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Evaluating the **Cl**imate and Air Quality **I**m**p**acts of **S**hort-Liv**e**d Pollutants

Collaborative Project

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Impacts of the ECLIPSE set of emission control measures on air quality and climate metrics

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ABSTRACT

This paper reveals considerable benefits of the ECLIPSE set of emission control measures both for human health and the GTP20/GWP100 climate metrics. Just for India and China alone, implementation of these measures could save annually up to 900,000 cases of premature deaths from air pollution in the long run. At the same time, they would reduce climate forcing, especially in the near-term. The GTP20 indicator of European emissions of short- and long-lived greenhouse gases (including CO_2) could be reduced by more than half, and of Chinese emissions by one third.

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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1 Introduction

Climate policies under the UNFCCC framework currently address only greenhouse gases (GHGs) with relatively long lifetimes. In addition to these longer-lived GHGs, shorter-lived substances (especially ozone and aerosols including black carbon) – collectively called short-lived climate pollutants (SLCPs)– also can make significant contributions to climate change, especially in the near term, but are currently not included in the UNFCCC.

At the same time, these substances deteriorate air quality at the hemispheric, regional and local scales and contribute to a wide range of harmful effects on human health and vegetation. Because of their air quality impacts, these substances are already subject to specific air quality management strategies throughout the world. However, these strategies do currently not consider climate impacts or how the synergies between air quality and climate change strategies could be maximized.

This report summarizes work conducted under the FP7 ECLIPSE project on a sub-set of emission reduction measures that would simultaneously benefit climate change and local air quality. Out of the full range of available air pollution control measures, WP7 of ECLIPSE has identified a sub-set that would achieve the largest reductions for two alternative climate metrics, i.e., for the GTP20 (the Global Temperature Potential over 20 years) and the GWP100, i.e., the Global Warming Potential over 100 years. These metrics have been developed under WP4 of ECLIPSE , and the selection of promising measures described in detail in Deliverable D7.3 of the ECLIPSE project.

This report quantifies the improvements in air quality and resulting effects on human health and vegetation that would result from the implementation of these measures in Europe and China. It also provides their effects on the selected climate metrics, which can then be compared with the outcomes of the GCM model experiments that have been conducted under the ECLIPSE project.

This report is organized as follows: Section 2 recalls the ECLIPSE set of emission control measures and summarizes their impacts on emissions. Section 3 presents the health impacts from these emission reductions, and Section 4 discusses their effect on climate metrics.

2 A set of measures that result in simultaneous air quality and climate benefits

This report examines the impacts of a set of emission control measures that simultaneously benefit air quality and climate, on human health. The work employs the baseline projection of global emissions that has been developed under ECLIPSE WP1, and estimates the emission reduction potential from a set of measures that have been identified in WP7 as beneficial for air and climate objectives.

2.1 Baseline emission projections

In the baseline case, global anthropogenic emissions of CH_4 are expected to increase by approximately one third between 2000 and 2050 as a consequence of growing population and higher levels of economic activities. At the same time, anthropogenic emissions of BC, OC, CO and SO_2 are likely to stabilize or even slightly decline at the global level, due to changes in lifestyles and industrial structures that are implied by the anticipated economic development, as well as due to progressing implementation of current air pollution emission control legislation.

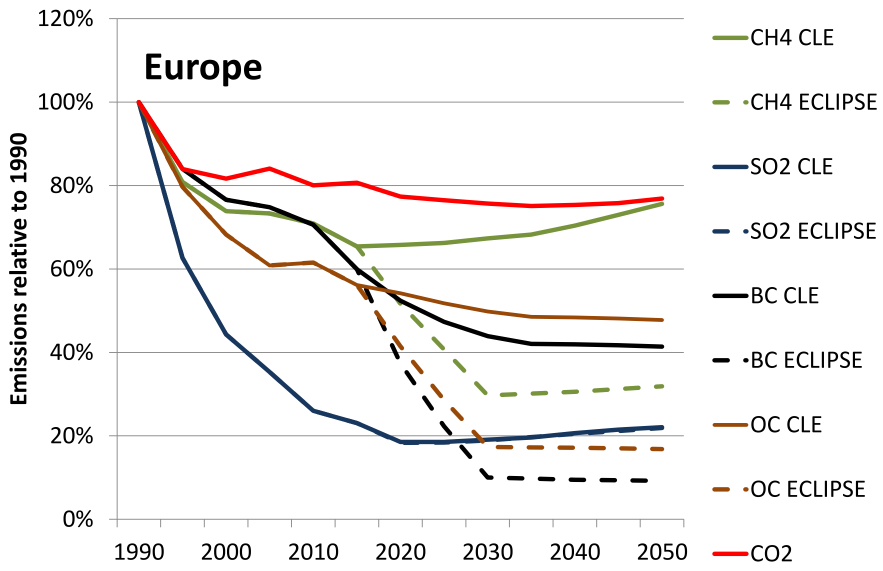

Figure 1: Evolution of emissions of the Baseline Current legislation (CLE) and the ECLIPSE scenarios for Europe (incl. European part of Russia), relative to 1990

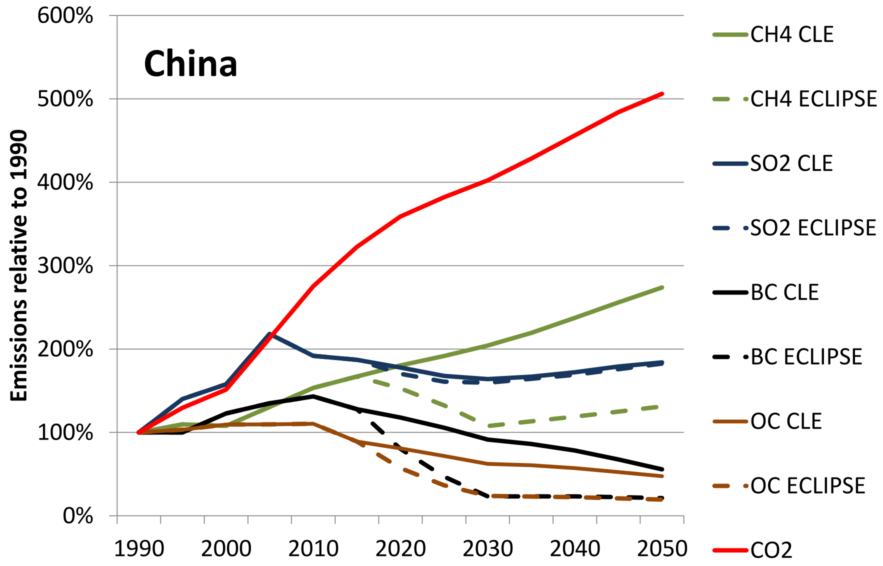

Figure 2: Evolution of emissions of the Baseline Current legislation (CLE) and the ECLIPSE scenarios for China, relative to 1990

