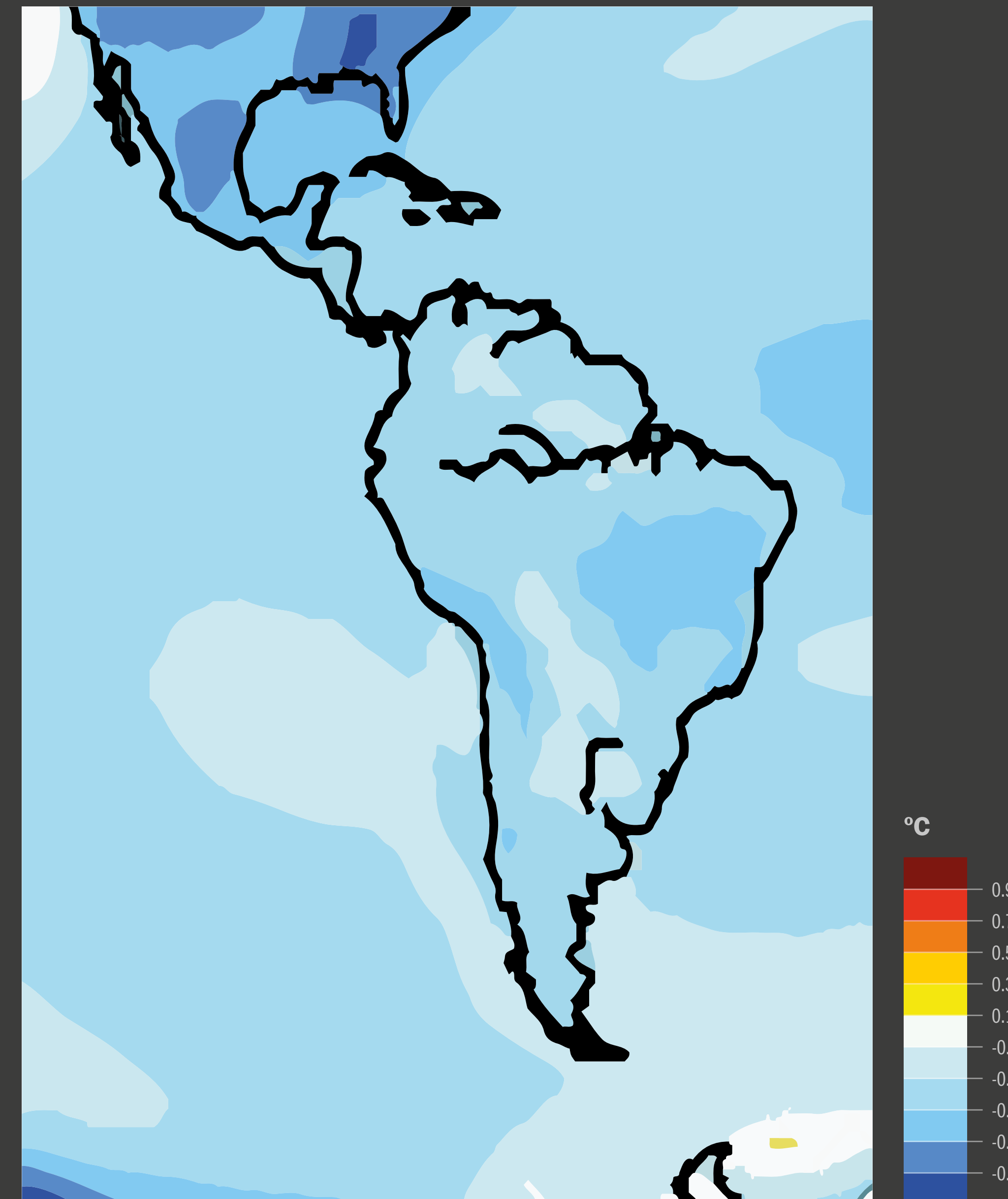


FIGURE 6

Increase in temperature projected by the GISS model using RCP8.5 emissions. Left: temperature in the 2070s relative to 2010 – RCP8.5 is very similar to the reference scenario used in this assessment. Right: the reduction in regional temperature across LAC from the implementation of the SLCP measures (CH_4; incomplete combustion and HFCs) relative to the reference scenario, according to long-term runs using the GISS model.







The implementation of the proposed SLCP measures would lead to a reduction in absolute temperature increases across Latin America in 2050, by up to 0.9° C in parts of Mexico, and across almost all parts of LAC by more than 0.3° C, which could significantly reduce the temperature increase projected in the reference scenario.

The highest temperature decrease due to the implementation of the SLCP measures is 0.7-0.9° C in northern Mexico, and in South America the largest decrease from the reference scenario temperature is 0.5–0.7° C in central Brazil and in parts of the Andes in Argentina, Bolivia, Chile and Peru. Estimates for most areas of South America indicate a reduction of 0.3–0.5° C from the reference Scenario temperature.

The temperature increase in the Caribbean is estimated to reduce by 0.3–0.7° C in comparison to the temperature projected in the reference scenario. Results are broadly similar under the climate scenario, with spatial patterns generally quite similar but magnitudes of reduced warming slightly less. This is caused by large ocean areas nearby.

The GISS model shows that implementing the SLCP measures will reduce temperature increases in the Andes by 2050 by 0.3–0.7° C. This can be compared with the current increase in the region of 0.7° C since 1950 and glaciers in the mountain range have shrunk by an average of 30–50 per cent since the 1970s.

