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SLCP assessment for the Latin America and Caribbean. Final Report (Version 1.0)

Klimont, Z., Höglund-Isaksson, L., Heyes, C., Purohit, P., Schöpp, W., Rafaj, P., Kiesewetter, G., Borken, J. and Sander, R.

IIASA Report
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IIASA

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This report was written by Zbigniew Klimont with contributions from Lena Höglund-Isaksson, Chris Hayes, Pallav Purohit, Wolfgang Schöpp, Peter Rafaj, Gregor Kiesewetter, Jens Borken, and Robert Sander from the International Institute for Applied Systems Analysis (IIASA).

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Disclaimer

Executive Summary

This Final Report summarizes the IIASA contributions to the SLCP Assessment for LAC project.

IIASA has delivered all agreed outputs with respect to modelling work required to develop baseline and mitigation scenarios where key SLCP mitigation measures were identified. The results in form of gridded emission fields were provided to the impact and climate modelling groups involved in the project.

The developed protocol for data collection allowed to acquire a harmonized data set on emissions within the region for which a number of issues were identified and it was compared with the GAINS database, leading to its improvement. This exchange between the national experts and IIASA modelling team opens up a possibility for further collaboration where also ROLAC will play a role as the information has been stored there. The final historical inventories have been harmonized with the global GAINS database and served development of scenarios.

While the GAINS model has been further developed to consider specific LAC circumstances and availability of new data, the baseline and mitigation scenarios were developed in a consistent way with the global UNEP/WMO Assessment allowing a comparison of the results. The finally selected SLCP measures include additional options which were not part of the global assessment, for example, reduction of gas flaring, introduction of Marques brick kilns, shale gas options, and options to mitigate HFCs.

IIASA has provided inputs to several chapters of the Assessment, primarily to Chapter 2 and 4 but consulted the progress and intermediate results with the lead authors of chapter 3 and especially chapter 5. IIASA has contributed coordinating lead author (CLA) of the chapter 2 (Zbigniew Klimont), several lead authors (LAs) for chapter 2 and 4 (Lena Höglund, Pallav Purohit, Zbigniew Klimont), as well as several contributing authors in both chapters. IIASA has been co-authoring the Summary for the Decision Makers (SDM) document where Zbigniew Klimont served as a member of the Regional Assessment Core Team and was part of the SDM writing team.

IIASA has participated in a series of face to face meetings as well as in several calls where consultation between the LAC national experts, author and modelling teams has taken place.

More information on the Internet

More information about the GAINS methodology and interactive access to input data and results is available at the Internet at http://gains.iiasa.ac.at.

Upon request access to the on-line version of the specific LAC GAINS version of the model set up temporarily for the duration of the project, can be granted. This was organized for the initial stages of the development of the model so that there will be a possibility to review and monitor changes and data in the model.

The gridded data sets of emissions developed within the project has been made available online on the IIASA website:

http://www.iiasa.ac.at/web/home/research/researchPrograms/air/Global_emissions.html

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List of acronyms

LAC	Latin America and Caribbean
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies model
SLCP	Short-Lived Climate Pollutants
GDP	Gross domestic product
IIASA	International Institute for Applied Systems Analysis
RCP	Regional Concentration Pathways
IEA	International Energy Agency
FAO	United Nations Food and Agriculture Organization
GWP	Global Warming Potential
GTP	Global Temperature Potential
RTP	Regional temperature Potential
kt	kilotons
Mt	million tons
CH_4	methane
BC	Black carbon
OC	Organic carbon
NH_3	Ammonia
NO_x	Nitrogen oxides
PM2.5	Fine particulate matter
SO_2	Sulphur dioxide
NMVOC	Non-methane volatile organic compounds

1 Introduction

The global black carbon and tropospheric ozone assessment (UNEP/WMO 2011) stressed that the global results need further elaboration at the regional level to validate and develop further the assessment of efficiency of actions focusing on the 16 measures. The CCAC established several initiatives addressing specific sectors and regions. Further on the CCAC proposed to develop regional assessment studies and the first region that is the subject of that Assessment is Latin America and Caribbean (LAC). The project started in June 2014 and the modelling work was completed in the autumn of 2015 while writing the full report continued into 2016. The report was sent to review while the Summary for the Decision Makers (SDM) was written in winter and spring of 2016. The SDM was presented in May 2016 at UNEP headquarters in Nairobi.

IIASA had two primary tasks in the project, (i) develop emission scenarios and identify key SLCP (short lived climate pollutants) mitigation measures where LAC specific information is considered and (ii) contribute to writing the assessment report.

This report documents the work performed until the end of the project, including development of the datasets and scenarios provided to the impact modelling teams and writing of the assessment report as well as the SDM. This report provides the analysis of the results including several of the issues that have been have been discussed and presented at the project meetings.

2 GAINS model development

The GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies) model (Amann *et al* 2011) has been used in the assessment for the development of a harmonized emission dataset for the LAC region and respective mitigation scenarios where SLCP measures were applied. The model was used in the global assessment (UNEP/WMO 2011), however, it was recognized that a number of extensions and updates need to be performed to apply it to a particular region. The updates include spatial resolution of the model and development of all associated data on activities, emission factors, control strategies, characterization of region specific measures (if necessary), the inclusion of the new regional radiative forcing metrics, and development of the new dedicated on-line portal for the project. A brief summary of the updates is given in the following text.

The model extensions discussed below were performed in the first months of the project as they were essential for the development of the baseline and mitigation strategies which were provided to the impact modelling teams late spring-early summer 2015.

2.1 Spatial resolution

The global application of the GAINS model, as used in the global assessment, distinguished five regions in the LAC area: Argentina, Brazil, Chile, Mexico, and Other LAC. As discussed at the first meeting of the Assessment (Panama, June 2014) there is a need to improve spatial resolution. IIASA has proposed new country resolution, which after discussion with the national expert teams participating in the project, was finalized at the meeting in Natal, Brazil (September, 2014). We have agreed to distinguish 13 regions: Mexico, Central America, Caribbean, Colombia, Venezuela, Ecuador, Peru, Brazil, Bolivia, Chile, Paraguay, Argentina, and Uruguay. This is illustrated in Figure 2.1.

Beyond improving the regional resolution for LAC in the GAINS model, IIASA has reviewed the spatial proxies for gridding of emissions. Emissions are provided to the impact modelling teams in 0.5 ^{o} x 0.5^{o} longitude-latitude grid. So far, IIASA has used for gridding proxies that were applied in the development of the RCP (Regional Concentration Pathways) scenarios for the IPCC, used in the AR5 report. Over time these have been updated and adapted to the needs of specific projects; this project benefits from updated information that has been already integrated in GAINS in the last years but there was no focus on sectors particularly important to LAC.

For LAC assessment, we have discussed a number of specific sectors where importance of updating information about the spatial distribution of sources was highlighted; this discussion took place at the meeting in Natal, Brazil (September, 2014). IIASA has pointed out the need for locally available information on spatial data for informal industries like brick manufacturing as well as non-ferrous metals smelters, oil and gas industry production sites, and residential cooking on solid fuels.

Unfortunately, IIASA has not received any specific pattern for brick kilns and cooking stoves and therefore it remains as it was used in the global assessment. However, for oil and gas industry the updated information about flare locations was used to allocate emissions from this sector. Also a new gridding layer addressing emissions from non-ferrous metals (copper, nickel, lead, etc.) smelters have been created. IIASA has identified key plants and their capacities using international databases and created respective proxy layer for each of the regions distinguished in the process.

Figure 2.1: Regional resolution used in the LAC Assessment

2.2 Activity data

The change in spatial resolution of the model required modifications to the GAINS database. IIASA has imported and converted energy and agriculture statistical data for the 13 regions used in the assessment. Further the projections of activities were developed for the regions. The original projections originate from the IEA and FAO global scenarios (International Energy Agency 2012, Alexandratos and Bruinsma 2012) and do not have detailed regional and sector resolution as used in GAINS. IIASA applies historical sectoral resolution and own databases to allocate sources to the finer spatial scale.

Additionally, the model requires a number of assumptions going beyond standard statistical data, including size distribution of installations, types of stoves used in the residential sector, allocation of diesel fuel use in non-road machinery sector, split of brick production into different kiln types, split of livestock into manure management systems, etc. We have used our own database and consulted these with experts participating in the LAC assessment, especially for residential cooking and heating (e.g., Berrueta *et al* 2008, Masera *et al* 2007, Pine *et al* 2011, Ruiz-Mercado *et al* 2011), to develop respective parameterization. For energy data, the harmonized data format for exchange of information (see section 3.1) was used to improve the allocation of fuel use in transport sector.

Some sectors required update to its structure to accommodate for the specific production characteristics in the LAC region. This is especially the case for brick manufacturing, oil and gas industry, and waste sector.

- For brick sector, GAINS global model was originally developed with the focus on the largest production global region, Asia, and therefore some of the technologies were not specifically distinguished, for example Marques Kilns. We have introduced these in the model drawing on regional studies in LAC (e.g., Bellprat 2009, EELA 2011, PRAL 2012, Stratus Consulting 2014, SwissContact 2014a, 2014b, Erbe 2011).
- For oil and gas industry distinguishing more regions in GAINS for LAC, required additional parameterization of the sector to assure improved representation of this sector in each country, especially important for Venezuela, which was not a separate region before.
- An important model extension for oil and gas industry includes a distinction of the shale gas as a separate activity.
- Waste management is a key sector for methane emissions; IIASA has improved resolution in this sector, specifically distinguishing the municipal and industrial wastewater treatment.

2.3 Mitigation measures

To accommodate for specific circumstances in the LAC region some adaptations and extensions of the model were necessary. As mentioned earlier the brick sector and oil and gas industry sectors required a revision and new parameterization including specific characteristics of mitigation measures appropriate for the included regions.

IIASA has developed the new structure of the model accommodating for the new measures and created a default dataset drawing on the literature data and own experience and later consulted it and reviewed as appropriate using data from national experts provided during the project. And so several national (Bellprat 2009, PRAL 2012, Erbe 2011, EELA 2011) reports as well as information from CCAC's brick initiative (Stratus Consulting 2014, SwissContact 2014a) were used to improve characterization of the brick sector in GIANS, specifically energy efficiency and pollutant emissions of alternative kiln designs, including Marques Kiln (Márquez 2011a, 2011b, Cardenas *et al* 2012), which was not part of the solution in the global assessment.

While use of kerosene for lighting is not a large sector in LAC, we have included an option of switching away from kerosene following the global change to the GAINS model.

We have reanalysed the venting and flaring emissions from oil and gas industry and introduced explicit options for mitigation of emissions from gas flaring leading to reduction of black carbon emissions. This measure has not been used in the global assessment.