Table 1: Emissions for the Baseline Current legislation (CLE) and ECLIPSE scenarios for Europe (kilotons, CO_2 Mtons)

		1990	2000	2010	2020	2030	2040	2050
CH_4	CLE	56.4	41.7	40.0	37.1	38.0	39.7	42.7
	ECLIPSE				29.2	16.7	17.3	18.0
SO_2	CLE	38.3	17.0	10.0	7.1	7.3	7.9	8.4
	ECLIPSE				7.0	7.2	7.8	8.4
NO_x	CLE	27.3	18.9	14.5	11.1	9.4	9.0	9.1
	ECLIPSE				9.5	7.8	7.7	7.8
VOC	CLE	26.5	17.7	12.1	10.0	9.2	9.1	9.2
	ECLIPSE				8.0	4.2	4.2	4.2
BC	CLE	0.8	0.6	0.6	0.4	0.4	0.3	0.3
	ECLIPSE				0.3	0.1	0.1	0.1
OC	CLE	1.3	0.9	0.8	0.7	0.6	0.6	0.6
	ECLIPSE				0.5	0.2	0.2	0.2
CO	CLE	91.0	61.7	46.5	36.3	33.8	34.6	35.5
	ECLIPSE				29.4	20.3	21.9	22.8
NH_3	CLE	7.6	5.8	5.3	5.4	5.5	5.6	5.7
	ECLIPSE				5.3	5.4	5.5	5.6
CO_2		7.2	5.9	5.8	5.6	5.4	5.4	5.5

Table 2: Emissions for the Baseline Current legislation (CLE) and ECLIPSE scenarios for China (kilotons, CO_2 Mtons)

		1990	2000	2010	2020	2030	2040	2050
CH_4	CLE	33.7	36.3	51.6	60.7	68.7	79.9	92.2
	ECLIPSE				51.4	36.3	40.0	44.1
SO_2	CLE	16.3	25.7	31.2	28.9	26.7	28.0	30.0
	ECLIPSE				27.7	26.0	27.5	29.7
NO_x	CLE	8.0	13.5	23.0	29.2	31.1	34.8	37.0
	ECLIPSE				27.2	29.1	32.3	34.3
VOC	CLE	14.5	18.6	22.9	26.0	23.8	24.6	25.3
	ECLIPSE				19.5	8.2	8.5	8.7
BC	CLE	1.3	1.7	1.9	1.6	1.2	1.1	0.7
	ECLIPSE				1.1	0.3	0.3	0.3
OC	CLE	3.7	4.1	4.1	3.0	2.3	2.1	1.8
	ECLIPSE				2.1	0.9	0.8	0.7
CO	CLE	116.9	154.1	188.7	187.1	153.3	151.1	139.8
	ECLIPSE				156.2	110.3	113.0	110.2
NH_3	CLE	9.5	11.3	14.5	16.0	17.5	18.1	18.6
	ECLIPSE				15.9	17.3	17.9	18.5
CO_2		3.9	6.0	10.9	14.2	15.9	18.0	20.0

2.2 *Promising measures that would offer substantial reductions in climate impacts*

Emissions of individual short-lived substances have impacts on near-term climate change, some of them heating and others cooling. At the same time, virtually all emission control measures have simultaneous impacts on a wide range of emitted substances. Only the net effect on forcing that results from these emission changes will determine the overall effect of a particular measure.

As the net effect of specific emission control measures can be positive or negative, a small portfolio with the most important measures has been identified that could yield in 2030 the largest reductions in radiative forcing from short-lived substances at the global scale. Other measures that have only relatively small net impact or would even increase radiative forcing are excluded from this portfolio.

This analysis employed the technology and emission databases of the IIASA GAINS (Greenhouse gas – Air pollution Interactions and Synergies) model, which estimates mitigation potentials for the full range of air pollutants and greenhouse gases of approximately 2000 emission control measures in 168 regions in the world.

The analysis estimated, for each of the 2000 mitigation measures included in GAINS, their impacts on the emissions of all pollutants that are affected (i.e., CH_4, CO, BC, OC, SO_2, NO_x, VOC, CO_2) in each source region. In a further step, the net effect of these emission changes on radiative forcing at the global scale has been estimated for each measure, and measures have been ranked accordingly.

Finally, out of the about 130 measures that lead to lower radiative forcing, the top 17 measures have been selected that collectively achieve nearly 90% of the overall mitigation potential (Figure 3). These measures are not simply theoretical constructs but many of these measures are already applied today, at least in some parts of the world.

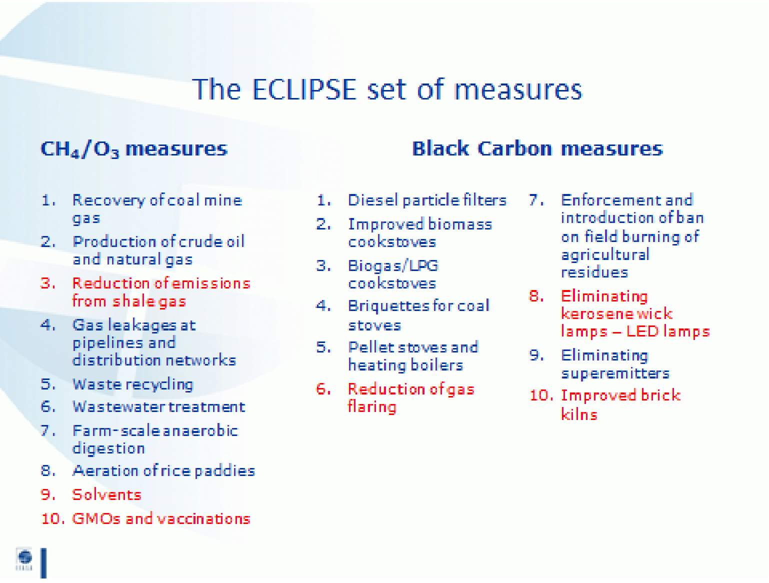

Figure 3: The ECLIPSE set of win-win emission reduction measures that result in improved air quality and climate indicators

This analysis has been conducted for the new set of emission projections that have been developed by ECLIPSE (see WP1), taking into account recent information on additional emission sources and control measures that could potentially have a succinct impact on temperature increase. As a result of this new information, compared to the original set of emission reduction measures that has been presented in the seminal SLCF assessment (Shindell et al. 2012), the ECLIPSE package includes now a number of new intervention options:

- Reduction of emissions from shale gas operations
- Reduction of solvents emissions
- Use of GMOs and vaccines to reduce CH_4 emissions
- Control of emissions from gas flaring
- Replacement of kerosene lamps with LED or other lights
- Improved brick kilns.