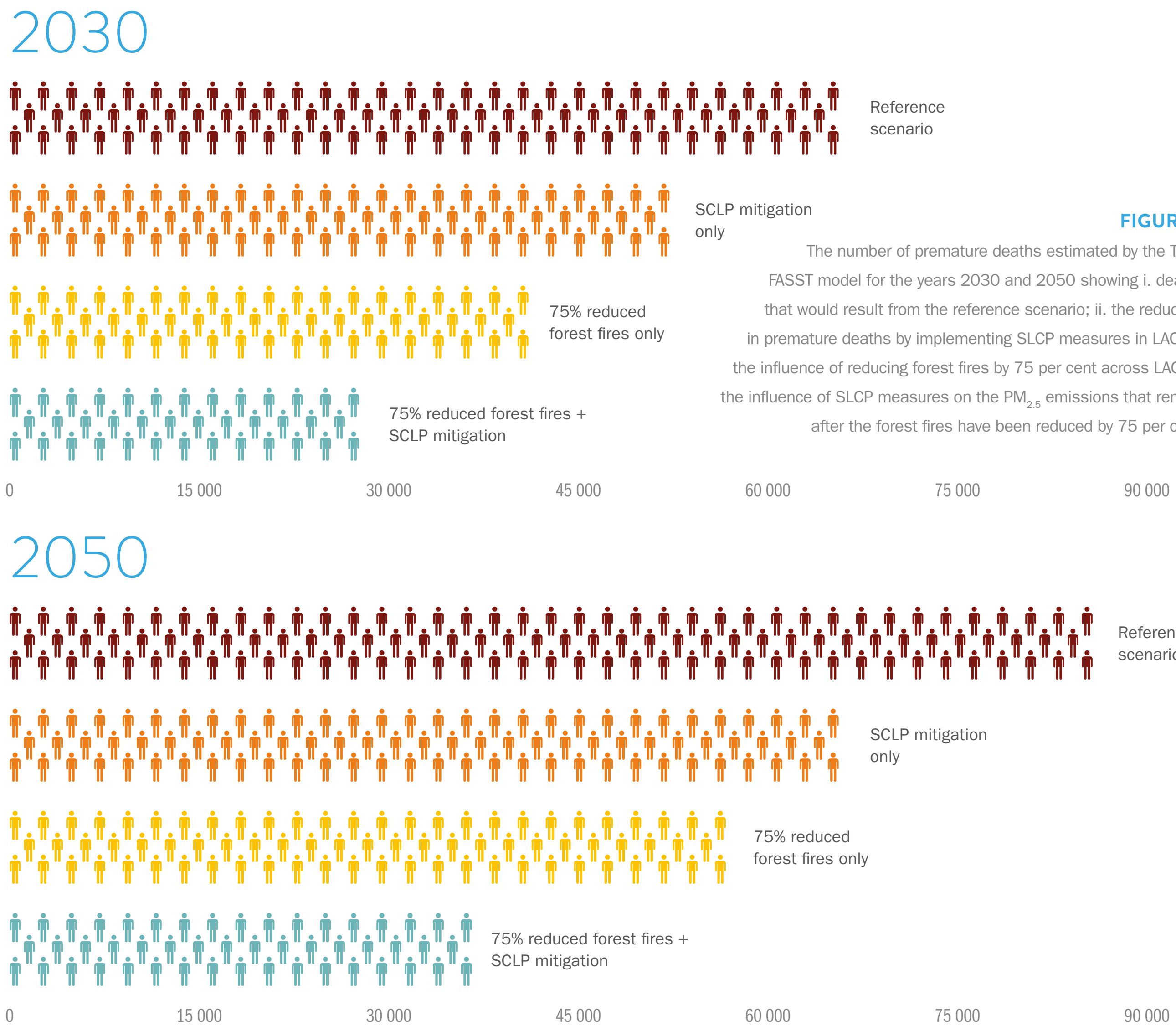


FIGURE 7

The number of premature deaths estimated by the TM5-FASST model for the years 2030 and 2050 showing i. deaths that would result from the reference scenario; ii. the reduction in premature deaths by implementing SLCP measures in LAC; iii. the influence of reducing forest fires by 75 per cent across LAC; iv. the influence of SLCP measures on the $PM_{2.5}$ emissions that remain after the forest fires have been reduced by 75 per cent.

Note that the TM5-FASST results represent only one of the three models used and so the values for the reference and SLCP mitigation scenario are slightly different from the average of the three models, but variation between the models is low.

Implementing the suggested SLCP measures would reduce premature mortality from $PM_{2.5}$ by about 21 per cent by 2030 and about 26 per cent by 2050, compared with the total number of premature deaths that would result from the reference scenario's emissions.

Forest fires emissions cause a large proportion of the deaths from exposures to $PM_{2.5}$ in South America, and implementing a 75 per cent reduction in emissions would reduce premature mortality across LAC from $PM_{2.5}$ by about 37 per cent in 2030 and by a further 34 per cent by 2050. By implementing all the suggested SLCP measures and reducing forest fires could reduce premature mortality in LAC from exposure to outdoor $PM_{2.5}$ by about 57 per cent in 2030 and 58 per cent in 2050, in comparison to the reference scenario.

If forest fire emissions were reduced by 75 per cent across LAC, the SLCP measures would become more important for reducing premature deaths. Without forest fire emission reductions, SLCP measures avoid 21 per cent of $PM_{2.5}$-related premature deaths in 2030, and 26 per cent in 2050. But if forest fire emissions were reduced, the SLCP measures would avoid about a third of remaining $PM_{2.5}$-related premature deaths in 2030, and 36 per cent in 2050.

The implementation of the suggested clean cooking and heating measures would deliver considerable health benefits by reducing indoor exposure to $PM_{2.5}$, especially amongst women, reducing deaths by 28–65 per cent depending on the cause, and reducing deaths of children less than 5 years old by 60 per cent. Across LAC in 2010, there were an estimated 70 000 premature deaths related to indoor $PM_{2.5}$ exposure related the use of solid fuels for cooking and heating.

It is estimated that changing traditional solid fuel for such clean fuels as liquid petroleum gas (LPG) in stoves would, for women, reduce 51 per cent of premature deaths from ischaemic heart disease, 65 per cent from lung cancer; and a 28 per cent from strokes. The benefits for men would be lower – 36, 58 and 27 per cent reduction in deaths, respectively. There would also be a 60 per cent reduction in deaths from acute lower respiratory infections in children less than 5 years old.

The reduction in O_3 concentrations from implementation of the suggested SLCP measures could result in a reduction of premature mortality of 20 per cent in 2030 and 40 per cent in 2050.

Implementing the suggested SLCP measures in LAC, could, therefore, result in considerable reductions in mortality due to O_3, although the absolute numbers are lower than from the reduction of exposure to $PM_{2.5}$ pollution.

Of the strategies that address climate change, the SLCP scenarios have a far greater effect on premature mortality than do the CO_2 scenarios in LAC. Implementation of CO_2 and SLCP strategies together will, however, provide the greatest benefits for health, although not a much higher than with the suggested SLCP measures alone.

Implementing the CO_2 measures is crucial to constraining average global warming by the end of the century to 2^{o} C, but it results in a significantly smaller reduction in premature mortality than if the SLCP measures were implemented. For O_3, the climate measures result in an 11 per cent reduction of deaths in 2030 and 19 per cent in 2050. The impact of climate measures on premature mortality from $PM_{2.5}$ pollution, a 6 per cent reduction in premature deaths in 2030 and 8 per cent in 2050, is also considerably lower than the benefits from implementing the SLCP measures.