Since shale gas is recognized as a separate sector, the measures to bring emissions down to best practice comparable to the levels of conventional gas production practices have been added to the model. This is also a new measure.

Introduction of the measures required update and development of new control strategies in GAINS; control strategies describe the implementation of environmental policies in the baseline – the current legislation CLE case – and mitigation cases – maximum implementation rates to achieve specific targets.

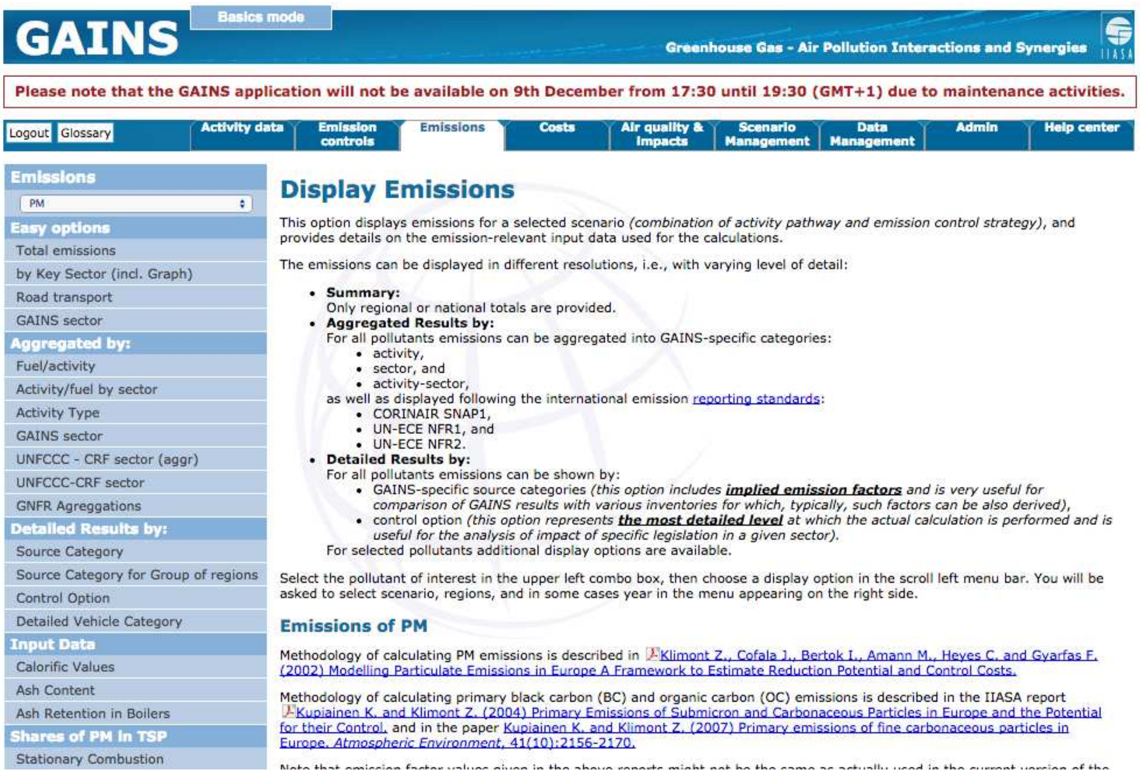
2.4 Radiative forcing metrics

In the global assessment a GWP100 (global warming potential with the time horizon of 100 years) metrics was used to support the identification of key mitigation measures, which reduce radiative forcing and lead to improved air quality. While we use the same principle in searching for mitigation measures, the actual metrics has been revised and following the ECLIPSE project developments (Stohl *et al* 2015) and we decided to use GTP (global temperature potential) with a time horizon of 20 years (GTP20) but including also regional metrics (RTP) specifically developed for this project. Effectively, instead of using one global value for each pollutant across the globe, we used a specific set of forcing numbers for Central America, South America, Sea Region. These were developed by CICERO (Oslo, Norway) following the principles described in (Aamaas *et al* 2015).

IIASA has implemented these regional metrics in the GAINS model and developed an algorithm to use them to identify measures.

2.5 On-line portal

Access to the on-line version of the specific LAC GAINS version of the model was granted to the project participants, specifically to enhance communication with the national experts. It was set up temporarily for the duration of the project and access was granted upon request. This was organized for the initial stages of the development of the model so that there will b a possibility to review and monitor changes and data in the model.



3 National inventories

One of the objectives of the project is to initiate collaboration between the national expert groups, the modelling team, and eventually within LAC region to stimulate exchange of information and establishing common format of collecting data.

One of the essential elements for the project are the national and regional emission inventories. We have started discussion about the availability of such inventories and associated data early in the project and an assessment of these efforts is presented in the Chapter 2 of the LAC Assessment as well as discussed briefly here in section 3.2 and 4.

3.1 Data formats

Since emission inventories are typically prepared in various formats, depending on the purpose, recipient organization, etc., we have discussed the process of harmonization for the purpose of the LAC Assessment. IIASA has led the development of the format for harmonized collection of available emission inventories as well as associated data (the co-chairs of chapter 2 of the Assessment followed up with the national representatives to provide respective information). The latter included mostly emission factors as their availability (or information about the sources) is essential for evaluation of completeness of the inventories as well as comparison to other sources, including the model used in this Assessment.

The three figures (snapshot of tables) provide information about the actual format of the tables that have been developed for that purpose and then distributed to all respective experts in LAC.

The IIASA team has also processed the GAINS model results to provide the emission estimates in the aggregated and detailed format as given in Figure 3.1 and 3.2. This allowed for comparison and discussion of the national inventories vs model estimates, see section 4.

AGGREGATED EMISSIONS - summary table

Country:
Year:
Units: Gg / year (kton / year)
Reference:

Sector	NOx *(as NO2)*	NMVOC	CH4	CO	SO2 *(as SO2)*	NH3 *(as NH3)*	BC	OC	PM2.5	PM10	N2O	HFCs
Power plants and industrial boilers												
Industrial processes												
Residential commercial combustion												
Transport (1)												
Fossil fuel extraction and distribution (2)												
Waste												
Agriculture												
Open burning of biomass (3)												
TOTAL	0	0	0	0	0	0	0	0	0	0	0	0

(1) Includes inland navigation, national sea shipping, aviation (landing and take-off only; no cruise); excludes international shipping. Non-exhaust (tyre, break wear) are also included
(2) Includes emissions from oil and gas production, distribution and storage. Emissions from flaring and gasoline stations are also included
(3) Includes open burning of agricultural residues

Figure 3.1: Template for providing aggregated emissions for key sectors and all relevant pollutants.

DETAILED EMISSION TABLE

Country:	
Year:	
Units:	Mg / year (tons / year)
Reference:	

Sector	Fuel/Subsector	NOx *(as NO2)*	NMVOC	CH4	CO	SO2 *(as SO2)*	NH3 *(as NH3)*	BC	OC	PM2.5	PM10	N2O	HFCs
Power plants													
	Coal												
	Oil												
	Gas												
	Other												
Industrial boilers													
	Coal												
	Oil												
	Gas												
	Other												
Industrial processes													
	Non-ferrous metals												
	Oil refineries												
	Brick production												
	Other												
Diesel generators													
Residential-commercial combustion													
	Fuelwood (solid biomass)												
	Coal												
	Gas												
	Other												
Transport													
Diesel	Heavy duty trucks and busses												
	Light duty vehicles and cars												
	Agricultural tractors												
	Rail												
	Other non-road machinery												
	Shipping												
Gasoline	Light duty vehicles and cars												
	Motorcycles												
Ethanol	Light duty vehicles and cars												
LPG	Busses												
	Light duty vehicles and cars												
Non-exhaust (1)	Heavy duty trucks and busses												
	Light duty vehicles and cars												
Other	Other transport including aviation												
Fossil fuel extraction and distribution													
	Coal mining												
	Oil production (2)												
	Oil products storage & distribution (3)												
	Gas production												
	Gas distribution (4)												
	Other												
Waste													
	Municipal Solid Waste (landfill)												
	Waste water												
	Industrial waste												
	Trash burning												
	Other, including waste incineration												
Agriculture													
	Livestock (cattle)												
	Livestock (pigs)												
	Livestock (other)												
	Mineral nitrogen fertilizer application												
	Rice production												
	Other agriculture												
Open burning of biomass													
	On-filed agricultural residues												
	Forest fires												
	Savannah fires												
TOTAL		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

(1) Non-exhaust include emissions from brake, tyre and road wear
(2) Includes flaring
(3) Includes fugitive emissions from storage of crude oil at terminals, refinery, storage of gasoline and other products in refinery and depots as well as emissions from gasoline stations
(4) Includes fugitve emissions from high pressure (long distance) and low pressure pipelines, including distribution to final cconsumers

Figure 3.2: Template for providing more detailed emissions by sector and all relevant pollutants.

EMISSION FACTORS

Country:
Year:

Sector	Fuel/Subsector	Units	NOx	NMVOC	CH4	CO	SO2	NH3	BC	OC	PM2.5	PM10
Power plants												
	Coal	g/GJ										
	Oil	g/GJ										
	Gas	g/GJ										
Industrial boilers												
	Coal	g/GJ										
	Oil	g/GJ										
	Gas	g/GJ										
Industrial processes												
	Non-ferrous metals	g/kg										
	Oil refineries	g/kg										
	Brick production	g/kg										
Diesel generators		g/GJ										
Residential-commercial combustion												
	Fuelwood (solid biomass)	g/GJ										
	Coal	g/GJ										
	Gas	g/GJ										
Transport (1)												
Diesel	Heavy duty trucks and busses	g/GJ										
	Light duty vehicles and cars	g/GJ										
	Agricultural tractors	g/GJ										
	Rail	g/GJ										
	Other non-road machinery	g/GJ										
	Shipping	g/GJ										
Gasoline	Light duty vehicles and cars	g/GJ										
	Motorcycles	g/GJ										
Ethanol	Light duty vehicles and cars	g/GJ										
LPG	Busses	g/GJ										
	Light duty vehicles and cars	g/GJ										
Non-exhaust (2)	Heavy duty trucks and busses	g/km										
	Light duty vehicles and cars	g/km										
Fossil fuel extraction and distribution												
	Coal mining	g/kg										
	Oil production (3)	g/kg										
	Oil products storage & distribution (4)	g/GJ										
	Gas production	g/GJ										
	Gas distribution (5)	g/GJ										
Waste												
	Municipal Solid Waste (landfill)	g/kg										
	Waste water	g/m3										
	Industrial waste	g/kg										
	Trash burning	g/kg										
Agriculture												
	Livestock (cattle)	kg/head										
	Livestock (pigs)	kg/head										
	Livestock (other)	kg/head										
	Mineral nitrogen fertilizer application	g/kg N										
	Rice production	g/kg										
Open burning of biomass												
	On-filed agricultural residues	g/kg										
	Forest fires	g/kg										
	Savannah fires	g/kg										

(1) You can also report emisison factors in g/km, where appropriate. Please change the units in the table accordingly
(2) Non-exhaust include emissions from brake, tyre and road wear
(3) Includes flaring
(4) Includes fugitive emissions from storage of crude oil at terminals, refinery, storage of gasoline and other products in refinery and depots as well as emissions from gasoline stations
(5) Includes emissions from high pressure (long distance) and low pressure pipelines, including distribution to final cconsumers

Figure 3.3: Template for providing key emission factors used in national inventories.