2.3 Impacts on emissions

The impacts of these measures have been explored for the baseline scenario that is described in Deliverable D1.6.

These 17 measures achieve for the baseline case up to 80% reductions of BC and OC, reduce PM2.5 and CO by 50-60%, methane by 40%, NO_x by 30%, but they affect SO_2 and CO_2 emissions only marginally. In contrast, full application of all 2000 measures would reduce all compounds by 70-90%, except methane (-45%) and CO_2. The climate scenario without further emission controls, due to its lower consumption of fossil fuels and the CH_4, leads to 30% lower CO_2, CH_4 and SO_2 emissions and 20% lower NO_x, but does not significantly change emissions of BC, OC and CO. Thus, the 17 measures would yield similar reductions in these emissions as in the baseline case, and are therefore independent from climate policies.

At the global level, for both scenarios the largest potential for reductions of BC, OC and CO emissions emerges in the residential and transport sectors. However, in developing countries a sizeable potential has been identified for brick kilns, coke ovens and open burning of agricultural waste. For CH_4, largest potentials exist for fossil fuel production and distribution, waste treatment and livestock.

About two thirds of the total potential is offered by technical measures, with the important exception of BC, for which technical measures will only deliver half of the total potential reductions, and CH_4 where only little potential remains for non-technical measures. While measures are directed at BC and OC components of particulate matter, total primary PM2.5 emissions will decline to a lesser extent.

3 Health impacts of an implementation of the ECLIPSE set of measures

The GAINS model (Amann et al. 2011b) has been used to estimate the health effects from the set of the 17 measures that have been selected for ECLIPSE. As mentioned above, the analysis takes full account of the co-control of emission control measures on multiple pollutants, i.e., that measures simultaneously affect several substances at the same time.

GAINS quantifies the impacts of changes in the precursor emissions of fine particulate matter, i.e., primary emissions of PM2.5, as well as SO_2, NO_x, NH_3 and VOC as precursors for secondary (organic and inorganic) aerosols on the population exposure to PM2.5 in Europe, China and India.

GAINS estimates premature mortality that can be attributed to this long-term exposure to outdoor pollution, in terms of reduced statistical life expectancy and in cases of premature deaths (Amann et al. 2011a). Calculations follow the recommendations of the findings of the WHO review on health impacts of air pollution (WHO, 2003, WHO, 2007) and recent analyses conducted for the Global Burden of Disease (BG) project (Lim et al. 2012; Burnett, R.T. 2010), relying the results of the American Cancer Society cohort study (Pope et al., 2002) and its re-analysis (Pope et al., 2009). It uses cohort- and country-specific mortality data extracted from life table statistics to calculate for each cohort the baseline survival function over time. As the relative risk function taken from Pope et al., 2002 applies only to cohorts that are at least 30 years old, younger cohorts were excluded from this analysis. To reflect different causes for deaths between developed and developing countries, the lower range of relative risk factors found for the US population has been applied to China and India. Future premature mortality is estimated from country-specific death rates projected by the WHO (WHO 2010), which are applied to UN population projections (UN-ESA 2011).

3.1 Europe

With these assumptions, it is estimated that in the EU the loss of statistical life expectancy will reduce from 7.5 months in 2010 to 5.2 months in 2030, due to changes in the energy structure and progressing implementation of current emission control legislation. The ECLIPSE measures would reduce statistical life shortening by another 0.9 months. This would then result in 4.3 months of lost life expectancy, which is only slightly above the target of 4.1 months that has been set by the European Commission in its 2013 Clean Air Policy proposal (EC 2013a; EC 2013b; Amann et al. 2014).

Population in non-EU countries would gain approximately one month life expectancy from the implementation of the ECLIPSE measures in 2030 (Figure 4). Results for individual countries are presented in Table 3.

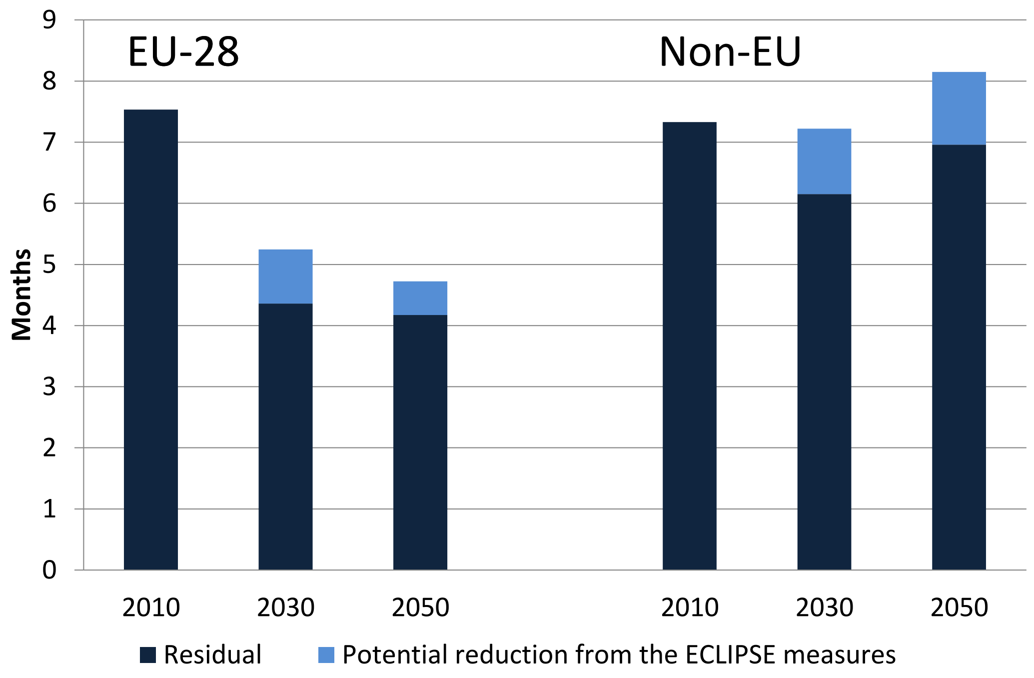

Figure 4: Loss of statistical life expectancy due to the exposure to PM2.5 (months) in Europe