The reduction in O_3 concentrations from the suggested SLCP measures avoids the annual loss of about 3-4 million tonnes of soybean, maize, wheat and rice.

The models estimate similar benefits of O_3 reduction resulting from the implementation of the suggested SLCP measures of about 3-4 million tonnes of avoided annual losses for these four crops, which represents about 1.1–1.3 per cent of their total yield across LAC. The crop most affected is soybean, with avoided losses of about 1.7 per cent, about 2.3 million tonnes.

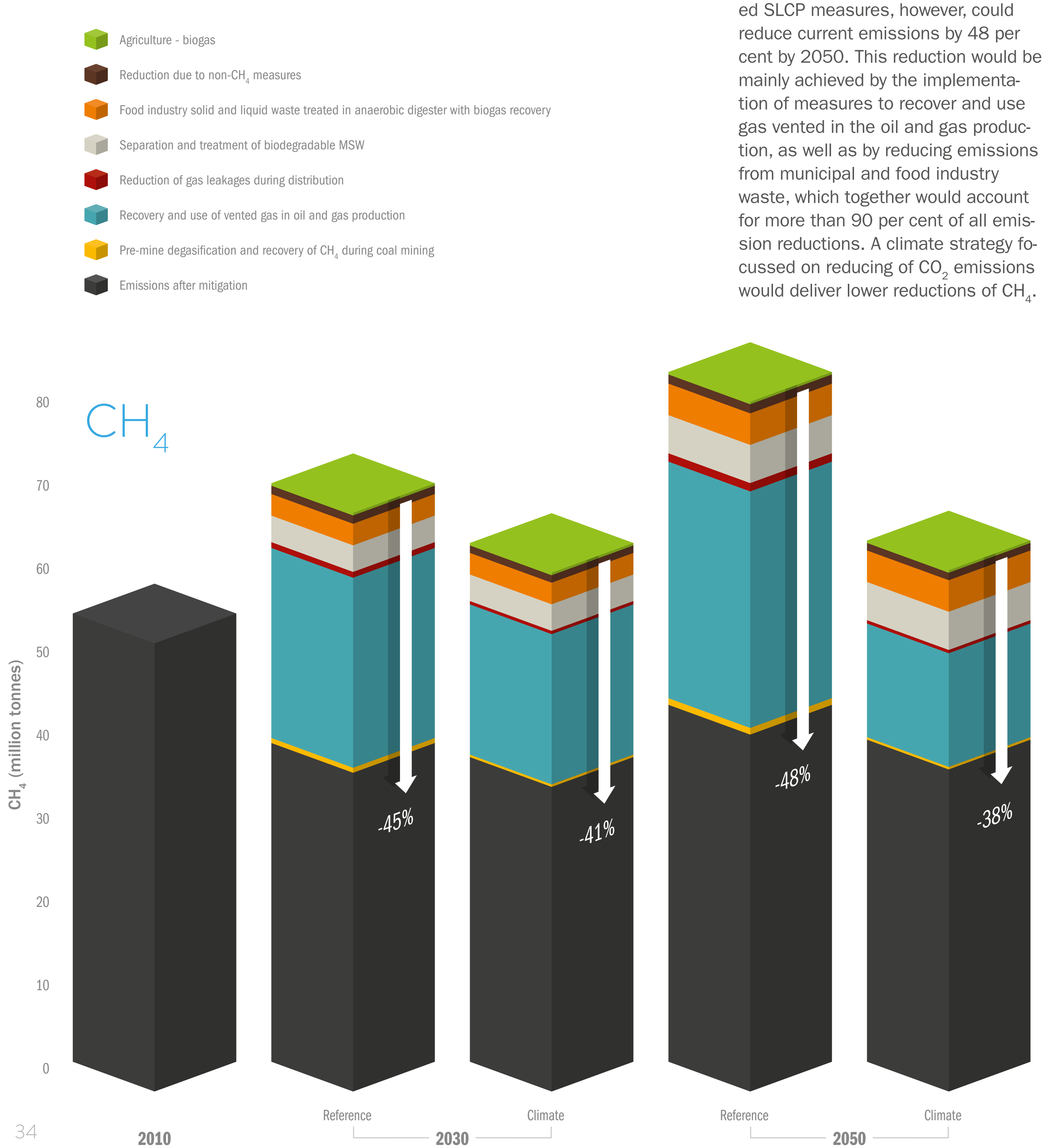
The climate scenario also results in reduced O_3 impacts on crops, but the benefit, at 1.5–2 million tonnes, is not as large as achieved by the implementation of the suggested SLCP measures. Implementing the SLCP measures under the climate scenario provides the greatest benefit at 3.5-4.5 million tonnes, but this is not much larger than from implementing the SLCP measures alone. The benefits in 2050 are about twice as large as those realized by the O_3 reductions in 2030.

The implementation of the suggested HFC measures can almost completely eliminate this greenhouse gas, avoiding the climate impacts of HFCs before they grow any larger, and achieving further benefits by catalysing improvements in appliance energy efficiency.

The reduction of HFC emissions through a phase-down under the Montreal Protocol and parallel measures would reduce the climate forcing effects of HFCs in 2050 to below their current levels, effectively eliminating a climate threat before it develops. Furthermore, transitioning away from HFCs could catalyse other climate benefits through improvements in the energy efficiency of refrigerators, air conditioners, and other products and equipment that use HFC refrigerants. Linking a transition away from HFC refrigerants to improvements in the energy efficiency of room air conditioners could significantly reduce peak-load energy demand and has the potential to avoid the use of energy equivalent to the total generation capacity of 93 medium-size power plants in Brazil, Chile, Colombia, and Mexico.

FIGURE 8

Emission reductions of CH_4 in 2030 and 2050 from the full implementation of measures (SLCP mitigation scenario) in LAC compared to the reference and climate scenarios.



Most of the climate, human health, agricultural and ecosystem benefits could be achieved in LAC though the implementation of measures focusing on CH_4, HFCs and emissions from incomplete combustion, including BC and its co-emitted substances.