3.2 Completeness of the national inventories

The collected emission inventories and respective activity data have been analysed for completeness. Figure 3.2 provides an overview of completeness of the provided data by several LAC countries. Most of the countries appear to report key air pollutants and GHG (green area) while for particulate matter species there is a lot less information (red area). Analysis of completeness of inventories shows however that in a number of cases some important elements of the inventories are missing or are not sufficiently complete. The dark green elements in this figure indicate countries and pollutants where, according to IIASA analysis, the data is adequate, although more analysis is needed to inform about the quality and drawing on this improve parameterization of the models and consequently emissions used subsequently in modelling.

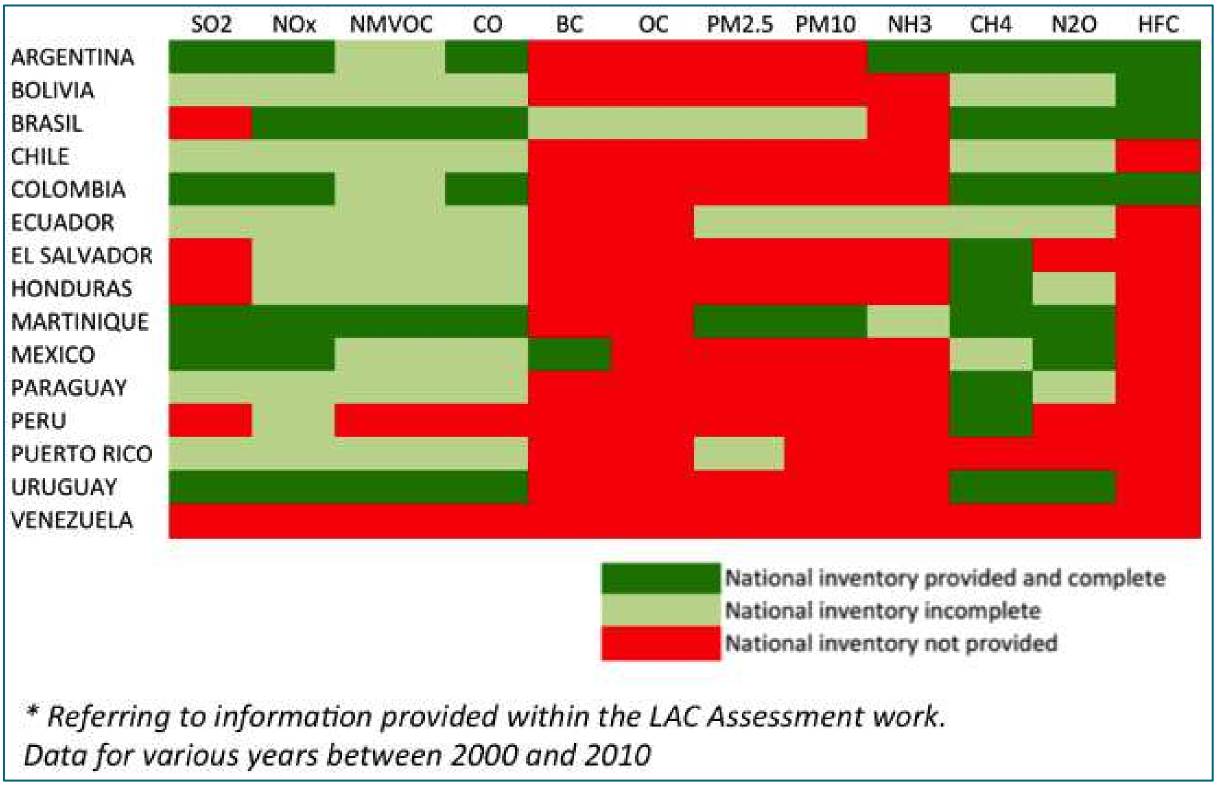


Figure 3.4: Availability and completeness of national emission data* in LAC region

Some of the key elements that are missing in a number of inventories include (in square brackets [] the number of countries for which the respective source was missing in submitted data):

- [6] Residential combustion
- [6] Agricultural waste burning
- [3] Transport
- [3] Agriculture
- [2] Waste
- [8] Fossil fuel extraction and distribution

Furthermore, it is important to note that depending on the region, provided inventories cover period 2000-2010 but a complete set for any given year were not available. The data that was actually provided is included in the full Assessment report, specifically its Annexes.

4 National inventories versus GAINS model

As indicated earlier, during the project several further developments of the modelling tool have been undertaken as well as the national inventories served to improve of the model. We have compared the current emission estimates with the ones used in the global assessment (UNEP/WMO 2011), see Figure 4.1. There are several differences which are well understood and stem from both better national representation of activities and emission factors as well as new model developments including re-evaluation of methane from fossil fuel production and the whole agriculture sector, which resulted in changes for ammonia (NH_3). Total CO_2 emissions remain nearly the same as only small adjustments occurred to the total energy use across the region.

These updates have some implications for the mitigation potential, especially that it can be addressed at the national rather than the whole LAC region level. See also discussion in section 5.2.

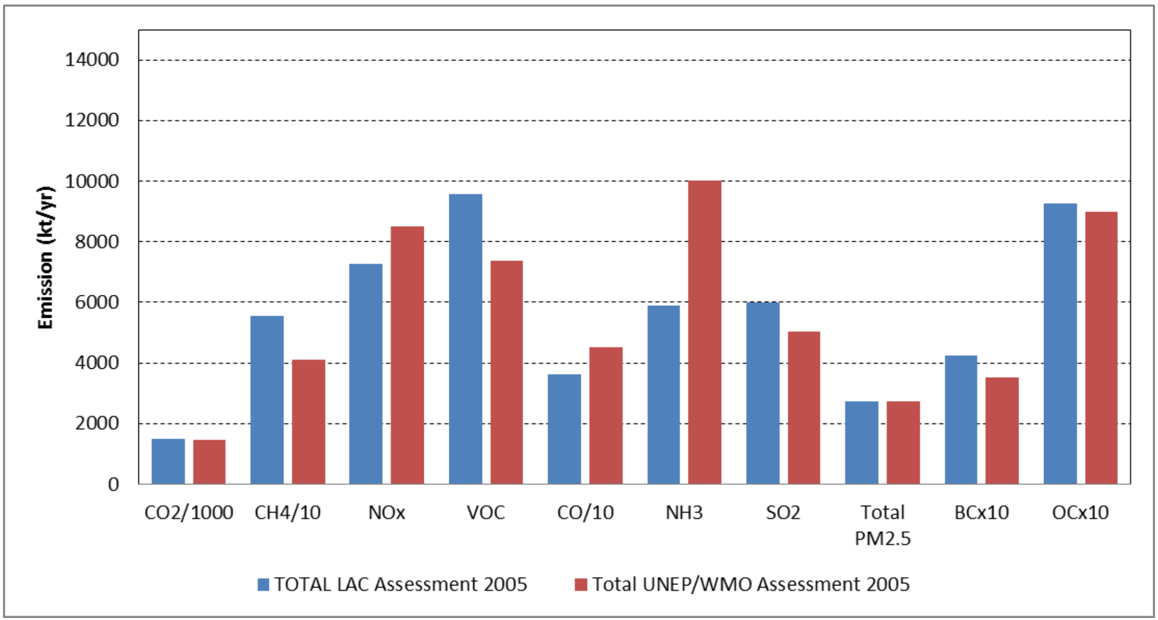


Figure 4.1: LAC emissions for different substances in 2005 in this LAC Assessment compared with the 2005 emissions used in the global Assessment of 2011 (UNEP/WMO 2011).

A closer look at the national estimates vs GAINS model is provided in few examples shown in figures 4.2 to 4.4. We constrain ourselves to few examples where fairly complete national inventory data was available. Comparison of CH_4 emissions presented in Figure 4.2 and 4.3 shows a relatively good agreement at a total level as well as for agriculture and waste emissions. Exception is Mexico where the difference is larger and it is due to underreporting of emission from waste sector which was confirmed by the national experts and the final Assessment report, which is currently under review, will include the correction; the GAINS estimate is consistent with the numbers reported for this sector by Mexico under SNAP. Another feature visible in this comparison is that GAINS is systematically higher due to the estimates for oil and gas industry losses where several countries like Mexico, Bolivia do not report any emissions and other seem to be underreporting this sector. GAINS methodology and global estimates have been documented in (Höglund-Isaksson 2012) and re-evaluated for Latin American countries within this project.

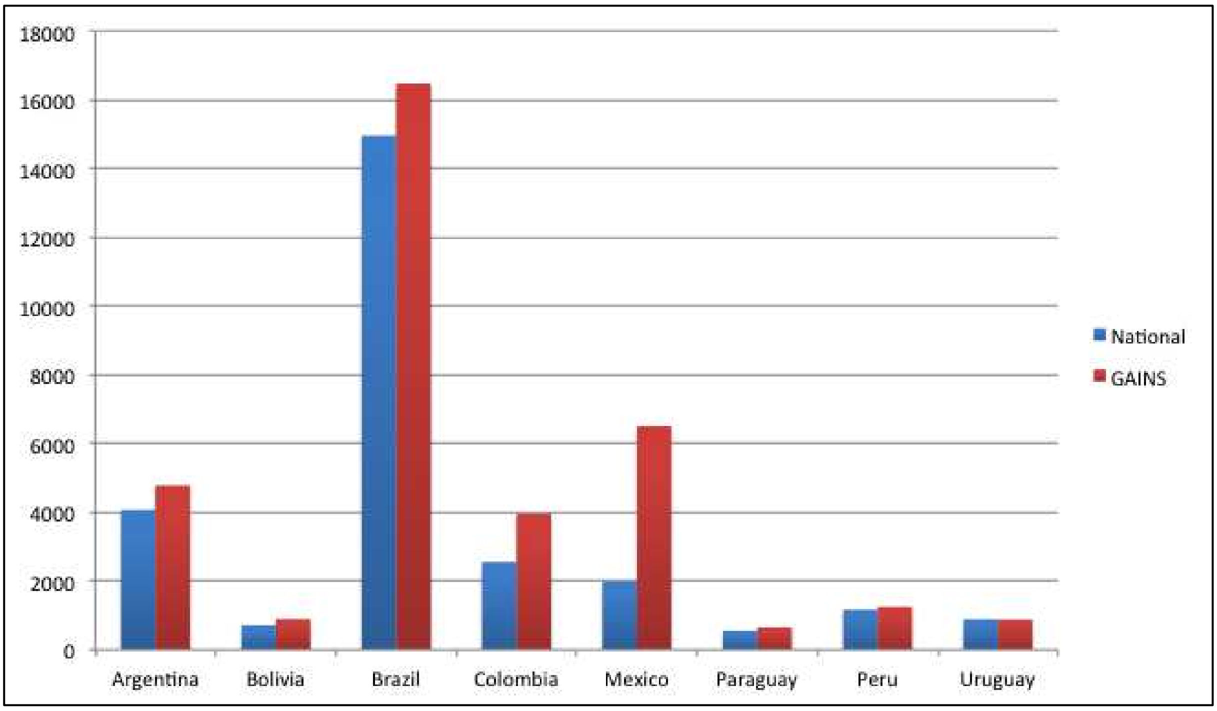


Figure 4.2: CH_4 estimates for countries with near-complete source coverage; all sources kt CH_4