Table 3: Loss of statistical life expectancy in Europe due to the exposure to PM2.5, 2010, baseline projections for 2030 and 2050, and the improvements that would be delivered by the ECLIPSE measures (months)

	2010	2030 CLE	Potential gains from ECLIPSE	2050 CLE	Potential gains from ECLIPSE
Albania	6.2	4.3	-0.7	4.5	-0.5
Austria	6.3	4.5	-0.6	4.2	-0.5
Belarus	6.9	6.2	-0.7	6.6	-0.7
Belgium	8.6	6.2	-0.9	5.6	-0.4
Bosnia-H.	7.4	4.2	-0.4	4.7	-0.3
Bulgaria	10.3	5.8	-0.9	5.7	-0.7
Croatia	7.2	4.7	-0.6	4.7	-0.5
Cyprus	5.8	6.2	-0.4	6.7	-0.2
Czech Republic	8.4	5.9	-0.8	5.5	-0.7
Denmark	5.7	3.7	-0.8	3.0	-0.2
Estonia	4.9	3.9	-0.8	3.6	-0.5
Finland	3.7	2.9	-0.4	2.8	-0.3
France	7.0	4.6	-0.9	4.0	-0.4
Germany	7.0	5.1	-0.5	4.5	-0.3
Greece	10.3	6.4	-1.5	6.0	-1.0
Hungary	9.1	6.1	-0.9	5.9	-0.8
Ireland	3.0	2.3	-0.2	2.1	-0.1
Italy	9.5	6.3	-0.6	5.5	-0.4
Latvia	5.6	4.4	-0.9	4.2	-0.6
Lithuania	6.4	4.9	-0.7	4.8	-0.5
Luxembourg	7.9	5.4	-0.7	5.0	-0.4
Macedonia	7.7	4.1	-0.5	4.2	-0.4
Malta	7.7	4.3	-1.4	3.0	-0.1
R. Moldova	8.3	6.7	-0.8	7.2	-0.8
Netherlands	7.4	5.3	-0.8	4.6	-0.3
Norway	2.1	1.9	-0.1	2.0	0.0
Poland	12.1	8.5	-1.9	7.7	-1.2
Portugal	6.0	4.2	-1.0	3.6	-0.5
Romania	9.9	6.5	-1.6	6.5	-1.4
Russia	6.9	7.8	-1.3	9.0	-1.4
Serbia-M.	9.7	5.2	-0.7	5.5	-0.6
Slovakia	8.5	6.0	-1.1	5.8	-1.0
Slovenia	7.0	5.0	-0.8	4.6	-0.6
Spain	5.9	4.4	-1.1	3.9	-0.7
Sweden	3.1	2.4	-0.3	2.2	-0.2
Switzerland	5.8	4.1	-0.3	4.0	-0.3
Ukraine	9.0	7.8	-1.0	8.6	-1.1
UK	5.3	3.8	-0.8	3.4	-0.5
Total	7.5	5.9	-0.9	5.8	-0.8

3.2 Asia

In China and India, the potential health gains from the implementation of the ECLIPSE measures are significantly larger (Figure 7).

In China, the ECLIPSE measures would reduce population-weighted exposure to PM2.5 by three to four μg/m^3, which however is only a small share of the current level of approximately 80 μg/m^3. (Figure 5). Nevertheless, this exposure reduction would extend the life expectancy of the population of approximately 1.8 months (Table 6), and reduce the premature deaths attributable to fine particulate matter pollution by 150,000 – 200,000 cases per year (Table 4).

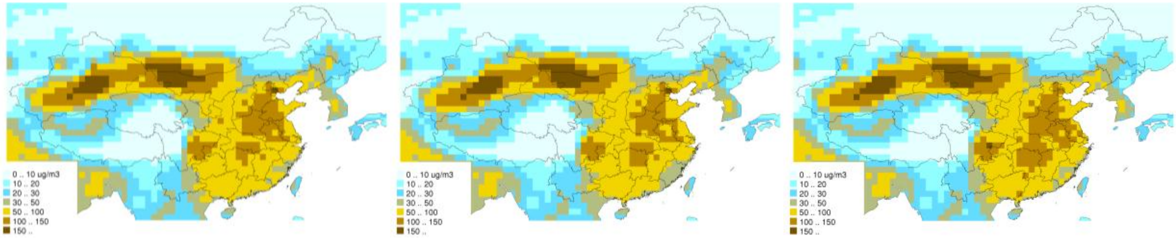

Figure 5: PM2. 5 concentrations in China. Left: 2010; middle: 2030 current legislation, right: 2050, current legislation

According to the GAINS calculations, Indian population, on average, is currently exposed to 63 μg/m^3 PM2.5 (Table 5). The rapid increase in energy consumption accompanying the ambitious economic development plans, together with lacking regulations on emission controls for important sources (e.g., power generation) and poor enforcement of existing laws (e.g., for vehicle pollution controls) will lead to a steep increase in PM2.5 levels in India.

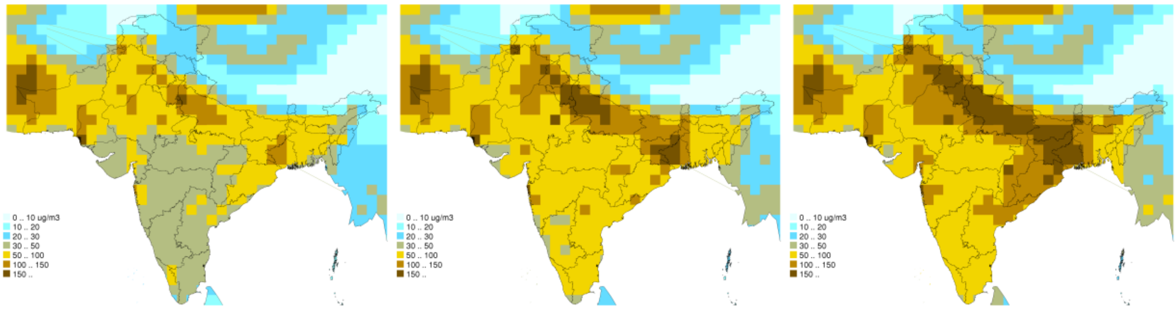

Figure 6: PM2. 5 concentrations in India. Left: 2010; middle: 2030 current legislation, right: 2050, current legislation

Unless additional emission controls are implemented and effectively enforced, it is estimated that average exposure would rise to almost 100 μg/m^3 in 2030, and to almost 120 μg/m^3 in 2050. If no saturation of health impacts is assumed for such high levels (there are no cohort studies available for such high concentrations), with conservative assumptions GAINS estimates approximately 850,000 cases annually of premature deaths from air pollution in 2010. This compares to currently 320,000 fatalities from traffic accidents in India.