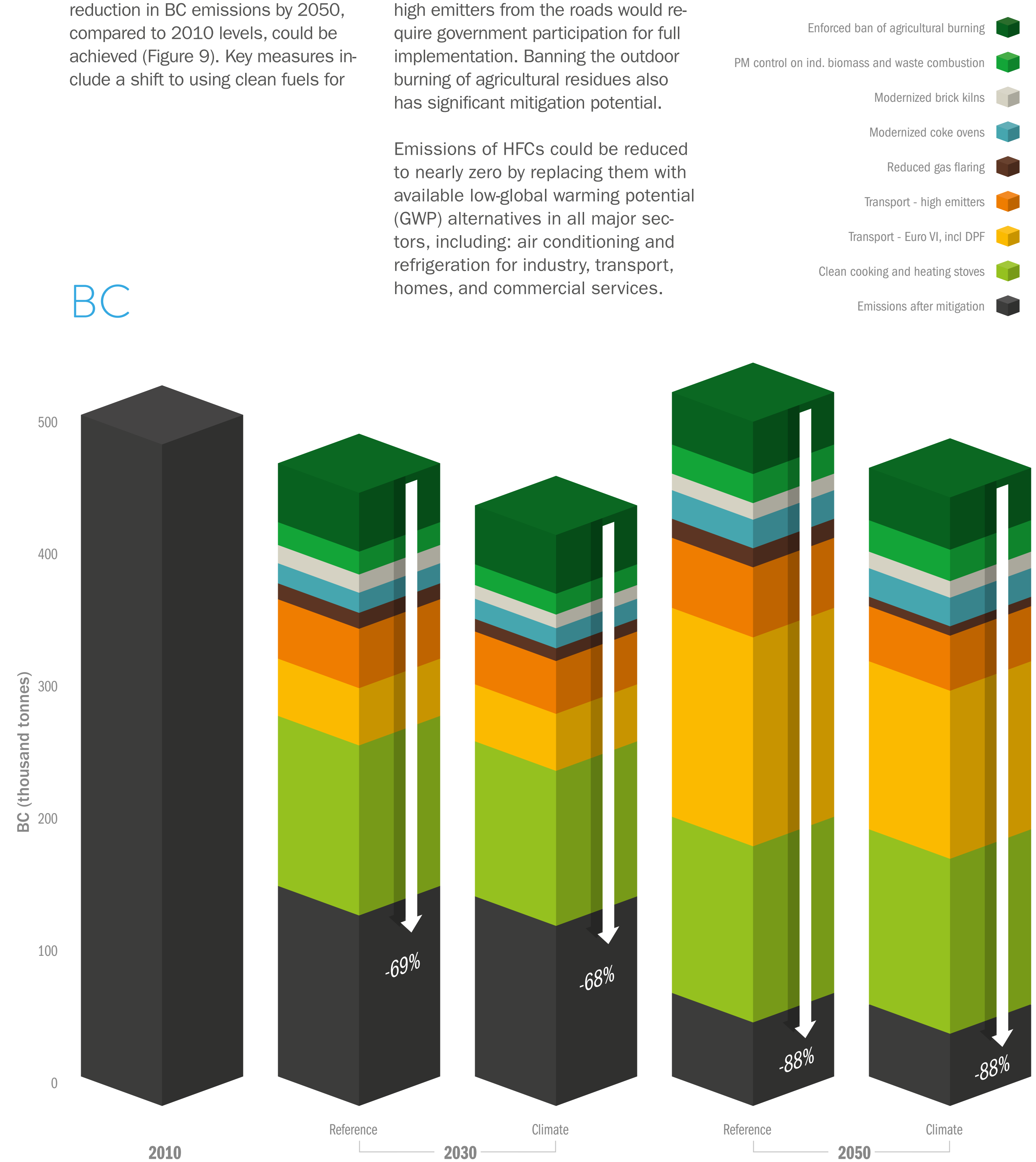
If no measures are implemented, the reference scenario suggests that CH_4 emissions would continue to increase, reaching more than 80 million tonnes by 2050, compared to about 54 million tonnes in 2010 (Figure 8). The implementation the suggested SLCP measures, however, could reduce current emissions by 48 per cent by 2050. This reduction would be mainly achieved by the implementation of measures to recover and use gas vented in the oil and gas production, as well as by reducing emissions from municipal and food industry waste, which together would account for more than 90 per cent of all emission reductions. A climate strategy focussed on reducing of CO_2 emissions would deliver lower reductions of CH_4.

Full implementation of measures to mitigate $PM_{2.5}$ emissions could lead to significant reductions in primary particle emissions (BC and OC) and in NO_x emissions that lead to secondary nitrate particles. Up to an 88 per cent reduction in BC emissions by 2050, compared to 2010 levels, could be achieved (Figure 9). Key measures include a shift to using clean fuels for residential cooking and heating stoves, which would involve vulnerable populations adopting cultural changes. Measures associated with improved technology for diesel trucks and buses (EURO VI including DPF) and removal of high emitters from the roads would require government participation for full implementation. Banning the outdoor burning of agricultural residues also has significant mitigation potential.

Emissions of HFCs could be reduced to nearly zero by replacing them with available low-global warming potential (GWP) alternatives in all major sectors, including: air conditioning and refrigeration for industry, transport, homes, and commercial services.

FIGURE 9

Emission reductions of BC in 2030 and 2050, from the full implementation of measures (SLCP mitigation scenario) in LAC compared to the reference and climate scenarios.



Key message 5

Efforts and experience reducing some SLCPs are already in place across LAC and could be scaled up if identified barriers were overcome.

The modelling carried out for this assessment has highlighted the potential for mitigation of SLCP emissions from a small number of suggested measures. A few of these have already been implemented or are currently being considered at national and subnational scales within LAC. The full implementation modelled in this assessment requires the strengthening of current policies, as well as more efficient, sustainable and widespread penetration of the measures across the region. Barriers to full implementation, however, need to be recognized and overcome if the identified mitigation potential is to be achieved. A national and regional discussion could be initiated to address SLCPs in the LAC regions as a whole.

Examples of integrated frameworks for coordinated management of climate change mitigation and air quality actions are already in place, showing the effectiveness of leveraging institutional synergies. Chile and Mexico, recognizing that integrating policies for climate and clean air can significantly reduce the cost of achieving objectives in both sectors, have implemented appropriate strategies. Chile has unified the two functions in a single department, the Division of Air Quality and Climate Change within the Ministry of Environment. Mexico, on the other hand, has enacted the General Law on Climate Change (LGCC), which provides a legal framework regulating climate change policies and includes the National Strategy of Climate Change (ENCC) and the Special Programme on Climate Change (PECC). Both the ENCC and PECC incorporate greenhouse gases and SLCPs as part in the mitigation strategies. Such efforts need to be synchronized with the goals of other governmental institutions, as has been done in Chile and Mexico, where ministries of energy, transportation, finances and even housing have coordinated their policies to achieve the maximum effect.