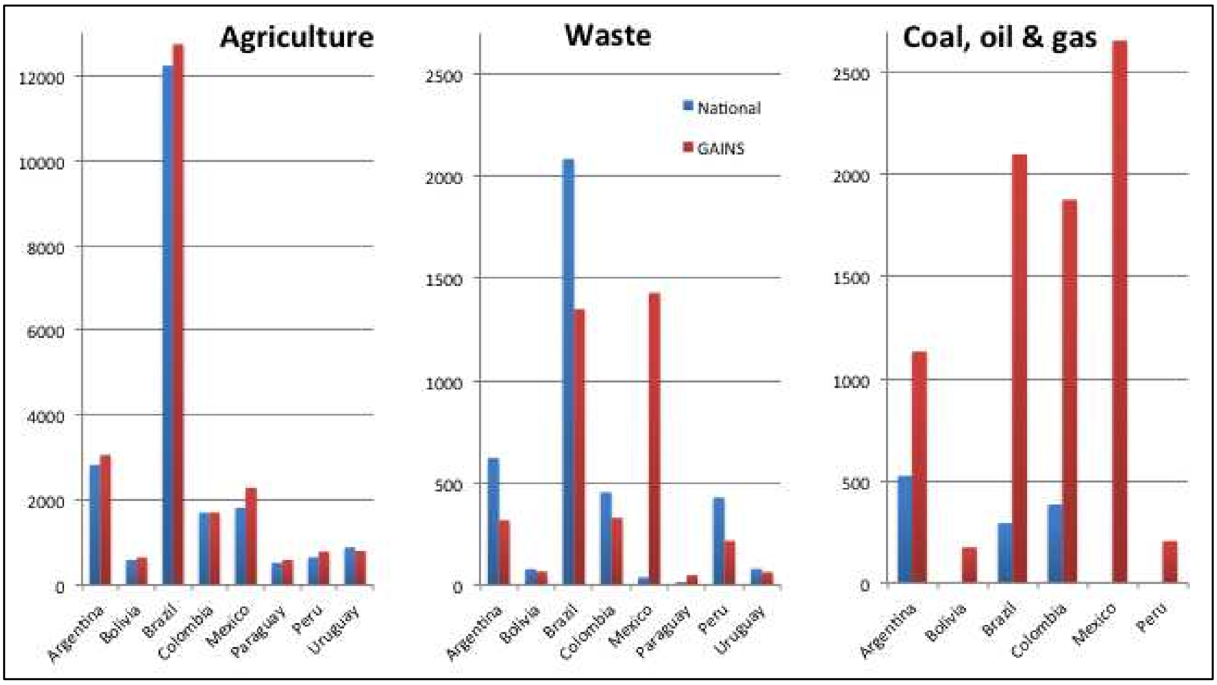


Figure 4.3: CH_4 estimates for key sources; kt CH_4

The comparison for NO_x (Figure 4.4) shows an acceptable match for several countries with GAINS typically estimating slightly higher emissions. One of the reasons is that GAINS includes a systematic assessment of high emitting vehicles which are missing in the inventories. For some countries the differences are, however, larger. For example, the comparison for Chile shows that the national estimate is significantly higher than GAINS but a closer look at the emissions from transport sector (the right panel of Figure 4.4) identifies a rather strange feature of the national inventory; emissions from transport represent virtually 100% of the reported total and they appear higher than the total transport emissions of Mexico which is rather unlikely and needs to be investigated.

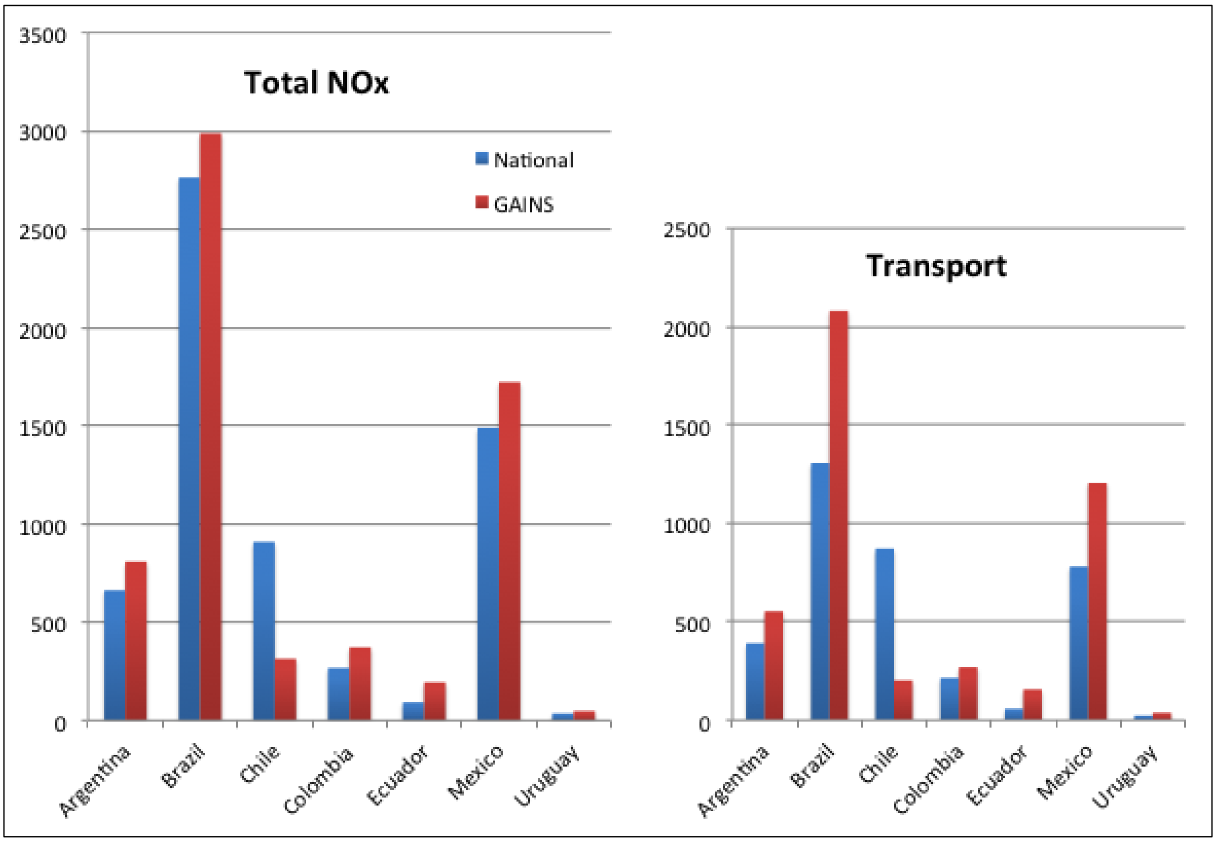


Figure 4.4: Comparison of NOx estimates for countries with near-complete source coverage, kt NO_2

5 Reference scenario for modelling

This section illustrates key features of the base year emissions and the reference scenario developed with the GAINS model. These results have been shared and discussed with the national teams and collaborators within the project. Finally, these estimates were provided to the impact and climate modelling teams as gridded emission sets.

5.1 Key features of GHG and air pollutants emissions in LAC

Figure 5.1 illustrates regional shares of anthropogenic emissions of greenhouse gases and several air pollutants for 2010. While not surprisingly the large countries like Brazil and Mexico appear to dominate the emissions of most species, in case of methane Venezuela takes a very significant share.

For several pollutants the pattern looks similar to that of CO_2 but for SO_2 and particulate matter the patterns are different owing to important role of non-ferrous smelters and residential sector where either strong reliance on solid fuels or exclusively on liquid and gaseous fuels is the reason. Of course in case of ammonia the picture is dependent on the importance of livestock production and therefore not aligned with CO_2 pattern.