For 2030, without air pollution controls, PM2.5 exposure would increase by more than 50%. At the same time, population is expected to increase as well, and the numbers of people older than 30% for which air pollution impacts are calculated by the current methodology, even more. Combined, these factors would let the premature deaths from air pollution grow by approximately 125% to 1.9 million cases in 2030. Continuation of these trends would then lead to 3.7 million premature deaths in 2050.

Against this background, the ECLIPSE measures, which target the most polluting activities, would lead to substantial improvements in the livelihood of the Indian population. In 2030, implementation would avoid more than 400,000 cases of premature deaths (through reducing average exposure by 22 μg/m^3), and almost 700,000 in 2050.

Using the loss in statistical life expectancy as an alternative metric, the ECLIPSE measures would gain 11-12 months to the Indian population. As indicated in Table 7, there are large spatial variations across India, both in total air pollution impacts as well as in the benefits of the ECLIPSE measures.

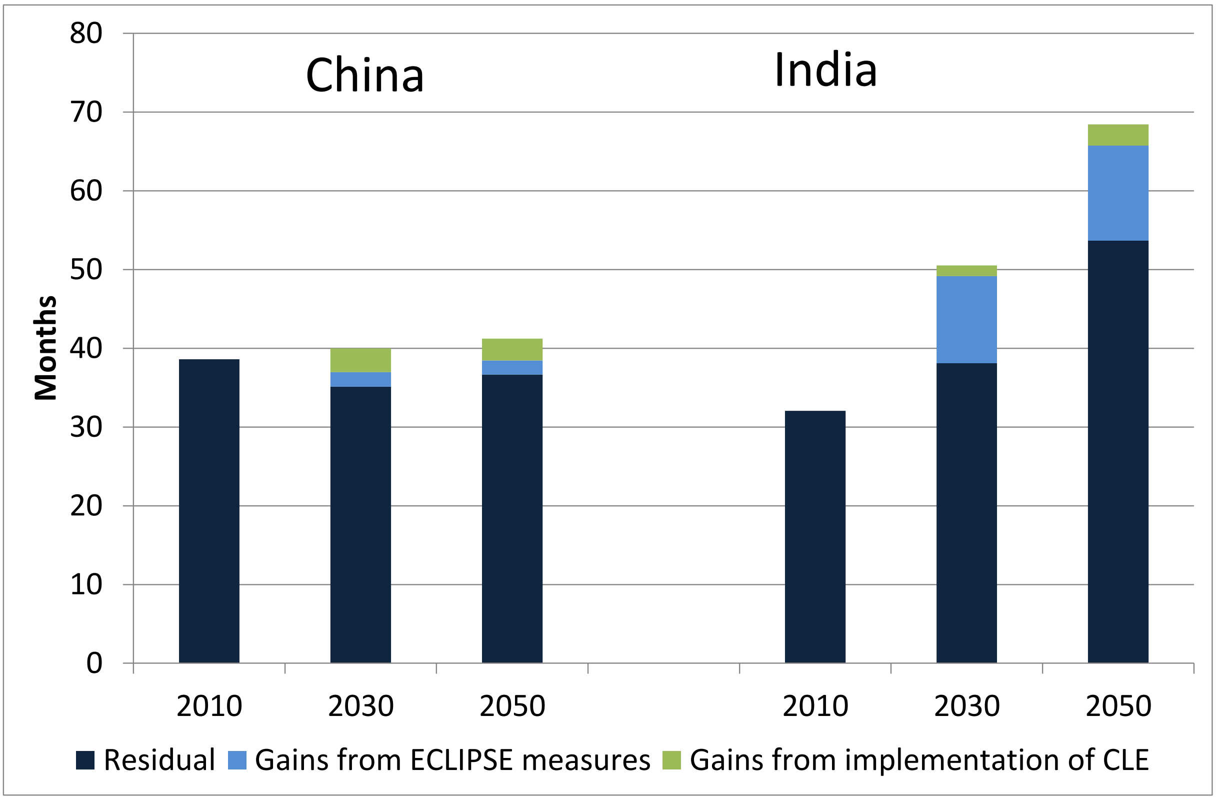

Figure 7: Loss of statistical life expectancy due to the exposure to PM2.5 in China and India (months)

Table 4: Population exposure to PM2.5 and attributable premature deaths in China

	2010	2030		2050	
		CLE	ECLIPSE	CLE	ECLIPSE
Population-weighted exposure to PM2.5 (µg/m^3)	78	75	71	78	75
Deaths >30 years (1000s)	8770	12661	12661	18066	18066
Deaths attributable to PM2.5 (1000s)	2064	2853	2711	4234	4038
Potential gains from the ECLIPSE measures (1000s)	0		-142		-196

Table 5: Population exposure to PM2.5 and attributable premature deaths in India

	2010	2030		2050	
		CLE	ECLIPSE	CLE	ECLIPSE
Population-weighted exposure to PM2.5 (µg/m^3)	63	96	74	128	105
Deaths >30 years (1000s)	6785	9895	9895	14608	14608
Deaths attributable to PM2.5 (1000s)	850	1901	1473	3752	3063
Difference (1000s)			-427		-689

Obviously, these estimates are associated with considerable uncertainties, resulting from the general imponderability about future economic development, imperfections in the modelling of the formation and dispersion of PM2.5 in the atmosphere, especially at the urban scale that affects population exposure, and the lack of long-term epidemiological studies at such high concentration levels. In principle, the GAINS model can quantify the implications of all these uncertainties. However, the resulting uncertainty ranges will critically depend on the assumptions on the uncertainties of each factor, which in themselves are rather uncertain. Furthermore, the overall robustness is critically influenced by co-variances between different factors, which are not fully understood for all areas. As mentioned, the numbers presented above are derived from conservative assumptions of all parameters, so that resulting health effects are likely to be in the lower range.