Current policies for reducing $PM_{2.5}$ emissions will lead to decreased O_3 and BC concentrations. Although many countries in LAC do not specifically consider SLCPs, some of these pollutants, including O_3 and $PM_{2.5}$, are regulated and monitored as part of air quality attainment plans. Several countries – Brazil, Chile, Colombia, Mexico and Paraguay, among others – currently have or are contemplating measures to reduce $PM_{2.5}$ in their efforts to mitigate urban air pollution that will entail BC reductions. Important efforts to strengthen the air quality standards, harmonising them with the WHO guidelines, are under way, and are a good example of what needs to be strengthened.

Nationally Determined Contributions (NDCs) can be a tool of mutual support for climate action, SLCP reductions and sustainable development, and can drive policy and investment at local, national, and global levels. Countries in the region are already considering greenhouse gas mitigation action under the 2015 Paris Agreement. Energy, transport, waste management and agriculture are already considered as targeted sectors within the NDCs of several LAC countries. These sectors also represent the best opportunities for mitigating CO_2 and SLCPs. Furthermore, Chile and Mexico have highlighted the importance of reducing BC emissions in their NDCs. Moreover, Mexico has pledged a 51 per cent reduction below business as usual in BC emissions by 2030.

TABLE 2
Sectorial analysis of NDCs submitted by LAC Countries.

NOTE
* Countries that pledged to reduce emissions from "all economic sectors".

	Energy	Transport	Waste	Agriculture	Buildings	Mining	Industrial processes	Forests and land use
Antigua and Barbuda	■	■	■	■				■
Argentina	■	■	■	■			■	■
Bahamas	■							■
Barbados	■		■	■			■	■
Belize	■	■						■
Bolivia	■							■
Brazil*	■	■	■	■	■	■	■	■
Chile	■	■	■	■	■	■	■	■
Colombia*	■	■	■	■	■	■	■	■
Costa Rica*	■	■	■	■	■	■	■	■
Cuba	■			■				
Dominica	■	■	■	■			■	■
Dominican Republic	■		■	■			■	■
Ecuador	■							■
El Salvador	■	■	■	■				
Grenada	■		■					■
Guatemala	■		■	■			■	■
Guyana	■							■
Haiti	■		■	■				■
Honduras	■		■	■			■	
Jamaica	■							
Mexico	■		■	■			■	■
Panama	■							■
Paraguay*	■	■	■	■	■	■	■	■
Peru	■		■	■			■	■
St. Kitts and Nevis*	■	■	■	■	■	■	■	■
St. Vincent and the Grenadines	■		■	■			■	■
Suriname	■							
Trinidad and Tobago	■	■					■	
Uruguay	■		■	■			■	■
Venezuela	■	■		■			■	■

UNEP / CCAC

Examples of implementation of the key measures for reducing BC and CH_4 are already available in the region. This assessment identified the key measures in the transport, residential, agriculture, small industry and oil and gas sectors that would deliver most of the reductions needed for BC and co-emitted substances. Similarly, key measures for the coal, oil and gas; waste and agriculture sectors that will deliver most of the CH_4 reductions were identified. The lessons learnt from the following implementation cases in Table 3 should be the basis for up scaling .

The regional plan of action on atmospheric pollution could be used as the vehicle to reduce SLCPs in LAC. This would allow the widespread implementation of the suggested SLCP measures across the region; it would also provide a framework for coordinated action, support by the Regional Network on Atmospheric Pollution. The regional plan of action will be reviewed by 2018 and this represents a unique opportunity to further scaling up action within the key sectors identified in this assessment.

Remaining barriers for the implementation and broader penetration of measures in LAC

The detailed analysis carried out in this assessment shows that, despite differences among countries and sectors, there are common needs to be addressed within the region. Comprehensive and coordinated policies, laws and regulations are crucial for advancement in all sectors, but it should be acknowledged that many countries still lack an appropriate legal framework through which policies can be developed and implemented.

Moreover, some countries lack information on pollutants, not just SLCPs, and even national standards for criteria pollutants (CO, lead (Pb), NO_2, O_3, PM and SO_2) There is an urgent need to generate information at all levels to fully understand the processes and options to mitigate SLCPs in LAC. Complete and public information can help raise awareness and improve participation of stakeholders in developing stronger and more effective networks and participatory processes.

While there are already laws and regulations in place in some of the LAC countries, these often lack concrete indicators to monitor progress, which impedes measurement of advancements, evaluation of results and the incorporation of needed adjustments. For example, there is an official regulation in Mexico that since 2009 mandates the distribution of low-sulphur fuel as part of the national policy to improve air quality; this, however, is still to be implemented. One of the main challenges identified by the assessment is the lack of ***effective enforcement***, with penalties for noncompliance. Enforcement of existing laws would also stimulate the development of further policies needed to encourage and upscale implementation of the measures identified in this assessment.

Governments need to also consider economic instruments that take the social and environmental costs and benefits from the mitigation of SLCPs into account. Making sure that there are economic incentives in place, and effective financial mechanisms and resources to promote the changes needed is crucial for all sectors. Economic instruments, such as an increase in fuel prices and financial support for improved cookstoves, have been shown to contribute to the advances needed. Many of the effective measures required for CH_4, BC and other SLCP mitigation are new to the LAC region – for example, reducing CH_4 emissions through the minimization or elimination of fugitive emissions in the oil and gas sector and emerging shale gas exploration. Therefore, making sure that financial resources are available for the implementation of the necessary technology and infrastructure should be a priority for LAC and the international community.

In addition, all sectors have identified the need to *build capacity* because of the need for scientific and technical expertise to monitor emissions, implement available technologies and generate information. Strengthening networks, sharing lessons learned and best practices are among the possibilities that LAC could exploit to increase their capacity.

In summary, governments throughout the LAC region need to create an enabling environment for the implementation of SLCP policies and the key measures identified in this assessment. Establishment and enforcement of policies together with information, the active participation of stakeholders, and the inclusion of economic incentives could deliver the needed outcomes. Moreover, the coordination of the different sectors of each country is a key factor for the success of the implementation of the measures; environmental agencies should find synergies with the goals of other ministries or institutions that may have more influence in mainstream public policies adopted by the governments.