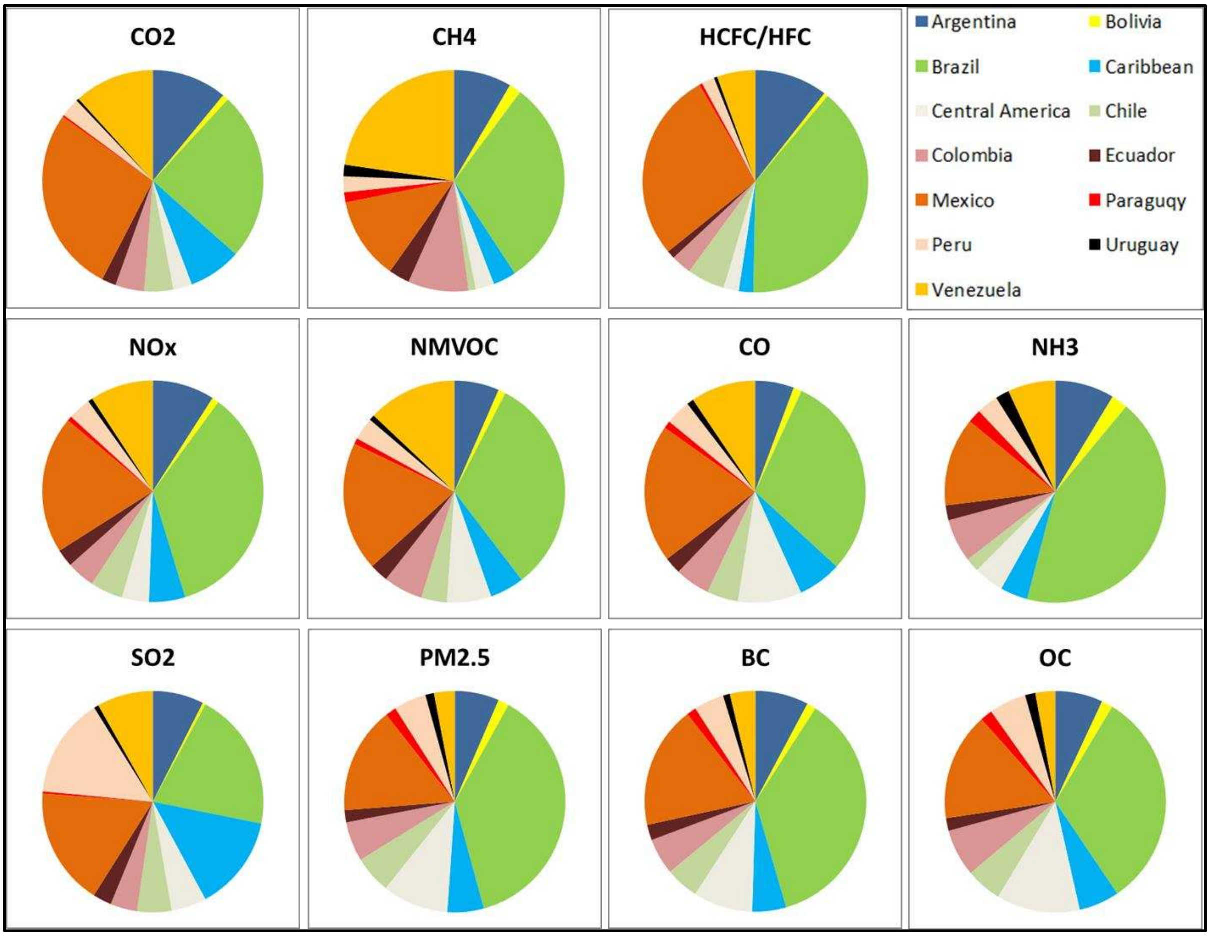


Figure 5.1: Relative contribution of countries and regions distinguished in the analysis to the total emissions of various species in the LAC region in 2010; *GAINS model estimate*

Figure 5.2 shows the sectoral contribution across different pollutants at the level of the total LAC region in 2010 as estimated in the GAINS model. The structure looks fairly different for each of the species shown in the figure. Some of the features resemble the rather typical distribution, for example the structure for methane or NMVOC. While for BC and NO_x the share of transport is very large considering that several countries belong to developing countries where typically BC would have a larger share of residential sector and NO_x higher share of power and industry. These features are however, compatible with the activity data for the region. At the same time this has implications for the SLCP mitigation opportunities.

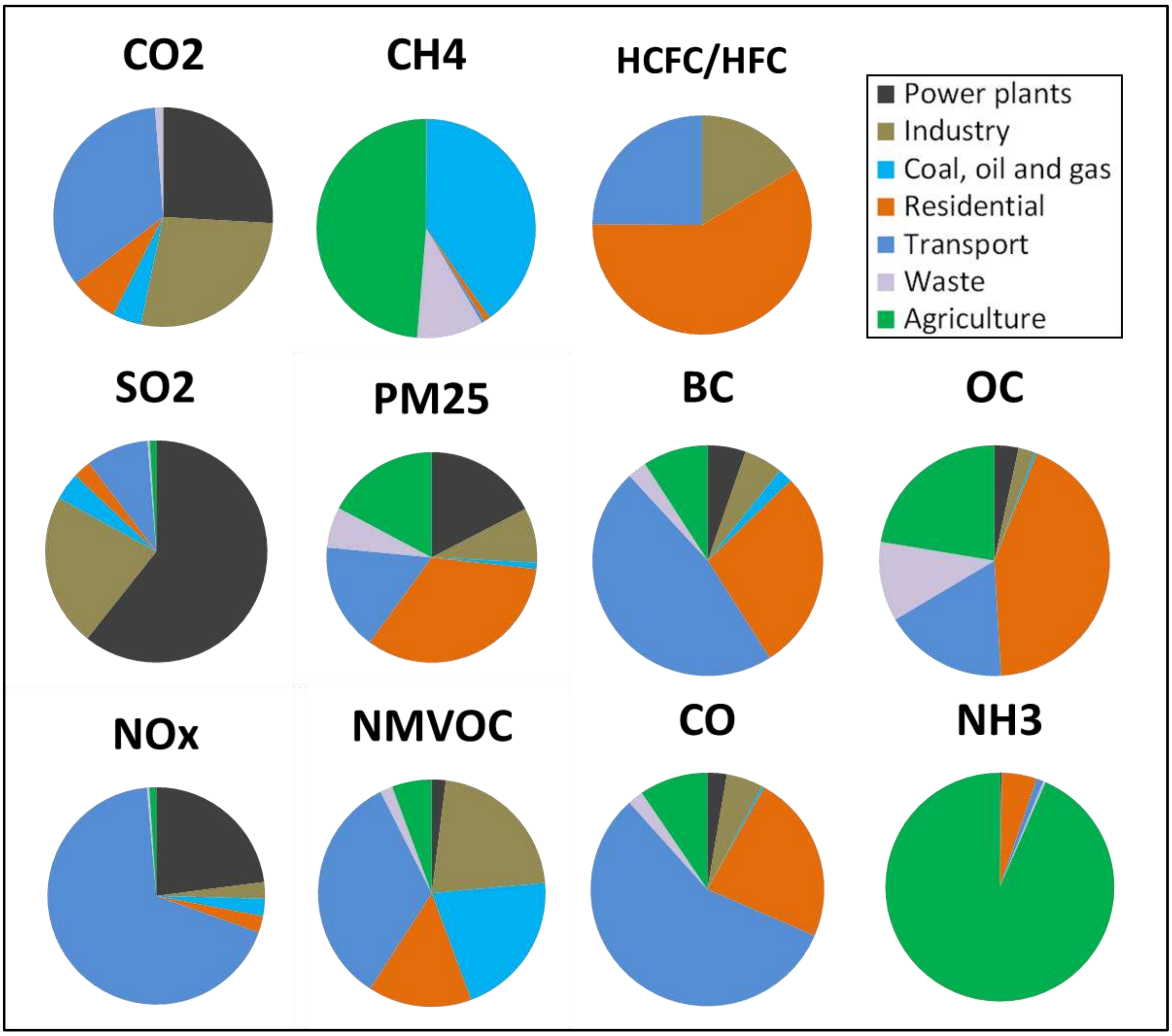


Figure 5.2: Sectoral distribution of emissions of key air pollutants, HFCs, and methane in LAC in 2010; *GAINS model estimation*

5.2 Developing baseline scenarios for LAC

After establishing the base year emissions IIASA has developed the Reference scenario which is based on the energy drivers derived from the IEA energy projections (International Energy Agency 2012) and FAO projections for agriculture (Alexandratos and Bruinsma 2012). While the energy projections are available at the relatively coarse spatial and sectoral resolution, specifically not including each individual country for the modelling region, IIASA distributed the respective data into

GAINS model structures using detailed information form the historical statistics and own databases. Figure 5.3 summarizes key indicators of growth for the whole region, relative to 2010.

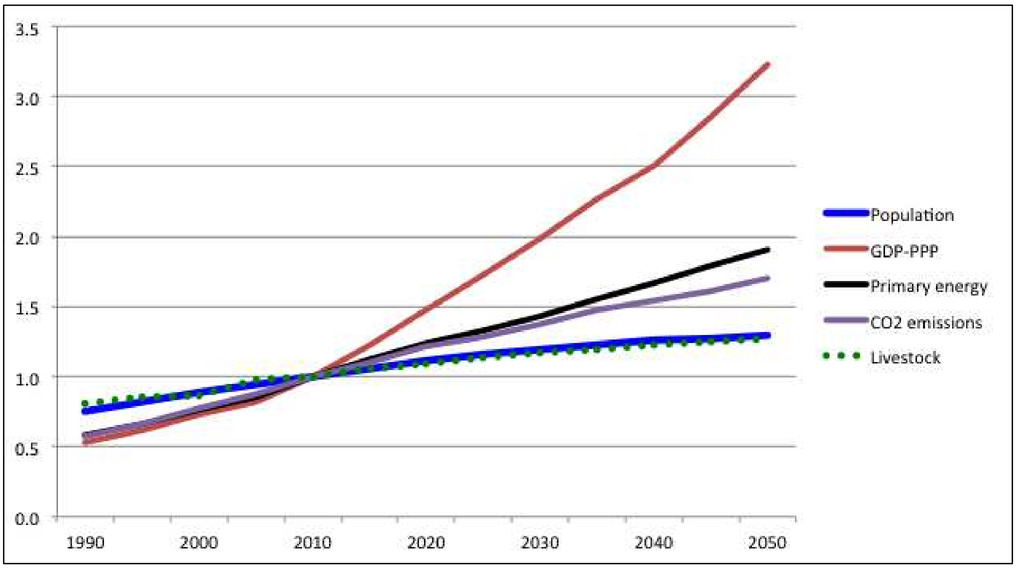


Figure 5.3: Macroeconomic indicators and CO2 emissions in the LAC assumed in the IEA and FAO reference projections; *Change relative to 2010*

The reference scenario includes assumptions that the current legislation (environmental laws as of 2014 documented in international and national documents, which were available from the literature or were provided within the project activities) is timely and efficiently implemented but there is no further development beyond what has been committed so far. Figure 5.4 shows the trends in emissions estimated for the period 2000-2050 in the reference scenario.