Table 6: Loss in statistical life expectancy from exposure to PM2.5 in China, for the Current legislation (CLE) scenario and the potential gains from the ECLIPSE set of measures (months)

	2010	2030 CLE	Potential gains from ECLIPSE	2050 CLE	Potential gains from ECLIPSE
Anhui	48.8	47.9	-2.7	51.0	-2.4
Beijing	55.3	49.6	-3.2	45.9	-3.3
Chongqing	51.2	51.0	-2.0	54.6	-1.7
Fujian	21.5	19.4	-0.5	20.8	-0.5
Gansu	16.1	16.1	-0.5	16.4	-0.4
Guangdong	30.3	27.6	-0.8	29.5	-0.8
Guangxi	35.0	33.4	-1.1	36.5	-1.1
Guizhou	32.6	31.3	-0.9	33.6	-0.8
Hainan	12.8	11.2	-0.2	11.7	-0.2
Hebei	52.8	50.7	-3.5	49.9	-3.6
Heilongjiang	10.9	9.4	-0.9	9.1	-0.8
Henan	57.0	53.7	-3.4	53.5	-3.2
Hubei	47.3	47.5	-2.0	50.6	-1.8
Hunan	46.7	48.7	-1.3	53.0	-1.3
Inner Mongolia	8.8	8.4	-0.4	8.6	-0.4
Jiangsu	46.5	44.9	-2.3	47.5	-2.2
Jiangxi	38.8	39.8	-1.1	43.3	-1.0
Jilin	17.8	15.7	-1.4	15.3	-1.3
Liaoning	29.3	27.3	-2.1	26.9	-2.1
Ningxia	14.9	14.8	-0.7	14.7	-0.6
Qinghai	11.1	10.6	-0.5	9.9	-0.4
Shaanxi	34.7	32.4	-1.6	32.0	-1.4
Shandong	48.3	45.0	-3.1	45.8	-3.4
Shanghai	39.8	39.7	-1.6	41.8	-1.8
Shanxi	36.5	34.7	-2.1	35.2	-2.0
Sichuan	50.8	48.5	-2.3	51.8	-2.0
Tianjin	58.3	56.7	-4.3	55.8	-4.6
Tibet_Xizang	2.1	2.1	0.0	2.0	0.0
Xinjiang	9.0	7.6	-0.5	7.3	-0.4
Yunnan	17.0	16.5	-0.4	17.5	-0.3
Zhejiang	29.6	28.1	-0.8	29.6	-0.8
Total	38.6	37.0	-1.8	38.5	-1.8

Table 7: Loss in statistical life expectancy from exposure to PM2.5 in India, for the Current legislation (CLE) scenario and the potential gains from the ECLIPSE set of measures (months)

	2010	2030 CLE	Potential gains from ECLIPSE	2050 CLE	Potential gains from ECLIPSE
Andaman Nicobar	4.8	7.0	-0.3	9.1	-0.3
Andhra Pradesh	22.1	37.5	-6.0	51.2	-6.6
Arunachal Pradesh	10.6	13.5	-2.2	18.4	-1.9
Assam	27.0	33.1	-7.2	42.5	-6.4
Bihar	42.4	57.5	-14.4	73.8	-14.7
Chandigarh	42.9	62.9	-18.1	85.0	-20.4
Chhattisgarh	24.4	43.4	-6.5	59.6	-7.5
Dadra Nagar Haveli	17.8	28.1	-4.8	37.4	-5.5
Daman Diu	14.9	22.8	-4.2	29.7	-4.8
Delhi	94.0	139.3	-60.8	191.9	-73.4
Goa	13.1	20.9	-2.9	28.1	-3.3
Gujarat	21.8	33.1	-7.1	42.8	-7.9
Haryana	48.1	71.3	-20.1	97.5	-22.8
Himachal Pradesh	19.1	30.1	-5.7	42.2	-6.2
Jammu Kashmir	21.9	28.7	-8.6	36.2	-8.7
Jharkhand	43.1	73.1	-12.7	99.0	-14.1
Karnataka	16.5	26.4	-4.6	35.6	-5.2
Kerala	19.3	27.2	-4.6	36.8	-5.0
Madhya Pradesh	21.0	32.9	-5.8	43.5	-6.1
Maharashtra	19.7	30.8	-6.9	40.5	-7.7
Manipur	23.4	29.6	-5.6	38.0	-5.0
Meghalaya	28.4	38.0	-5.3	51.2	-4.9
Mizoram	20.9	27.2	-3.4	34.3	-3.1
Nagaland	17.2	22.3	-2.4	29.9	-2.2
Orissa	28.3	47.7	-6.6	65.8	-7.3
Pondicherry	15.2	24.0	-4.0	32.7	-4.5
Punjab India	44.9	64.4	-18.4	85.8	-20.6
Rajasthan	23.1	37.0	-7.6	48.7	-8.1
Sikkim	11.4	16.0	-1.8	20.6	-1.9
Tamil Nadu	18.5	29.4	-4.7	40.9	-5.3
Tripura	31.5	40.1	-7.5	49.7	-6.8
Uttar Pradesh	48.0	70.6	-16.6	94.8	-17.7
Uttranchal	26.6	39.1	-8.5	52.4	-8.7
West Bengal	43.4	67.3	-13.1	90.3	-14.3
Total	32.1	49.2	-11.1	65.7	-12.1

4 Climate impacts

4.1 Methodology

As mentioned above, the measures have been selected that they simultaneously benefit air quality and climate objectives. While their health impacts from reduced air pollution have been assessed above with the GAINS model, quantification of their climate impacts was one of the major objectives of the ECLIPSE project. To this end, ECLIPSE followed two avenues to explore their climate impacts:

- The selection of the set of promising measures has been based on suitable climate metrics that have been developed in WP4 of ECLIPSE. Subsequently, the same metrics have been employed to derive the response of these climate impact indicators towards the emission reductions that emerge from the implementation of the ECLIPSE set of measures (compared to the 'current legislation' reference scenario).

- Alternatively, both the ECLIPSE baseline emission projection as well as the emission trajectories that result from the implementation of the ECLIPSE set of measures have been used as input for GCM model experiments in WP5. A separate report compares the outcomes of the full GCM runs with the estimates derived from the climate impact indicators.