TABLE 3
Selected measures already implemented in LAC.

Black Carbon and co-emitted substances

Transport	Implement improved vehicle technology, including Euro VI on new vehicles and DPFs	The DPF programme for buses in Chile and Colombia is a good example. The **main challenge** remains in the availability of ultra-low sulphur fuel with an appropriate regulation framework to guarantee the introduction of a new emissions standard for fuel to make it compatible with the advanced vehicle technologies.
	Elimination of high emitting vehicles	Mexico, through a fiscal incentive applicable in replacing freight units more than ten years old and for vehicles less than six years old, has eliminated over 25 000 older units. The **main challenge** remains in enforcing emissions standards and providing incentives for fleet turnover.
	Implement more efficient mobility in cities	Bus Rapid Transit (BRT) systems have been implemented in several major cities in LAC countries, including in Argentina, Brazil, Chile, Colombia, Ecuador, Guatemala, Mexico and Peru that provide more efficient mobility while reducing emissions and exposure of passengers to harmful pollutants.
Residential	Introduction of improved biomass cookstoves and/or the use of LPG	Several improved biomass cookstoves have been introduced in the LAC region, for example Justa stoves from Honduras, Malena from Bolivia, Onil from Guatemala, Patsari from Mexico and Turbococina from El Salvador. The **main challenge** to more widespread penetration remains – overcoming cultural practices. The use of LPG for cooking has been widely promoted in many LAC countries, leading to mixed wood-LPG users. In the Dominican Republic, due to the introduction of LPG cookstoves in 2010, the proportion of the population using firewood has been reduced from 86 per cent to only 10 per cent. By 2014, about 300 000 LPG cookstoves had been installed in Peru.
Agriculture	Enforced ban of open field agricultural burning	The Agro-environmental Protocol that Brazil's Sugarcane Industry Association (UNICA) has established has reduced the areas in which fire is used about 27 per cent. Other countries have implemented bans in their regulatory framework but enforcement remains the **main challenge**. Since 1990, Argentina and Brazil, with 29 and 32 million hectares respectively in 2014, 70–80 and 86 per cent of their total crop area, have led the adoption of no-till techniques in LAC, and this technique is spreading quickly. In Paraguay and Uruguay no-till techniques are now used on 90 per cent and 82 per cent of total crop area, respectively. The **main challenge** includes the availability of resources and adequate policies to promote the adoption of no-till agriculture.
Oil and gas	Reduced gas flaring	Mexico has restricted gas flaring for PEMEX, the state-owned petroleum company, through the enhancement of standards.
Industry	Modernized brick kilns	Several improved brick kilns have been implemented in LAC; for example, MK2 kilns developed in Mexico and other modernized kilns used in several LAC countries have been demonstrated to reduce emissions and improve energy efficiency compared to traditional open-top kilns. The **main challenge** remains in the informal nature of this industry in many countries and a lack of emissions standards. Peru has designed nationally appropriate mitigation action (NAMA) for the brick sector, which could contribute to sector modernization.

Methane

Sector	Measure	Example
Fossil fuel production and distribution	Recovery and use of vented gas in oil and gas production Reduction of gas leakage during distribution	A NAMA scheme for the whole oil and gas sector, to be financed with international funds, has been designed in Mexico.
	Pre-mine degasification and recovery of CH_4 during mining	In Barranquilla, Colombia, an international cooperation project for CH_4 recovery in a power plant was approved in 2015.
Waste	Separation and treatment of biodegradable MSW	Colombia aims to achieve carbon neutrality in the solid waste sectors by integrated solid waste management programmes and creating incentives for the private sector. A NAMA has been designed as part of the integrated approach. The **main challenge** of preventing improper practices, including waste picking, open burning and uncontrolled landfills remains.
	Solid and liquid food-industry waste treated in anaerobic digesters with biogas recovery	Rio de Janeiro is treating 800 tonnes of MSW per day, integrating anaerobic digestion for biogas production, aerobic digestion for compost, incineration and recycling.
	Landfill gas capture and electricity generation	The State owned SIMEPRODE in Monterrey, Mexico currently runs a 12.7 megawatt (MW) plant and is projected to fuel a 25-MW plant in 2016.
	Upgrade primary wastewater treatment to secondary and tertiary treatment with gas recovery and overflow control	Several countries in LAC have installed modern wastewater treatment technologies with biogas capture systems to generate electricity. The **main challenge** of developing adequate policy to facilitate the adoption of modern technologies remains.
Agriculture	Anaerobic digestion – biogas recovery from biomass	Brazil is already implementing massive electricity generation projects using sugar cane biomass.
	Biogas development in livestock manure management	Costa Rica initiated the biogas programme of the Costa Rican Electricity Institute (ICE) a decade ago, with bio-digesters and electricity generators installed on large pig, dairy and poultry farms and cooperatives.
	Application of manure as fertilizer	Feedlots in Argentina and Brazil have produced manure compost as fertilizers generating significant economic and environmental benefits. The **main challenges** for improved livestock management include enforcing regulations and providing economic incentives for good practice.

Hydrofluorocarbons

Sector	Measure	Example
Industry and services	Technology conversion to lower-GWP or not-in-kind alternatives	Argentina and Brazil have both begun installing supermarket refrigeration systems utilizing mainly CO_2 and ethylene glycol instead of HFCs. Colombia is installing district cooling in the city of Medellin as part of its old chillers replacement project. The **main challenges** for wider implementation include the high cost and availability of low-GWP alternatives, setting standards, energy efficiency losses and flammability.
	Control, regulate and monitor imports, use and emissions of HFC products and equipment	Belize, Colombia and Jamaica require all importers and users of HFCs to obtain environmental licenses and provide annual emissions reports. The **main challenges** of developing adequate policies for HFC management, incentives and standards remain.

Concluding remarks

Through this assessment, it is clear that the LAC region has the opportunity to reduce near-term climatic impacts while benefiting from emission reductions through the small number of identified measures. In particular, improvements in urban transport could lower levels of urban air pollution, reducing health effects and improving efficiency in this sector. Reducing CH_4 emissions would have many beneficial effects, including reducing O_3 damage to crops and improving health outcomes. What remains a challenge is facilitating the widespread implementation of such technologies and practices nationally and regionally. Making sure that financial, institutional and human resources are available for the implementation of needed technology and infrastructure should be a priority for the region and the international community.