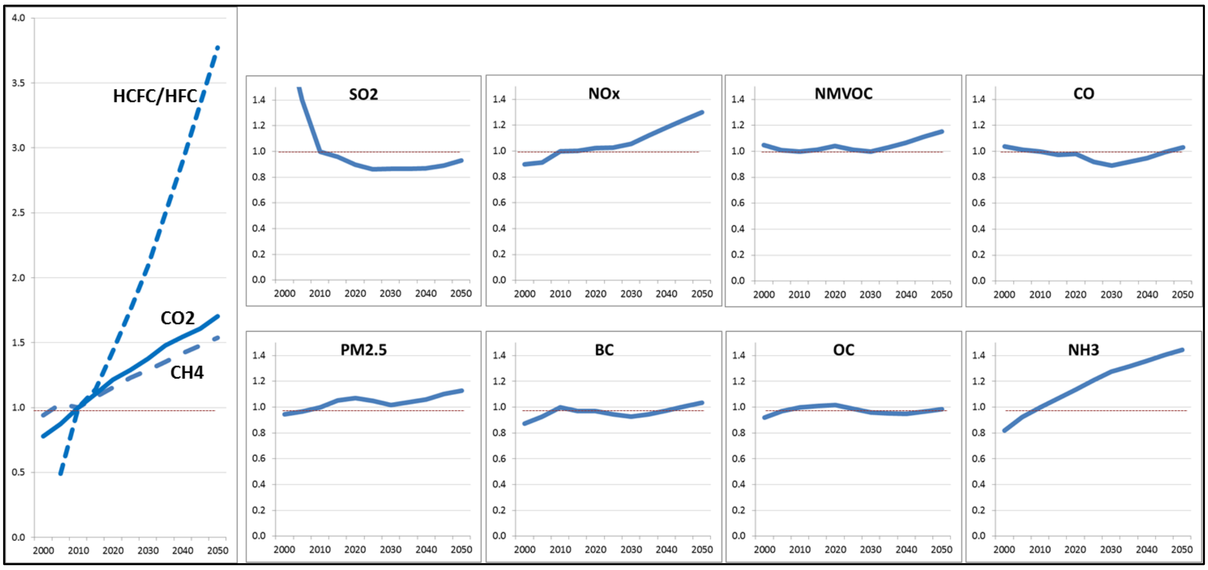


Figure 5.4: Development of greenhouse gases, HFCs, and air pollutant emissions in the current legislation reference scenario used in the assessment; *Changes relative to 2010*

The next three figures illustrate the reference emission developments for methane, black carbon, and HFCs emissions. The projection shows different trajectories for methane and HFCs (Figure 5.5

and 5.7) where continued growth is expected, while BC emission are estimated to stabilize, or even decline slightly in the next decades before potentially increasing again if no further legislation is introduced (Figure 5.6).

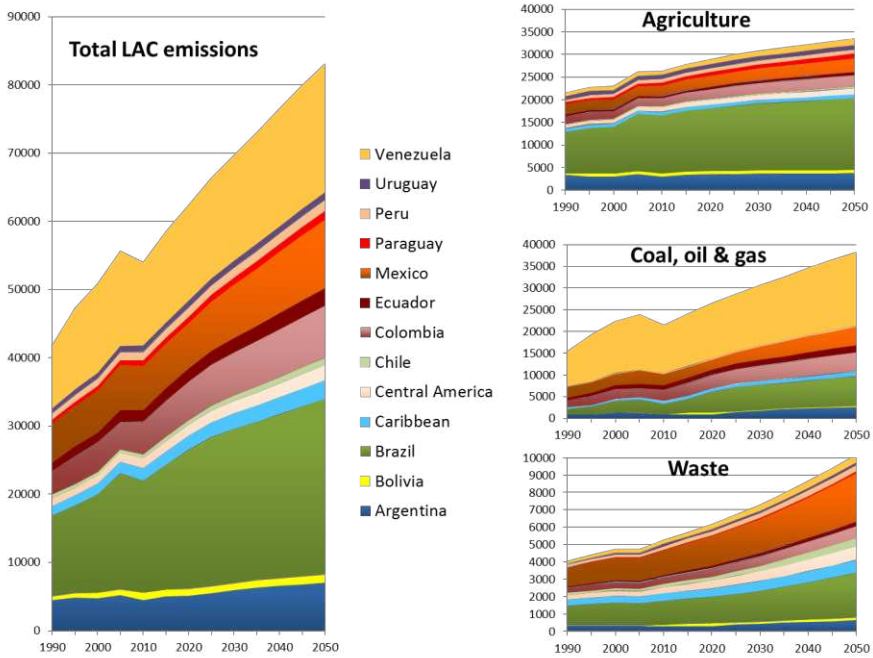


Figure 5.5: Reference scenario for methane emissions in the LAC region and for key sectors.

The Reference developments show also that the structure does not change dramatically in the baseline trajectory offering mitigation potential in sectors like oil and gas production, waste and agriculture for methane and residential combustion and transport for black carbon. At the same time the opportunities are different across the countries.

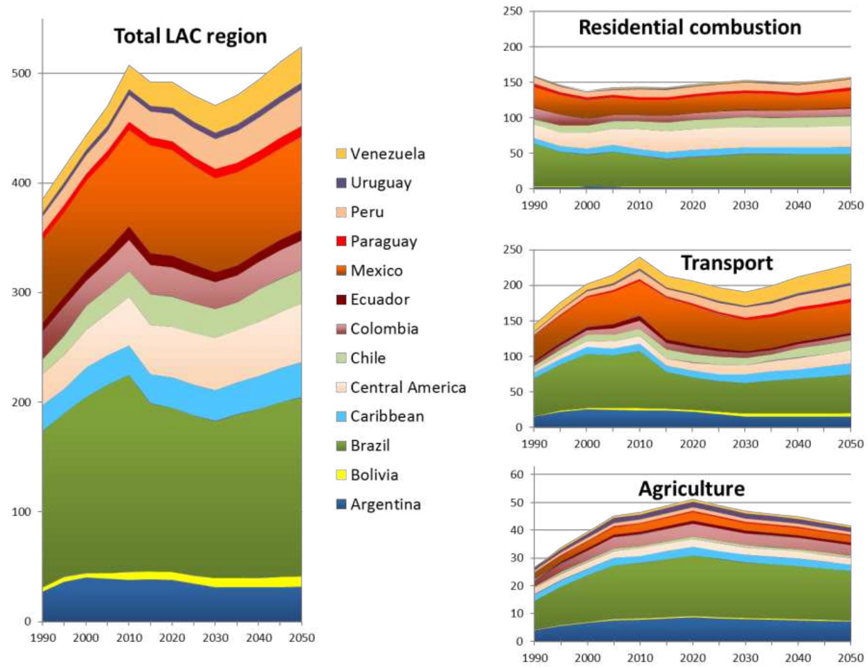


Figure 5.6: Reference scenario for BC emissions in the LAC region and for key sectors.

This assessment includes explicit projections of HFCs emissions for the LAC region (Figure 5.7); this is a new component of the GAINS model and the global Assessment (UNEP/WMO 2011) did not include dedicated HFCs projections. The estimates for specific sectors and their evolution have been discussed with few key regional experts involved in the LAC assessment as well as CCAC.

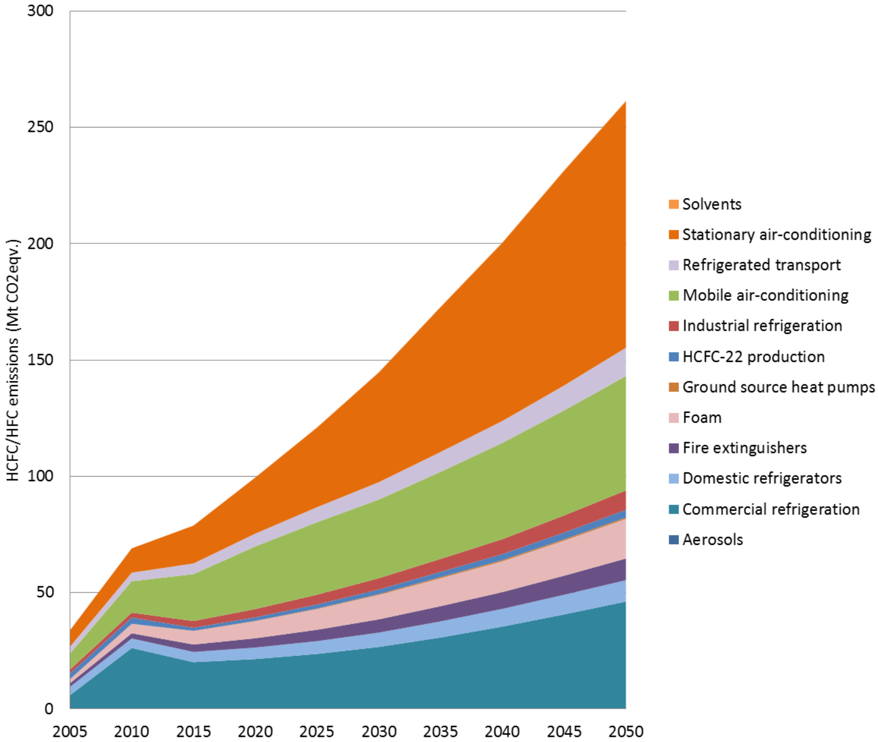


Figure 5.7: Reference scenario for HCFC/HFC emissions in the LAC region by sector.

The Figure 5.8 shows how the new baseline for 2030, developed in this study, compares with the baseline used in the global Assessment in 2011. While the energy demand in the projection is nearly the same, as indicated by the CO_2 emissions, there are important differences in emissions for a number of species. For example, methane emissions are larger, primarily due to a new assessment of emissions from oil and gas industry including explicit consideration of shale gas resources but also the new model resolution allows for better representation of regional emissions and results in a different total. Ammonia emissions are significantly lower in the new estimated which is the result of country specific characteristics that have been introduced; however, ammonia does not play a role in the SLCP strategy. Re-estimation of NMVOC emissions brought a significant increase in emissions in the new baseline which has been driven by improved solvent use assessment but also revision of legislation for transport sector.

For particulate matter, including BC and OC, the changes are not very large at the total LAC level but there is a change in the ratio of BC/OC with new estimates showing a higher share of BC in PM emissions. Additionally, the new estimates have a more realistic distribution between regions and sectors that is of high relevance for the assessment of mitigation opportunities.

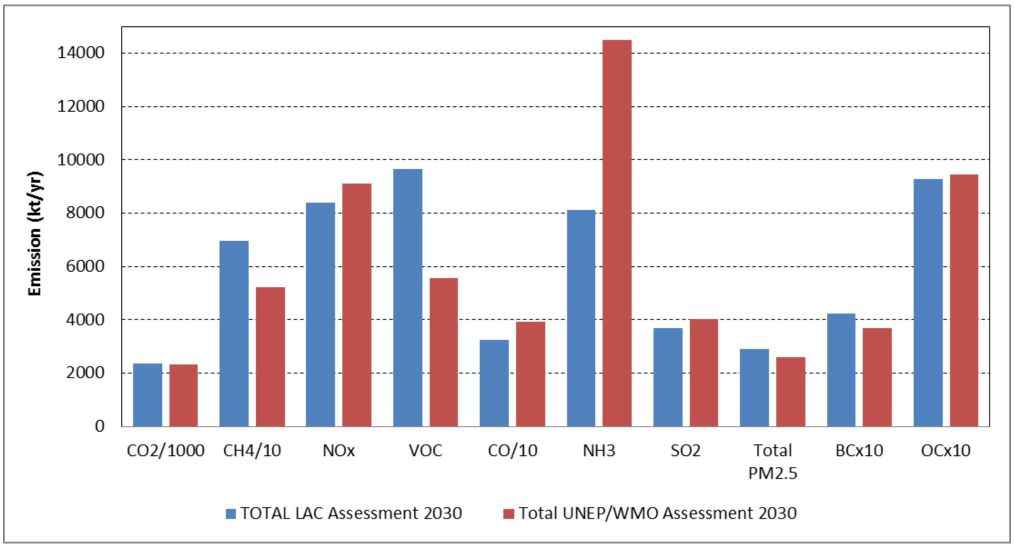


Figure 5.8: LAC emissions for different substances in 2030 in this LAC Assessment compared with the 2030 emission estimates used in the UNEP/WMO Assessment of 2011

6 Developing mitigation scenarios

The mitigation scenarios developed in this study follow the same principles as the ones used in the global assessment, i.e., minimizing radiative forcing from air pollutants and climate while also improving air quality. As indicated above new regional metrics has been used to identify measures but also we have engaged in discussion with the national experts to create a scenario where regionally specific implementation constraints are considered for cook stoves.