This report provides the evolution of the two climate impact indicators (metrics) of the two ECLIPSE scenarios. Two alternative metrics, reflecting different time horizons, have been used, i.e., the GTP20 (the Global Temperature Potential over 20 years) and the GWP100, i.e., the Global Warming Potential over 100 years. These metrics have been developed under WP4 of ECLIPSE , and the selection of promising measures described in detail in Deliverable D7.3 of the ECLIPSE project. The numerical values for these metrics have been computed for four different world regions (i.e., Europe, China, Marine Shipping, and the Rest of the World), and distinguish emissions during the summer and winter half years, respectively. The assessment here applies the seasonal climate metrics to seasonal emissions, with different temporal patterns for different pollutants, sectors and world regions (Table 8).

Table 8: Climate metrics used for the selection of the ECLIPSE set of emission controls

	GTP 20	GWP 100
SO2 Europe Summer	-818.94	-224.741
SO2 Europe Winter	-270.239	-74.1614
SO2 China Summer	-487.475	-133.777
SO2 China Winter	-204.605	-56.1497
SO2_WD Summer	-933.578	-256.201
SO2_WD Winter	-601.399	-165.041
BC Europe Summer	5224.121	1432.293
BC Europe Winter	2297.104	629.7952
BC China Summer	4991.767	1368.589
BC China Winter	1954.981	535.9955
BC Rest of the World Summer	6881.022	1886.564
BC Rest of the World Winter	5275.636	1446.417
OC Europe Summer	-1606.65	-440.401
OC Europe Winter	-862.762	-236.493
OC China Summer	-1176.6	-322.52
OC China Winter	-543.154	-148.885
OC Rest of the World Summer	-1332.79	-365.332
OC Rest of the World Winter	-1338.26	-366.831
NH3 Europe Summer	-102.063	-27.9826
NH3 Europe Winter	-66.5388	-18.2429
NH3 China Summer	-49.5783	-13.5928
NH3 China Winter	-95.1115	-26.0766
NH3 Rest of the World Summer	-38.8884	-10.662
NH3 Rest of the World Winter	-60.6873	-16.6386
OC Europe Summer	-1606.65	-440.401
OC Europe Winter	-862.762	-236.493
OC China Summer	-1176.6	-322.52
OC China Winter	-543.154	-148.885
OC Rest of the World Summer	-1332.79	-365.332
OC Rest of the World Winter	-1338.26	-366.831
NOX Europe Summer	-34.7161	-19.0901
NOX Europe Winter	-16.1697	-8.31161
NOX China Summer	22.18693	-4.28193
NOX China Winter	-31.4115	-14.0771
NOX Rest of the World Summer	-11.3297	-23.6612
NOX Rest of the World Winter	-18.4186	-26.1638
CO Europe Summer	15.28273	5.079139
CO Europe Winter	15.75916	5.418426
CO China Summer	14.86592	4.904716
CO China Winter	18.42923	6.087484
CO Rest of the World Summer	14.13252	4.786999
CO Rest of the World Winter	14.39564	5.053662
VOC Europe Summer	17.99427	10.58781
VOC Europe Winter	-6.52715	0.916499
VOC China Summer	30.74057	10.89361
VOC China Winter	26.03821	8.465533
VOC Rest of the World Summer	21.16068	11.95678
VOC Rest of the World Winter	11.37545	9.68094
CH_4 global	100.828	46.84704

To mimic the implementation of emission control policies as realistically as possible, these metrics assume gradual linear phase-in of a given emission reduction policy/measure over 15 years, and persistence of the regulation after its full implementation. As discussed in the WP4 reports, this temporal pattern, which reflects the impacts of actual policy decisions, delivers different results than the analysis for pulse emissions, which has been frequently used in the past.

4.2 Climate indicator metrics for European emissions

With the climate metrics developed in ECLIPSE WP4, implementation of the ECLIPSE set of measures would cut the GTP20 indicator, i.e., the impact of European CO_2 and SLCP emissions on global temperature in 20 years, by more than half compared to the baseline (Figure 8). The dominating contribution would emerge from the CH_4 mitigation measures, and control of other short-lived substances (including black carbon) would play a lesser role. Obviously, the impact on the GWP100 is much smaller, and would reduce this metric by 10-15% (Figure 9). It is noteworthy that for both metrics the net contributions from non-methane SLCPs is negative, essentially due to the high importance of SO_2 emissions.

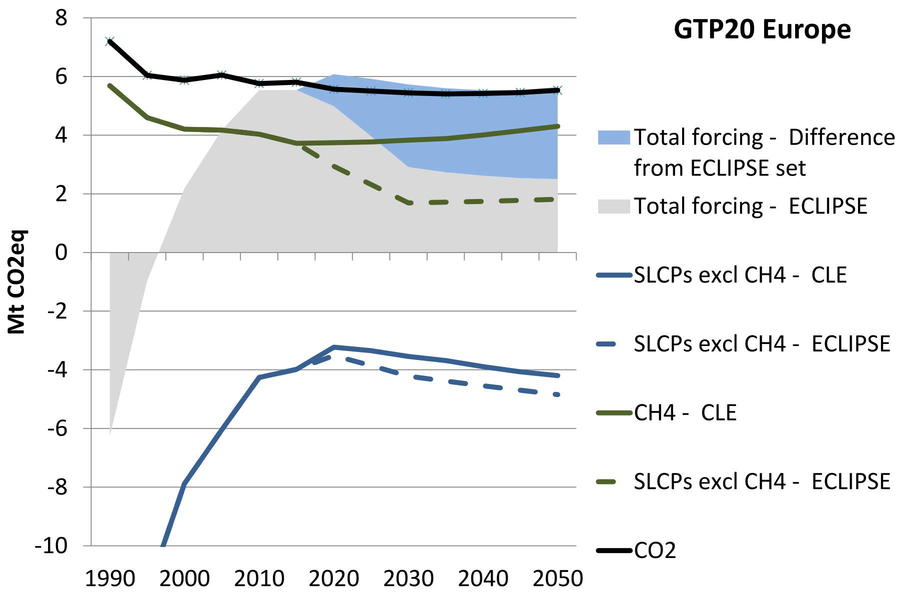

Figure 8: GTP20 indicator for the Baseline Current legislation (CLE) and the ECLIPSE scenarios for Europe (incl. European part of Russia)