This study also makes clear that it is essential to reduce CO_2 emissions in parallel with efforts to reduce SLCP emissions, because in the end, over the long term, CO_2 dominates warming. Nevertheless, in the short term many of the negative impacts of climate change in the region could be alleviated through a series of measures that will also improve development in the region.

Acknowledgements

The United Nations Environment Programme and the Climate and Clean Air Coalition are thankful with the Co-Chairs, the Advisory Group, the Leads and Contributing Authors, the Editors, and the SDM- Writing Team for their critical contribution to the development of this assessment.

The following experts and researchers have provided input to the assessment and contributed to this report in their individual capacity. Affiliations are mentioned for identification purposes only.

CO-CHAIRS

Paulo Artaxo (University of Sao Paulo-USP, Brazil) and Graciela Raga (National Autonomous University of Mexico-UNAM).

REGIONAL ASSESSMENT CORE TEAM

Graciela Raga (National Autonomous University of Mexico-UNAM); Paulo Artaxo (University of Sao Paulo-USP, Brazil); Zbigniew Klimont (International Institute for Applied System Analysis-IIASA, Austria); Johan Kuylenstierna (Stockholm Environment Institute, University of York, UK); Richard Mills (International Union of Air Pollution Prevention Associations-IUAPPA, UK); María Amparo Martínez-Arroyo (National Institute of Ecology and Climate Change-INECC, Mexico); Marisela Ricárdez-García, Juan Carlos Bello, Martina Otto and Volodymyr Demkine (UNEP).

SDM WRITING TEAM

Graciela Raga (National Autonomous University of Mexico-UNAM); Paulo Artaxo (University of Sao Paulo-USP, Brazil); Zbigniew Klimont (International Institute for Applied System Analysis-IIASA, Austria); Johan Kuylenstierna (Stockholm Environment Institute, University of York, UK); Nathan Borgford-Parnell (Institute for Governance and Sustainable Development-IGSD, USA); Marisela Ricárdez-García (UNEP); Luisa Molina (Molina Centre for Energy and the Environment-MCE2, USA); Volodymyr Demkine (UNEP) and Sunday Leonard (CCAC Secretariat).

FULL REPORT

Chapter 1: Introduction

Coordinating Lead Authors: Laura Gallardo Klenner (Centre for Climate and Resilience Research-CR2, Chile); Olga L. Mayol-Bracero (University of Puerto Rico-UPR) and Luis Carlos Belalcazar Ceron (National University of Colombia).

Contributing Authors: Romina Picolotti (Centre for Human Rights and Environment-CEDHA, Argentina) and Piedad Martín (UNEP).

Chapter 2: Drivers, Regional Emissions and Measurements

Coordinating Lead Authors: Darrel Baumgardner (National Autonomous University of Mexico-UNAM) and Maria de Fatima Andrade (University of Sao Paulo-USP, Brazil).

Lead Authors: Zbigniew Klimont (International Institute for Applied System Analysis-IIASA, Austria); Johan Kuylenstierna (Stockholm Environment Institute, University of York, UK); Suely Machado Carvalho (Nuclear and Energy Research Institute-IPEN, Brazil); Nathan Borgford-Parnell (Institute for Governance and Sustainable Development-IGSD, USA); Olga L. Mayol-Bracero (University of Puerto Rico-UPR); Megan Melamed (University of Colorado, USA); Rodrigo Seguel (University of Chile); Marcos Andrade (Higher University of San Andres-UMSA, Bolivia); Carlos Rudamas (University of El Salvador-UES); Gustavo Sosa-Iglesias (National Institute of Oil-INP, Mexico); Gerardo Ruiz-Suárez (National Autonomous University of Mexico-UNAM); Odon Sanchez-Ccoyllo (National Meteorology and Hydrology Service of Peru-SENAMHI, Peru); Jean Ometto (National Institute for Space Research-CCST/INPE, Brazil); María Cazorla (San Francisco University of Quito-USFQ, Ecuador); Lena Höglund-Isaksson (International Institute for Applied System Analysis-IIASA, Austria); Pallav Purohit (International Institute for Applied System Analysis-IIASA, Austria); Omar Masera Cerutti (National Autonomous University of Mexico-UNAM); Paulo César Medina (University San Nicolas de Hidalgo of Michoacan- UMSNH, Mexico); Nicolas Hununeeus (University of Chile); José Abraham Ortínez (National Institute of Ecology and Climate Change-INECC, Mexico); Laura Dawidowski (Atomic Energy Commission, Argentina); Daven Henze (University of Colorado, USA) and Néstor Rojas (National University of Colombia).

Contributing Authors: Ademilson Zamboni (Institute of Energy and Environment-IEMA, Brazil); Rita Ynoue (University of Sao Paulo-USP, Brazil); Anne Mee Thompson (National Aeronautics and Space Administration-NASA, USA); Juan Carlos Antuña Marrero (Meteorological Centre of Camagüey Province, Cuba); Manuel Cupeiro (National Meteorological Service, Argentina); Chris Heyes, Wolfgang Schöpp, Jens Borken and Peter Rafaj (International Institute for Applied System Analysis-IIASA, Austria); René Parra (San Francisco University of Quito-USFQ, Ecuador) and Thiago Nogueira (University of Sao Paulo-USP, Brazil).

Chapter 3: Impacts of short-lived climate pollutants (SLCP) on climate, water and food security, human health, biodiversity and ecosystem services

Coordinating Lead Authors: Laszlo Nagy (University of Campinas-UNICAMP, Brazil) and Agnes Soares da Silva (Pan-American Health Organisation-PAHO).

Lead Authors: Horacio Riojas-Rodríguez (National Institute of Public Health-INSP, Mexico); Grea Litai Moreno Banda (National Institute of Public Health-INSP, Mexico); Johan Kuylenstierna, Harry Vallack and Chris Malley (Stockholm Environment Institute, University of York, UK); Drew Shindell (Duke University, USA); Rita Van Dingenen (Joint Research Centre, European Commission) and Daven Henze (University of Colorado, USA).