The scenarios were developed for LAC and also for the whole world as that is needed for the climate model. All of them were prepared in the same format as the reference set.

6.1 Principles behind measure selection

For each of the reference scenarios (baseline and climate) we have performed an analysis of the forcing change associated with each measure in the GAINS model where every technology includes information about emissions of each considered GHG and pollutant. Such analysis has used the latest dataset on the baseline emissions as discussed above and the final emission factor and technology database of the GAINS model where all extensions and updates were already incorporated. This analysis has produced a long list of measures but typically the first few make the bulk of mitigation potential. We have made a decision to constrain the list of measures to the most relevant in terms of their contribution to the total potential and so a list of about 20 methane and product of incomplete combustion measures were selected to cover over 90% potential to reduce radiative forcing. For HFCs, the mitigation potential is close to 100%. Table 6.1 summarizes the SLCP measures selected across the LAC region following this procedure. While all measures are relevant in the region, the list of measures achieving significant reductions in specific countries varies as is indicated in examples given in section 6.2 of this report and discussed in more detail in the full assessment report in chapter 4 and also chapter 5.

These measures were then the basis to construct the so called ‘control strategy’, which describes the landscape and extend of control technology application. The ‘SLCP’ measures were applied on top (in addition) to the current legislation set so that the air quality does not detoriate. Finally, the application measures in this ‘SLCP’ scenario was only limited by the technical constraints and not considering any economic of political limitations. Such control set was also applied to the climate mitigation scenario that was developed in this project based on the 2 degree (or 450 ppm CO_2) energy pathway of the IEA (International Energy Agency 2012).

Finally, the scenario with a limited application of clean cook stoves based on the advice from the national experts was constructed.

Table 6.1. Measures selected in the SLCP mitigation scenario for LAC

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	○ Separation and treatment of biodegradable municipal waste (MSW) ○ Food industry solid & liquid waste treated in anaerobic digester with biogas recovery
Coal mining	○ Pre-mine degasification and recovery of CH_4 during mining
Agriculture	○ Anaerobic digestion - biogas
Measures addressing incomplete combustion (affecting BC and co-emitted species)	
Households	○ Clean cooking & heating stoves
Transport	○ Euro VI on new vehicles, including particle filters (DPF) ○ Eliminating high emitting vehicles
Industry	○ Modernized coke ovens ○ Modernized brick kilns ○ High efficiency particulate matter controls in industrial biomass & waste combustion
Agriculture	○ Enforced ban of open field agricultural burning
Oil and gas production	○ Reduced gas flaring
HFCs measures	
Transport	○ Switch to low GWP HFC alternatives in mobile air conditioning
Industry and services	○ Implementation of good practices* ○ Training of servicing technicians ○ Technology conversion to lower-GWP or not-in-kind alternatives ○ Reduce the charge size and improve energy efficiency. ○ Ban imports of products containing high-GWP HFCs, unless essential ○ Retrofit/replacement of refrigerants with lower GWP alternatives provided the equipment allows this can be done safely and without jeopardizing energy efficiency.

*Including leakage control, improved components, end-of-life recovery, etc.

6.2 Key results

Figure 6.1 compares the key scenarios for the LAC region. The reference case (*Reference*) is shown against the climate mitigation scenario (*Climate*) and then for each of them the mitigation (*SLCP*) case (see section 6.1) was applied.

As expected there is a significant potential to reduce CH_4, HFCs, and also black carbon. The latter brings a number of associated reductions, especially for OC, PM2.5, CO and to some extend also for NMVOC and NO_x but very little of SO_2 and virtually no co-benefit for ammonia (NH_3). It is also important to note that the climate mitigation scenario (*Climate*) does not bring any significant reductions for BC or OC as it does not include access policy to eliminate biomass from cooking. More details about the reference and mitigation scenarios is available in the full assessment report; chapter 4.

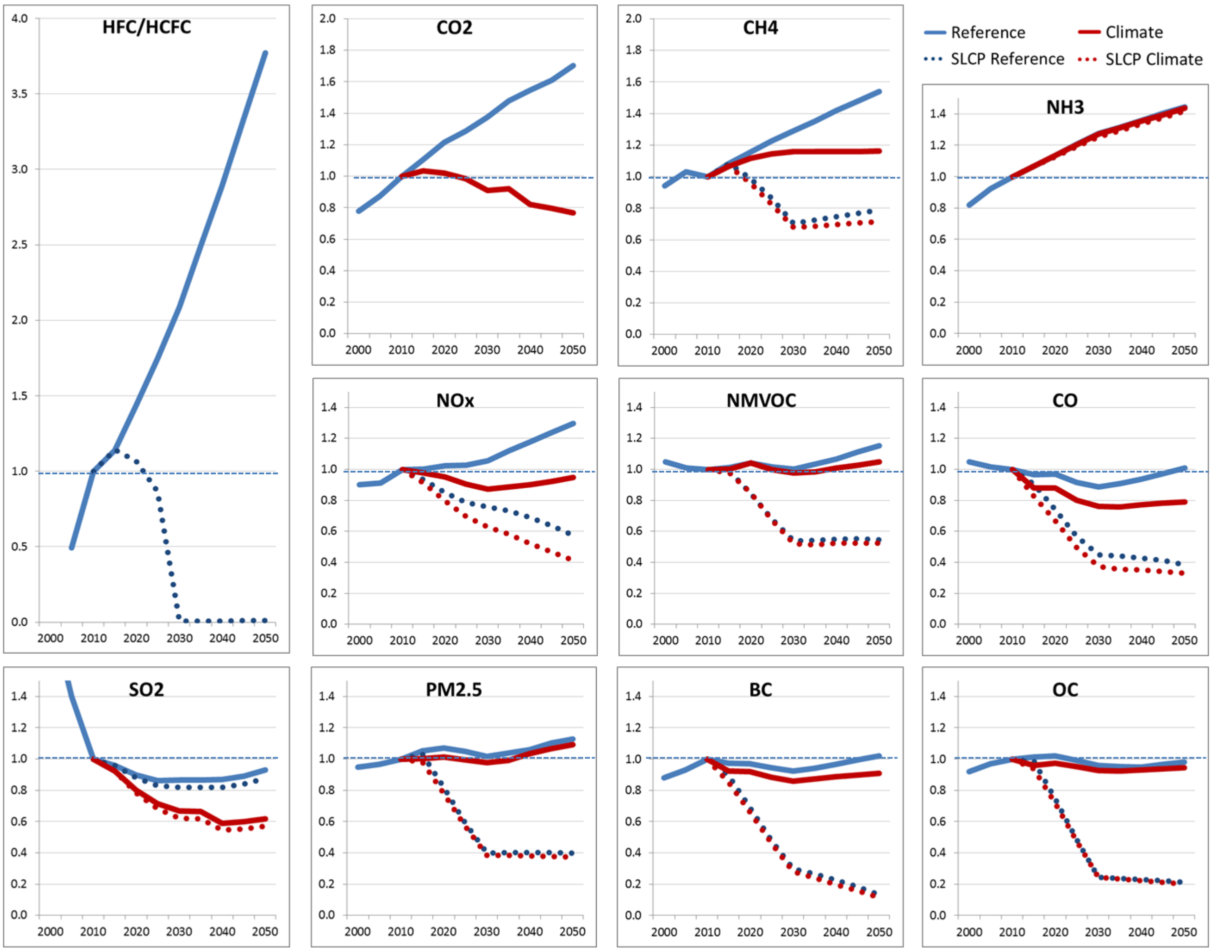


Figure 6.1: Baseline vs SLCP mitigation scenarios, comparison of LAC emissions for different substances for the whole modelling horizon; *changes relative to the year 2010*

The measures selected in the SLCP Mitigation Scenario bring about large reductions in black carbon emissions as shown in Figure 6.2. The whole bars in that figure represent the Reference Scenario emissions, i.e., no additional measures are implemented beyond the current legislation that is included in both Reference and Climate Reference scenarios.

When SLCP mitigation is applied to both the Reference and Climate Mitigation scenarios, the relative mitigation potential due to the SLCP mitigation scenario is nearly the same. At the same time, the mitigation potential increases significantly over time from about 69% in 2030 to about 88% in 2050. The major reason for this is the increased penetration of measures in the transport sector, which combined with the expected high growth of transportation activities leads to higher mitigation potential. The second largest opportunity relates to clean cooking and heating stoves where the reduction potential also increases towards 2050 owing to the assumption that, in the longer-term, barriers to adoption of new technology will be gradually overcome, and more of the poor efficiency cookstoves could be replaced.

While the Figure 6.2 illustrates the mitigation potential at the level of the whole region, similar reductions are achievable at level of single countries, varying from 70 to 90%, and in most cases the same measures are of importance, especially transport sector that is dominating mitigation potential in nearly all countries, followed by clean cooking and heating stoves. For the other sources there is a larger variability across the region, see detailed discussion and illustration in the full assessment report, chapter 4, 5, and Annex 4.1.

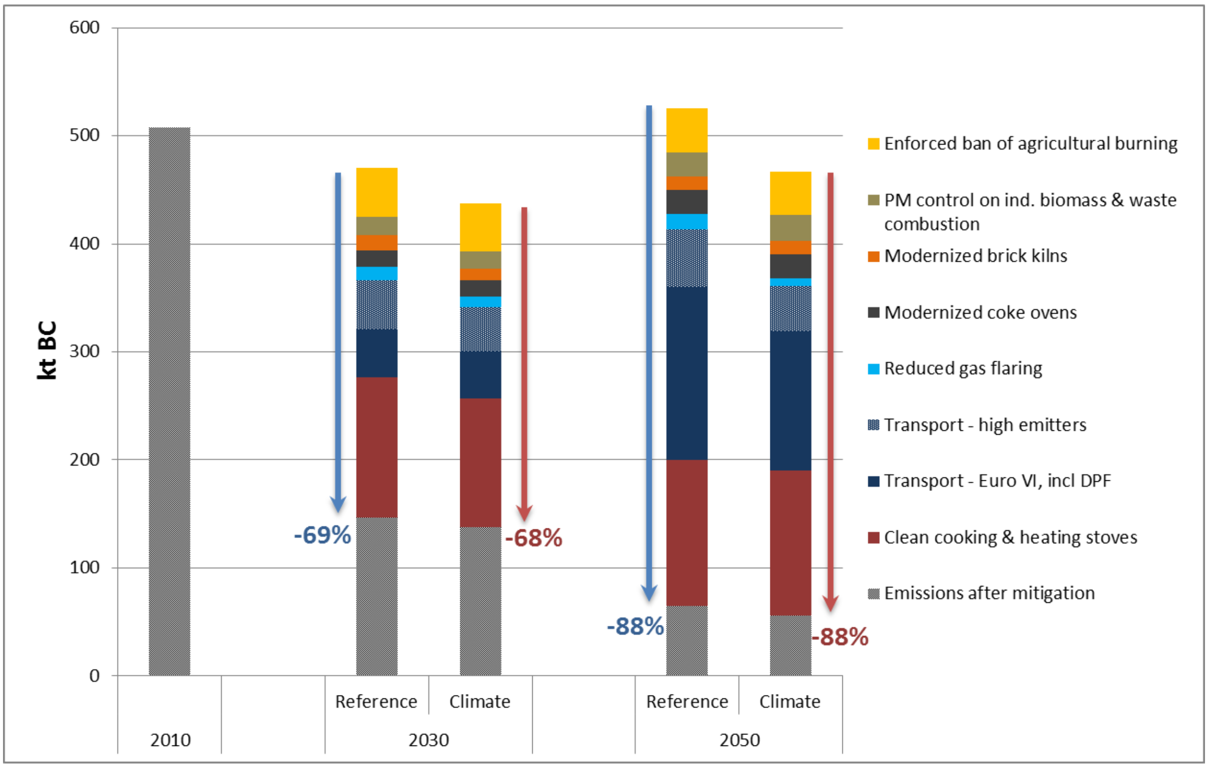


Figure 6.2: Emission reductions of black carbon (BC) in 2030 and 2050, compared to the Reference and Climate scenarios, from the full implementation of SLCP measures (in the SLCP Mitigation scenario) in all parts of LAC

In contrast to BC, emissions of methane in the Reference Scenario are projected to increase significantly (see the full bars in Figure 6.3) and the selected measures could reduce emissions by nearly 50% by 2050. The estimated mitigation potential in the Climate Reference scenario is lower, at about 40% (Figure 6.3). This is because achieving climate mitigation goals is associated with a reduced demand for fossil fuels, which translates into lower oil and gas production in the region and, consequently, lower emissions from one of the key sectors and this also reduces the potential for mitigation of methane emissions.

It is assumed that methane measures can be effectively implemented within the next few decades as, for all of them, the respective technologies are available and there is enough experience in other parts of the world (Höglund-Isaksson 2012, UNEP/WMO 2011, USEPA 2013) and to some extent also in the LAC region (see for detailed discussion in the chapter 5 of the full assessment report).

At the regional level, mitigation of methane emissions from the oil and gas production sector represents about 60-75% of the total reduction potential, depending on the time period and scenario. The next most important measures are separation and treatment of biodegradable municipal solid waste with over 10% of reduction (nearly 20% in 2050 in the Climate scenario) and treatment (with gas recovery) of solid and liquid waste in food industry bringing nearly 10% reduction (about 15% in 2050 in the Climate Reference scenario). There are strong differences across the region as to which measures appear most promising but oil and gas, MSW, and industrial waste dominate in all countries; for more details see chapter 4,5, and Annex 4.1 in the full report.

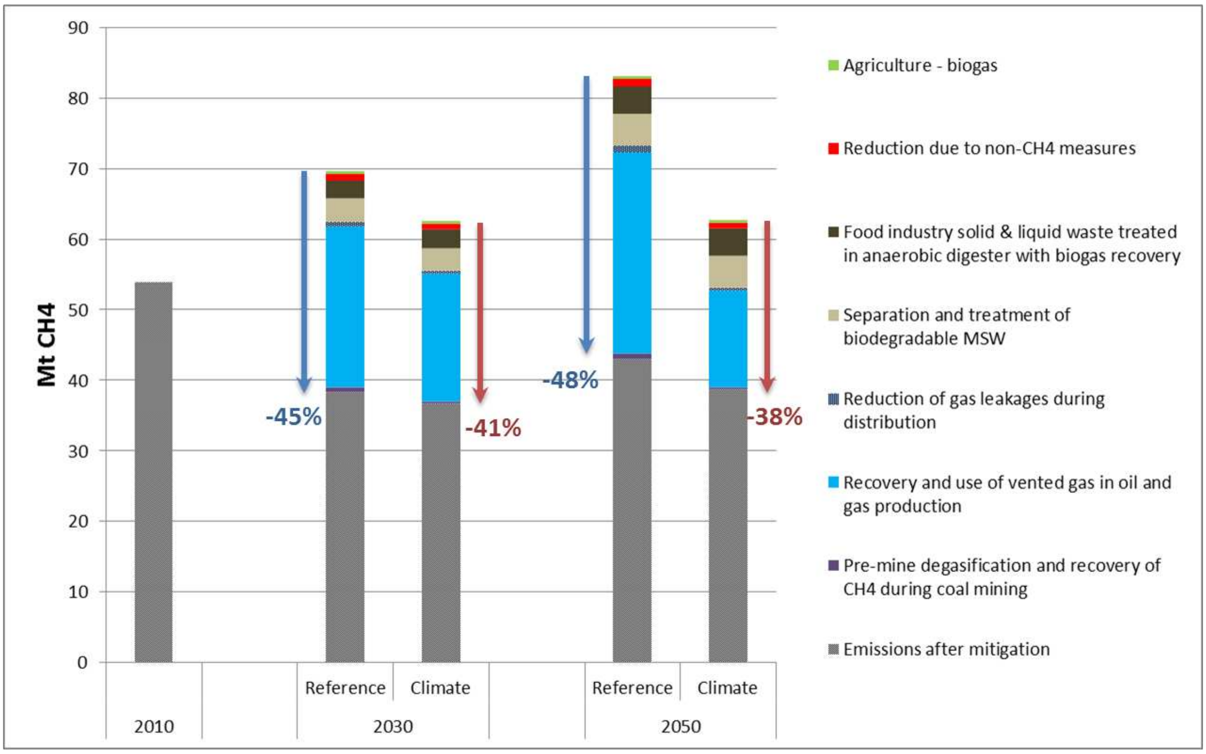
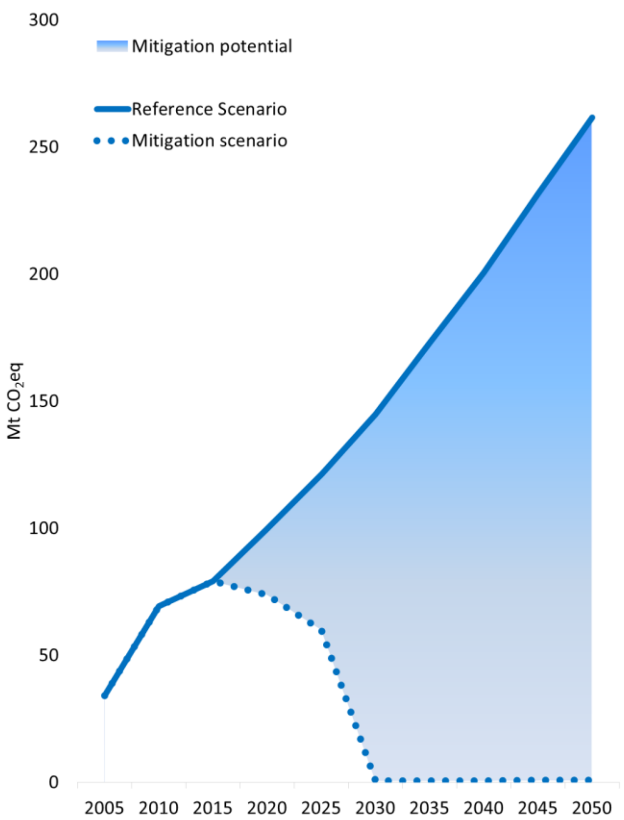


Figure 6.3: Emission reductions of methane (CH_4) in 2030 and 2050, compared to the Reference and Climate scenarios, from the full implementation of measures (SLCP Mitigation scenario) in LAC.



Significant mitigation potential has been estimated for HFCs emissions. The maximum technical mitigation potential (MTFR) is presented against the Reference Scenario for the LAC region and is depicted by the dotted line in Figure 6.4. In 2050, the technical mitigation potential exceeds 98 percent of Reference Scenario emissions. The key seven HFCs measures (Table 6.1) address emissions of HFCs by refrigerants in transport, industry and services.

Figure 6.4: HFC emissions in Reference and Mitigation scenarios in the LAC region in the period 2005-2050 estimated in the GAINS model.

7 Providing data to impact models

From the beginning of June 2015, the datasets with baseline emissions and later on in July with the mitigation cases were provided to the several modelling groups assessing concentrations of various species as well as impacts in the base year and future and finally climate impacts. The data was provided for several scenarios as gridded datasets for the period 1990-2050 in five year intervals and 0.5^{o}x0.5^{o} longitude-latitude grid.

IIASA carried discussion with the modelling teams about the formats, sources of additional data needed including small extra calculations including assessment of average lifetimes of specific HCFCs and HFCs. IIASA has also participated and contributed to the discussion of the impact results presented in detail chapter 3 and 4, especially with respect to climate and health impacts.

8 Participation and contribution to the project meetings

IIASA has participated in a number of meetings associated with the Assessment. More specifically, the kick-off meeting in June 2014 in Panama, the follow up meeting in September 2014 in Natal (Brazil), the author meeting in January 2015 in Mexico City, and the high level policy consultation meeting in September 2015 in Mexico City where the preliminary results of the Assessment were presented to the representatives of several institutions including Ministries of Environment and air quality departments from most of the countries of Latin America and Caribbean.

At all of these meeting IIASA delivered one or several presentations, which are available along the minutes of the meetings from the repository, organized by INEEC and ROLAC.

Finally, IIASA has been writing or contributing to several parts of the report, primarily chapter 2, 4, Annexes to full report, and SDM.

9 Next steps

While the technical work on the databases, development of scenarios and contributing to the writing of the report has been completed, we are still awaiting the comments of the reviewers to the full report. Consequently, once the review is completed, IIASA will work on the response to the reviewers and if necessary revision of the final assessment document.

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