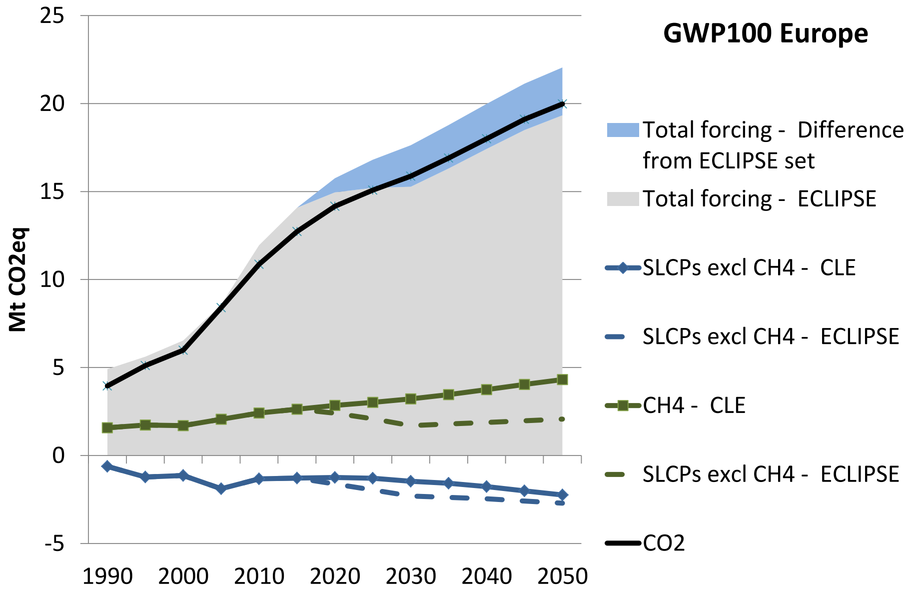

Figure 9: GWP100 indicator for the Baseline Current legislation (CLE) and the ECLIPSE scenarios for Europe (incl. European part of Russia)

4.3 Climate indicator metrics for Chinese emissions

A similar pattern emerges for China, for which the ECLIPSE measures would reduce the GTP20 indicator (including CO_2 emissions) by approximately 30% in the long-run (Figure 10)Black carbon would offer a somewhat larger reduction potential than in Europe, especially in the next 10-15 years. For GWP100, the net impact of the SLCP measures in relative terms (compared to OC2) is in the same order as in Europe (Figure 11).

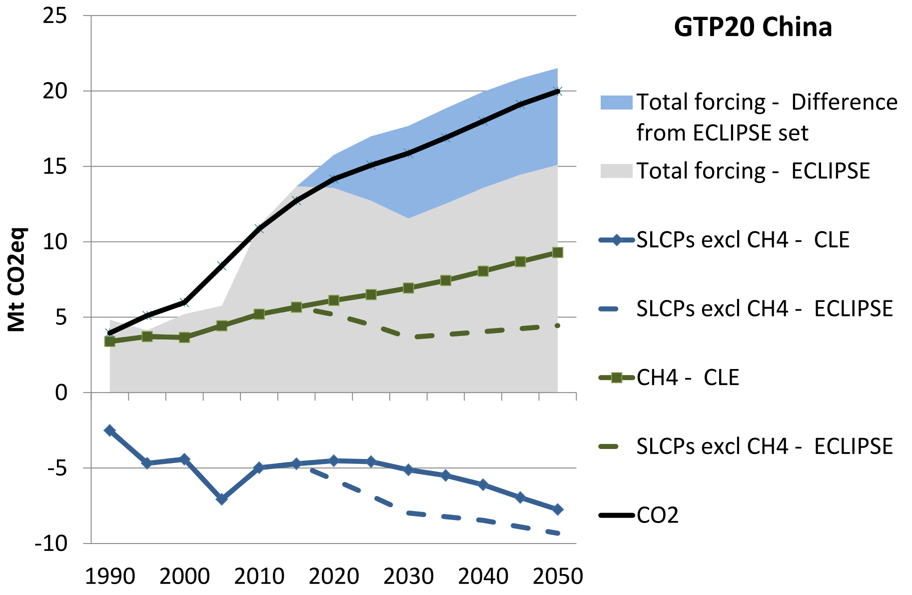

Figure 10: GTP20 indicator for the Baseline Current legislation (CLE) and the ECLIPSE scenarios for China

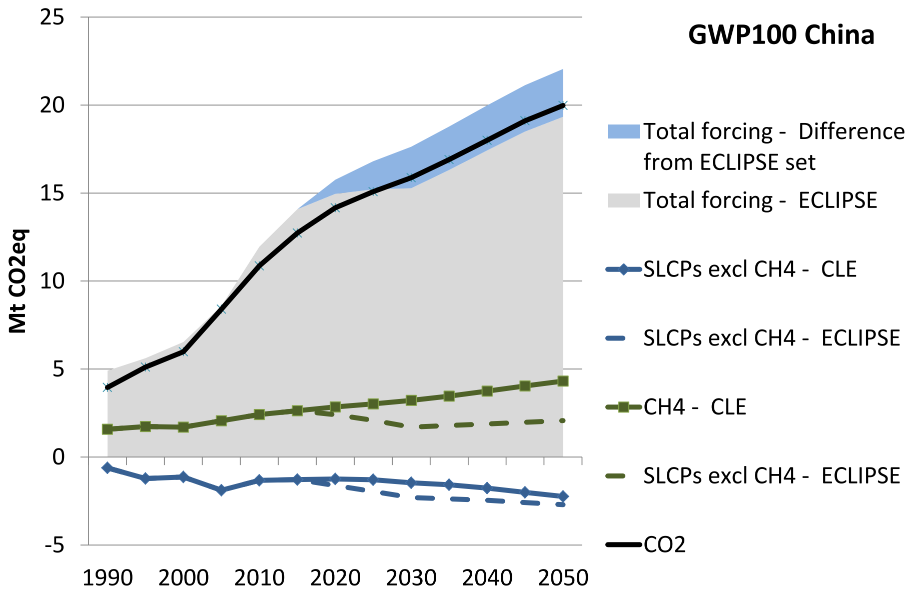

Figure 11: GWP100 indicator for the Baseline Current legislation (CLE) and the ECLIPSE scenarios for China

5 Conclusions

The analysis reveals considerable benefits of the ECLIPSE set of measures both for human health and the GTP20 and GWP100 climate metrics. Just for India and China, implementation of these measures could save annually up to 900,000 cases of premature deaths from air pollution in the long run. At the same time, they would reduce climate forcing, especially in the near-term. The GTP20 indicator of European emissions of short- and long-lived greenhouse gases (including CO_2) could be reduced by more than half, and of Chinese emissions by one third.

Further work is required to quantify the implications of these emission changes on climate at the regional scale, and to validate them with comprehensive GCM models.

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