Contributing Authors: Marcos Buckeridge (University of Sao Paulo-USP, Brazil); Patrick Bourgeron (University of Colorado, USA); Marck Williams (University of Colorado, USA); Eduardo Assad (Brazilian Agricultural Research Corporation-EMBRAPA, Brazil); Stephan Halloy (National University of Chilecito, Argentina); Aaron van Donkelaar (Dalhousie University, Canada); Randall Martin (Harvard-Smithsonian Centre for Astrophysics, USA); Neal Fann (Environmental Protection Agency-EPA, USA) and James McPhee (University of Chile).

Chapter 4: SLCP measures, the potential reduction in emissions, and benefits for near-term climate and air quality

Coordinating Lead Authors: Zbigniew Klimont (International Institute for Applied System Analysis-IIASA, Austria) and Johan Kuylenstierna (Stockholm Environment Institute, University of York, UK).

Lead Authors: Lena Höglund-Isaksson and Pallav Purohit (International Institute for Applied System Analysis-IIASA, Austria); Suely Carvalho (Nuclear and Energy Research Institute-IPEN, Brazil); Nathan Borgford-Parnell (Institute for Governance and Sustainable Development-IGSD, USA) Harry Vallack (Stockholm Environment Institute, University of York, UK); Drew Shindell (Duke University, USA); Rita Van Dingenen (Joint Research Centre, European Commission) and Daven Henze (University of Colorado, USA).

Contributing Authors: Omar Masera Cerutti, (National Autonomous University of Mexico-UNAM); Gianni López (Centro Mario Molina, Chile); Jose Abraham Ortínez (National Institute of Ecology and Climate Change-INECC, Mexico); Gustavo Sosa-Iglesias (National Institute of Oil-INP, Mexico); Alberto Mendoza Domínguez (Tecnológico de Monterrey-ITESM, Mexico); Wolfgang Schöpp, Jens Borken and Chris Heyes (International Institute for Applied System Analysis-IIASA, Austria); Gregory Faluvegi (NASA Goddard Institute for Space Studies and Centre for Climate Systems Research, Columbia University, USA); Marianne Tronstad Lund and Borgar Aamaas (Centre for International Climate and Environmental Research Oslo-CICERO, Norway); Arturo Gavilán (National Institute of Ecology and Climate Change-INECC, Mexico) and Ernesto Alvarado (University of Washington-UW, USA).

Chapter 5: Implementation of identified measures across LAC-progress and opportunities

Coordinating Lead Authors: Luisa Molina (Molina Centre for Energy and the Environment-MCE2, USA) and Víctor Hugo Páramo (National Institute of Ecology and Climate Change-INECC, Mexico).

Lead Authors: Astrid Puentes and Florencia Ortuzar (Inter-American Association for the Environment Defence-AIDA); Sergio Zirath and Ivan Islas (National Institute of Ecology and Climate Change-INECC, Mexico); Rodrigo Gonzalez (Molina Centre for Energy and the Environment-MCE2, USA); Omar Masera Cerutti (National Autonomous University of Mexico-UNAM); Jon Bickel (Swisscontact, Peru); José Abraham Ortínez (National Institute of Ecology and Climate Change-INECC, Mexico); Octavio Castelán Ortega (Autonomous University of Mexico State- UAEM, Mexico); Andreas Jenet (Tropical Agricultural Research and Higher Education Centre- CATIE, Costa Rica); Gabriel Pereira (Federal University of São João del-Rei- UFSJ, Brazil); Arturo Gavilán (National Institute of Ecology and Climate Change-INECC, Mexico); Adalberto Noyola (National Autonomous University of Mexico-UNAM); José Ignacio Huertas (Tecnológico de Monterrey-ITESM, Mexico); Gustavo-Sosa (National Institute of Oil-INP, Mexico); Suely Machado Carvalho (Nuclear and Energy Research Institute-IPEN, Brazil); Nathan Borgford-Parnell (Institute for Governance and Sustainable Development-IGSD, USA).

Contributing Authors: Thalia Hernández, Carolina Inclán and Dennis Gastelum (National Institute of Ecology and Climate Change-INECC, Mexico); Paulo César Medina (University San Nicolás de Hidalgo of Michoacan-UMSNH, Mexico); Mohamed Benaouda (Autonomous University of Mexico State-UAEM, Mexico); Juan Carlos Ku-Vera (Autonomous University of Yucatan-UADY, Mexico); Leah Germer, Oscar Coto, Cristobal Villanueva and Francisco Casasola (Tropical Agricultural Research and Higher Education Centre-CATIE, Costa Rica); Francielle da Silva Cardozo (Federal University of São João del-Rei-UFSJ, Brazil); Carlos Escamilla (Tecnológico de Monterrey-ITESM, Mexico); Guillermo Encarnación and Martha Ramírez (National Institute of Ecology and Climate Change-INECC, Mexico); Patricia Güereca (National Autonomous University of Mexico-UNAM); María Elena Huertas (Technological University of Bolivar, Colombia) and Daniel Prato (Tecnológico de Monterrey-ITESM, Mexico).

Chapter 6: From Assessment to Action

Coordinating Lead Authors: Romina Picolotti (Centre for Human Rights and Environment-CEDHA, Argentina); Richard Mills (International Union of Air Pollution Prevention Associations-IUAPPA, UK); Graciela Raga (National Autonomous University of Mexico-UNAM); Nathan Borgford-Parnell (Institute for Governance and Sustainable Development-IGSD, USA).

Contributing Author: Sebastián Tolvett (Metropolitan University of Chile).

UNEP TEAM

Leo Heileman, Mara Murillo, Jacqueline McGlade, Marisela Ricárdez-García, Juan Carlos Bello, Francesco Gaetani, Andrea Salinas, Suzanne Howard, Martina Otto, Volodymyr Demkine, Andrea Brusco and Maria Amparo Lasso.

CCAC SECRETARIAT

Helena Molin-Valdés, Sunday Leonard, Tiy Chung and Sophie Bonnard.

DESIGN AND LAYOUT

Mateo L. Zúñiga and Andrés Barragán (Puntoaparte Bookvertising, Colombia).

COPYEDITING

Bart Ullstein (UK).

SPECIAL ACKNOWLEDGEMENTS

Dirk Jan Leo Olivié (Norwegian Meteorological Office); Robert Sander (International Institute for Applied System Analysis-IIASA, Austria); Alejandra López and Jessica González (National Institute of Ecology and Climate Change-INECC, Mexico).

Thanks

UNEP

CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

Summary
for Decision Makers

Integrated Assessment of Short-Lived Climate Pollutants in Latin America and the Caribbean

Improving air quality while contributing to climate change mitigation

UNEP

CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS